GEOLOGICAL SURVEY OF NEW JERSEY
HENRY B. KÜMMEL, State Geologist

in Co operation with

NEW JERSEY STATE AGRICULTURAL EXPERIMENT STATION
JACOB G. LIPMAN, Director

BULLETIN 10

The Mechanical and Chemical Composition of the Soils of the Sussex Area

NEW JERSEY

By

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Chemical Analyses
By
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Analysis of Soils—Methods Used
By
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Field work done in co-operation with the
Bureau of Soils of the U. S. Department of Agriculture

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FOREWORD.

This bulletin constitutes a portion of the report on the soil survey of the Sussex area in North Jersey. The work has been conducted co-operatively by the Bureau of Soils of the United States Department of Agriculture, the Geological Survey of New Jersey, and the New Jersey State Agricultural Experiment Station. In conducting this survey, it has been the aim of the persons in charge to prepare a good soil map of the region, and to determine, further, the chemical nature of the several soil types. An agricultural canvass has also been made of the Sussex area, with a view to securing data relating to the practices that are likely to affect the fertility of the soils under consideration. The soil map and the accompanying discussion of the different types are being published as a separate report. A discussion of the mechanical and chemical composition of the soil samples, collected in the course of the survey, is presented in this bulletin; while a discussion of the results of the agricultural canvass is to appear as the third bulletin of this series.

As is shown by the analysis given in the following pages, the soils of the Sussex area are very often deficient in lime. They are well supplied with potash, containing, in many instances, enormous amounts of this constitutent. They are also well supplied with phosphoric acid, but frequently respond to applications of commercial fertilizer containing this constituent in an available form. The valley soils of the Sussex area are extremely fertile wherever they are properly drained. They are best suited for the production of hay and miscellaneous forage crops, and for dairy and beef cattle. They will also grow good crops of maize. Certain portions of these valley lands consist of muck or peat, now and then underlaid by shell marl. Such areas are well adapted for the growing of onions, celery, lettuce and a number of other vegetable crops. The upland soils, where they are sufficiently deep and not too steep, are suited for the production of corn, small grains, forage crops and fruit. In general it may be said that the important agricultural industries of the Sussex area will consist, in the main, of dairying, poultry raising and fruit growing. The black valley soils will be utilized to a constantly increasing extent for the production of vegetables. The development of the soils of the Sussex area will depend on the recognition, on the part of the farmers, of the fact that most of their soils are sour and are badly in need of lime. The farmers will have to recognize, also, that the soils of the Sussex area are not as mellow as they should be, because of the insufficient amount of vegetable matter contained in them. For this reason, lime and green manures will be employed with success in the building up of these soils. The prevailing rotations will have to be modified, so as to permit a more frequent growing of leguminous crops. Soil improvement will thus be made possible with relatively slight expenditures for commercial fertilizers. A fuller discussion of the proper application of the facts discovered in the survey of the Sussex area, and practical suggestions for the improvement of the agricultural conditions in this region, will be given in the forthcoming report on the agricultural canvass of the Sussex area.

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Soils of the Sussex Area, New Jersey.

BY A. W. BLAIR AND HENRY JENNINGS.

Contents.

DESCRIPTION OF THE AREA.

LOCATION.

The Sussex area is located in the extreme northern part of the State of New Jersey. Its northern boundary is the New York State line; on the west, Delaware River separates it from

Pennsylvania, while its eastern limit is longitude 74° 20′, and its southern, latitude 40° 56′. It embraces practically all of Sussex County, the northern part of Warren, western part of Passaic and Northern portion of Morris Counties. Its area is 788 square miles.

TOPOGRAPHY.

The Sussex area has five conspicuous topographic divisions, namely, Delaware Valley, Kittatinny Mountain, Kittatinny Valley, Highlands of New Jersey, and a portion of the Piedmont Plateau. The Delaware Valley covers all that portion of the area west of Kittatinny Mountain. It is marked by a steep ridge known as Wallpack Ridge, and also by flat terraces in the valley on the east and the Delaware River terraces on the west. Though of comparatively small area, this section offers possibilities for raising truck crops.

To the southeast of Delaware Valley, Kittatinny Mountain traverses the area in a northeast-southwest direction. A striking feature of this mountain is its even crest, which for miles has an average elevation of about 1,500 feet, but rises to a maximum of 1,809 feet at High Point. With the exception of Culvers Gap, a steep-sided wind gap, and Delaware Water Gap, the ridge is uninterrupted by any passes.

East of Kittatinny Mountain is a broad, rolling upland valley 10 to 13 miles in width, and 800 to 1,200 feet lower than the mountain, known as Kittatinny Valley. In general the altitude in the eastern part is from 300 to 600 feet below that portion next to Kittatinny Mountain. Seen from the high elevations which bound it on either side, it appears low and flat, but to one within the valley its floor is a succession of steep, rolling hills and ridges, trending in a general northeast-southwest direction, separated by several sub-valleys of considerable width and length. The chief streams follow these valleys, along which the tributary streams have dissected the intervening ridges. In its larger features its topography has been determined by its geologic structure, the higher elevations being underlain by resistent shale and slate, while the sub-valleys are mostly of more soluble limestone.

Southeast of Kittatinny Valley is the elevated belt of country known as the Highlands of New Jersey. It occupies nearly one-half the area described in this report, and, although interrupted by several large valleys, it can be regarded as a unit. This region has an average elevation of 1,100 to 1,300 feet, above which rise rounded knobs to a maximum elevation of 1,496 feet, and below which the streams have eroded valleys of varying width and depth. Two of these, Vernon Valley, extending northeast from Hamburg to the State line, and the upper Wallkill Valley, stretching 10 miles southwest from Franklin Furnace, can be regarded as branches of Kittatinny Valley, which penetrate the west margin of the Highlands, and are separated from the main valley by semi-isolated mountain masses. Both of these valleys are narrow, not exceeding 2 miles in width, and of the two, Vernon Valley is of the most importance agriculturally.

Another important structural feature is the great valley extending southwest from Greenwood Lake to Newfoundland, Oak Ridge and beyond the limits of the area. In the vicinity of Newfoundland and Oak Ridge the valley widens greatly, and was at one time a section of considerable agricultural importance. Adjoining this valley are steep-sided, even-crested ridges, resembling in structure Kittatinny Mountain and known as Green Pond, Copperas, Kanouse and Bearfoot Mountains. Both they and the Greenwood Lake-Longwood Valley are due to a belt of limestone and shale, sandstone and conglomerate in the midst of the crystalline rocks which underlie most of the Highlands.

The fifth physiographic province represented is in the extreme southeast, where a small portion of the Triassic or red shale lowland is included in the region studied. Its elevation is about 180 feet and its area 2 square miles. Farther south this province develops into a broad, rolling lowland of excellent agricultural possibilities.

DRAINAGE.

The Sussex area is drained by tributaries of three river systems—Delaware, Hudson and Passaic. West of the Kittatinny Valley the drainage is into the Delaware, either direct or by small tributaries. In Kittatinny Valley the run-off goes into the Hudson or Delaware basins. The drainage of the northern part of the Kittatinny Valley goes into the Wallkill or its tributaries, which empty into the Hudson near Newburg. In the southern part of the valley the drainage is into the Paulinskill or Pequest River, and minor tributaries which empty into the Delaware at points south of the present area. The Pequannock River, the master-stream of the eastern section of the area, crosses the Highlands to the southeast. Much of its course is merely a rocky gorge along the sides of which there is barely room for a railroad and highway.

In addition to those mentioned there are many small streams which dissect the Highlands and eventually find an outlet into Passaic River.

The area is well supplied with natural lakes and ponds, of which Lake Hopatcong, Culvers Lake, Beaver Lake, Swartswood Lake and Macopin Lake are the most important. These lakes attract many city visitors during the vacation period.

In the upper part of the Pequannock drainage basin three large reservoirs have been constructed at Clinton, Oak Ridge, and Canistear. These supply the city of Newark with its water. Large tracts of land adjacent to these reservoirs have been purchased and at the present time are being reforested to prevent pollution and maintain the water supply.

CLIMATE.

The climate of the northern part of the State of New Jersey is moderately cold in winter and cool in summer. This climatic condition has an important influence in attracting city visitors during the summer vacation period. From data collected at the four climatological observation stations it appears that while it is a comparatively small part of the State, there is a considerable difference in the length of the growing season within the boundaries of the area surveyed. This difference is especially noticeable in the length of the season between the first and last killing frost. At Layton the length of the growing season for a period of ten years has been 137 days without frost, at Charlotteburg 146, at Sussex 161, and at Newton 171. From field observations it appears that the difference even in the same location between low-lying lands and those at a greater elevation cannot be overemphasized. At the low levels frosts frequently kill corn and other tender crops, while fields at an elevation of 100 to 200 feet higher show little or no effect.

Where the ground is not properly drained during the winter season there is danger that grain crops will be heaved and winter-killed. In the spring, fruit buds are liable to be injured by late frost. The remedy for this would be the selection of sites which would retard the early development of the buds. The northwest slopes are several days later in the development of the buds than those to the southeast. This location, however, in many cases has the disadvantage of being exposed to the strong prevailing winds.

Precipitation, as a rule, is distributed quite evenly throughout the year, though there are occasional seasons when there are periods of drought. Usually damage done during these periods is especially noticeable on the lighter soils of the section. Ordinarily about 3 to 4 inches of rainfall can be expected during each month.

POPULATION AND TRANSPORTATION.

The settlement of Sussex area started about 1680, though the exact date is not definitely known. The present population, except at the quarrying and mining centers, is made up principally of the descendants of the original settlers with occasional representatives from some of the European countries. Satisfactory labor is difficult to secure on the farms, as it is claimed that the manufacturing industries offer better pay with shorter hours than the farm.

The towns of the area in order of importance are: Newton, Butler, Sussex, Blairstown, Franklin Furnace, Hamburg, Branchville, Ogdensburg, Andover, Sparta, Marksboro and Vernon, with numerous smaller hamlets.

The transportation facilities of the area are exceptionally good. The main and branch lines of the Delaware, Lackawanna and Western Railroad cross the area. Another direct line to New York is the New York, Susquehanna and Western Railroad, which connects from near the Delaware Water Gap to the eastern part of the area. The Lehigh and New England Railroad traverses Kittatinny and Vernon valleys from the north to the south. Other smaller roads furnish connections to various points.

AGRICULTURE.

The Sussex area was first developed agriculturally in the upper Delaware Valley, according to Small's "History of Sussex and Warren Counties." This was about 1680, though the exact date is not definitely known. From the beginning of settlement in the area agriculture was the leading industry, though the section was prospected and its mineral resources recognized at an early date. The early settlers, who were Dutch, Huguenots, German, Quaker and Puritan, raised a diversity of crops, mainly subsistence crops. During these early times the farm implements were few and of very rude construction. The ground was scratched rather than cultivated. The products sold were usually such as could be easily transported to more or less distant markets. It was frequently necessary to undertake long, tedious trips extending through several days. The soils are naturally adapted to grass, and this was fed to cattle, which, after being fattened, were driven to market.

When the agricultural resources became known the Sussex area, especially Kittatinny Valley, attracted so many settlers that production could not keep pace with the subsistence needs of the population. In 1790 the area comprising Sussex County had a population exceeded by but one county in the State. About this time grist mills were erected on the valuable power sites in various parts of the area. This gave an impetus to the growing of grain which could be sold at remunerative prices.

The following figures showing the changes in the agriculture of Sussex County give a good idea of the growth of the agriculture of the area as a whole.

In 1825 it is estimated that the principal exports of Sussex County were 900 tons of butter and 3,000 tons of pork and other meat. At this time such products as milk, young calves, poultry, eggs and potatoes were of little value except for consumption on the home farms. Fruits were grown successfully, but comparatively little use was made of them. Indian corn, timothy and clover were not introduced into the county until a comparatively late date.

The plow and harrow used in 1825 were of about the same construction as those used by the early settlers, showing a slow development. Nevertheless, there were advances in the scope of agricultural practices during the first fifty years of the nineteenth century. It was recognized that the drowned lands had great value and possibilities as early as 1804, though their development did not take place until a much later time.

Until the railroads entered the county the principal products sold continued to be beef, butter and swine. The milk produced was skimmed and fed to pigs, while the cream was made into butter. These products were easily transported and brought good prices. Very soon after the railroads entered the area the shipment of milk was started. This industry has increased, especially in Sussex and Warren Counties. In 1870 1,317,791 gallons were shipped from Sussex County, and in 1900 12,588,855 gallons. The following figures relating to the agriculture of the area are taken from the census reports of the United States for the years indicated:

	1850.	1860.	1870.	1880.	1890.	1900.	1910.
Acres improved,	149,582	175,894	157,403	180,846	191,743	178,431	161,283
Acres unimproved,	94,895	86,335	....	72,842	55,997	78,465	77,028
Cash value of farms and buildings,	$8,390,180	$11,105,233	$13,264,703	$9,801,524	$7,748,320	$6,834,120	$8,358,090
Value of implements,	$213,465	$292,290	$356,810	$291,946	$345,580	$393,010	$553,836
Value of live stock,	$1,049,719	$1,396,472	$1,660,947	$1,052,293	$1,171,360	$1,406,100	$1,949,874
Value of all products for year,	....	....	$2,526,710	$1,670,239	$1,745,830	$1,149,250	....
Value of dairy products,	....	....	....	....	....	....	....
Value of orchard products,	$3,307	$18,896	$39,701	$40,521	....	$104,941	....
Number of horses,	4,390	5,026	4,230	4,546	4,785	6,288	4,785
Number of neat cattle,	25,549	29,129	22,213	26,003	28,597	32,195	33,353
Number milch cows,	16,816	19,240	17,376	18,903	21,264	22,013	22,972
Number sheep,	8,309	6,127	3,976	5,171	5,131	4,832	2,960
Number swine,	30,115	25,164	14,414	17,028	12,735	6,512	4,958
Bushels corn,	459,254	505,341	432,776	571,484	398,737	527,770	486,825
Bushels oats,	151,011	274,915	268,477	229,534	222,675	130,090	134,224
Bushels rye,	229,795	238,232	105,306	98,300	70,471	71,390	53,286
Bushels wheat,	66,006	25,167	64,508	30,560	18,606	20,670	16,815
Bushels potatoes,	110,020	113,093	81,006	94,788	52,767	150,241	96,913
Tons hay,	37,711	43,078	40,335	40,059	59,945	39,081	62,093
Bushels buckwheat,	178,188	142,552	72,870	119,899	35,977	63,220	48,695
Gallons milk,	....	....	1,317,791	4,183,145	10,797,483	12,588,855	....
Pounds butter,	1,816,610	2,042,987	1,455,788	1,190,571	697,362	342,916	....
Value of fertilizer,	....	....	....	$10,077	$3,028	$14,940	$19,803

GEOLOGY OF THE AREA.

SOILS.

Origin.—The soils of the Sussex area are chiefly, although not entirely, of glacial origin. During the glacial period the moving ice field, as it slowly advanced, tended to drag along with it the soil which had been formed in pre-glacial times by the disintegration and decomposition of the various underlying rock formations. Armed with this material, the ice sheet, acting as a flexible rasp, tended to break and grind off even the solid rock itself. As it advanced some of this material lodged under the ice and new material was picked up, while at the front edge of the glacier, where the melting equaled the rate of advance, this rock débris accumulated in an ever-increasing amount. In places where the drainage from the ice was concentrated along certain lines the finest part of the material was swept away by the swiftly-flowing water, and the coarser material was deposited as sand and gravel. As the rate of melting gradually exceeded the rate of advance, and the front of the ice sheet receded, a mantle of débris, coarse and fine indiscriminately mingled and of varying thickness, was deposited. This sheet of stony clay, technically called till, and the beds of clay, sand, and gravel deposited by the streams issuing from the ice sheet form the basis of most of the present soils of the Sussex area.

The till is composed chiefly of material derived from the rock formation on which it rests. While this is true, it also contains a considerable percentage of material derived from more remote regions which the ice had carried longer distances. In general, the thinner the till the greater the proportion of local material. Inasmuch as the grinding action of the ice is great, all material (except the very hardest) which was transported far was ground to powder. Hence the percentage of distantly derived material is larger in the finer portion of the till than it is in the coarser portion.

Inasmuch as the ice which reached this region traversed rock formations of many kinds, and since the region itself contains a number of geological formations, the till presents several distinct phases which depend chiefly upon the character of the underlying rock.

Locally, the mantle of glacial drift was so thin that the present soil is practically the result of the decay and disintegration of the underlying rock. Essentially the same result occurs in those areas where the till is almost entirely of local material, and the admixture of foreign material is extremely limited. In such cases the soil or subsoil, although technically derived from glacial material, may not be greatly unlike a soil or subsoil resulting solely from the disintegration of the rock beneath.

The upland types of soil fall naturally into soil series based generally on geological differences which influence their structure and general characteristics. They are closely related to the underlying rock formations which have entered so largely into the glacial till from which the soils were principally derived. A second class of soil formations is made up of materials derived from deposits of glacial waters, during and immediately following the recession of the ice. These are classed as terrace soils. A third group of soils comprises those derived from material eroded from higher localities and deposited, for the most part, during high water on the bottom lands along the streams.

CLASSIFICATION OF SOILS.

The detail soil survey consists in indicating on a map the location and extent of the different soil types.

The unit in the soil survey is the soil type which possesses certain more or less definite characteristics. In the determination of the soil type several factors are taken into consideration. These are (1) geological origin of the soil, whether residual, glacial, or alluvial; (2) texture which deals with the porosity, granulation, friability and their relation to the physical or mechanical composition of the soils, such as the percentage of gravel, sand, silt or clay; (3) structure which deals with the arrangement of the soil particles; (4) the organic content; (5) color; (6) depth; (7) drainage; (8) topographic position as it affects agricultural value; (9) native vegetation, as tree growth and kind; (10) chemical composition and reaction.

Many types in a given section will grade one into another with respect to many of these characteristics.

Soil types may be grouped in several different ways. Soils because of being composed of particles of different size may be grouped according to the relative proportion of the particles of the different sizes which they contain. This classification or grouping is known as the soil class and is based on texture.

The mechanical analysis of soils is the process of separating the soil particles less than 2 mm. (2/25 of an inch) into seven grades and determining the various percentage relations in order to determine the class to which the soil belongs. In this way it is determined whether it is a sand, loam, clay or some intermediate class. In addition to the fine earth many soils contain large particles which, if of comparatively small size, are called "gravel," and if of large size are called "stones." Because the different classes grade into each other, the line of separation between classes is necessarily an arbitrary one.

It has been found that certain sets of soil classes are so closely related as to source of material, method of formation, topographic position and coloration that the different types constitute merely a gradation in texture of an otherwise uniform material. Soils of this character are grouped together into what is called a soil series. A complete soil series consists of material similar in many other characteristics but grading in texture from stones and gravel through different grades of sands and loams to heavy clay.

Color characteristics form one of the most noticeable physical features, and are of great assistance in separating the soils into different series.

Soil Constituents.
- Organic Matter (composed of vegetable and animal remains.)
- Inorganic Matter, (Used in mechanical analyses.)
  - mm.
  - Clay, ... 0.005—0
  - Silt, ... 0.05—0.005
  - Very Fine Sand, 0.1—0.05
  - Fine Sand, ... 0.25—0.1
  - Medium Sand, .. 0.5—0.25
  - Coarse Sand, ... 1—0.5
  - Fine Gravel, ... 2—1
- Gravel.
- Stones.

CLASSIFICATION OF SOILS, BASED UPON THEIR MECHANICAL COMPOSITION.*

CLASS.	1 Fine Gravel 2–1 mm.	2 Coarse Sand 1–0.5 mm.	3 Medium Sand 0.5–0.25 mm.	4 Fine Sand 0.25–0.1 mm.	5 Very Fine Sand 0.1–0.05 mm.	6 Silt 0.05–0.005 mm.	7 Clay 0.005–0 mm.
Coarse sand,	More than 25% of 1 and 2.		Less than 50% of 3, 4 and 5.			Less than 20% of 6 and 7.	
Sand,	More than 25% of 1, 2 and 3.			Less than 50% of 4.		Less than 20% of 6 and 7.	
Fine sand,	Less than 25% of 1, 2 and 3.			More than 50% of 4.		Less than 20% of 6 and 7.	
Very fine sand,					More than 50% of 5.	Less than 20% of 6 and 7.	
Sandy loam,	More than 25% of 1, 2 and 3.					20 to 50% of 6 and 7.	
Fine sandy loam,	Less than 25% of 1, 2 and 3.			More than 50% of 4.		20 to 30% of 6 and 7.	
Sandy clay,						Less than 20% of 6.	
						20 to 50% of 6 and 7.	
Loam,						Less than 50% of 6.	Less than 20% of 7.
						More than 50% of 6 and 7.	
Silt loam,						More than 50% of 6.	Less than 20% of 7.
						More than 50% of 6 and 7.	
Clay loam,						Less than 50% of 6.	20 to 30% of 7.
						More than 50% of 6 and 7.	
Silty clay loam,						More than 50% of 6.	20 to 30% of 7.
						More than 50% of 6 and 7.	
Clay,							More than 30% of 7.
						More than 50% of 6 and 7.	

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* From U. S. D. A. "Soil Survey Field Book," 1906, pp. 17 and 18; and U. S. D. A. "Bulletin No. 78, Bureau of Soils," p. 12.

SOIL ANALYSIS AS RELATED TO CROP PRODUCTION AND SOIL IMPROVEMENT.

Much has been said both in favor of and against the chemical analysis of soils as a means of determining their plant food requirements. It is generally admitted that while such an analysis does show the total amount of plant food present, it fails, on the other hand, to show how much is available for the immediate demands of the plant. For this latter reason some have held that there is little value in the chemical analysis of soils.

If by chemical analysis is meant the analysis of a single sample taken from only one spot on the farm, by a person not skilled in such work, then the value of such analysis may indeed be questioned. Much care and good judgment should be exercised in taking the samples, for if they do not represent the type, then the analysis cannot be considered reliable, and is, consequently, of little value.

If, on the other hand, the samples are carefully collected by a person skilled in this kind of work, then the results of a chemical analysis, when interpreted in the light of crop requirements, cannot fail to be of value when we come to the subject of laying out systems of soil improvement and putting up fertilizer mixtures for special crops.

To make this clear we may suppose that analysis has been made of two samples of soil, one of which yields 0.2% of total potash and the other 2.5%. (Such differences actually occur in the soils of New Jersey.) The 0.2% found in the first soil is equivalent to 4,800 pounds of potash in an acre to a depth of 8 inches (approximately 2,400,000 pounds of soil). The 2.5% is equivalent to 60,000 pounds of potash in the same amount of soil. Here is a difference between the two soils of nearly 28 tons of potash. Is there anyone who has studied the subject carefully and is willing to say that there is no difference in the treatment which the two soils should receive and the kind of crops which will give the best returns? It must be admitted that in neither case do we know how much of this potash is available for the immediate needs of the plants. However, until the contrary has been fully proved it is fair to assume that the second soil will yield more available plant food than the first. Certainly we know with respect to the second soil that here is a vast store of reserve potash, and if by cultural methods and the application of soil amendments we can render only a small fraction of this reserve supply available each year, we shall have an abundant supply for most crops, and at the same time we need have little fear of the exhaustion of the supply for many years to come. If our analysis shows that the subsoils contain as much or more potash than the soils, we find that we have here in an acre to the depth of 20 inches the enormous supply of 150,000 pounds (75 tons) of actual potash. With this information before us we can, at intervals, put in crops which will send their roots down into the subsoil and bring up some of the reserve supply; we can plow deep without fear of going beyond the supply of plant food, and we can employ cultural methods which will bring about a movement of the capillary moisture toward the surface.

With respect to the first sample, we find that the total supply of potash to the depth of 8 inches would be practically exhausted by 60 crops of potatoes. Here it would undoubtedly be necessary to supplement the natural supply by the addition of soluble potash salts. Thus our analysis may lead to entirely different treatment for the two soils.

In the same way analysis may show that one soil contains only 0.03% of nitrogen, equivalent to 720 pounds per 8-inch acre, while another may contain 0.2%, equivalent to 4,800 pounds per 8-inch acre. In the first instance it will be necessary to apply nitrogen in the form of commercial fertilizer for almost any crop that may be grown; in the second soil there is a liberal reserve supply, which, it is true, may not be readily available, but it is a potential factor which may be reckoned with in the cultivation of that soil. With proper cultural methods we may expect to render a part of this nitrogen available for each crop, and thereby reduce the bill for commercial fertilizers. If the analysis has shown that the soil is low in nitrogen and organic matter, it is an indication that the supply of humus is low. With this information at his command, the farmer can set out to restore the humus by the application of manure and by the use of leguminous crops, which will also increase the supply of available nitrogen.

On the other hand, if analysis shows that the soil is well supplied with organic matter, light is thrown on the important question of water-supply, the abundance of useful organisms, the depth to which we may safely plow, the time of planting, etc.

It is not here maintained that a "complete" analysis of soil is necessary, nor is it claimed that the farmer should be left to interpret the results for himself. A plea is made, however, for the determination of certain constituents, a knowledge of which, with careful interpretation, will enable the farmer to handle his soil in a more intelligent manner. It must be remembered, however, that no amount of plant food that is naturally present in the soil, or that applied as commercial fertilizers, can compensate for careless, indifferent methods of soil management.

THE SOIL AS A SOURCE OF PLANT FOOD.

In the following pages will be found the chemical analyses of a large number of samples of soil representing the various types recognized in the Sussex area. As has already been pointed out, the chemical analysis gives us a knowledge of our resources which cannot be gained in any other way. A mechanical analysis throws much light on the agricultural possibilities of a soil, but there is still lacking a definite knowledge of the resources at our command. A summary of the agricultural methods in actual practice also gives us much valuable information on the subject, but we cannot always construct on these practices a safe plan of soil improvement, nor rely upon them to give us maximum crop returns, for again, in many instances, these practices are not based on a knowledge of the actual agricultural possibilities of the soil, but rather upon the customs of the community for a generation past. Just as the expert bookkeeper knows all the assets and liabilities of his company, so should the agricultural expert know all the assets and liabilities of the soil; that is, he should be familiar with the present agricultural practices; he should know the composition of the soil, both chemical and physical, and the composition and feeding habits of the crops to be grown; he should know the amount of rainfall and be familiar with the climatic conditions and topography of the country. Possessed of these facts, he can plan systems of soil improvement and crop extension which will be far-reaching in their results.

POTASH.

Analysis shows that the soils of the Sussex area are, almost without exception, rich in potash. Rarely is the total less than 1.5% and often it reaches 3.00% and over. It is further found that the subsoils are in most cases richer in this material than the soils. From these figures it may be shown that an acre to the depth of 20 inches contains about 90,000 to 180,000 pounds (45 to 90 tons) of actual potash. This is reserve capital which may be drawn upon by crops for hundreds of years without fear of exhaustion. It must be admitted that this is largely unavailable for crops at the present time, and that it may even be necessary to add some soluble potash fertilizers in some cases, but knowing that potash is present in large quantities, and knowing that mineral matter—even the solid rock—is constantly decomposing under the action of atmospheric agencies, we can adopt such methods and such systems as will aid in setting free this locked-up plant food. It is well known, for example, that under certain conditions, lime will take the place of potash in these comparatively insoluble minerals, thus liberating the potash so that it forms compounds which can be assimilated by the plant. Since the analysis shows most of these soils to be naturally deficient in available lime, we can with confidence lay down the proposition that an application of lime or ground limestone will put into circulation for plant growth some of this stored-up potash capital. It is equally well understood that when organic matter decays in the soil carbon dioxide is formed, and when dissolved in the soil water acts as a solvent for the mineral matter of the soil. In this connection Clarke[1] says: "In a fertile region organic matter is abundant, and great quantities of carbonic acid are

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[1] The Data of Geochemistry, p. 72. See also Rocks, Rockweathering and Soils, by G. P. Merrill, pp. 237–38, and Soils, by E. W. Hilgard.

generated by its decay. This carbonic acid absorbed by the ground water of the soil, acts as a solvent of mineral matter, and carbonates are carried into the streams more abundantly than other salts." There is abundant proof that percolating ground waters do remove large quantities of mineral matter from the soil. Clarke[1] cites calculations made by T. Mellard Reade, on the amount of solid matter annually dissolved by water from the rocks of England and Wales. He estimates that the total annual run-off from the area in question carries in solution 8,370,630 tons of dissolved mineral matter, or 143.5 tons for each square mile of surface. Clarke[2] also reports the amount of saline matter carried annually to the sea by four American rivers, the St. Lawrence, Potomac, Mississippi and Colorado, as 143,834,400 tons, an amount equal to 79.6 tons per square mile. Sellards[3] estimates that from Central Peninsular Florida dissolved mineral matter is being carried into the sea at the rate of a little more than 400 tons per square mile annually. In this connection he says: "That underground water is efficient as a solvent is evident from the analyses of well and spring waters. Rain water entering the earth with almost no solids in solution returns to the surface through springs and wells with a load of mineral solids in solution determined by the length of time it has been in the ground, the distance traveled and the character of the rocks and minerals with which it comes in contact."

Since carbon dioxide, which results from the decay of organic matter in the soil, aids in bringing into solution the mineral constituents required by plants, it follows that increasing the organic matter in a soil naturally well supplied with potash, will aid in making this potash available. This organic matter can be supplied in the form of stable manure and green manure crops to be turned under. On such soils as the majority of those encountered in the Sussex area it is doubtful if soluble potash salts will be required to any great extent provided proper cultural methods are adopted.

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[1] Loc. cit., p. 89.

[2] Loc. cit.

[3] Preliminary Report on the Underground Water Supply of Central Florida. Florida Geological Survey, Bull. No. 1.

PHOSPHORIC ACID.

The soils of the Sussex area are usually well supplied with phosphoric acid. From the tables of analyses it will be seen that there is in most cases about 0.12 to 0.16% of this compound soluble in strong hydrochloric acid in the surface 8 inches, while the amount in the section 12 to 20 inches is almost invariably a little lower. If we assume that the average is represented by the lower figure, 0.12%, it means that in an acre to the depth of 20 inches there are 7,200 pounds of phosphoric acid. Since the average crop removes not more than 15 pounds of phosphoric acid per acre it is plain that we have here in the surface 20 inches enough phosphoric acid for nearly 500 crops. Taking Hilgard's estimate of 0.11% of phosphoric acid as a fair average for soils in humid regions, it is seen that the soils of the Sussex area are slightly above the average in this constituent. As in the case of the potash it must be admitted that much of this phosphoric acid is not immediately available, but with the proper methods of handling, it will gradually become available, so that usually only light applications of phosphates will be required.

LIME.

With reference to lime Hilgard says that in humid soils it varies from 0.1% in light sandy soils to 0.25% in clay loams, 0.3% in heavy clay soils, and that it may even rise to 1 or 2 per cent. to advantage. Judged by this standard most of the soils of the Sussex area are deficient in lime, at least in what we may term available lime.

As has already been intimated applications of lime would tend to make available some of the large supply of potash which is found here; it would also correct any acid condition which may exist, and put the soil in a more favorable condition for the beneficial bacteria which are such an important asset to the farmer in rendering plant food available. There are outcrops of limestone in many places in this section of the State, and this could easily be burned for use as lime, or ground fine to be used in the raw form.

A study of the soil analyses reported in the following tables shows that in nearly all the samples the magnesia is distinctly in excess of the lime. An exception to this rule is noted in the muck soils where the lime is in excess of the magnesia. In a few cases, notably the Gloucester stony sandy loam and the Genesee loam the magnesia is only slightly in excess of the lime so that the ratio is usually 1 to 1 and a fraction. In many of the samples the ratio is about 1 to 3 or 4, while in others it is 1 to 10 or 12, and in some as high as 1 to 24.

In this connection the question naturally arises, does this excess of magnesia over lime render these soils less productive than they otherwise would be? If Loew's theory that fertile soils generally show an excess of lime over magnesia is correct, then may it not be possible to increase the productiveness of these soils by heavy aplications of lime?

MAGNESIA.

Although magnesia is not usually regarded as a plant food in the same sense that nitrogen, phosphoric acid and potash are, still its almost entire absence, or its presence in large amounts, may have a marked influence on crop production.

In this connection Loew[1] says: "An excess of magnesia acts injuriously on plants, an observation made frequently and long ago. The increase of lime is the only decisive remedy. The plants thrive best when the ratio of lime to magnesia does not pass certain limits. Too little magnesia in relation to lime may retard development, while too much magnesia in relation to lime may injure the crop still more." On page 15 the same author says: "Every farmer ought to know the ratio of the easily assimilable portion of lime to magnesia in his soil, as with such knowledge he can tell when liming is needed and if magnesia will prove injurious. Soils with much magnesia are more to be feared than those with too little." After discussing the relation of lime to magnesia in many soils from various parts of

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[1] Liming of Soils from a Physiological Standpoint. Bull. No. 1, Bureau of Plant Industry, U. S. D. A., p. 10.

the United States and foreign countries, Loew[1] says: "It will be seen from the above review—

1. That the ratio of lime to magnesia ranges between wide limits.

2. That in the majority of cases lime predominates over magnesia.

3. That in all the instances of great fertility the soil never shows any marked excess of magnesia over lime, but, on the contrary, generally more lime than magnesia."

The following from May's[2] Summary of results from his studies of the relation of lime and magnesia to plant growth bears directly on this question: "Soil analyses show that lime and magnesia are widely distributed in soils and generally in sufficient quantities for the direct needs of plants. They are not always in the best proportions to each other from a physiological standpoint, for favoring plant growth. Magnesia in a soil in great excess over lime in a finely divided or soluble condition is noxious to the growth of plants. With a great excess of lime over magnesia the physiological action of the plant is hindered and it exhibits phenomena of starvation. An excess of lime counteracts the poisonous effects of magnesia, while the more favorable proportion of the two bases obviates the poor nutrition of the plant.

The best proportion of soluble lime to soluble magnesia for the germination and growth of plants is about molecular weight 5 to 4, or actual weight 7 to 4."

Hilgard[3] says: "In the case of soils containing much magnesia, the proper proportion between it and lime may be disturbed by the greater ease with which lime carbonate is carried away by carbonated waters in the subsoil, thus leaving the magnesia in undesirable excess in the surface soil. Hence the great advantage of having in a soil, from the outset, an ample proportion of lime. From this point of view alone, then, the analytical determination of lime and magnesia in soils is of high practical value."

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[1] Loc. cit.

[2] Experimental—Study of the Relation of Lime and Magnesia to Plant Growth. Bull. No. 1, Bureau of Plant Industry, U. S. D. A.

[3] Soils, p. 383.

Discussing the results obtained on the lime-magnesia ratio as influenced by concentration, Gile[1] says: "From this work it appears that we have to do not so much with the ratio of lime to magnesia as we have to do with the relation between whatever salt is in excess and all the other salts. That is, the question is not the simple one of a balancing of lime with magnesia, but a balancing of lime or magnesia with all the other nutrients. If the mere ratio in which lime and magnesia are present is the only factor operative, we should anticipate the yield to be affected by the ratio of these two salts in dilute as well as in concentrated solutions and independently of the other salts present. Such however, was not found to be the case. The facts, then, seem to point to the following conclusions: The toxicity of an excess of lime or magnesia is not due simply to an unfavorable ratio between these two salts alone, but to an unfavorable proportion between the salt which is in excess and all the other salts present."

In some pot experiments conducted at the New Jersey Experiment Station[2] it has been shown that magnesia, in excessive amounts, does have an injurious effect upon plant growth, and further that this injurious effect may be counteracted to some extent by the use of lime. The question cannot be fully answered, however, until field experiments have been conducted with a view to determining just what will be the effect of applications of lime to these soils in which there is an excess of magnesia. The question involved emphasizes the importance of determining the amount of lime and magnesia in soil-survey work.

NITROGEN.

One-tenth of one per cent. of nitrogen is, by some authorities, considered adequate for soils in humid regions. The surface soils of the Sussex area are above this amount, on the average. Even the subsoils—12 to 20 inches—usually contain 0.04 or 0.05%, which is as much as is frequently found in surface soils. If we take the average amount of nitrogen in all the soils as 0.15%,

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[1] Gile, P. L. Porto Rico Agrl. Expt. Station, Bulletin No. 12, p. 23.
[2] Report Soil Chemist and Bacteriologist, 1911.

we find that an acre to a depth of 8 inches contains 3,600 pounds of nitrogen. While this amount may at first thought seem large, we must not overlook the fact that nitrogen, more than any other of the materials, is being constantly leached out of the soil, and that the average crop will remove 40 to 60 pounds of it. Furthermore, much of this nitrogen is in the form of undecomposed vegetable matter and is not available except as it is gradually transformed into nitrates by natural agencies at work in the soil. A more liberal use of lime and deeper and more thorough cultivation will aid in transforming this nitrogen into plant food. With the more general use of leguminous crops to restore the humus thus used up, and to add to the stores of nitrogen already present, it should not be necessary to use large amounts of nitrogenous commercial fertilizers on these soils.

SOIL SERIES REPRESENTED.

The following series and types of soil occur in the Sussex area.

Till Soils	Dutchess	Loam Shale Loam Stony Loam
	Dover	Loam Stony Loam Fine Sandy Loam
	Gloucester	Loam Sandy Loam Stony Loam Stony Sandy Loam
	Wallpack	Silt Loam Stony Loam Shale Loam Fine Sandy Loam
	Lackawanna	Loam Stony Loam
Reworked Materials	Hoosic	Loam Sandy Loam Gravelly Loam
	Chenango	Loam Fine Sandy Loam Sandy Loam Silt Loam Fine Sand Sand
	Fox	Gravelly Loam

Alluvial Soils..........	Genesee Loam Papakating Silt Loam Wallkill Silty Clay Loam

Muck.

The distribution and character of the above soils are given in a separate bulletin on the Report on the Soil Survey of the Sussex Area, to which reference should be made for further data regarding them. The following discussion relates mainly to their mechanical and chemical constitution.

DUTCHESS SERIES.

The Dutchess soils are found in Kittatinny Valley and are characterized by the presence of varying quantities of slate and shale, differing with the individual type. The surface soils are grayish-brown when moist, becoming decidedly gray on drying. With the exception of the small area in the neighborhood of Postville, the series is confined to Kittatinny Valley. The types recognized are the loam, shale loam and stony loam.

Following are the results of the mechanical analyses of a series of samples of these soils collected during the survey:

RESULTS OF MECHANICAL ANALYSES OF REPRESENTATIVE SAMPLES OF THE DUTCHESS SERIES.

Soil Type.	Soil Number.	Coarse Gravel. Over 2 mm.	Fine Earth. Und. 2 mm.	Fine Gravel. 2–1	Coarse Sand. 1–0.5	Medium Sand. 0.5–0.25	Fine Sand. 0.25–0.1	Very Fine Sand. 0.1–0.05	Silt. 0.05–0.005	Clay. .005–0.000
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Loam, 0–8 inches, ...	99	16.4	83.6	2.9	4.1	3.1	10.0	17.3	45.4	17.0
Loam, 12–20 inches, ...	100	13.7	86.3	2.0	4.2	3.8	10.4	11.0	46.2	21.4
Loam, shaley phase, 0–7 inches, ...	95	23.3	76.7	6.0	5.0	3.2	7.5	6.3	54.9	16.9
Loam, shaley phase, 12–20 inches, ...	96	38.5	61.5	6.1	6.3	3.8	8.3	9.9	46.6	18.9
Shale loam, 0–7 inches, ...	119	45.2	54.8	8.4	5.9	3.8	7.8	5.9	49.7	18.4
Shale loam, 12–20 inches, ..	120	67.9	32.1	13.4	10.1	5.5	10.1	10.4	29.9	20.5

Dutchess Loam.

Chemical analyses of six soils and eight subsoils of the Dutchess loam type, taken from different localities are given in table on p. 32. From the analyses, averages have been made which will enable us the more easily to compare the soil with the subsoil and also this with other types.

The difference between the amount of insoluble matter in the soil and subsoil, as shown by these averages, is not great. There is in the soil 0.28% and in the subsoil 0.45% of potash soluble in strong hydrochloric acid, and 1.44% and 2.15% respectively of total potash. From this it appears that approximately one-fifth of the potash present is soluble in strong acid. This amount is above the average usually set for potash in the soils of the humid regions. It will be observed, too, that there is more potash in the subsoil than in the soil, both acid soluble and total. With proper treatment as to cultural methods, such a soil should require a minimum amount of potash in the form of commercial fertilizers. The averages show that this type is very deficient in lime, the average for the soils being only 0.08%, while several of the subsoils contain only a trace. Magnesia, on the other hand, is present in much larger amounts.

From the averages we find that the ratio of lime to magnesia in the soil is 1 : 8.5 and in the subsoil 1 : 5.1. We may also note here that there is more lime in the soil than in the subsoil, while the opposite is true of the magnesia.

There is more alumina than iron present in both soil and subsoil, and more of each in the soil than in the subsoil. The phosphoric acid soluble in strong hydrochloric acid is, in the soil, 0.135% and in the subsoil 0.107%, while the total phosphoric acid is slightly more in each case. Since Hilgard's standard for phosphoric acid in a productive soil is about 0.10%, it is seen that these soils, when judged by this standard, come well within the limits with respect to phosphoric acid. Hilgard further points out that a large supply of lime or humus or both may offset a smaller percentage of phosphoric acid, apparently by bringing about a greater availability.

The nitrogen in the soil is 0.161%, which is more than one and one-half times the 0.10% which Hilgard considers ordinarily adequate. In the subsoil it is 0.05%. If we assume that an acre of land to a depth of 8 inches weighs 2,400,000 pounds, we find that an acre of this soil to the depth of 8 inches contains 3,864 pounds of nitrogen. The carbon dioxide is so low as to be almost negligible, and we may therefore regard the total carbon as organic carbon. Of this there is 1.8%, which is equivalent to 43,680 pounds of carbon in an acre to a depth of 8 inches.

With the exception of lime, this type of soil is fairly well supplied with those substances which are generally considered under the head of fertilizers and soil amendments. The liberal use of lime would no doubt improve the physical condition of the soil and at the same time it would aid in making the other materials more available, especially the potash and nitrogen. In connection with lime, legumes could be used to good advantage to increase the supply of available nitrogen.

Dutchess Loam (shaley phase).

This type is represented by four samples of soil and four of subsoil. It is quite similar in chemical composition to the shale loam. Slight differences are to be noted, however. It is poorer in lime, magnesia and nitrogen, but is richer in phosphoric acid. It contains in the soil on the average about nine times as much magnesia as lime. The total phosphoric acid present is equivalent to about 5,000 pounds per 8-inch acre, while the nitrogen is equivalent to nearly 4,000 pounds per 8-inch acre. The total carbon present is equivalent to nearly 45,000 pounds per 8-inch acre, and this carbon is practically all of organic origin. This may be looked upon as a source of humus, though no doubt much of it is very old and therefore decays with exceeding slowness. As already pointed out, applications of lime will aid in the decomposition of this organic matter, but of even greater value in improving these soils will be a more general use of green manure crops to furnish a readily available supply of humus and nitrogen.

Dutchess Shale Loam.

This type is quite similar in composition to the loam. There are, however, a few differences which may be pointed out. There is distinctly less insoluble matter, the amount in both soil and subsoil being less than 80%. This is due in part at least to the fact that these soils contain more iron and alumina and more volatile matter than the loam soils. It also probably indicates a soil of somewhat finer texture.

The ratio of acid soluble to total potash is 1 : 4.72 and 1 : 5.3 in the soil and subsoil respectively. The ratio of lime to magnesia is 1 : 7.7 and 1 : 19 in the soil and subsoil respectively.

The potash, lime and magnesia in the surface soil are one-third to one-fourth higher in this type than in the loam, while the iron and alumina, as already pointed out, are distinctly higher. There is here, as in the loam, more alumina than iron and more of each in the subsoil than in the soil. The phosphoric acid in the soil is slightly less than in the loam, but if we take an average of the soil and subsoil we find that the two types are about the same; there is in each case a little more total than acid soluble phosphoric acid. In the soil there is 0.213%, and in the subsoil 0.07% of nitrogen. This is an unusually high percentage and is equivalent to approximately 5,000 pounds of nitrogen in an acre to the depth of 8 inches. The total carbon which, on account of the small amount of carbon dioxide may be considered as organic carbon, is distinctly higher than in the loam.

This soil contains more potential or reserve plant food than the loam, and there is good reason to believe that with liming, good cultural methods, and the use of legumes, it will yield excellent crops.

DUTCHESS LOAM.

Location,	1½ Mi. S. W. of Unionville.		½ Mi. East Drake's Pond.		2 Mi. N. Quarryville.		1 Mi. S. E. of Lafayette.		¾ Mi. N. Branchville.		½ Mi. N. W. of Greenville.				Average.	
	22-12-3-6-8-6*		22-31-5-7-2-6		22-12-3-6-8-6		22-31-3-6-1-7		22-21-4-2-7-5		21-44-3-4-8-8					
Depth of Sampling,	0–8″	12–20″	0–8″	12–20″	0–8″	12–20″	0–8″	12–20″	0–7″	12–20″	0–8″	8–18″	18–28″	28–36″		
Soil Number,	53	54	65	68	85	86	99	100	103	104	125	126	127	128	Soil	Sub-soil
Insoluble Matter,	80.34	86.28	82.62	81.83	83.70	87.02	88.22	84.39	81.64	86.25	80.39	82.69	82.97	82.93	82.82	84.30
Soluble Silica, SiO_2,	.05	.06	.06	.05	.03	.04	.05	.05	.06	.07	.05	.03	.04	.02	.05	.045
Potash, K_2O,	.33	.40	.27	.22	.31	.38	.21	.41	.25	.36	.33	.59	.62	.65	.28	.45
Soda, Na_2O,	.06	.07	.09	.07	.09	.09	.09	.11	.10	.10	.07	.09	.06	.07	.083	.082
Lime, CaO,	.09	.05	.08	.05	.02	.02	.05	.04	.01	.01	.23	Trace	Trace	Trace	.08	.02
Magnesia, MgO,	.72	.92	.62	1.00	.54	.65	.63	.88	.50	.45	1.07	1.44	1.46	1.40	.68	1.02
Manganese Oxide, Mn_3O_4,	.04	.02	.04	.04	.01	.03	.03	.03	.03	.03	.09	.07	.07	.07	.04	.045
Ferric Oxide, Fe_2O_3,	3.05	3.39	3.32	2.62	2.86	3.54	2.41	4.10	3.00	3.92	3.64	4.82	4.82	4.96	3.05	4.02
Alumina, Al_2O_3,	5.50	4.98	5.22	5.45	4.81	4.54	3.67	5.43	4.98	4.26	5.60	5.65	5.90	5.57	4.96	5.22
Phosphorus Pentoxide, P_2O_5,	.169	.105	.133	.082	.112	.093	.076	.07	.148	.098	.175	.128	.139	.139	.135	.107
Sulphur Trioxide, SO_3,	.03	.01	.08	.04	.07	.08	.06	.04	.05	.05	.10	.07	.04	.09	.065	.052
Carbon Dioxide, CO_2,	.03	.015	.025	.015	.035	.03	.03	.035	.05	.025	.06	.035	.05	.01	.038	.027
Volatile Matter,	9.42	3.89	7.64	8.45	7.50	3.56	4.39	4.50	8.98	3.80	8.12	4.32	3.89	3.75	7.67	4.52
Nitrogen,	.203	.058	.136	.052	.178	.045	.089	.037	.193	.040	.169	.068	.052	.049	.161	.05
Total Carbon,	2.16	.329	1.49	.347	2.28	.308	.895	.22	2.35	.353	1.75	.27	.122	.095	1.82	.255
Total Potash,	1.11	1.50	1.61	2.00	1.01	1.28	2.09	2.32	1.18	1.79	1.63	2.63	2.99	2.72	1.44	2.15
Total Soda,	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Total Phosphorus Pentoxide,	.219	.111	.145	.097	.134	.100	.087	.074	.168	.102	.205	.130	.143	.145	.16	.112
Hygroscopic Moisture,	......	......	......	......	......	......	......	......	......	......	1.54	.76	.76	.76	1.54	.76

* According to a system adopted by the State Geological Survey, these figures indicate the exact location.

DUTCHESS LOAM. (SHALEY PHASE.)

Location,	1½ Mi. W. of Newton.		1½ Mi. E. of Libertyville.		1 Mi. S. E. Unionville.		1¼ Mi. S. Stillwater.		Average.	
	21-35-4-5-5-9		22-12-8-1-8		22-13-1-2		21-34-8-4-8-2			
Depth of Sampling,	0–8″	12–20″	0–8″	12–20″	0–7″	12–20″	0–7″	12–20″		
Soil Number,	43	44	59	60	95	96	121	122	Soil	Sub-soil
Insoluble Matter,	78.36	81.31	79.63	87.98	79.70	82.25	82.61	84.66	80.07	84.05
Soluble Silica, SiO_2,	.06	.02	.06	.04	.08	.08	.05	.03	.062	.042
Potash, K_2O,	.33	.37	.38	.29	.29	.39	.26	.35	.315	.350
Soda, Na_2O,	.05	.21	.05	.04	.08	.07	.05	.09	.057	.102
Lime, CaO,	.08	.04	.11	.09	.12	.07	.12	.00	.107	.05
Magnesia, MgO,	1.09	1.14	.97	1.04	.66	.87	.92	1.00	.910	1.012
Manganese Oxide, Mn_3O_4,	.06	.06	.03	.02	.09	.03	.08	.04	.065	.037
Ferric Oxide, Fe_2O_3,	4.25	4.45	3.88	4.03	3.78	4.46	3.76	4.63	3.917	4.392
Alumina, Al_2O_3,	6.39	6.14	6.04	6.40	5.49	6.03	4.91	5.38	5.707	5.989
Phosphorus Pentoxide, P_2O_5,	.218	.172	.171	.10	.172	.151	.183	.114	.186	.109
Sulphur Trioxide, SO_3,	.05	.05	.05	.04	.06	.06	.08	.08	.06	.0575
Carbon Dioxide, CO_2,	.03	.025	....	.01	.06	.025	.045	.015	.034	.019
Volatile Matter,	8.56	5.58	8.40	5.76	8.86	5.09	7.04	3.64	6.215	5.017
Nitrogen,	.2065	.078	.161	.054	.187	.054	.137	.043	.173	.057
Total Carbon,	2.19	.835	1.65	.244	2.13	7.18	1.54	.198	1.877	.497
Total Potash,	1.58	1.80	1.73	2.04	1.47	1.81	1.94	2.52	1.680	2.042
Total Soda,	....	....	....	....	....	....	....	....	....	....
Total Phosphorus Pentoxide,	.259	.176	.215	.117	.202	.16	.185	.122	.215	.144
Hygroscopic Moisture,	....	....	....	....	....	....	....	....	....	....

DUTCHESS SHALE LOAM.

Location,	1½ Mi. E. of Augusta. 22-21-9-1-2-9		2 Mi. W. of Newton. 21-35-4-2-2-6		5 Mi. N. of Sussex. 22-12-2-6-4-5		2⅔ Mi. W. of Middleville. 21-33-3-9-4-5		2 Mi. S. of Stillwater. 21-34-7-9-4-5		Average.	
Depth of Sampling,	0–7″	12–20″	0–8″	12–20″	0–8″	12–20″	0–7″	12–20″	0–7″	12–20″		
Soil Number,	71	72	75	76	88	87	119	120	179	180	Soil	Sub-soil
Insoluble Matter,	79.13	85.25	74.62	78.51	72.40	77.60	78.14	74.90	75.45	78.90	75.95	79.03
Soluble Silica, SiO_2,	.06	.05	.07	.05	.05	.03	.05	.03	.08	.06	.06	.044
Potash, K_2O,	.25	.28	.31	.40	.56	.60	.24	.36	.35	.29	.34	.39
Soda, Na_2O,	.07	.05	.06	.07	.08	.10	.08	.11	.08	.11	.074	.088
Lime, CaO,	.07	.02	.18	.12	.02	.02	.24	.04	.16	.16	.13	.07
Magnesia, MgO,	.39	.72	1.20	1.32	1.16	1.28	.89	1.50	1.34	1.77	1.00	1.32
Manganese Oxide, Mn_3O_4,	.02	.02	.04	.03	.05	.03	.02	.01	.11	.03	.05	.02
Ferric Oxide, Fe_2O_3,	3.02	2.62	4.98	4.91	5.53	5.58	3.87	6.46	5.05	6.05	4.49	5.12
Alumina, Al_2O_3,	4.52	5.77	6.58	8.13	7.93	8.30	6.67	8.05	7.96	6.78	6.73	7.41
Phosphorus Pentoxide, P_2O_5,	.098	.115	.08	.077	.126	.135	.173	.24	.207	.194	.137	.152
Sulphur Trioxide, SO_3,	.04	.03	.06	.04	.07	.08	.09	.14	......	......	.06	.07
Carbon Dioxide, CO_2,	.047	.02	.065	.025	.065	.035	.05	.035	.04	.015	.053	.026
Volatile Matter,	12.39	5.08	11.63	6.28	12.09	6.56	9.75	7.97	9.42	5.52	11.06	6.28
Nitrogen,	.179	.048	.222	.065	.273	.079	.213	.090	.18	.071	.213	.071
Total Carbon,	1.88	.343	2.70	.645	3.02	.533	2.43	.774	2.10	.368	2.43	.53
Total Potash,	1.21	.81	1.75	1.85	1.56	1.86	1.51	2.77	2.00	3.04	1.606	2.06
Total Soda,	......	......	......	......	......	......	......	......	......	......	......	......
Total Phosphorus Pentoxide,	.100	.117	.106	.084	.157	.146	.192	.247	.23	.195	.157	.158
Hygroscopic Moisture,	......	......	......	......	......	......	......	......	......	......	......	......

DOVER SERIES.

The soils of the Dover series occur in the limestone districts of Kittatinny, Sparta, and Vernon valleys. The series is characterized by the presence of limestone boulders and outcropping of the underlying limestone formation. This gives the surface of much of this series a warty appearance. The soils invariably have a brown surface with a yellow subsoil. The Dover soils have a greater producing power than any of the other series of the area. The types recognized are the loam with a light phase, stony loam, and fine sandy loam.

The following mechanical analyses give the relative differences in texture of this series.

RESULTS OF MECHANICAL ANALYSES OF REPRESENTATIVE SAMPLES OF THE DOVER SERIES.

SOIL TYPE.	Soil Number.	Coarse Gravel. Over 2 mm.	Fine Earth. Und. 2 mm.	Fine Gravel. 2–1 mm.	Coarse Sand. 1–0.5	Medium Sand. 0.5–0.25	Fine Sand. 0.25–0.1	Very Fine Sand. 0.1–0.05	Silt. 0.05–0.005	Clay. 0.005–0.000
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Loam, 0–6 in., ..	146	25.0	75.0	5.2	6.6	5.1	13.9	7.6	49.0	12.3
Loam, 12–20 in., .	147	20.6	79.4	3.9	6.3	4.7	11.6	9.3	38.6	25.5
Loam, Light Phase, 0–8 in., .	169	16.4	83.6	4.4	8.7	7.4	18.1	11.4	38.4	11.4
Loam, Light Phase, 12–20 in.,	170	16.8	83.2	4.0	9.1	8.5	20.2	15.1	30.4	12.8
Stony Loam, 0–8 in., ...	73	32.4	67.6	2.11	2.39	2.62	12.02	25.05	35.10	20.14
Stony Loam, 12–20 in., ...	74	31.9	68.1	3.49	3.89	3.81	15.44	24.74	28.46	20.65
Fine Sandy Loam, 0–8 in., ...	101	6.5	93.5	.9	1.1	2.1	17.0	24.3	43.6	10.9
Fine Sandy Loam, 12–20 in., ...	102	6.7	93.3	.5	1.7	2.4	18.4	30.5	35.0	11.4

Dover Loam and Dover Stony Loam.

The Dover soils are regarded as glaciated soils which occur in limestone districts. A large part of the material from which they were formed is supposed to have been derived from limestone. If we may judge from the analyses here reported, the lime has already been largely leached out, for in neither the loam nor the stony loam do we find the average for the soils reaching 0.2%, the amount reported by Hilgard as the average for the soils of the humid regions of the United States. In the loams, the average for the subsoils is slightly higher than for the soils, while in the stony loams the reverse is true. The average for the acid soluble potash in the loams is in the soil 0.203% and in the subsoil 0.448%; the total potash in the soil and subsoil is 2.46% and 2.92% respectively. The soil, both loam and stony loam, contains approximately three times as much magnesia as lime. The total phosphoric acid is, for the soil, 0.134%, and for the subsoil 0.126%, while the nitrogen is 0.145% and 0.048% for the soil and subsoil respectively. The stony loam contains slightly less of the plant food materials—nitrogen, phosphoric acid, potash, and lime—than the loam.

Dover Fine Sandy Loam.

Only one sample of the Dover fine sandy loam is reported. In this sample the percentage of insoluble matter is very nearly the same in both soil and subsoil, the average being about 89%, which is higher than is found in most of the types. The potash content does not differ greatly from that of the Dutchess and Gloucester series. It may be pointed out that the total potash is less in the subsoil than in the soil. The lime present is little more than a trace, while the magnesia also is low. The ratio of lime to magnesia is in the soil about 1 : 12 and in the subsoil 1 : 10. The low nitrogen and carbon indicate a deficiency of organic matter. The phosphoric acid is slightly lower than has been observed in most of the types.

DOVER LOAM.

Location,	¾ Mi. N. of North Church. 22-5-6-7-8-9		Squire's Corners. 21-43-3-1-3-5		2 Mi. N. of Vernon. 22-13-9-3-9-3		Average.	
Depth of Sample,	0"-6"	12"-20"	0"-8"	12"-20"	0"-6"	12"-20"		
Sample Number,	49	50	215	216	146	147	Soil.	Sub-soil.
Insoluble Matter,	88.36	84.03	87.48	85.08	84.96	82.16	86.93	83.75
Soluble Silica, SiO_2,	.04	.04	.04	.03	.07	.05	.05	.04
Potash, K_2O,	.17	.46	.21	.37	.23	.51	.203	.448
Soda, Na_2O,	.08	.07	.04	.09	.09	.14	.07	.10
Lime, CaO,	.14	.14	.09	.06	.16	.57	.13	.259
Magnesia, MgO,	.62	.86	.52	.60	.39	1.10	.51	.85
Manganese Oxide, Mn_3O_4,	.02	.05	.10	.04	.06	.10	.06	.063
Ferric Oxide, Fe_2O_3,	2.38	2.88	2.65	4.43	2.98	4.96	2.67	4.09
Alumina, Al_2O_3,	3.73	6.59	3.41	4.99	2.13	5.11	3.09	5.56
Phosphorus Pentoxide, P_2O_5,	.079	.061	.116	.133	.144	.145	.113	.113
Carbon Dioxide, CO_2,	.015	.025	.025	.015	.035	.370	.025	.136
Volatile Matter,	4.40	4.92	5.29	4.22	8.96	4.75	6.21	4.63
Nitrogen,	.108	.044	.132	.038	.197	.063	.145	.048
Total Carbon,	1.06	.222	1.51	.268	2.05	.632	1.54	.374
Total Potash,	1.77	2.43	2.79	2.64	2.82	3.71	2.46	2.92
Total Soda,	....	....	.29	.62	.91	.96	.60	.79
Total Phosphorus Pentoxide,	.096	.068	.128	.138	.18	.172	.134	.126
Hygroscopic Moisture,	....	....	....	....	2.32	1.51	2.32	1.51

DOVER LOAM. (LIGHT PHASE.)

Location,	⅔ Mi. N. of Hardistonville. 22–22–6–6–9–4		1 Mi. N. W. of Franklin Furnace. 22–22–8–6–6–3		Average.	
Depth of Sample,	0″–8″	12″–20″	0″–8″	12″–20″		
Sample Number,	169	170	171	172	Soil.	Sub-soil.
Insoluble Matter,	87.58	88.69	86.17	85.93	86.87	87.31
Soluble Silica, SiO_2,	.06	.05	.07	.02	.065	.035
Potash, K_2O,	.07	.28	.19	.39	.13	.335
Soda, Na_2O,	.03	.06	.08	.06	.055	.06
Lime, CaO,	.26	.19	.22	.21	.24	.20
Magnesia, MgO,	.68	.84	.54	.90	.61	.87
Manganese Oxide, Mn_3O_4,	.05	.06	.04	.06	.045	.06
Ferric Oxide, Fe_2O_3,	2.62	3.05	3.05	3.93	2.835	3.49
Alumina, Al_2O_3,	3.56	3.92	3.58	4.73	3.570	4.325
Phosphorus Pentoxide, P_2O_5,	.158	.088	.135	.143	.146	.1155
Carbon Dioxide, CO_2,	.035	.02	.035	.015	.035	.0175
Volatile Matter,	4.96	2.71	5.69	3.32	5.32	3.015
Nitrogen,	.115	.026	.153	.136	.138	.083
Total Carbon,	1.38	.278	1.52	.38	1.45	.329
Total Potash,	2.73	2.95	2.78	3.66	2.755	3.31
Total Soda,	.90	1.08	1.06	1.12	.98	1.10
Total Phosphorus Pentoxide,	.169	.098	.167	.145	.168	.1215
Hygroscopic Moisture,	1.19	.93	1.28	1.02	1.235	.975

DOVER STONY LOAM.

Location,	1½ Mi. W. of Monroe Corners. 22-22-7-1-8-8		⅓ Mi. N. of Iliff's Pond. 22-31-5-8-7-8		1½ Mi. S. W. of Stillwater. 21-33-9-6-3-8		Average.	
Depth of Sampling,	0″-8″	12″-20″	0″-8″	12″-20″	0″-4″	12″-20″		
Soil Number,	73	74	81	82	213	214	Soil.	Sub-soil.
Insoluble Matter,	84.61	83.32	87.80	86.03	87.59	82.87	86.667	84.07
Soluble Silica, SiO_2,	.06	.05	.01	.01	.03	.03	.033	.03
Potash, K_2O,	.18	.32	.18	.33	.15	.30	.170	.317
Soda, Na_2O,	.04	.06	.04	.09	.09	.06	.057	.070
Lime, CaO,	.17	.13	.20	.15	.09	.06	.153	.113
Magnesia, MgO,	.62	.87	.45	.78	.46	.70	.510	.787
Manganese Oxide, Mn_3O_4,	.02	.05	....	.03	.01	.035	.015	.038
Ferric Oxide, Fe_2O_3,	2.50	3.03	2.43	3.50	2.05	4.73	2.327	3.753
Alumina, Al_2O_3,	4.12	6.84	4.02	5.16	3.53	6.09	3.890	6.030
Phosphorus Pentoxide, P_2O_5,	.086	.086	.061	.04	.083	.094	.077	.073
Sulphur Trioxide, SO_3,	.03	.04	.05	.04	....	....	.040	.040
Carbon Dioxide, CO_2,	.03	.10	.045	.02	.03	.02	.035	.047
Volatile Matter,	7.60	4.96	4.67	3.72	6.08	4.98	6.117	4.555
Nitrogen,	.103	.041	.077	.028	.156	.039	.112	.036
Total Carbon,	1.13	.346	1.08	.268	2.05	.95	1.420	.521
Total Potash,	1.51	1.92	1.36	1.81	2.49	3.04	1.787	2.257
Total Soda,	....	....	....	....	.50	.94	.500	.940
Total Phosphorus Pentoxide,	.102	.095	.064	.048	.107	.095	.091	.079
Hygroscopic Moisture,	....	....	....	....	....	....	....	....

Dover Fine Sandy Loam.

Location,	200 yds. S. E. of Monroe's Corners. 22-22-7-6-9-7	
Depth, of Sampling,	0"-8"	12"-20"
Soil Number,	101	102
Insoluble Matter,	88.84	89.08
Soluble Silica, SiO_2,	.05	.04
Potash, K_2O,	.21	.54
Soda, Na_2O,	.06	.13
Lime, CaO,	.02	.05
Magnesia, MgO,	.25	.50
Manganese Oxide, Mn_3O_4,	.03	.02
Ferric Oxide, Fe_2O_3,	2.28	2.57
Alumina, Al_2O_3,	3.40	4.12
Phosphorus Pentoxide, P_2O_5,	.121	.092
Sulphur Trioxide, SO_3,	.06	.04
Carbon Dioxide, CO_2,	.035	.02
Volatile Matter,	4.48	2.89
Nitrogen,	.097	.024
Total Carbon,	1.02	.251
Total Potash,	1.88	1.18
Total Soda,	....	....
Total Phosphorus Pentoxide,	.137	.168
Hygroscopic Moisture,	....	....

GLOUCESTER SERIES.

The soils of the Gloucester series occur chiefly on the crystalline rocks of the Highlands. They are derived immediately from the mantle of glacial drift, but since this is chiefly local in origin, the soils of this series are all characterized by the presence of materials derived from the underlying gneiss through their mechanical disintegration and chemical decomposition. These soils, as a rule, are sandy and stony. All are more or less characterized by the presence of small mica fragments, which are thoroughly mixed with the soil mass, and in some cases give the soils a slightly greasy feel.

The following types are represented: Rough stony land, loam, stony loam, sandy loam and stony sandy loam.

Mechanical analyses are as follows:

RESULTS OF MECHANICAL ANALYSES OF REPRESENTATIVE SAMPLES OF GLOUCESTER SERIES.

SOIL TYPE.	Soil Number.	Coarse Gravel. Over *2 mm.*	Fine Earth. Und. *2 mm.*	Fine Gravel. *2–1*	Coarse Sand. *1–0.5*	Medium Sand. 0.5–0.25	Fine Sand. 0.25–0.1	Very Fine Sand. 0.1–0.05	Silt. 0.05–0.005	Clay. 0.005–0.000
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Loam, 0–10 in., .	135	14.8	85.2	3.0	6.7	6.2	14.9	11.1	46.2	11.7
Loam, 12–20 in., .	136	32.6	67.4	5.7	9.6	8.3	17.5	13.9	31.1	13.5
Stony Loam, 0–7 in., ...	154	15.1	84.9	4.1	4.9	4.5	14.3	11.7	46.5	13.8
Stony Loam, 12–20 in., ...	155	31.2	68.8	2.7	4.3	4.2	15.4	15.0	44.9	13.3
Stony Sandy Loam, 0–7 in., .	131	27.7	77.5	4.0	10.4	9.3	21.2	12.6	32.1	10.3
Stony Sandy Loam, 12–20 in.,	132	22.5	72.3	5.2	11.4	9.5	19.6	14.6	30.2	9.3
Sandy Loam, 0–8 in., ...	41	15.7	84.3	9.31	11.1	7.64	21.87	12.99	26.37	10.85
Sandy Loam, 12–20 in., ...	42	13.4	86.4	11.1	12.47	8.68	22.68	13.14	22.46	10.17

In this series analyses have been made of sixteen soils and sixteen subsoils, as follows: five of loam, three of sandy loam, four of stony loam and four of stony sandy loam. The four types are quite similar in chemical composition, though there are some important differences between this series and the Dutchess series.

The soils and subsoils of the Gloucester series are higher in insoluble matter, lime and potash than those of the Dutchess series. On first thought the higher percentage of insoluble matter might seem to indicate less plant food. This does not, however, seem to be the case with the Gloucester series. There is more lime and potash than there is in the Dutchess series and nearly as much phosphoric acid and nitrogen, but there is less iron and alumina and total carbon.

The average amount of total potash in the soil for the four types is 2.60%, while the amount in the subsoil is even greater, The average amount of acid soluble potash in the soils is 0.17%, or about 1/15 of the total, while in the subsoil it is 0.245%.

The average amount of lime in the soil is 0.31% and the magnesia 0.54%, which gives a ratio of lime to magnesia of 1 : 1.74.

The ratio in the loam is 1 : 2.46, in the sandy loam 1 : 1.15, in the stony loam 1 : 3, and in the stony sandy loam 1 : 1.23. It may be of interest to note that in this series the ratio nowhere exceeds 1 : 3.

The average amount of total carbon in the four types is, 1.72%, which is about ⅛ less than the amount found in the Dutchess series. It may be pointed out that the sandy loam, which is the lowest in nitrogen, is also lowest in total carbon, while the stony loam, which is the highest in nitrogen, is also highest in total carbon. Since the carbon is practically all of organic origin (there being scarcely more than a trace of carbon dioxide present), there is, in an 8-inch acre of this soil, over 40,000 pounds of organic carbon. This represents organic matter which, under proper methods, may be looked to to supply nitrogen and humus. Taking the averages, there is in this series invariably more alumina than iron; and, with one exception, more of both in the subsoil than in the soil.

GLOUCESTER LOAM.

Location,	1 Mi. E. of Mulford.		2 Mi. N. E. of Sparta.		½ Mi. S. of Glenwood.		4¾ Mi. E. of Vernon.		1 Mi. N. E. of Monroe Corners.		Average.	
	22-31-6-6-8-4		22-32-5-6-3-2		22-13-6-8-1-2		22-14-9-7-9-7		22-22-8-5-5-1			
Depth of Sampling,	0–8″	12–20″	0–10″	12–20″	0–8″	12–20″	0–8″	12–20″	0–10″	12–20″		
Soil Number,	66	67	135	136	152	153	156	157	165	166	Soil	Sub-soil
Insoluble Matter,	79.62	80.35	85.23	88.27	86.37	85.99	83.96	86.77	87.57	90.33	84.55	86.34
Soluble Silica, SiO_2,	.05	.06	.04	.04	.07	.03	.03	.03	.07	.06	.05	.04
Potash, K_2O,	.17	.34	.19	.26	.26	.39	.29	.44	.14	.18	.21	.32
Soda, Na_2O,	.06	.06	.12	.19	.08	.07	.08	.09	.07	.06	.08	.09
Lime, CaO,	.29	.32	.38	.33	.19	.18	.05	.04	.40	.18	.26	.21
Magnesia, MgO,	.71	1.01	.62	1.01	.54	.84	.79	1.04	.54	.47	.64	.87
Manganese Oxide, Mn_3O_4,	.03	.02	.10	.10	.10	.02	.03	.01	.02	.01	.06	.03
Ferric Oxide, Fe_2O_3,	2.57	3.12	2.91	3.32	2.35	2.35	2.80	3.72	1.86	2.85	2.50	3.07
Alumina, Al_2O_3,	5.13	7.14	4.07	3.68	3.83	6.18	4.49	4.26	3.59	3.07	4.22	4.86
Phosphorus Pentoxide, P_2O_5,	.108	.078	.083	.064	.118	.073	.112	.073	.124	.10	.109	.078
Sulphur Trioxide, SO_3,	.06	.05	.06	.06	....	....	....	....	....	....	.06	.05
Carbon Dioxide, CO_2,	.02	.015	.03	.017	.065	.02	.06	.02	.02	.01	.04	.016
Volatile Matter,	10.87	7.27	6.63	3.25	5.93	3.75	7.03	3.28	5.89	2.73	7.27	4.06
Nitrogen,	.121	.031	.152	.061	.149	.046	.185	.062	.141	.046	.150	.049
Total Carbon,	1.39	.238	1.06	.513	1.73	.30	1.96	.306	1.81	.431	1.59	.358
Total Potash,	2.64	3.55	2.88	3.48	1.90	2.30	2.48	2.28	3.00	2.95	2.58	2.91
Total Soda,	....	....	1.48	1.21	1.07	1.02	2.02	1.08	1.15	1.25	1.43	1.14
Total Phosphorus Pentoxide,	.113	.084	.108	.079	.14	.079	.138	.091	.144	.113	.129	.089
Hygroscopic Moisture,	....	....	1.29	1.23	1.64	1.44	1.88	.80	1.38	.65	1.55	1.03

GLOUCESTER SANDY LOAM.

Location,	2 Mi. S. E. of Iliff's Pond. 22–31–9–8–1–9		3¼ Mi. S. of Sparta. 22–41–3–6–9–6		1½ Mi. S. of Sparta. 22–32–8–4–8–1.		Average.	
Depth of Sampling,	0″–6″	12″–20″	0″–8″	12″–20″	0″–8″	12″–20″	Soil.	Sub-soil.
Soil Number,	41	42	123	124	137	144		
Insoluble Matter,	84.43	88.66	85.09	86.70	84.55	86.85	84.60	87.40
Soluble Silica, SiO_2,	.03	.04	.03	.01	.05	.23	.03	.09
Potash, K_2O,	.14	.19	.13	.18	.16	.28	.14	.22
Soda, Na_2O,	.11	.17	.11	.05	.09	.09	.10	.10
Lime, CaO,	.59	1.21	.37	.51	.39	.35	.45	.69
Magnesia, MgO,	.59	.69	.44	.62	.53	.71	.52	.67
Manganese Oxide, Mn_3O_4,	.05	.03	.09	.05	.06	.04	.07	.04
Ferric Oxide, Fe_2O_3,	3.27	3.17	3.98	5.07	4.03	4.82	3.76	4.35
Alumina, Al_2O_3,	3.98	3.38	3.55	3.56	3.83	3.83	3.79	3.59
Phosphorus Pentoxide, P_2O_5,	.168	.104	.156	.107	.145	.11	.156	.107
Sulphur Trioxide, SO_3,	.05	.04	.00	.08	....	....	.045	.085
Carbon Dioxide, CO_2,	.06	....	.10	.04	.065	.02	.075	.05
Volatile Matter,	6.41	2.06	6.03	3.07	6.01	3.13	6.15	2.75
Nitrogen,	.137	.028	.139	.030	.118	.032	.131	.03
Total Carbon,	1.84	.285	1.07	.217	1.01	.22	1.31	.24
Total Potash,	2.94	3.08	3.17	3.14	3.08	3.24	3.06	2.89
Total Soda,	....	....	....	....	1.86	1.45	.186	1.45
Total Phosphorus Pentoxide,	.187	.103	.161	.121	.177	.108	.175	.11
Hygroscopic Moisture,	....	....	1.23	.97	1.99	.78	1.61	.87

GLOUCESTER STONY LOAM.

Location,	1½ Mi. W. of Sparta. 22-31-6-9-9-9		3½ Mi. E. of Vernon. 22-24-2-1-5-4		⅓ Mi. N. of Glenwood. 22-13-6-5-1-1		1½ Mi. S. of Vernon. 22-23-3-7-3-3		Average.	
Depth of Sampling,	0-7″	12-20″	0-8″	12-20″	0-7″	12-20″	0-7″	12-20″		
Soil Number,	142	143	150	151	155	154	158	159	Soil	Sub-soil
Insoluble Matter,	82.59	85.47	79.62	85.38	89.15	89.65	85.40	86.08	84.19	86.64
Soluble Silica, SiO_2,	.16	.11	.05	.06	.03	.04	.04	.02	.07	.057
Potash, K_2O,	.18	.26	.28	.33	.17	.17	.19	.27	.205	.257
Soda, Na_2O,	.07	.06	.21	.25	.07	.06	.08	.12	.11	.12
Lime, CaO,	.40	.41	.08	.06	.05	Trace	.23	.16	.19	.157
Magnesia, MgO,	.78	.95	.53	.71	.48	.69	.48	.69	.57	.76
Manganese Oxide, Mn_3O_4,	.07	.04	.02	.045	.02	.01	.01	.04	.03	.034
Ferric Oxide, Fe_2O_3,	3.57	4.41	2.98	2.52	2.03	1.61	3.39	4.35	2.99	3.22
Alumina, Al_2O_3,	5.17	4.59	4.94	5.91	2.62	5.09	3.33	3.93	4.01	4.88
Phosphorus Pentoxide, P_2O_5,	.166	.145	.142	.122	.078	.063	.118	.122	.126	.113
Sulphur Trioxide, SO_3,										
Carbon Dioxide, CO_2,	.05	.015	.065	.025	.05	.02	.05	.035	.054	.024
Volatile Matter,	7.33	3.79	10.82	4.76	5.15	2.73	6.45	4.11	7.44	3.85
Nitrogen,	.164	.036	.223	.094	.143	.033	.165	.062	.174	.056
Total Carbon,	1.89	.307	3.61	.775	1.60	.274	1.97	.68	2.27	.509
Total Potash,	2.48	2.89	1.72	1.90	1.72	2.09	2.99	3.57	2.22	2.61
Total Soda,	1.06	1.14	.87	.97	1.56	1.61	1.61	1.56	1.27	1.32
Total Phosphorus Pentoxide,	.181	.144	.167	.132	.095	.095	.13	.141	.143	.128
Hygroscopic Moisture,	1.67	1.05	2.88	1.55	1.32	.79	1.41	1.11	1.82	1.12

GLOUCESTER STONY SANDY LOAM.

Location,	1 Mi. S. of Sparta. 22-32-7-6-5-2		2¼ Mi. S. W. Sparta. 22-32-7-8-7-4		3 Mi. E. of Sparta. 22-32-6-9-2-9		3⅓ Mi. W. Vernon. 22-13-7-8-2-5		Average.	
Depth of Sampling,	0–7″	12–20″	0–7″	12–20″	0–8″	12–20″	0–8″	12–20″		
Soil Number,	131	132	133	134	138	139	160	161	Soil	Sub-soil
Insoluble Matter,	87.29	89.34	85.66	87.19	77.11	83.03	86.38	89.03	84.11	87.15
Soluble Silica, SiO_2,	.04	.03	.05	.05	.04	.03	.03	.03	.04	.035
Potash, K_2O,	1.10	.12	.14	.19	.16	.23	.14	.18	.13	.18
Soda, Na_2O,	.11	.14	.15	.13	.08	.10	.11	.10	.11	.12
Lime, CaO,	.33	.30	.32	.41	.49	.56	.24	.25	.35	.38
Magnesia, MgO,	.41	.43	.41	.68	.56	.64	.32	.34	.43	.52
Manganese Oxide, Mn_3O_4,	.03	.03	.06	.04	.12	.07	.02	.01	.06	.04
Ferric Oxide, Fe_2O_3,	2.69	3.05	3.71	4.18	6.20	6.67	2.11	1.64	3.68	3.88
Alumina, Al_2O_3,	3.14	3.31	3.72	4.37	5.40	4.89	4.54	4.73	4.20	4.32
Phosphorus Pentoxide, P_2O_5,	.099	.095	.120	.101	.285	.163	.104	.112	.152	.118
Sulphur Trioxide, SO_3,	.07	.06	.06	.06	....	....	....	....	.06	.06
Carbon Dioxide, CO_2,	.035	.085	.035	.01	.08	.05	.06	.03	.05	.044
Volatile Matter,	5.64	3.06	5.32	2.54	9.21	3.47	6.29	3.63	6.61	3.18
Nitrogen,	.12	.045	.097	.023	.196	.046	.143	.055	.139	.042
Total Carbon,	1.31	.36	1.15	.219	2.71	.451	1.73	.556	1.72	.40
Total Potash,	2.28	2.33	2.92	2.68	2.44	3.08	2.48	2.60	2.53	2.67
Total Soda,	....	....	....	....	1.67	1.00	1.98	2.22	1.82	1.61
Total Phosphorus Pentoxide,	.119	.104	.131	.112	.321	.166	.124	.124	.174	.126
Hygroscopic Moisture,	.86	.80	1.17	.76	2.68	1.25	1.48	1.22	1.55	1.00

LACKAWANNA SERIES.

The soils of the Lackawanna series as they occur in the area overlie the red shales of the Highfalls formation, which are found on the west slope of Kittatinny Mountain. They are characterized by their red color, and are locally called "red shell (shale) lands." Only two types of this series were encountered in the present area. They are the loam and stony loam. The mechanical analyses of the Lackawanna loam are shown in the table, p. 49, while the chemical composition of the type is given in connection with the Wallpack series (p. 52).

RESULTS OF MECHANICAL ANALYSES OF REPRESENTATIVE SAMPLES OF THE LACKAWANNA LOAM.

SOIL TYPE.	Soil Number.	Coarse Gravel. Over 2 mm.	Fine Earth.	Fine Gravel. 2–1	Coarse Sand. 1–0.5	Medium Sand. 0.5–0.25	Fine Sand. 0.25–0.1	Very Fine Sand. 0.1–0.05	Silt. 0.05–0.005	Clay. 0.005–0.000
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Loam, 0–9 in., ...	199	48.	52.	7.16	3.49	4.26	9.44	13.96	46.33	15.36
Loam, 12–20 in., .	200	33.	67.	7.31	3.75	4.37	10.13	14.36	45.23	14.85

MECHANICAL ANALYSES OF REPRESENTATIVE SAMPLES OF THE WALLPACK SERIES.

SOIL TYPE.	Soil Number.	Coarse Gravel. Over 2 mm.	Fine Earth.	Fine Gravel. 2–1	Coarse Sand. 1–0.5	Medium Sand. 0.5–0.25	Fine Sand. 0.25–0.1	Very Fine Sand. 0.1–0.05	Silt. 0.05–0.005	Clay. 0.005–0.000
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Silt Loam, 0–7 in., ...	183	20.	80.	6.4	4.9	5.23	8.72	9.96	45.71	19.05
Silt Loam, 12–20 in., ...	184	10.8	89.2	6.6	4.5	4.48	7.06	10.85	42.54	23.94
Shale Loam, 0–7 in., ...	207	49.	51.	11.7	3.87	2.23	2.23	2.53	50.07	27.4
Shale Loam, 12–20 in., ...	208	64.	36.	13.3	7.55	4.16	3.06	2.00	31.78	38.12

The discussion of the chemical composition of the type is found in connection with the Wallpack series.

WALLPACK SERIES.

The Wallpack series is found exclusively on the Wallpack Ridge west of Kittatinny Mountain. This series overlies the various limy shales and limestones of this region. It is distinguished from the Dover series by the cherty character of the rock fragments and varying physical characteristics.

Four types are represented, a silt loam with a heavy subsoil phase, fine sandy loam, shale loam and stony loam.

The mechanical analyses appear on page 49.

Wallpack Silt Loam. Wallpack Silt Loam, Heavy Subsoil Phase. Lackawanna Loam.

The samples representing these three types are so similar in chemical composition that it seems proper to discuss them together. The amount of insoluble matter is higher than in the Dutchess, Gloucester or Hoosic series, and corresponds more nearly to the Dover series. Both the acid-soluble and total potash are somewhat lower than in the Dutchess, Gloucester or Hoosic series. With the exception of one sample of the Wallpack heavy silt loam, they are all deficient in lime—only a trace being reported in most cases. This is hardly to be expected in the Wallpack silt loam, since it is underlain by a limestone formation. It is, however, only another indication of the ease with which the lime is leached out of soils, even those that originally contained a large amount of lime. In most cases the magnesia ranges from 0.4 to 0.6%, and, comparing this with the small amount of lime that is present, it is at once seen that the magnesia is decidedly in excess. Of the three samples the Lackawanna loam is lowest in phosphoric acid, and the Wallpack loam, heavy subsoil phase, is the highest. There appears to be a wider difference in the amount of phosphoric acid found in the soil and subsoil than is usually the case in the loam soils of the area. In the majority of the cases represented here there is little more than a trace of carbon dioxide, which indicates that practically all of the carbon is of organic origin. The average amount of nitrogen in the soil is about 0.14% and in the subsoil about 0.04%. In some respects these types chemically resemble the Chenango series, though they are richer in nitrogen than the Chenango soils.

LACKAWANNA LOAM.

Location,	½ Mi. E. Wallpack Centre. 21–24–4–3–9–8		1 Mi. S. E. Hainesville. 21–15–4–7–3–3		Average.	
Depth of Sample,	0″–9″	12″–20″	0″–7″	12″–20″	Soil.	Sub-soil.
Sample Number,	199	200	205	206		
Insoluble Matter,	84.83	87.56	89.39	91.46	87.11	89.51
Soluble Silica, SiO_2,	.05	.08	.07	.03	.055	.055
Potash, K_2O,	.28	.31	.22	.34	.25	.325
Soda, Na_2O,	.045	.03	.07	.06	.057	.045
Lime, CaO,	TRACE	TRACE	....	.02	TRACE	.01
Magnesia, MgO,	.57	.60	.33	.48	.45	.54
Manganese Oxide, Mn_3O_4,	.045	.04	.04	TRACE	.042	.02
Ferric Oxide, Fe_2O_3,	2.39	2.84	1.66	2.32	2.02	2.58
Alumina, Al_2O_3,	4.24	4.38	3.40	2.95	3.82	3.66
Phosphorus Pentoxide, P_2O_5,	.123	.097	.134	.07	.128	.083
Carbon Dioxide, CO_2,	.015	.01	.005	.01	.01	.01
Volatile Matter,	7.27	4.09	5.06	2.31	6.16	3.2
Nitrogen,	.172	.049	.097	.025	.134	.037
Total Carbon,	2.10	.49	1.451	.213	1.775	.351
Total Potash,	1.07	1.21	.80	1.17	.935	1.19
Total Soda,	.50	.48	.36	.36	.43	.42
Total Phosphorus Pentoxide,	.149	.121	.136	.073	.142	.097

WALLPACK SILT LOAM.

Location,	½ Mi. W. of Layton. 21-14-8-5-2-3		2 Mi. N. W. Layton. 21-14-8-2-3-5		Average.	
Depth of Sample,	0"-7"	12"-20"	0"-7"	12"-20"		
Sample Number,	183	184	211	212	Soil.	Sub-soil.
Insoluble Matter,	86.31	87.82	87.98	90.46	87.14	89.14
Soluble Silica, SiO_2,	.07	.05	.06	.03	.065	.04
Potash, K_2O,	.12	.31	.18	.29	.15	.30
Soda, Na_2O,	.08	.07	.06	.07	.07	.07
Lime, CaO,	.04	.06	TRACE	TRACE	.02	.03
Magnesia, MgO,	.76	.97	.43	.54	.59	.75
Manganese Oxide, Mn_3O_4,	.015	.035	.03	.015	.022	.025
Ferric Oxide, Fe_2O_3,	2.72	3.21	1.95	2.50	2.33	2.85
Alumina, Al_2O_3,	3.80	4.49	3.14	3.57	3.47	4.03
Phosphorus Pentoxide, P_2O_5,	.119	.06	.155	.064	.137	.062
Carbon Dioxide, CO_2,	.04	.01	.01	.005	.025	.007
Volatile Matter,	5.91	2.98	6.25	2.66	6.08	2.82
Nitrogen,	.146	.038	.144	.04	.145	.039
Total Carbon,	1.62	.28	1.95	.341	1.785	.31
Total Potash,	1.16	1.57	.74	1.26	.95	1.415
Total Soda,	.54	.61	.36	.39	.45	.50
Total Phosphorus Pentoxide,	.127	.075	.198	.086	.162	.08

WALLPACK SILT LOAM. (HEAVY SUBSOIL PHASE.)

Location,	½ Mi. N. Bevans. 21-14-8-8-8-7		2 Mi. N. Layton. 21-14-6-8-1-5		Average.	
Depth of Sample,	0"-8"	12"-20"	0"-7"	12"-20"	Soil.	Sub-soil
Sample Number,	185	186	209	210		
Insoluble Matter,	86.75	90.33	88.03	90.06	87.39	90.19
Soluble Silica, SiO_2,	.08	.06	.05	.01	.065	.035
Potash, K_2O,	.19	.15	.18	.25	.185	.20
Soda, Na_2O,	.05	.07	.06	.044	.055	.057
Lime, CaO,	.22	.03	.05	TRACE	.135	.015
Magnesia, MgO,	.42	.58	.42	.57	.42	.575
Manganese Oxide, Mn_3O_4,	.03	.015	TRACE	.015	.015	.015
Ferric Oxide, Fe_2O_3,	2.03	2.50	2.00	2.70	2.03	2.55
Alumina, Al_2O_3,	3.65	3.31	3.25	3.39	3.45	3.35
Phosphorus Pentoxide, P_2O_5,	.202	.071	.151	.097	.176	.084
Carbon Dioxide, CO_2,	.04	.01	.02	.005	.03	.007
Volatile Matter,	6.55	2.88	5.78	2.96	6.16	2.92
Nitrogen,	.153	.042	.135	.041	.144	.041
Total Carbon,	1.78	.293	1.71	.273	1.745	.283
Total Potash,	.97	1.19	.80	1.31	.885	1.25
Total Soda,	.45	.47	.40	.36	.42	.41
Total Phosphorus Pentoxide,	.222	.088	.173	.106	.197	.097

Wallpack Shale Loam.

This type is represented by only one soil and one subsoil. It is fairly well supplied with the fertilizing elements—nitrogen, phosphoric acid, potash and lime. The percentage of nitrogen is unusually high, being equivalent to more than 5,000 pounds per 8-inch acre. The subsoil also contains more nitrogen than the majority of samples found in this region. The ratio of lime to magnesia in the soil is approximately 1 : 3. Such a soil will require a minimum of commercial fertlizers if good cultural methods are adopted.

WALLPACK SHALE LOAM.

Location,	1 Mi. S. W. Hainesville. 21-14-6-5-9-1	
Depth of Sample,	0"-7"	12"-20"
Sample Number,	207	208
Insoluble Matter,	82.62	82.72
Soluble Silica, SiO_2,	.07	.06
Potash, K_2O,	.27	.38
Soda, Na_2O,	.07	.05
Lime, CaO,	.25	.11
Magnesia, MgO,	.74	1.04
Manganese Oxide, Mn_3O_4,	.035	.03
Ferric Oxide, Fe_2O_3,	2.12	3.85
Alumina, Al_2O_3,	4.79	5.63
Phosphorus Pentoxide, P_2O_5,	.148	.192
Carbon Dioxide, CO_2,	.050	.035
Volatile Matter,	8.40	5.78
Nitrogen,	.226	.106
Total Carbon,	2.76	.891
Total Potash,	1.36	2.20
Total Soda,	.52	.43
Total Phosphorus Pentoxide,	.186	.213

HOOSIC SERIES.

The soils of the Hoosic series occur on sand and gravel deposits made by glacial waters during the closing stages of the ice period. Both soil and subsoil are characterized by rounded, water-worn pebbles and the absence of boulders, except in very rare instances. In distribution they are not limited in elevation, although found more frequently along valley bottoms than on hilltops, and they occur in all parts of the district. The members of the series are the Hoosic loam, Hoosic sandy loam and Hoosic gravelly loam.

RESULTS OF MECHANICAL ANALYSES OF REPRESENTATIVE SAMPLES OF THE HOOSIC SERIES.

SOIL TYPE.	Soil Number.	Coarse Gravel. Over 2 mm.	Fine Earth. Und. 2 mm.	Fine Gravel. 2–1	Coarse Sand. 1–0.5	Medium Sand. 0.5–0.25	Fine Sand. 0.25–0.1	Very Fine Sand. 0.1–0.05	Silt. 0.05–0.005	Clay. 0.005–0.000
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Loam, 0–8 in., . .	79	15.99	84.01	4.75	4.42	2.77	9.10	22.46	38.66	18.91
Loam, 12–20 in., .	80	34.1	65.9	5.22	4.88	3.0	9.90	22.49	34.09	19.90
Gravelly Loam, 0–7 in., ...	91	30.5	69.5	4.9	6.5	4.4	13.6	11.9	42.6	15.2
Gravelly Loam; 12–20 in., ...	92	40.8	59.2	7.0	11.4	7.4	18.2	14.8	27.4	12.8
Sandy Loam, 0–6 in., ...	45	7.21	92.79	5.39	8.72	8.07	24.40	11.02	27.34	15.80
Sandy Loam, 12–20 in., ...	46	47.9	52.1	18.06	22.34	12.18	15.98	5.69	16.12	11.68

Hoosic Loam.

This type is represented by four samples of soil and four of subsoil. The acid-soluble potash in the soil is 0.25% and in the subsoil 0.41%. The total potash in the soil and subsoil is 1.79% and 2.39% respectively. The average amount of lime in the soil is 0.19%, which is practically the amount named by Hilgard as the average for the soils of the humid region of the United States. The average for the total phosphoric acid in the soils is 0.196 and in the subsoils 0.14%, while the nitrogen in the soils is 0.17% and in the subsoils 0.05%.

From the above figures it is seen that these soils are fairly well supplied with nitrogen, phosphoric acid, potash and lime—enough for many crops provided they can be made available. Thorough cultivation and the more general use of green manure crops will help to unlock this stored-up plant food.

Hoosic Sandy Loam.

This type is very similar in chemical composition to the loams of this series. From an examination of the two tables it is seen that the sandy loam does not contain quite as much of the fertilizing constituents as the loam, although it could not be considered greatly deficient in any of these materials. With good cultural methods and the use of green manures the productiveness of these soils can be distinctly increased.

Hoosic Gravelly Loam.

This type is represented by seven samples of soil and subsoil. The average figures for these seven samples, both soils and subsoils, are very similar to the average for the four samples of Hoosic loam. Indeed, from a chemical standpoint a separation could hardly be made. From the mechanical standpoint, however, the gravelly loam contains a higher percentage of fine gravel and a lower percentage of clay. This also is a soil which with proper treatment can be brought into a good state of productiveness.

HOOSIC LOAM.

Location, ...	½ Mi. W. of Baleville.		1 Mi. S. E. of Augusta.		1½ Mi. W. Hamburg.		½ Mi. N. Layton.		Average.	
	22-21-7-7-4-8		22-21-8-2-8-9		22-22-9-2-1-4		21-14-9-2-7-7			
Depth of Sampling, ...	0–8″	12–20″	0–8″	12–20″	0–8″	12–20″	0–7″	12–20″	Soil	Sub-soil
Soil Number, ...	79	80	83	84	167	168	203	204		
Insoluble Matter, ...	82.97	85.19	81.40	79.94	84.83	78.78	82.57	86.84	82.94	82.69
Soluble Silica, SiO_2, ...	.04	.04	.02	.02	.02	.07	.07	.05	.04	.045
Potash, K_2O, ...	.21	.33	.31	.48	.24	.50	.23	.35	.247	.415
Soda, Na_2O, ...	.04	.06	.07	.14	.08	.12	.09	.08	.07	.10
Lime, CaO, ...	.23	.09	.25	.11	.21	.23	.08	.02	.192	.112
Magnesia, MgO, ...	.66	.71	.76	.92	.54	1.41	.59	.77	.64	.95
Manganese Oxide, Mn_3O_4, ...	.06	.02	.04	.04	.05	.07	.11	.10	.065	.057
Ferric Oxide, Fe_2O_3, ...	3.15	3.57	3.73	5.03	3.57	4.95	2.15	2.73	3.15	4.07
Alumina, Al_2O_3, ...	5.14	5.35	5.55	7.20	4.15	8.21	4.95	5.21	4.95	6.49
Phosphorus Pentoxide, P_2O_5, ...	.065	.088	.135	.125	.124	.185	.38	.13	.176	.132
Sulphur Trioxide, SO_3, ...	.07	.06	.08	.05	....	....	....	....	.075	.055
Carbon Dioxide, CO_2, ...	.07	.015	.055	.03	.04	.03	.025	.015	.047	.022
Volatile Matter, ...	7.53	4.27	7.52	5.62	5.77	5.13	8.93	4.02	7.44	4.76
Nitrogen, ...	.168	.045	.173	.066	.131	.056	.211	.047	.171	.053
Total Carbon, ...	2.00	.403	1.97	.557	1.65	.466	2.68	.393	2.075	.455
Total Potash, ...	1.19	1.75	1.60	1.49	3.36	5.04	1.00	1.29	1.79	2.39
Total Soda, ...	....	....	....	....	.93	.79	.49	.48	.71	.63
Total Phosphorus Pentoxide, ...	.096	.093	.154	.138	.149	.186	.385	.13	.196	.139
Hygroscopic Moisture, ...	....	....	....	....	....	....	....	....	....	....

HOOSIC SANDY LOAM.

Location,	¼ Mi. East of Augusta. 22-21-8-1-6-8		1½ Mi. N. of Sussex. 22-12-6-8-9-1		15 Rods East of Mulford. 22-31-5-6-9-7		2 Mi. N. W. of Lafayette. 22-21-8-8-2-8		Average.	
Depth of Sampling,	0–6″	12–20″	0–8″	12–20″	0–8″	12–20″	0–7″	12–20″		
Soil Number,	45	46	61	62	78	77	89	90	Soil	Sub-soil
Insoluble Matter,	84.58	83.48	79.88	82.28	87.41	85.51	84.97	86.06	84.21	84.33
Soluble Silica, SiO_2,	.05	.05	.06	.06	.04	.04	.04	.04	.05	.05
Potash, K_2O,	.32	.52	.32	.45	.23	.35	.30	.32	.29	.41
Soda, Na_2O,	.11	.08	.06	.05	.06	.11	.06	.08	.07	.08
Lime, CaO,	.17	.06	.17	.29	.20	.18	.15	.06	.17	.15
Magnesia, MgO,	.68	1.13	.82	1.07	.64	1.06	.72	.89	.71	1.04
Manganese Oxide, Mn_3O_4,	.09	.04	.09	.03	.03	.03	.04	.03	.06	.03
Ferric Oxide, Fe_2O_3,	2.81	3.93	3.75	3.91	5.02	4.47	3.71	3.25	3.32	3.89
Alumina, Al_2O_3,	5.04	6.29	5.68	6.71	4.07	4.86	3.62	5.15	4.60	5.75
Phosphorus Pentoxide, P_2O_5,	.154	.145	.189	.192	.088	.085	.147	.135	.144	.139
Sulphur Trioxide, SO_3,	.08	.06	.04	.07	.06	.07	.06	.05	.06	.06
Carbon Dioxide, CO_2,	.03	.01	.045	.005	.035	.017	.05	.035	.04	.017
Volatile Matter,	6.03	3.97	9.07	5.02	4.29	3.28	6.20	3.75	6.40	4.00
Nitrogen,	.128	.055	.195	.056	.079	.030	.119	.037	.13	.044
Total Carbon,	1.30	.36	1.45	.399	1.08	.205	1.31	.241	1.28	.30
Total Potash,	1.75	2.08	1.10	1.93	2.09	1.95	2.33	2.74	1.82	2.18
Total Soda,	....	....	....	....	....	....	....	....	....	....
Total Phosphorus Pentoxide,	.183	.160	.213	.193	.090	.090	.168	.139	.163	.145
Hygroscopic Moisture,	....	....	....	....	....	....	....	....	....	....

Hoosic Gravelly Loam.

Location,	½ Mi. E. of Branchville.		1½ Mi. N. E. of Sussex.		¼ Mi. S. E. of Papakating.		1¼ Mi. W. of Lafayette.		3½ Mi. N. of Sparta.		1 Mi. N. W. of Vernon.		Layton.		Average.	
	22-21-4-9-6-7		22-12-9-3-7-7		22-21-6-3-8-4		22-31-2-3-4-1		22-32-1-6-4-2		22-13-9-4-9-1		21-14-9-4-6-8			
Depth of Sampling,	0-8″	12-20″	0-8″	12-20″	0-8″	12-20″	0-7″	12-20″	0-8″	12-20″	0-8″	12-20″	0-7½″	12-20″	Soil	Sub-soil
Soil Number,	51	52	55	56	69	70	91	92	140	141	148	149	201	202		
Insoluble Matter,	80.19	82.48	79.06	83.54	81.15	85.59	82.12	83.90	82.52	82.64	85.94	83.38	83.55	86.17	82.08	83.96
Soluble Silica, SiO_2,	.03	.03	.05	.05	.09	.07	.07	.08	.05	.09	.07	.03	.05	.06	.06	.06
Potash, K_2O,	.35	.40	.47	.48	.36	.38	.36	.42	.25	.45	.34	.48	.30	.37	.347	.426
Soda, Na_2O,	.05	.05	.12	.06	.06	.05	.06	.08	.07	.07	.08	.54	.12	.05	.08	.13
Lime, CaO,	.14	.09	.14	.06	.02	.05	.09	.03	.23	.14	.27	1.47	.08	Trace	.14	.26
Magnesia, MgO,	.81	.85	1.11	1.18	.82	1.03	.93	1.07	.79	1.29	.81	1.53	.65	.97	.84	1.13
Manganese Oxide, Mn_3O_4,	.03	.06	.05	.03	.05	.03	.03	.04	.12	.04	.09	.03	.08	.07	.06	.04
Ferric Oxide, Fe_2O_3,	3.42	3.34	4.35	3.93	4.25	2.93	3.21	2.64	3.56	5.41	3.31	3.50	2.52	3.18	3.52	3.56
Alumina, Al_2O_3,	5.53	6.78	5.55	6.16	5.16	5.84	5.70	6.74	4.89	5.45	3.69	4.54	4.71	4.83	4.75	5.76
Phosphorus Pentoxide, P_2O_5,	.235	.185	.214	.179	.094	.093	.136	.120	.203	.125	.13	.145	.175	.094	.17	.134
Sulphur Trioxide, SO_3,	.10	.09	.04	.02	.03	.02	.13	.05	......	......	......	......	......	......	.07	.04
Carbon Dioxide, CO_2,	.035	.025	.03	.02	.015	.03	.055	.025	.05	.01	.05	.109	.035	.01	.038	.033
Volatile Matter,	9.21	5.54	9.02	4.44	7.52	3.70	7.07	5.02	7.16	4.72	5.12	4.46	8.00	4.36	7.58	4.60
Nitrogen,	.206	.079	.225	.066	.144	.04	.149	.045	.180	.051	.138	.037	.195	.056	.177	.053
Total Carbon,	2.23	.548	2.08	.477	1.46	.204	1.55	.316	2.47	.389	1.41	.72	2.63	.58	1.98	.462
Total Potash,	1.24	1.73	1.86	1.81	1.69	2.16	1.55	1.77	3.18	4.16	2.36	2.48	1.13	1.30	1.858	2.201
Total Soda,	......	......	......	......	......	......	......	......	2.00	.44	.94	1.53	.86	.35	1.27	.77
Total Phosphorus Pentoxide,	.251	.193	.236	.199	.113	.101	.150	.126	.215	.126	.167	.147	.205	.111	.191	.143
Hygroscopic Moisture,	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......

FOX GRAVELLY LOAM.

This soil, like those of the Hoosic series, is derived from stratified material but occurs in a limestone section. A large part of the material making up the soil and subsoil is limestone and the soil consequently has a higher agricultural value.

The mechanical analysis is as follows:

SOIL TYPE.	Soil Number.	Coarse Gravel. Over 2 mm.	Fine Earth. Und. 2 mm.	Fine Gravel. 2–1	Coarse Sand. 1–0.5	Medium Sand. 0.5–0.25	Fine Sand. 0.25–0.1	Very Fine Sand. 0.1–0.05	Silt. 0.05–0.005	Clay. 0.005–0.000
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Gravelly Loam, 0–7 in., ...	94	27.3	72.7	5.5	6.3	3.0	5.2	8.9	52.9	18.1
Gravelly Loam, 12–20 in., ...	93	56.3	43.7	13.1	12.1	5.4	8.9	4.3	36.6	19.5

Only one sample of this soil was analyzed. As in the Chenango loam the potash is practically the same in the soil and subsoil. The ratio of acid soluble to total potash is 1 : 3.93. The insoluble matter constitutes nearly 80%, which is less than is found in the loams generally, excepting the Dutchess series. The ratio of lime to magnesia in the soil is 1 : 3.7 and in the subsoil it is 1 : 8. There is more alumina than iron and more of each in the subsoil than in the soil. The phosphoric acid is about 0.15% in both soil and subsoil. The percentage of nitrogen in the soil is 0.183, which is above the average. This is equivalent to nearly 4,400 pounds per 8-inch acre. The ratio of nitrogen to total carbon is 1 : 10.5.

FOX GRAVELLY LOAM.

Location,	1⅓ Mi. S. of Newton. 21-35-4-9-9-6	
Depth of Sampling,	0″–7″	12″–20″
Soil Number,	94	93
Insoluble Matter,	79.57	79.84
Soluble Silica, SiO_2,	.06	.06
Potash, K_2O,	.31	.40
Soda, Na_2O,	.08	.08
Lime, CaO,	.23	.14
Magnesia, MgO,	.85	1.11
Manganese Oxide, Mn_3O_4,	.06	.04
Ferric Oxide, Fe_2O_3,	3.75	5.09
Alumina, Al_2O_3,	5.92	7.19
Phosphorus Pentoxide, P_2O_5,	.149	.147
Sulphur Trioxide, SO_3,	.08	.07
Carbon Dioxide, CO_2,	.07	.025
Volatile Matter,	8.63	5.85
Nitrogen,	.183	.067
Total Carbon,	1.92	.474
Total Potash,	1.38	1.41
Total Soda,	....	....
Total Phosphorus Pentoxide,	.159	.150
Hygroscopic Moisture,	....	....

CHENANGO SERIES.

The soils of the Chenango series occur in the upper Delaware Valley. They are soils having a brown to dark-brown surface and vary in texture with the different types. This series represents deposits made by the river when it was flowing at a higher level than at the present time. The types mapped are a silt loam, loam, fine sandy loam, sandy loam, fine sand, and sand.

Following are the results of mechanical analyses of representive samples of the different types:

RESULTS OF MECHANICAL ANALYSES OF REPRESENTATIVE SAMPLES OF THE CHENANGO SERIES.

SOIL TYPE.	Soil Number.	Coarse Gravel. Over 2 mm.	Fine Earth. Und. 2 mm.	Fine Gravel. 2–1	Coarse Sand. 1–0.5	Medium Sand. 0.5–0.25	Fine Sand. 0.25–0.1	Very Fine Sand. 0.1–0.05	Silt. 0.05–0.005	Clay. 0.005–0.000
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Fine Sandy Loam, 0–10 in., ...	189	.14	99.8	.23	.06	2.6	32.11	16.67	39.30	8.92
Fine Sandy Loam, 12–20 in., ...	190	0.00	100.	.02	.05	.74	26.71	19.47	43.54	9.57
Loam, 0–10 in., ..	181	.03	99.7	.03	.22	.81	16.3	23.88	47.02	11.74
Loam, 12–20 in.,.	182	0.00	100.	.04	.07	.37	10.51	26.80	48.41	13.80
Silt Loam, 0–10 in., ...	187	0.00	100.	.12	.40	1.94	9.84	11.25	57.37	19.09
Silt Loam, 12–20 in., ...	188	0.00	100.	.025	.36	1.66	11.67	13.84	50.65	21.82
Sandy Loam, 0–8 in., ...	191	3.0	97.	7.93	13.6	26.18	24.78	5.08	15.33	7.11
Sandy Loam, 12–20 in., ...	192	4.7	95.	8.96	12.5	25.73	28.37	5.69	12.94	5.74
Fine Sand, 0–10 in., ...	197	.3	99.7	.135	.460	8.38	49.35	18.88	18.13	4.678
Fine Sand, 12–20 in., ...	198	0.00	100.	.03	.40	7.06	31.36	16.7	33.78	10.78
Sand, 0–8 in., ...	193	0.00	100.	.45	11.5	40.88	27.59	7.95	7.53	4.15
Sand, 12–20 in., .	194	0.00	100.	.73	13.96	40.78	26.25	4.42	8.97	5.00

The Chenango series of soils are high in insoluble matter, the average for the six types being close to 90%. On the other hand nearly all the members of the series contain a lower percentage of plant food constituents than most of the series encountered in the area. The acid-soluble potash varies from 0.14 to 0.34%, while the highest total potash is 1.59 and the lowest 0.65%. In most cases not more than a trace of lime was found, the highest being 0.1% in the loam. The magnesia varies from 0.3% to 0.56%. Throughout the series the iron and alumina are unusually low, as is also the volatile matter. The acid-soluble phosphoric acid varies from 0.06 to 0.18 with an average in both soils and subsoils of 0.1%. In nearly all cases the total phosphoric acid is slightly higher than the acid-soluble. The nitrogen and total carbon are both low, indicating a deficiency of humus.

CHENANGO FINE SANDY LOAM.

Location,	1 Mi. N. Montague. 21–5–7–5–1–7		1½ Mi. N. W. Layton. 21–14–5–8–7–3		Average.	
Depth of Sample,	0″–10″	12″–20″	0″–8″	12″–20″		
Sample Number,	189	190	195	196	Soil.	Sub-soil.
Insoluble Matter,	90.40	91.91	88.67	91.86	89.53	91.88
Soluble Silica, SiO_2,	.07	.07	.07	.04	.07	.055
Potash, K_2O,	.11	.21	.14	.16	.125	.185
Soda, Na_2O,	.14	.06	.06	.05	.1	.055
Lime, CaO,	....	.06	TRACE	TRACE	TRACE	.03
Magnesia, MgO,	.50	.45	.40	.47	.45	.46
Manganese Oxide, Mn_3O_4,	.04	.045	.05	.01	.045	.027
Ferric Oxide, Fe_2O_3,	2.03	1.91	1.89	2.18	1.96	2.04
Alumina, Al_2O_3,	2.94	2.96	3.24	2.95	3.09	2.95
Phosphorus Pentoxide, P_2O_5,	.097	.08	.181	.069	.139	.074
Carbon Dioxide, CO_2,	.027	.01	.02	.005	.023	.007
Volatile Matter,	3.78	2.18	5.30	2.27	4.54	2.22
Nitrogen,	.07	.029	.118	.022	.094	.025
Total Carbon,	.89	.435	1.46	.21	1.175	.322
Total Potash,	1.16	1.21	.76	.94	.96	1.075
Total Soda,	.97	.37	.34	.44	.655	.405
Total Phosphorus Pentoxide,	.118	.082	.213	.071	.165	.076

CHENANGO LOAM.

Location,	2 Mi. N. W. Hainesville. 21-14-3-4-7-6		2 Mi. S. W. Bevans. 21-24-4-1-1-6		Average.	
Depth of Sample,	0-10″	12-20″	0-7″	12-20″		
Sample Number,	181	182	130	129	Soil	Sub-soil
Insoluble Matter,	89.39	89.54	90.09	89.81	89.74	89.625
Soluble Silica, SiO_2,	.07	.06	.05	.05	.06	.055
Potash, K_2O,	.26	.17	.27	.27	.265	.220
Soda, Na_2O,	.08	.08	.14	.09	.110	.085
Lime, CaO,	.10	.10	.10	.07	.10	.085
Magnesia, MgO,	.50	.56	.43	.57	.465	.565
Manganese Oxide, Mn_3O_4,	.06	.10	.08	.10	.07	.10
Ferric Oxide, Fe_2O_3,	2.41	2.88	2.44	3.21	2.425	2.545
Alumina, Al_2O_3,	3.24	2.98	2.88	3.23	3.060	3.105
Phosphorus Pentoxide, P_2O_5,	.095	.087	.134	.147	.114	.117
Carbon Dioxide, CO_2,	.02	.025	.065	.02	.042	.022
Volatile Matter,	4.01	3.53	3.46	2.60	3.735	3.065
Nitrogen,	.094	.062	.076	.047	.085	.054
Total Carbon,	.996	.593	.713	.265	.854	.429
Total Potash,	1.47	1.59	1.13	1.48	1.300	1.535
Total Soda,	.65	.55	....	....	.65	.55
Total Phosphorus Pentoxide,	.112	.109	.15	.153	.131	.131

	CHENANGO SILT LOAM.		CHENANGO SANDY LOAM.		CHENANGO FINE SAND.		CHENANGO SAND.	
Location,	3 Mi. S. W. Tri-States Rock. 22-1-4-8-7		1 Mi. S. W. Montague. 21-14-3-3-4-7		2 Mi. N. W. Layton. 21-14-5-7-5-2		2 Mi. N. W. Hainesville. 21-14-2-9-3-3	
Depth of Sample,	0"-10"	12"-20"	0"-8"	12"-20"	0"-10"	12"-20"	0"-8"	12"-20"
Sample Number,	187	188	191	192	197	198	193	194
Insoluble Matter,	87.64	88.89	91.25	94.18	92.92	91.06	92.99	92.71
Soluble Silica, SiO_2,	.07	.05	.08	.05	.07	.03	.08	.08
Potash, K_2O,	.16	.34	.14	.15	.21	.22	.137	.14
Soda, Na_2O,	.08	.07	.045	.065	.11	.04	.04	.04
Lime, CaO,	.06	.01	.04	.02	.02	TRACE	TRACE	TRACE
Magnesia, MgO,	.56	.51	.30	.32	.33	.50	.33	.34
Manganese Oxide, Mn_3O_4,	.15	.11	.045	.015	.065	.05	.01	.015
Ferric Oxide, Fe_2O_3,	2.82	3.20	1.39	1.34	1.89	2.41	1.94	2.10
Alumina, Al_2O_3,	3.99	3.61	2.63	2.43	2.18	2.95	2.35	2.78
Phosphorus Pentoxide, P_2O_5,	.136	.132	.156	.082	.063	.118	.104	.09
Carbon Dioxide, CO_2,	.025	.015	.020	.005	.01	.01	.02	.005
Volatile Matter,	4.25	2.89	3.78	1.69	2.13	2.52	2.01	1.70
Nitrogen,	.079	.032	.087	.023	.038	.029	.032	.014
Total Carbon,	.84	.339	1.06	.132	.387	.222	.398	.118
Total Potash,	1.44	1.55	.65	.78	1.11	1.24	.71	.896
Total Soda,	.55	.52	.28	.32	.48	.47	.25	.27
Total Phosphorus Pentoxide,	.158	.132	.169	.09	.076	.12	.117	.094

GENESEE SERIES.

The better-drained bottom land soils of the area are represented by the Genesee loam. Where there is little danger from inundation it is a valuable type for the production of cultivated crops, especially corn. Following are the mechanical analyses of this type:

RESULTS OF MECHANICAL ANALYSES OF A REPRESENTATIVE SAMPLE OF GENESEE LOAM.

SOIL TYPE.	Soil Number.	Coarse Gravel. Over 2 mm.	Fine Earth. Und. 2 mm.	Fine Gravel. 2–1	Coarse Sand. 1–0.5	Medium Sand. 0.5–0.25	Fine Sand. 0.25–0.1	Very Fine Sand. 0.1–0.05	Silt. 0.05–0.005	Clay. 0.005–0.000
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Loam, 0–8 in., ..	57	6.1	94.9	1.17	1.74	3.29	14.89	24.17	34.78	21.09
Loam, 12–20 in.,	58	4.4	95.6	.2	1.47	1.98	19.30	27.56	28.21	22.72

Genesee Loam.

Two samples of soil and two of subsoil were analyzed from the Genesee loam. The sample from near Sparta is low in acid-soluble potash, and unusually high in total potash, the ratio being 1 : 17.4. The ratio of acid-soluble to total potash in the soil and subsoil of the Sussex sample is 1 : 5.48 and 1 : 4.9 respectively. It is of interest to note that the amount of potash in an acre of the Sparta sample to the depth of 20 inches is 177,600 pounds (88.8 tons), but that a comparatively small proportion of this, 10,200 pounds (5.1) tons, is soluble in strong hydrochloric acid.

The ratio of lime to magnesia in the soil and subsoil of the Sparta sample is 1 : .82 and 1 : 1 respectively, while in the Sussex sample it is 1 : 4.7 and 1 : 5.3. From the amount of carbon dioxide present in the Sparta sample it is apparent that this soil contains considerable carbonate of lime or magnesia or both. The Sussex samples, on the other hand, are low in lime and contain scarcely more than a trace of carbon dioxide. The average amount of phosphoric acid in the two samples is about the same as is found in the loams generally and there is slightly more in the subsoil than in the soil.

GENESEE LOAM.

Location,	1½ Mi. N. E. of Sparta. 22-32-5-5-1-9		S. of Road Across Clove River in Sussex. 22-12-8-9-1-6		Average.	
Depth of Sampling,	0″-8″	12″-20″	0″-8″	12″-20″		
Soil Number,	163	164	57	58	Soil.	Sub-soil.
Insoluble Matter,	79.74	84.50	81.46	83.66	80.60	84.08
Soluble Silica, SiO_2,	.06	.04	.10	.07	.08	.05
Potash, K_2O,	.18	.16	.23	.36	.20	.26
Soda, Na_2O,	.09	.12	.04	.04	.06	.08
Lime, CaO,	1.42	.74	.16	.15	.79	.44
Magnesia, MgO,	1.17	.75	.75	.80	.96	.77
Manganese Oxide, Mn_3O_4,	.07	.07	.04	.04	.05	.05
Ferric Oxide, Fe_2O_3,	3.53	4.64	3.23	3.45	3.38	4.04
Alumina, Al_2O_3,	4.53	3.79	4.68	5.35	4.60	4.57
Phosphorus Pentoxide, P_2O_5,	.163	.086	.13	.074	.146	.08
Sulphur Trioxide, SO_3,	....	....	.07	.06	.07	.06
Carbon Dioxide, CO_2,	.72	.07	.03	.015	.37	.04
Volatile Matter,	8.94	5.25	9.22	5.76	9.08	5.50
Nitrogen,	.219	.097	.20	.065	.209	.081
Total Carbon,	2.58	.964	1.85	.45	2.21	.707
Total Potash,	2.98	2.95	1.26	1.76	2.12	2.35
Total Soda,	1.83	1.97	....	....	1.83	1.97
Total Phosphorus Pentoxide,	.172	.11	.163	.078	.167	.094
Hygroscopic Moisture,	2.00	1.70	....	....	2.00	1.70

PAPAKATING SILT LOAM.

The Papakating silt loam represents the more poorly drained bottom land soils of the area. They are characterized by the dark drab surface soil and the grayish subsoil. In no cases are cultivated crops successful on this type, though it offers bright prospects, where the drainage can be improved, as a pasture or grass land. Following are the mechanical analyses which show the relatively high amount of silt and clay, indicating it to be the heaviest soil in the area:

RESULTS OF MECHANICAL ANALYSES OF REPRESENTATIVE SAMPLES OF PAPAKATING SILT LOAM.

SOIL TYPE.	Soil Number.	Coarse Gravel. Over 2 mm.	Fine Earth. Und. 2 mm.	Fine Gravel. 2–1	Coarse Sand. 1–0.5	Medium Sand. 0.5–0.25	Fine Sand. 0.25–0.1	Very Fine Sand. 0.1–0.05	Silt. 0.05–0.005	Clay. 0.005–0.000
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Silt Loam, 0–7 in., ...	173	1.5	98.5	.8	2.1	1.7	6.2	7.4	67.5	13.9
Silt Loam, 12–20 in., ...	174	4.4	95.6	2.0	3.3	2.7	11.5	17.6	48.0	14.5

Two samples each of soil and subsoil of this type were analyzed. The potash does not differ greatly from the amount found in the Dutchess series. Like nearly all types so far examined, there is more of both acid-soluble and total potash in the subsoil than in the soil. The surface soil is characterized by a rather high percentage of lime, magnesia, nitrogen, and total carbon. The nitrogen in the surface soil is 0.35%, which is equivalent to 8,400 pounds per 8-inch acre. If only 1/100 part of this could be made available each year it would supply enough nitrogen for many crops. Lime and magnesia are present in the soil in the ratio of 1 : 1.87 and in the subsoil 1 : 2.55.

PAPAKATING SILT LOAM.

Location,	1 Mi. S. E. of Monroe Corners. 22-22-8-7-6-16		1½ Mi. S. W. of Sussex. 22-22-2-1-5-7-N. W.		Average.	
Depth of Sample,	0″-7″	12″-20″	0″-6″	12″-20″	Soil.	Subsoil.
Sample Number,	173	174	175	176		
Insoluble Matter,	....	....	....	....	....	....
Soluble Silica, SiO_2,	.06	.04	.05	.03	.05	.03
Potash, K_2O,	.25	.36	.35	.51	.30	.43
Soda, Na_2O,	.06	.20	.23	.08	.14	.14
Lime, CaO,	.62	.45	.31	.22	.46	.33
Magnesia, MgO,	.68	.89	1.04	.79	.86	.84
Manganese Oxide, Mn_3O_4,	....	.03	.03	.01	....	.02
Ferric Oxide, Fe_2O_3,	1.60	3.09	3.73	3.27	2.66	3.18
Alumina, Al_2O_3,	4.93	4.37	7.29	4.21	6.11	4.29
Phosphorus Pentoxide, P_2O_5,	.132	.114	.165	.047	.148	.08
Carbon Dioxide, CO_2,	.02	.015	.025	.025	.02	.02
Volatile Matter,	....	....	....	....	....	....
Nitrogen,	.345	.053	.353	.043	.349	.048
Total Carbon,	3.86	.40	.322	.254	3.54	.33
Total Potash,	1.89	2.39	1.41	1.25	1.65	1.82
Total Soda,	1.34	1.40	1.13	1.12	1.23	1.26
Total Phosphorus Pentoxide,	.152	.125	.185	.05	.168	.087
Hygroscopic Moisture,	3.29	1.11	3.80	.83	3.54	.97

MUCK.

Muck is found in varying sized sections over the entire area. It offers excellent possibilities for the development of intensive agriculture wherever it can be drained.

Under the heading of muck comes three samples of muck and a shell marl subsoil overlaid with humus. These samples are characterized by a low percentage of insoluble matter, potash, magnesia, iron and alumina. They are high in lime, volatile matter, nitrogen and total carbon. With two exceptions, the nitrogen is over 2%. The phosphoric acid corresponds closely with the amount usually found in the loam soils of this section.

With drainage, and thorough and deep cultivation to aid in oxidizing the poisonous compounds, many of these muck soils will prove well adapted to the growing of vegetables. Such soils, when well prepared, will require little or no commercial nitrogenous fertilizers. Such as are used should be in a readily available form, as there is an abundance of organic nitrogen present.

MUCK.

Location,	⅔ Mi. S. W. of Sparta. 22–32–7–3–4–4	3 Mi. S. Wood-bourne. 22–22–4–3–8–1	200 yds. E. of Owens. 22–13–4–3–6–3	1 Mi. W. of Vernon. 22–13–9–7–4–8	1 Mi. N. E. of Lafayette. 22–22–4–5–8–1	
					Muck.	Marl.
Depth of Sampling,	0″–36″	0″–36″	0″–36″	0″–36″	0″–10″	10″–36″
Soil Number,	145	47	48	162	97	98
Insoluble Matter,	36.18	6.62	3.23	2.57	8.01	36.27
Soluble Silica, SiO_2,	.06	.04	.05	.09	.07	.13
Potash, K_2O,	.16	.08	.04	.07	.06	.20
Soda, Na_2O,	.07	.04	.04	.08	.04	.06
Lime, CaO,	2.31	3.08	2.95	4.65	5.32	28.51
Magnesia, MgO,	.27	.34	.35	.33	.46	1.10
Manganese Oxide, Mn_3O_4,	TRACE	.01	.01	TRACE		.02
Ferric Oxide, Fe_2O_3,	2.46	.78	.72	1.03	1.78	2.03
Alumina, Al_2O_3,	1.78	.46	.13	.03	.70	1.73
Phosphorus Pentoxide, P_2O_5,	.158	.117	.113	.123	.140	.054
Sulphur Trioxide, SO_3,		.48	.50		.32	.47
Carbon Dioxide, CO_2,	.11	.18	.14	.60	1.25	21.33
Volatile Matter,	54.35	86.15	91.42	88.95	82.31	29.28
Nitrogen,	.1893	2.583	2.70	2.66	2.12	.197
Total Carbon,	6.16	38.80	42.23	39.07	28.91	8.38
Total Potash,	1.31	.10	.18	.08	.19	.76
Total Soda,				.12		
Total Phosphorus Pentoxide,	.186	.135	.157	.15	.156	.061
Hygroscopic Moisture,	12.28			31.94		

SUMMARY.

The soils of the Sussex area are generally well supplied with potash. There is almost invariably more in the subsoil than in the soil. In a majority of the samples the acid-soluble potash varies from about 0.2 to 0.3%, while the total is frequently as high as 2.00 to 3.00%.

Phosphoric acid is found in fair amounts; in some samples running close to 0.2%. There is slightly less in the subsoil than in the soil, while the total is only a little in excess of the acid-soluble.

Many of the soils are quite deficient in lime, while some contain only a trace of this material. Magnesia is almost invariably present in excess of the lime.

Many of the soils are fairly well supplied with nitrogen, though some, on the other hand, are quite deficient in this material. Generally there is about three to four times as much nitrogen in the soil as in the subsoil.

Applications of lime, together with more thorough cultivation, and a more extended use of green manure crops, will do much towards making these soils more productive than they are at present.

Dutchess Series.—These soils are low in lime and high in magnesia; they are generally fairly well supplied with nitrogen, phosphoric acid and potash.

Gloucester Series.—The Gloucester soils are generally well supplied with potash and lime, while magnesia is not greatly in excess, the lime magnesia ratio being about 1 : 3. They contain a fair amount of phosphoric acid and nitrogen.

Dover Series.—These soils are of limestone origin, though they now contain only moderate amounts of lime, less than 0.2% in several samples. The loam contains about the average amount of phosphoric acid and nitrogen and is high in total potash. The stony loam is low in phosphoric acid and nitrogen.

Hoosic Series.—The Hoosic soils are low in lime, less than 0.2% in most cases. They are well supplied with phosphoric acid and nitrogen.

Chenango Series.—These soils are very deficient in lime and are low in nitrogen and phosphoric acid.

Papakating Silt Loam.—This soil is well supplied with lime and has a high nitrogen content.

Lackawanna Loam.—Very deficient in lime and low in nitrogen and phosphoric acid.

Wallpack Silt Loam.—Low in lime and potash.

Wallpack Shale Loam.—High in nitrogen, fair amount of lime and potash.

Genesee Loam.—High in lime and nitrogen.

Analysis of Soils—Methods Used.

BY R. B. GAGE.

Contents.

Most of the methods used in making the determinations described herein are those recommended by the Association of Official Agricultural Chemists, or are modifications of those methods. Whenever it was found that the official methods could be shortened or better results secured by modifying them, this was done. In some cases methods not recommended by this association were used, but only after they had been checked with standard gravimetric methods and found to give accurate results.

Since a slight variation in manipulating most of these methods is accompanied by a corresponding change in the results secured, the manner in which they were carried out is described in more detail than would otherwise be done.

SAMPLE.

The samples analyzed consisted of that portion of the air-dried soil which passed a 1 m. m. sieve. These samples were kept in glass-covered jars and used without further drying.

The quantity of a sample used for some of the determinations was larger than that generally recommended. This often saved making a second acid digestion when some duplicate determination was desired. By working on from 2 to 10-gram samples the errors were reduced accordingly.

GENERAL COMMENTS ON THE METHODS USED.

The average soil is not composed of ingredients that are readily soluble or totally insoluble in the acid used for making the acid extraction, but contain certain minerals which are attacked very slowly. Even when the acid is of a definite strength and the digestion made in a given manner for a definite length of time, the quantity of soil dissolved varies with the style of flask used, and the manner in which these flasks sit on the water bath. A standard Jena Erlenmeyer 500 cm^3 flask 7 inches high and 4 inches in diameter was used for making all acid extractions. These flasks were placed on a water bath containing openings 3½ inches in diameter. The flasks were closed by a rubber stopper containing a glass condensing tube 20 inches long with an inside diameter of about ¼ inch. The water bath was boiling when the flasks were placed upon it.

The iron contents of the soil are reported as ferric oxide, yet some if not all of this metal exists in the ferrous condition in the soil. Since the ferrous oxide was not determined, no correction in the insoluble residue was made for this gain in weight during heating of the insoluble residue.

To secure a complete precipitation of phosphorus as ammonium phospho-molybdate that will be comparatively free from impurities, it is quite necessary that the solution be rich in ammonium nitrate and iron, and of about a certain acidity. This excess of iron aids very much in securing the desired acidity and at the same time reduces the chances of any molybdic acid precipitating with the phosphorus. Moreover, the ammonium phospho-molybdate precipitate appears to come down quicker and to be of a more uniform composition where the solution is in the condition given above.

When the phosphorus is precipitated in the manner given herein, the results secured by titrating the yellow precipitate with a standard alkali solution are just as accurate as those secured by gravimetric methods. This is not true, however, with materials containing over 1 per cent. of phosphoric pentoxide.

The method given to determine the total alkalies was checked on several soils with the J. Lawrence Smith method, and always gave the same or slightly higher results. It does not require the close attention or as much work as the latter method and the losses from volatilization are much reduced.

ACID EXTRACTION.

Twenty grams of the air-dried soil are digested with 200 cm^3 of dilute hydrochloric acid (see reagents) continuously on the water bath for 10 hours. The flasks are shaken by hand at the end of each hour so the contents will be thoroughly mixed. After digestion the solution is filtered at once through a double filter paper[1] directly into a 500 cm^3 graduated flask.

The filtrate should be perfectly clear and show no cloudiness. Otherwise some silt or clay has passed through the filter. When

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[1] The filters used were S. and S. Blue Label, 9 and 11 cm, respectively. The 9 cm paper is placed on the inside. This combination filters much quicker than when both papers are of the same size.

this happens, the solution should be refiltered if a soluble silica determination is made.

The insoluble residue is washed a few times by decantation and then on the paper with hot water until free from chlorides. It is ignited in a 30 cm³ platinum crucible, first over the Bunsen burner and then blasted. The residue should always be broken up during ignition. If not some of the filter paper at the bottom of the crucible may escape incineration.

If the analyst has the necessary apparatus and laboratory equipment, much time is saved by starting all the following determinations at once: soluble alkalies, sulphuric acid, total iron, soluble phosphoric acid, and a general analysis for alumina, ferric oxide, lime, magnesia and manganese oxide. Since each 25 cm³ of this solution corresponds to 1 gram of soil there is sufficient solution to make most determinations in duplicate if desired.

IRON, ALUMINA, LIME, MAGNESIA, ETC.

Transfer 50 cm³ of the stock solution to a 250 cm³ beaker, add 25 cm³ of strong hydrochloric acid, dilute to about 100 cm³, and then neutralize the excess of acid with ammonia before heating. The covered solution is heated nearly to boiling, from one-quarter to one-half gram of ammonium persulphate added and then ammonia in slight excess. The solution is kept near the boiling point for from 15 to 20 minutes after making it ammoniacal so the manganese and alumina will all be precipitated.

After the precipitate has settled, the solution is filtered at once. The precipitate is washed but a few times on the paper when it is returned to the beaker and dissolved in hot dilute nitric acid and reprecipitated in the same manner as before, except a smaller amount of ammonium persulphate is used and no hydrochloric acid is added. The solution is again filtered through the same paper as before and the precipitate washed free of chlorides with hot water. The small amount of the precipitate, which adheres to the sides of the beaker, is removed with a small piece of filter paper, and added to the major portion. The wet precipitate and paper are transferred at once to a 20 cm^3 platinum crucible, slowly ignited over a Bunsen burner and then blasted to a constant weight. Since this precipitate contains more or less ammonium nitrate, there is little danger of any iron oxide being reduced during ignition. These oxides are saved and their manganese contents determined in the manner given below. The alumina is determined by deducting the combined weights of the ferric oxide, phosphorus pentoxide, mangano-manganic oxide from the total weight of the oxides.[1]

The combined filtrates from these oxides should be concentrated to about 100 cm^3. A slight precipitate of iron and alumina may come down upon the addition of a few drops of ammonia at this point and should be filtered off and added to the other oxides. The hydrate of alumina is quite soluble in hot water when neutral. If the solution contains much organic matter, which is not destroyed by the persulphate, some of these metallic oxides are quite sure to be held in solution.

Unless the above solution contains a large excess of ammonium chloride, more or less magnesia will come down with the iron-alumina precipitate, and is not always removed by a second precipitation. The ammonium persulphate precipitates the manganese with the iron and alumina. If the soil is rich in lime, hydrogen peroxide free from sulphuric acid had better be used instead of the persulphate.

The second precipitation is necessary to secure the small amount of lime and magnesia carried down with the iron and alumina. It also shortens the final washing of the precipitate and reduces the loss by volatilization.

LIME.

The concentrated filtrates are heated to boiling and the lime is precipitated by the addition of about 10 cm^3 of a saturated

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[1] If the soil contains any titanium, more or less of it will go into solution, and will be precipitated with the iron and alumina, and a correction will have to be made for it. It had best be determined as given in Bulletin 305 of the U. S. Geological Survey.

solution of ammonium oxalate. The lime precipitate forms slowly in a coarse crystalline condition, for the solution is about neutral. After the lime has nearly all precipitated the solution is made distinctly ammoniacal and kept near the boiling point for about 30 minutes before filtering. The precipitate is collected on a thick, close-grained paper. When the precipitate is quite large, it is washed a few times by decantation and then dissolved in dilute nitric acid, a few drops of the ammonium oxalate solution added, and then re-precipitated by adding ammonia slowly to the hot solution. The bulk of the solution is kept as small as possible, and hot for about 20 to 30 minutes before filtering. The precipitate is washed with hot water, ignited and blasted to a constant weight.

This precipitate may contain a slight amount of manganese or alumina for which a correction in the lime content must be made. It should be dissolved in a little dilute nitric acid, washed into a small beaker, the manganese reduced with a few drops of sulphurous acid and the alumina precipitated by ammonia in the usual manner. The manganese is determined in the filtrate from the alumina in the same manner as given below. Very seldom more than traces of manganese will be found.

MAGNESIA.

The magnesium is precipitated as a phosphate in the usual manner. The solution is allowed to stand from 24 to 48 hours before filtering. If the soil contains over 5 per cent. of soluble magnesia, the clear solution should be decanted off, the precipitate dissolved in a little dilute nitric acid, a few drops of phosphate solution added, and the magnesium re-precipitated by the addition of ammonia drop by drop until the solution is strongly ammoniacal. After standing several hours this solution is filtered through the same paper used for the first solution. and washed free of chlorides with a 10 per cent. solution of ammonia, ignited very slowly over a Bunsen burner, then blasted to a constant weight.

The precipitate will often harden and burn white very slowly. When this happens moisten it with a few drops of strong nitric acid, evaporate off the excess of the same on the hot plate, heat very cautiously until the crucible becomes dull red, then blast and weigh. This precipitate should be dissolved in hot dilute nitric acid and tested for manganese. If the manganese is separated by hydrogen disulphide or bromine water, some is sure to be found with this precipitate.

MANGANESE.

The crucible containing the iron and alumina residue is filled about one-third full of fused $KHSO_4$ and heated gently over a low flame of the Bunsen burner until the mass has fused, when the heat is increased enough to just redden the bottom of the crucible. The crucible is kept covered and the heating continued until the residue has gone into solution. After the melt has cooled it is transferred to a small beaker, containing about 75 cm^3 of water and 5 cm^3 of sulphuric acid, and heated slowly until the fusion has dissolved. Often small flakes of silica will separate out. They should be filtered off and the silica determined in the usual manner. The amount thus found is deducted from the total weight of the oxides to get the true weight of the iron, alumina, mangano-manganic oxide and phosphoric pentoxide.

To the hot filtrate, or the unfiltered solution if the silica is not filtered off, from 2 to 10 cm^3 of silver nitrate solution are added according to the manganese content of the soil and then about 1 gram of ammonium persulphate, and the solution heated for about 15 minutes after the pink color of the permanganate has begun to show. This heating after the color of the manganese begins to show is quite necessary, for often the color developed is an old rose instead of a pink. This is caused in part by a brownish color produced by the action of the persulphate on the silver nitrate when too much nitrate has been added, and will often disappear on heating. Some of the color, however, is due to the yellow color given the solution by the iron present, and a correction must be made for it in preparing the standard. After the color has attained its maximum, the beaker is set in a pan of cold water, and when cool compared with a standard solution whose value in manganese is known.

This solution can best be prepared by diluting the required amount of the standard permanganate solution so each cm^3 will equal .00002 grams of MnO*. If the standard permanganate solution has a value of .0025 grams of iron per cm^3, 15.8 cm^3 of this solution diluted to 500 cm^3 will give a solution of the desired strength. Of this solution 50 cm^3 is transferred to a small beaker, 5 cm^3 of dilute sulphuric acid (1-1) added and a few drops of sulphurous acid to destroy the permanganate color. This color is again restored in the same manner as given above. This standard will show the true permanganate color, which will have a different tint from that of the sample on account of the iron in the latter. Just before removing the two solutions from the hot plate, and while they are at about the same temperature, add a solution of ferric nitrate, drop by drop, to the standard until it has the same color as the sample. This off color is more pronounced in the hot solution than when cooled, consequently it is much easier matched at this time. Unless this correction is made, it is impossible to compare the two solutions with any degree of satisfaction. It is taken for granted that the ferric nitrate contains no manganese.

When a solution is too rich in manganese, manganese dioxide will be precipitated, which gives the solution a brownish color that does not disappear on heating. When this happens, increase the volume of the solution by adding hot water, dissolve the precipitate in a few drops of sulphurous acid, and reheat after adding a little more persulphate. To prevent this formation of manganese dioxide, the volume of the solution may have to be increased to 500 cm^3 or more.

When cool the standard is transferred to a 100 cm^3 flask, diluted to the mark and well mixed. Each cm^3 now contains .00001 grams of MnO. The sample likewise is diluted to 250 cm^3 or 500 cm^3, according to the amount of manganese present, for the sample should always be lighter in color than the standard. Fifty cm^3 of the sample are transferred to a Nessler

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* A solution of this strength has about the proper depth of color.

cylinder, and known amounts of the standard added to another cylinder until the color is nearly the same, when the standard is diluted so each cylinder will contain about the same amount of liquid before the final reading is taken.

It is possible to determine one one-hundredth of one per cent. of MnO by this method, and for the small amount of MnO usually found in soils is much shorter and more accurate than any of the other methods. When the MnO content of the soil is above 1½ per cent., any slight error in reading the color will make quite an error in the final results. Consequently, in soils of this type, the manganese had better be determined by some other method.

While making this determination it is necessary to keep the room free from HCl fumes, and the water used must also be free from chlorides, for it is almost impossible to filter off traces of silver chloride, which will mar the end reading more or less. For a further description of this method as applied to rocks, see Bulletin U. S. Geological Survey No. 305, page 99.

SOLUBLE PHOSPHORUS AND SILICA.

Evaporate 125 cm^3 of the stock solution to complete dryness in a porcelain casserole on a water or steam bath. When nearly to dryness the residue is broken up several times so it will be completely dehydrated. If it is not thoroughly dry or is heated too high, an insoluble compound will be formed later, which may contain phosphorus. For this reason this evaporation cannot be made over an open flame or on a hot plate. When the residue has become thoroughly dry, cover the dish and add 20 cm^3 of strong nitric acid, and replace on the bath. The dish should be watched for a few moments, for if much organic matter is present the reaction will be quite vigorous. In the latter case, remove it from the bath for a few moments. The heating is continued until all the red fumes have been driven off. The solution is then diluted with hot water and filtered at once. The paper is transferred to a platinum crucible and the silica determined in the usual manner, while the phosphorus is determined in the filtrate in exactly the same manner as given under total phosphorus after the insoluble residue has been filtered off.

SOLUBLE ALKALIES.

Transfer 50 cm^3 of the stock solution to a 200 cm^3 platinum or silica dish, add about 1 cm^3 of strong sulphuric acid and evaporate to dryness. The excess of sulphuric acid is then slowly expelled and the residue heated very slowly to a dull red and kept at this temperature until the organic matter has been incinerated. More or less of the sulphates of iron and alumina will be reduced to the oxides, and will not go back into solution again. This reduces the bulk of the precipitates of these two metals very much, making the separation of the alkalies from them much easier.

The residue is taken up in about 100 to 125 cm^3 of water and digested until the soluble sulphates have gone into solution. The alumina and iron is precipitated by ammonia and filtered off. This precipitate should be thoroughly washed to remove as much of the alkalies held by it as possible. When a soil is high in soluble alkalies the iron-alumina precipitate should be washed back into the platinum dish, dissolved in a few drops of HCl, and re-precipitated to remove the alkalies held by it.

The filtrate is caught in a platinum dish and evaporated quickly to dryness and heated slowly to a dull red to drive off as much of the ammonium sulphate as possible. The residue is then digested with about 50 to 75 cm^3 of water, a few drops of ammonia and ammonium carbonate added, and the heat continued until about one-half the volume of the liquid has been evaporated off. The last trace of alumina will usually be thrown down during this evaporation, which will not be the case if the solution is filtered much sooner. The filtrate is collected in a weighed platinum dish and quickly evaporated to dryness, and the residue again heated to a dull red. It is always advisable to dissolve the residue in a little hot water and test again for alumina and lime in the same manner as given above before weighing. This last evaporation will also help to remove the last traces of ammonium sulphate. When the alkalies are free from alumina and lime they are heated to a dull red, cooled in a dessicator and weighed as sodium and potassium sulphates.

To separate the sodium and potassium, dissolve the sulphates in a little hot water, transfer to a 100 cm^3 silica dish, dilute to about 50–85 cm^3 depending on the weight of the alkalies, add about 5 cm^3 of hydrochloric acid and enough platinum chloride to convert both the sodium and potassium into the corresponding platinates.[1] The solution is concentrated either on the hot plate or the water bath until the residue is pasty when hot, but mostly solidifies on cooling. A dark ring should be prevented from forming around the outer edge of the residue by keeping it moistened with the mother liquid. The residue should be a yellow color and not red. It is then moistened with 50 to 75 cm^3 of alcohol (see reagents), and allowed to stand for several hours before filtering. The solution is finally filtered through a 7 cm^3 paper and the insoluble portion washed free from platinum chloride with the same alcohol. The paper and precipitate are removed from the funnel and placed on a large, open filter paper so the alcohol will quickly evaporate off. The funnel is also washed free from alcohol. When the paper is dry it is returned to the funnel, the potassium chloro-platinate dissolved in hot water and collected in a weighed platinum dish. The solution is evaporated to dryness on the water bath, cooled and weighed. This separation must be done in a room free from ammonia fumes.

The sodium sulphate is not always changed into the corresponding platinum salt during evaporation. When it is small in quantity it will all be dissolved in the alcohol and pass into the filtrate.

Since it is not very soluble in alcohol, it will often remain on the paper with the potassium chloro-platinate. In order to guard against this error, the residue after being freed from the platinum solution should always be washed with the ammonium chloride

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[1] The weight of sulphates by 17 gives the number of cubic centimeters of a 10 per cent. solution of platinum chloride required.

solution until any sodium sulphate contained therein has been dissolved. The residue is then freed of chlorides by washing with the alcohol solution.

It is always advisable to dissolve the potassium chloro-platinate after weighing in a little hot water acidified with a few drops of HCl and test for SO_3 with barium chloride. If a precipitate is secured, it should be filtered off, weighed, calculated to sodium sulphate and deducted from the total weight of the platinate. The barium sulphate precipitate does not appear to inclose much, if any, potassium. Higher results are most generally secured by weighing the alkalies as sulphates than when they are weighed as chlorides.

The weight of K_2PtCl_6 by 0.19411 will give the per cent. of K_2O it contains.

The weight of K_2PtCl_6 by 0.3589 will give the corresponding K_2SO_4 it represents.

The weight of Na_2SO_4 by 0.4368 equals Na_2O.

TOTAL IRON AND SULPHUR TRIOXIDE.

Fifty cubic centimeters of the stock solution are diluted to about 125 to 150 cm^3; 1 cm^3 of hydrogen peroxide is added to oxidize the iron, and the iron and alumina precipitated in the same manner as given under iron, alumina, etc. After the precipitate has settled it is filtered off at once, washed a few times with hot water, and then returned to the beaker. It is dissolved in about 25 cm^3 of hot dilute sulphuric acid, and when in solution filtered through the same filter into a 250-cm^3 Erlenmeyer flask. The solution is evaporated until fumes of sulphur trioxide come off freely. The heating should be continued until all HCl has been expelled and the organic matter destroyed. After cooling 75 cm^3 of water are added and the solution heated until the soluble sulphates have all dissolved. This may take a little time, for some of these sulphates dissolve quite slowly. When the solution has cleared, a definite amount of granulated zinc is added and the solution kept hot until it has all dissolved. The solution is then cooled by setting the flask in a pan of cold water and titrated at once with permanganate. A blank should always be run on the chemicals, for the zinc usually contains some iron. The top of the Erlenmeyer flask is closed with a 1-hole rubber stopper containing a small glass tube about 3 inches long to reduce the chances of oxidation.

If a manganese determination is not desired, or a more accurate determination of the iron is desired than can be obtained by this method, the iron should be reduced by H_2S, and determined in the manner given in U. S. Geological Survey Bulletin 305, page 90.

To the original filtrate from the iron and alumina, which has been caught in a large platinum dish, enough sodium carbonate is added to unite with all the sulphur trioxide present. The solution is then evaporated to dryness and the ammonium salts expelled slowly over a direct flame. The residue is dissolved in about 50 cm^3 of hot water and filtered into a small beaker. After the solution has come to a boil a few drops of HCl are added and then 5 cm^3 of a 10 per cent. solution of barium chloride. The beaker is set on the edge of the hot plate and allowed to evaporate nearly to dryness, so the barium sulphate will settle in a filterable condition. About 50 cm^3 of water are again added, and when the precipitate has settled it is filtered off, washed well with hot water, ignited over the Bunsen burner and weighed.

If the ferric chloride is not removed it will hold some of the barium sulphate in solution. The ammonium salts also tend to prevent a complete precipitation of the barium sulphate. The peroxide often contains sulphuric acid, and a correction should be made for the sulphur trioxide contained in the amount used.

TOTAL P_2O_5 IN SOILS BY THE $MgNO_3$ METHOD.

Treat 5 grams of the soil in a 3-3.5 inch porcelain dish with 6-8 cm^3 of the magnesium solution (see reagents) and evaporate to dryness over a low flame. The dish should be about 4 to 5 inches above the top of the burner. After the excess of water has been driven off, the flame is slowly raised until the bottom of the dish is quite red. The flame should be broad and cover as much of the bottom of the dish as possible, and the heating continued until all the nitrates have been decomposed. If the dish is covered with a watch glass a more uniform heat is secured, and the red fumes, being held in the dish, act as a guide in indicating when the decomposition of the nitrates has ceased. This decomposition must be complete, otherwise some P_2O_5 may remain in the residue. There is little danger of heating too high, as no P_2O_5 is lost at red heat.

After the dish has cooled, moisten the residue with a little water and then add 15 cm^3 of strong HCl, keeping the dish covered during the addition. Place the dish over a low flame and evaporate slowly to dryness. The cover should be moved a little to one side, and the flame kept low and about 5 inches below the bottom of the dish. The heating is continued with this size of flame until the residue has become quite white, but the flame should not be high enough to decompose any of the ferric chloride and redden the residue in the bottom of the dish. When this happens it is best to moisten the residue as before and re-evaporate. It may take some time to whiten the residue, but if it is not done an insoluble compound will be formed later, which will contain some P_2O_5. The flame should not be increased to hurry the action at this point.

After the residue has whitened as much as possible it is moistened with 15 cm^3 of strong HNO_3 and heated for a few minutes more than required to expel all the red fumes, cooled some, diluted with hot water and filtered. A thick filter paper is used. If the operation has been carried out as given above the filtrate is clear. Should it show a cloudiness, it indicates the dehydrate heating was not large enough, while, on the other hand, if the residue is found to be red in the bottom, the heat was too high or too large a flame was used.

After the addition of about 10 cm^3 of ferric nitrate solution and 25 cm^3 of C. P. ammonia, nitric acid is added, drop by drop, until the solution has a distinct light amber color. Comparison of the color, which is variable, should be made with the temperature of the solution at 50°-60° C. When the proper color is secured, 3 cm^3 more nitric acid is added to prevent the precipitation of any Al_2O_3 on concentrating. The solution is then evaporated down to about 75 cm, and should it get very dark red in color a little more acid is added. The solution should not be permitted to get too hot on adding the NH_3 and HNO_3, or some Al_2O_3 will precipitate. This does not go back into solution as easily as the Fe_2O_3. If the solution is too acid, the P_2O_5 will not all be precipitated, while, on the other hand, if too neutral, some alumina will separate out during the concentration or after the molybdate has been added. This white alumina precipitate will not dissolve in strong HNO_3, but will in strong HCl. Should it come down in very small amounts after the molybdate has been added, the determination is very little affected, if the yellow phospho-molybdate precipitate is titrated with KOH, but the result is affected if it is weighed. However, if it is large enough in quantity to prevent the proper washing of the phospho-molybdate precipitate it will spoil the determination. This alumina precipitate can easily be distinguished from the yellow phospho-molybdate precipitate, since it remains suspended in the solution much longer than the latter, and from molybdic acid, which crystallizes out on the sides of the flask. A soil high in soluble alumina will have to be made more acid than one low in the same. When the total "insoluble residue" is not above 75 per cent. the solution should be quite acid, unless the soluble part is very high in iron and organic matter. If much of this precipitate comes down, and the duplicates do not agree, the determination should be repeated, for when done correctly the results will not vary over 0.005 per cent. P_2O_5 in a sample containing 0.5 per cent. P_2O_5 or less.

After the solution has been evaporated to about 75 cm^3, and is of the right color at 50°–60°C., 10–20 cm^3 of molybdate solution (see reagents) are added, unless the soil contains over 0.5 per cent. P_2O_5, when more should be added. The temperature of the solution should be about 75°-80°C. when the molybdate is added, and after thorough mixing it is set in a warm place for a couple of hours before filtering.

If it is desired to weigh the yellow precipitate, filter into a gooch crucible, wash well with a 10 per cent. solution of ammonium nitrate and then with a 2 per cent. solution of HNO_3, and once or twice with cold water, to remove the free acid, dry in water bath, cool and weigh at once, for the precipitate gains weight very fast, and will even gain weight in a dessicator unless the $CaCl_2$ is very dry.

If it is desired to titrate with KOH, filter onto a thick filter paper and wash[1] well with the ammonium nitrate solution, which should be neutral. After the precipitate has been washed free from the molybdate solution it is washed a couple of times with cold distilled water, for the ammonium nitrate solution is usually acid. The paper and precipitate are transferred to the Erlenmeyer flask used, about 25 cm^3 of cold water added and enough standard KOH solution to make the solution distinctly alkaline after the paper has been reduced to pulp by shaking in the closed flask. After adding a few drops of phenol-phthalein, the solution is allowed to stand for about five minutes to see if the pink color is permanent, and then standard nitric acid is added until the pink color has just disappeared. The difference will give the per cent. P_2O_5 if the KOH solution is standardized as given elsewhere.

TOTAL POTASH AND SODA.

The material for this determination should be ground exceedingly fine in an agate mortar. Coarse material lengthens the time of evaporation and may escape complete decomposition. This finely-ground material loses moisture easily, and should be kept in an air-tight bottle.

Transfer 1 gram of the powdered sample to a 200 cm^3 platinum dish and ignite carefully over a Bunsen burner until all organic matter has been destroyed. This heating also helps the acid to decompose the insoluble minerals present.

The calcined residue is then moistened with water and about 50 cm^3 of hydrofluoric acid added. Enough sulphuric acid is also added to form sulphates of the metallic oxides. For an

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[1] If cold water is used at this point some molybdic acid will be thrown down and may not all be washed out of the yellow precipitate.

ordinary soil, from 5 to 8 drops will be sufficient. The solution is evaporated very slowly to dryness, so the acid will have ample time to decompose all the minerals. If the platinum dish is covered with one a size larger, the hydrofluoric acid is expelled very slowly. The residue is moistened again with about 25 cm^3 of hydrofluoric acid and the evaporation this time continued until all sulphuric acid has been driven off.

The residue is then digested with hot water until all the soluble salts have been dissolved. This may require some time if much lime is present. Two evaporations are usually sufficient to decompose most soils, but in case undecomposed minerals are seen or thought to be present, filter off the insoluble portion, ignite in a platinum crucible and treat the residue again with hydrofluoric and sulphuric acid, as above specified. This residue is added to the major portion of the sample after being dissolved in a little hot water.

In either case the iron and alumina are precipitated by ammonia. This precipitate is well washed to free it from alkalies. If the soil is high in alkalies it is often advisable to dissolve this precipitate in a little hydrochloric acid and re-precipitate to free it from enclosed alkalies. If the volume of the original solution is 200 cm^3 or more, and the precipitate washed well, a second precipitation is seldom required.

The filtrate is collected in a large platinum dish and quickly evaporated to dryness over a Bunsen burner. The determination is completed in the manner given for soluble alkalies.

CARBON DIOXIDE.

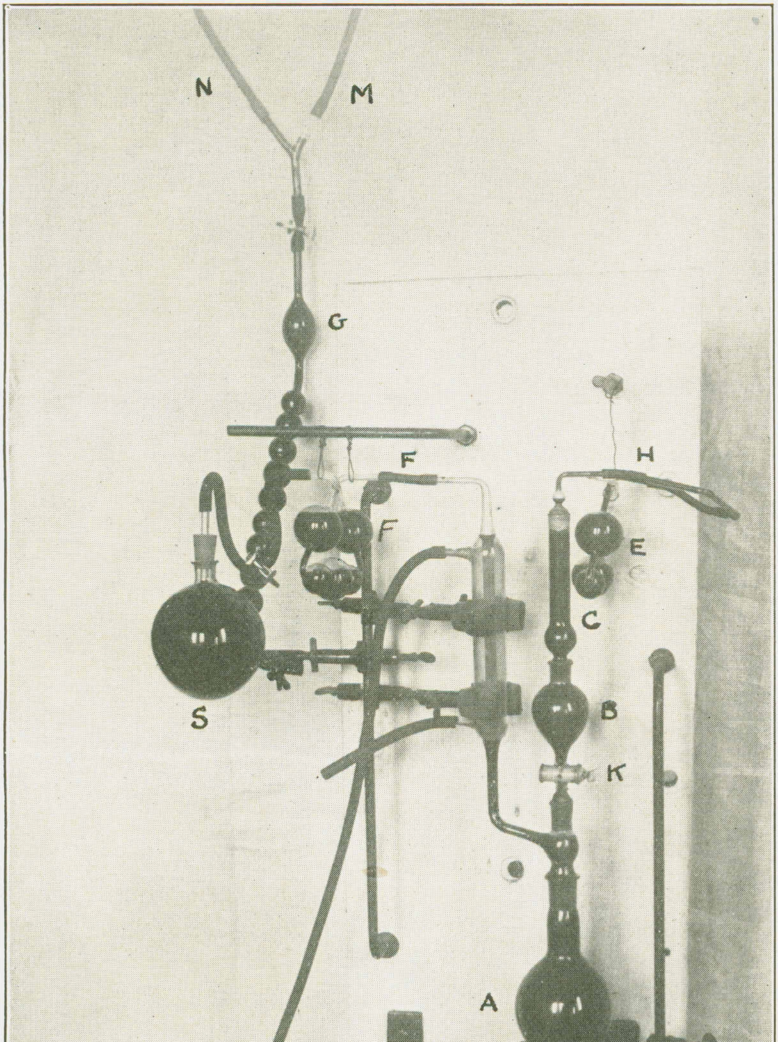
A modified form of the Knorr apparatus is used in making this determination. The CO_2 absorption bulbs were designed by the writer to reduce the chances of CO_2 being absorbed from the air during titration to a minimum. Very little time or attention is required in making a carbon dioxide determination with this apparatus, yet the results are very accurate. With five sets of this apparatus from 30 to 40 determinations can easily be made per day.

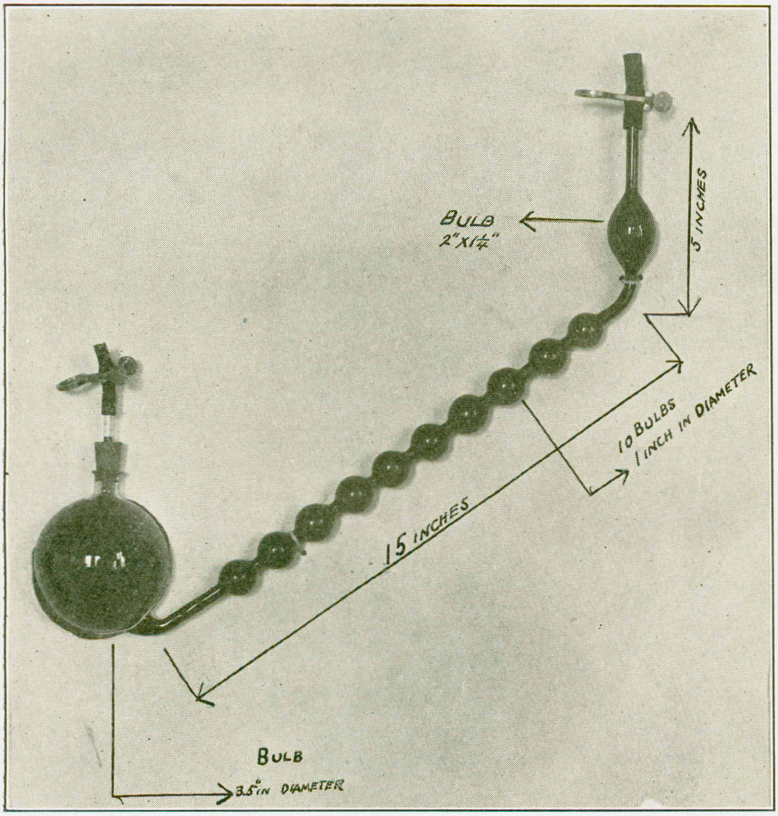
For soils not containing over one-half of 1 per cent of CO_2 a 10-gram sample is used. For those containing between one-half and 4 per cent. CO_2 a 5-gram sample is sufficient, and for soils above 4 per cent. and under 20 per cent. CO_2 a 1-gram sample is used.

The soil sample is introduced into the flask A (Plate I), which should always be dry. Air free from CO_2 is now passed through the apparatus until the flask A and absorption bulb S are free from CO_2. From 10 to 50 cm^3 of barium hydrate solution (see reagents), the amount depending on the CO_2 contents of the soil, are introduced into the bulb S and enough water added to bring the total volume of the solution up to about 60 cm^3. About 10 cm^3 of dilute hydrochloric acid (1 to 1) are introduced into the bulb B, which is quickly closed with stopper C containing soda lime. The tube H is connected with an air supply under slight pressure, and also free from CO_2. Bulbs E and F contain dilute solutions of potassium hydrate and silver nitrate, respectively.

The cock K is opened so the acid in bulb B will flow very slowly into flask A in order not to cause any sudden evolution of CO_2. The contents of the flask are then heated slowly and kept boiling until the absorbed CO_2 has been expelled. The air current connected to the tube H is allowed to asperate slowly through the apparatus during and after heating until all CO_2 has been removed from flask A. This will take an hour or more, for if the current of air does not flow slowly some CO_2 may pass through the absorption bulb S without being absorbed. For this reason, when working on soils rich in carbonates it is advisable to pass the gas through another bulb attached to the end of S, which contains about 5 cm^3 of barium hydrate solution diluted to the proper volume.

Without stopping the current of asperating air the upper end of bulb S is connected with the rubber tube G, which in turn is connected by means of a Y to the current of asperating air and also to a supply of neutral distilled water free from CO_2. The bulb S is now disconnected and held in a vertical position, so the liquid will flow down into the lower end of the bulb. A slight pressure on the clamp on M will quickly fill the top end of bulb S with


N
M
G
F
H
F
E
C
S
B
K
A


BULB
2"X1¼"
5 INCHES
10 BULBS
1 INCH IN DIAMETER
15 INCHES
BULB
3.5 IN DIAMETER

wash water, which is forced rapidly through the bulb by admitting a little air through N. When the contents of the bulb have all been washed into the larger lower chamber, a few drops of phenol-phthalein are added and the excess of barium hydrate titrated with a standard oxalic acid solution (see re-agents) without removing the liquid from the bulb. This gives the quantity of barium hydrate solution neutralized by the carbon dioxide, each cubic centimeter of which represents 0.1 per cent. of CO_2.

The opening into the bulb S should be kept closed as much as possible during washing and titrating. The barium carbonate is not decomposed by the oxalic acid. The titration end point is very sharp, for the white precipitate makes the least tint of pink easily distinguishable.

Plate II shows in detail a portion of the apparatus illustrated in Plate I.

STANDARD SOLUTIONS.

Standard Potassium Permanganate Solution.—This solution is made so that each cubic centimeter will equal 0.005 grams of iron. About 5.746 grams of permanganate are dissolved in 500 to 600 cm^3 of water. The solution is then boiled for 15 to 20 minutes and filtered through asbestos into a 200 cm^3 graduated flask. When the solution is cool the flask is filled to the mark and the contents well mixed. After standing 24 hours or more just 500 cm^3 are carefully drawn off with a dry pipette and standardized by titrating with ammonium oxalate. Six-tenths of a gram of this salt will require about 90 cm^3 of permanganate solution. The weight of the ammonium oxalate used, multiplied by 0.78644, equals the corresponding weight of iron when the atomic weight of iron is taken as 55.9.

Standard Potash Solution for P_2O_5 Titration.—The strength of this solution is made so that each cubic centimeter will equal 0.01 per cent of P_2O_5 when a 5-gram sample is used for this determination. If the soil contains over one-half of 1 per cent. of P_2O_5 a smaller sample had better be used. Such a solution will contain 9.0879 grams of potash per liter, or 1.81758 grams when a 1-gram sample is used.

To prepare this solution, dissolve 75 grams of KOH in about 200 cm^3 of water, transfer to a tall cylinder, add a few cubic centimeters of a saturated solution of barium hydrate to precipitate the carbonates, cork and allow to stand for at least 24 hours before using. Filter the solution into a 5-liter graduated flask and dilute to the mark. Do not try to wash the residue out of the cylinder or on the filter.

This solution is now standardized by titrating it against an oxalic acid solution of known strength. A solution containing 10.20809 grams of oxalic acid ($C_2H_2O_4.2H_2O$) per liter will just equal a solution containing 9.08790 grams of KOH per liter. This oxalic acid solution can, however, be of any convenient strength, but should be standardized by titrating with permanganate just before using, for it slowly loses its strength.

Standard Nitric Acid Solution for P_2O_5 Titration.—This solution is made so it will just equal the KOH solution and will then contain 10.207 grams of nitric acid per liter. It takes about 13 cm^3 of the ordinary nitric acid of 1.42 specific gravity per liter to make a solution of this strength. It is standardized by titrating it against the KOH solution. It is slowly decomposed by sunlight, and should be kept in light-proof bottles. When thus protected it will maintain its strength for many months.

Standard Oxalic Acid.—This acid must be free from oxalates if solutions of it are standardized with permanganate. The acid crystals contain too much hydroscopic moisture to secure any definite quantity of them by weighing. If exposed any length of time to the air or dried artificially some combined water is driven off, which also prevents their being weighed. The permanganate method of standardizing is by far the most accurate and shortest of any of the methods.

To prepare the C. P. crystals of this salt, dissolve about 500 grams of the ordinary acid crystals in hot water, add a few cubic centimeters of sulphuric acid and allow the solution to cool very slowly, so the crystals will be a good size. The mother liquor is decanted off, the crystals washed a couple of times by decantation and then re-dissolved and re-crystallized. After the fourth crystallization the crystals are dried quickly in a cool place and transferred at once to an air-tight bottle, which is kept in subdued light.

This acid must be purified in an atmosphere free from ammonia fumes, which it will quickly absorb. The crystallizing dishes should be kept in large dessicators during the crystallizing.

Ammonium Oxalate.—$(NH_4)_2C_2O_4.H_2O$.–142.16. The pure salt can be prepared by re-crystallizing some of the ordinary C. P. salt secured in the market. This is done in the same manner as given above for oxalic acid, except no sulphuric acid is added. These crystals are also kept in air-tight bottles.

Barium Hydrate Solution for CO_2 Determinations.—This solution is made of such a strength that each cubic centimeter corresponds to 0.1 per cent. of CO_2 when a 5-gram sample is used. Such a solution will contain 35.8547 grams of $Ba(OH)_2.8H_2O$ per liter, or equals 5 grams CO_2 per liter

To prepare this solution, transfer about 120 grams of the C. P. barium hydrate to a liter flask containing just 3 liters of water. This flask is kept closed with a rubber stopper, and after the barium hydrate has dissolved, the contents of the flask are thoroughly mixed by shaking. When the barium carbonate has settled 250 cm^3 are drawn off with a dry pipette and used to determine the strength of this solution by titrating against an oxalic acid solution that has been prepared for this purpose and the strength of which is known. The volume of water required to dilute the 2750 cm^3 so they will be of the same strength as the oxalic acid solution is thus secured. The chances of any CO_2 being absorbed are thus reduced to a minimum.

Oxalic Acid Solution for CO_2 Determinations.—An oxalic acid solution containing 14.32364 grams of oxalic acid per liter will just equal a solution containing 35.8547 grams of barium hydrate per liter, or is equal to 0.01270455 grams of iron per cubic centimeter when titrated with permanganate solution. To prepare this solution, transfer about 30 grams of oxalic acid to a 3-liter flask containing just 2 liters of water which is free from CO_2. Twenty-five cubic centimeters of this solution are drawn off with a dry pipette, transferred to an Erlenmeyer flask, 5 cm^3 of sulphuric acid and about 75 cm^3 of hot water added, and then titrated with standard permanganate solution. The quantity of water needed to dilute this solution so each cubic centimeter will contain 0.01432364 grams of oxalic acid is thus secured. The water used in preparing these solutions must be free from CO_2.

Factors:

Oxalic acid by 2.5033 equals barium hydrate.
Oxalic acid by 0.34907 equals carbon dioxide.
Oxalic acid by 0.886964 equals iron.
Barium hydrate by 0.13944 equals carbon dioxide.

REAGENTS.

Ferric Nitrate Solution.—A 10 per cent. solution of this reagent is prepared by dissolving the required weight in distilled water. This solution must be free from both manganese and phosphorous.

Platinum Chloride.—To prepare this solution, dissolve 10 grams of platinum chloride in 100 cm^3 of water. The combined weights of both the sodium and potassium sulphates or chlorides multiplied by 17 will give the number of cubic centimeters of this solution needed to convert these alkalies into platinates.

Silver Nitrate Solution.—This solution contains 2 grams of silver nitrate per liter. It is kept in a lightproof bottle.

Alcohol.—The alcohol used to prepare this solution must be free from ammonia and have a gravity greater than 0.86. It is prepared by diluting 5 volumes of 95 per cent. alcohol with 1 volume of water. This diluted solution should have a gravity of 0.86, and should always be tested with a hydrometer before using, for the ordinary 95 per cent. alcohol is seldom this strong.

Molybdic Acid Solution.—To prepare this solution, transfer 100 grams of molybdic acid to an 800 cm^3 beaker and add just enough water to make a paste of the acid. This paste is dissolved in 80 cm^3 of strong ammonia (0.90 gravity), and when in solution diluted with 400 cm^3 of water. No molybdic acid is precipitated out of this solution on standing, consequently it is kept as a stock solution from which the molybdic acid used to precipitate the phosphorus is prepared by slowly pouring 240 cm^3 of this solution into 500 cm^3 of cold, dilute nitric acid

(150 cm^3 of HNO_3 .gr. 1.42, to 350 cm^3 of water). The nitric acid should be stirred vigorously during this mixing and kept as cool as possible. This latter solution is then heated to and kept at about 75° to 80°C. for two hours, during which time more or less molybdic acid is thrown out of solution that might separate out with ammonium phospho-molybdate precipitate. This solution should stand for 24 hours before using.

June, 1913.

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