Issued March 31, 1915.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF SOILS—MILTON WHITNEY, Chief.

IN COOPERATION WITH THE OHIO AGRICULTURAL EXPERIMENT STATION, CHARLES E. THORNE, DIRECTOR; L. H. GODDARD, CHIEF, DEPARTMENT OF COOPERATION; GEORGE N. COFFEY, IN CHARGE SOIL SURVEY.

RECONNOISSANCE SOIL SURVEY OF OHIO.

BY

GEORGE N. COFFEY, OF THE OHIO AGRICULTURAL EXPERIMENT STATION, THOMAS D. RICE, OF THE U. S. DEPARTMENT OF AGRICULTURE, AND PARTY.

[Advance Sheets—Field Operations of the Bureau of Soils, 1912.]

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1915.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF SOILS,
Washington, D. C., June 2, 1914.

SIR: During the field season of 1912 a reconnoissance survey of the State of Ohio was made. This work was done in cooperation with the Ohio Agricultural Experiment Station, and was in charge of George N. Coffey and Thomas D. Rice. They were assisted by Charles N. Mooney, G. B. Maynadier, and H. C. Smith, of the United States Department of Agriculture, and A. L. Higgins, A. F. Kidder, and F. N. Meeker, of the Ohio Agricultural Experiment Station.

I have the honor to transmit herewith the manuscript report and map covering this area, and to recommend their publication as advance sheets of Field Operations of the Bureau of Soils for 1912, as provided by law.

Respectfully,

MILTON WHITNEY,
Chief of Bureau.

Hon. D. F. HOUSTON,
Secretary of Agriculture.

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RECONNOISSANCE SOIL SURVEY OF OHIO.

By GEORGE N. COFFEY, of the Ohio Agricultural Experiment Station, THOMAS D. RICE, of the U. S. Department of Agriculture, and Party.

INTRODUCTION.

NATURE AND PURPOSE OF THE SURVEY.

That soils differ in crop-producing power is one of the most universally recognized facts in agriculture. They may be watered by the same rain, warmed by the same sun, planted with the same seed, cultivated with the same care, and, in fact, treated exactly alike in all respects, but still, owing to inherent differences, the yields secured upon one soil may be two or three times as great as upon another. The fact, however, that all soils are not adapted to the same kind or variety of crop, do not require the same kind of fertilization or cultural treatment, and are not suited to the same system of farming is not so generally admitted or so well understood, although both experiments and experience indicate that the latter group of facts is just as true as the former.

A knowledge of the different types of soil occurring in a particular section becomes, therefore, an essential and fundamental basis for properly carrying on various lines of agricultural investigation, for without such knowledge definite advice is often impossible, or, if given, may not apply.

The primary purpose of the soil survey is, therefore, to furnish this knowledge in regard to the different types of soil found within a given area, to describe the characteristics and peculiarities of these different types, and to determine and show, as far as practicable, their location and distribution. In other words, the soil survey is simply the foundation upon which all lines of agricultural investigations, having to do with crop growth, must be built in order to develop a more rational system of agriculture.

Recognizing the absolute necessity of having this information as to the character of the soil in every section of the State, the Ohio experiment station began, during the summer of 1911, the making of a general soil survey of the State, and considerable work of a preliminary nature was accomplished, although no actual mapping was done. Before the opening of the field season of 1912, arrangements for carrying on the work in cooperation with the United States

Department of Agriculture were made, and as a result a reconnoissance survey of the entire State has been completed. However, in many sections it has not been possible to secure in this survey all the information desired, and further more detailed studies will be taken up in those counties where more complete knowledge is needed.

DESCRIPTION OF THE AREA.

LOCATION AND EXTENT.

The area surveyed includes the entire State of Ohio, embracing an approximate land area of 40,740 square miles.[1] The extreme southern part of the State extends a little south of 38° 30′ north latitude,

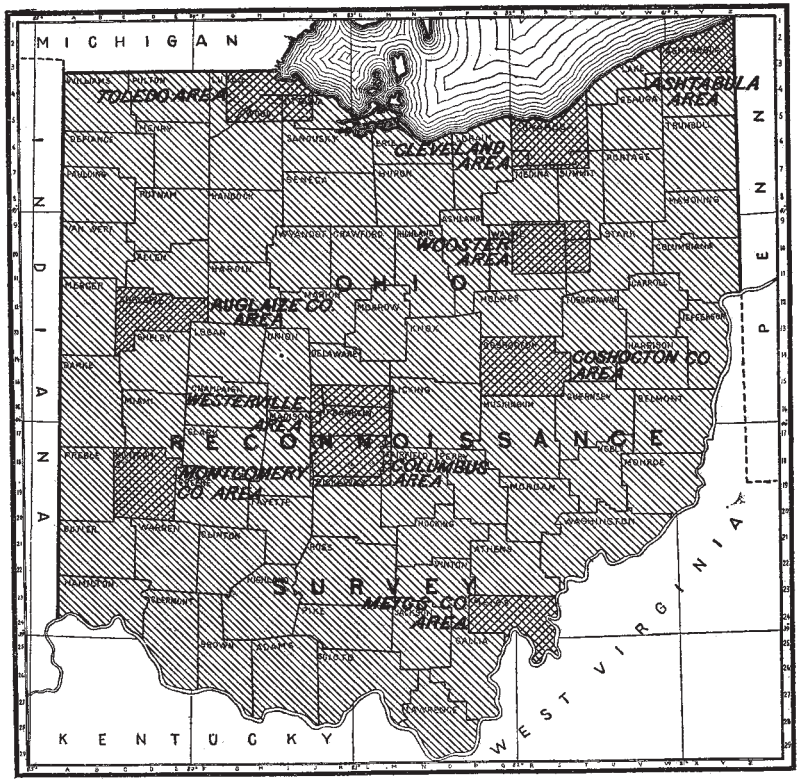


FIG. 1.—Sketch map showing areas surveyed in Ohio.

or about the same as Washington, D. C., St. Louis, Mo., and Sacramento, Cal. The northernmost point almost touches latitude 42°, which is approximately that of Cape Cod, Mass., and the northern boundary of California. The eastern boundary is a little west of 80° 30′ west longitude, while the western portion is a short distance

[1] See the area of Ohio in Ohio Topographic Survey, 1910, pp. 52–58.

west of 84° 45′. The State extends through a little more than 3° 30′ of latitude and 4° 15′ of longitude.

The southern and much of the eastern boundary of the State is very irregular in outline, following the north and west bank of the tortuous channel of the Ohio River. That portion of the northern boundary which is formed by Lake Erie is also more or less irregular, but the remaining boundary lines are straight. The longest distance through the State, from northeast to southwest, approximates 300 miles. Roughly speaking, however, the State might be considered a square, with a length and breadth of about 200 miles.

Ohio is exceptionally well situated both as regards transportation and markets. Although it is separated from Canada only by the waters of Lake Erie, the State is really very near the center of the country's population, manufactures, wealth, and trade. Almost all of the great highways of commerce from west to east pass through it. Railroads traverse it in every direction, giving quick and efficient service to all parts of the country. On the north Lake Erie and along the eastern and southern borders the Ohio River furnish excellent water transportation, and a large commerce is carried on upon these waters.

Within its own borders are many large towns and cities, Cleveland, Cincinnati, Columbus, Toledo, and Dayton all having between 100,000 and 600,000 inhabitants, and numerous smaller cities and towns are found in every part of the State. Pittsburgh, Buffalo, Detroit, Indianapolis, and Louisville are almost at its doors, and practically all of the larger cities in the United States can be reached in a few hours travel.

PHYSICAL FEATURES.

ALTITUDE.

Practically the entire area of the State lies between 500 and 1,500 feet above sea level. The only part of it which falls below the 500-foot contour is a narrow strip along the Ohio River, beginning just south of Gallipolis and extending to the Indiana line. Only a very small area, immediately west of Bellefontaine, in Logan County, rises above 1,500 feet. The highest altitude reached here is 1,540 feet, which constitutes the most elevated point in the State. The lowest point, which is at the extreme southwestern corner, is a little less than 440 feet, thus giving an extreme range in elevation of approximately 1,100 feet. Lake Erie has an altitude of 573 feet, or is about 140 feet higher than the Ohio River at Cincinnati.

Considerably more than one-half of the State lies between the 500 and 1,000 foot contours. The country so situated includes all of the northwestern part of the State, as well as the northern tier of counties bordering Lake Erie, and also the Miami and Scioto River valleys

and most of the country between the Muskingum and Scioto Rivers. Practically all the tier of counties bordering Pennsylvania from the Ohio River northward to Lake Erie have an elevation of less than 1,000 feet.

That part of the State which is above the 1,000-foot contour is mainly in the section of country between Chardon, Bucyrus, Marietta, and Steubenville. However, much of the central part of this section lies below this elevation. Beginning just south of the westward extension of the Scioto River in Hardin and Auglaize Counties and following the divide between the Scioto and Miami Rivers southward almost to the Ohio, just west of Portsmouth, is another large area which has an elevation of more than 1,000 feet. A third area, separated from this one by the Miami Valley, comprises most of the country between Eaton and Celina, covering a small portion of southern Mercer, nearly all of Darke, and the northwestern half of Preble Counties.

TOPOGRAPHY.

The broad surface features of the State have been determined by erosion acting on a series of rocks of unequal resistance. In detail, however, considerable variation in topography has been brought about in the glaciated area through an uneven deposition of glacial material. Where the underlying formations consist of limestone or soft shale the surface has been reduced to lower levels and smoother contours than where they are composed of resistant sandstone or conglomerate. Almost the entire western half of the State is underlain by limestone, but the formations in the southeastern section are made up largely of sandsone or shale. The former, being most resistant to weathering, gives rise to broken country.

In the glaciated section the details of the preglacial surface features have been modified in part by the smoothing off of the sharper and more rugged points, but mainly by filling up the preexisting valleys or lower places, thus giving a more rounded appearance to the hills and a more even topography. In some cases, however, where terminal moraines were formed, the glacial deposits were piled up in low hills and ridges, giving generally an undulating or occasionally a hilly surface. The greater part of the area, which was covered by the ice, is underlain by limestone or soft shale, while the unglaciated portion is underlain much more largely by sandstone, alternating with beds of soft shale, which accounts in a large measure for the more hilly topography in the latter section.

In Ohio there is a wide diversity in surface features, with a range from level plains with not more than 10 feet change in elevation for several miles, to rough hills with steep slopes, rising almost precipitously to a height of 300 to 500 feet above the stream valleys. In

the more nearly level areas water stands on the surface and drainage is somewhat deficient, while in the more hilly sections the rainfall runs off very rapidly and considerable damage is done by erosion. This marked contrast in surface features necessarily has a decided influence upon the adaptability of the land for agricultural purposes, as well as upon the type of agriculture which will prove most profitable. Because of this fact it was considered desirable to indicate upon the map not only the character of the soil but also the more pronounced differences in surface features.

The most accurate way of representing the character of the surface is, of course, by means of topographic maps, but these are not yet available for the entire State and a different system has been adopted. The topography has been divided into four different grades, or classes, and the general distribution of surfaces of each class shown upon the soil map by means of parallel lines running in different directions.

Class 1 includes sections where the surface is level or gently undulating and where artificial drainage of at least a large proportion of the land is usually necessary before cultivation can be successfully carried on. (See Pl. II.) This class is shown by horizontal rulings.

Class 2 includes areas where the surface varies from gently to strongly rolling and somewhat hilly. In this class there are practically no areas where the surface is so steep or broken that all of the land can not be readily cultivated. (See Pl. II.) This class is shown by northeast-southwest rulings.

In Class 3 are included areas where the surface is hilly to very steep and more or less broken. In practically all the country included in this class the surface is sufficiently hilly to interfere very seriously with cultivation, and, in fact, quite a large percentage is so steep that cultivation ought not to be attempted. The better part of this class consists of rounded hills, with many small, comparatively level areas well suited to general farming, but the topography of quite a large proportion makes it best suited to pasture or forestry. (See Pl. III, fig. 1.) This class is shown by northwest-southeast rulings.

Class 4 includes areas the surface of which is so very hilly, steep, and often stony and broken, that cultivation is practically impossible, and with the exception of some small areas the land is best used for forestry or pasture. (See Pl. III, fig. 2.) This class is shown by vertical rulings.

Each of these classes necessarily includes a considerable range in surface features. Many small areas of one class are included with another on the map, and there are other areas in which the surface features are between two of the different classes, so that it is quite difficult to decide with which it should be shown or just where the line between them should be drawn. However, this classification enables

one to get a very good idea of the general character of the surface features of any part of the State.

From a study of the map it will be seen that most of the hilly country (Classes 3 and 4) is confined to the southeastern part of the State, while other portions consist very largely of level to rolling plains (Classes 1 and 2). Because of this difference in surface features the State may be divided into two main physiographic regions, one consisting of deeply dissected hilly country and the other of level to rolling plains.

The boundary between these two main physiographic divisions is in some places very distinct, while in others there is a gradual grading of the hills into the plains. In the southern part of the State the change is so abrupt that the hills have the appearance of mountains when viewed from the more level plains to the west.

Beginning at the Ohio River, in eastern Adams County, the dividing line runs northeastward through Chillicothe to beyond Lancaster and, passing around Buckeye Lake, turns north, or somewhat north of west, to Mount Gilead and Mansfield. Between Mansfield and Canton there is no very distinct continuous line. However, the general trend of the hilly country is in an east and west direction, although geologically, and more or less topographically, the line might be considered as extending northeastward to Little Mountain, in Geauga County. There are many areas in the section between Mansfield, Chardon, and Canton which have surface features more like those of the hilly section than of the plains, but the country as a whole is more similar to the latter than the former. From Canton a rather distinct line of hills extends eastward to the Pennsylvania State line near East Palestine. However, some of the country along the Ohio-Pennsylvania line around and north of Youngstown is rather broken and has somewhat the nature of the hilly country. While there are some other areas north and west of the line just given, particularly along the Ohio, Miami, and Little Miami Rivers, and the highlands in Logan County, which have a more or less broken topography, the surface generally is decidedly less hilly than that to the east and south.

The hill country.—All of the country south and east of the line given above is included in the physiographic division known as the hill country, but there are some small areas within it where the surface features are not hilly, but level or gently rolling. In general, however, this part of the State is well described as consisting of a succession of hills and sharp-winding ridges, separated by deep, narrow valleys. Although the hill country proper occurs in the southeastern part of the State, there are many small areas in other sections, particularly along the streams, which have a decidedly hilly surface.

The hilly country represents the western extension of the Allegheny Plateau, which has been so deeply eroded and dissected that all remnants of the plateau surface have been removed.

The greatest amount of dissection has taken place along the Ohio River and its larger tributaries, where the hills rise rather abruptly to an altitude of 300 to 500 feet above the streams and the country is very hilly. As a rule the slopes are very steep, and more or less benchy, while the crests of the ridges are narrow, sharp, and irregular. Back from the main streams those of a minor character have not cut so deeply, and the hill slopes, as a whole, are less steep, the crest of the ridges more rounded, and the altitude above the valleys is not so great. Throughout practically all of the hilly section the surface features are so uneven that the ridge-crest roads are not free from heavy grades. Much of the land is entirely too steep for general farming, and a large part of the remainder is cultivated only with considerable difficulty.

Hard layers of sandstone or limestone, which are very resistant to erosion, tend to hold up the country where they occur, while layers of soft shale weather very rapidly and thus accelerate the rate at which the country is worn down. Sandstone and conglomerate, when thoroughly cemented, as they often are in this region, are very resistant to weathering, and therefore wherever a layer of these rocks outcrops, especially if near the top of the hill, the surface of the country is usually very rough and broken.

Generally speaking, the older Carboniferous formations, especially the Pottsville, which outcrop around the western border of the hilly country, contain a larger percentage of sandstone and conglomerate than is found elsewhere, and many parts of this section are therefore particularly rough, stony, and broken. The sandstone layers are apparently thickest and of most common occurrence in the section of country between Chillicothe and the Ohio River. This fact accounts for the rough character of the surface in parts of Scioto, Lawrence, Pike, eastern Adams, and Ross Counties. The isolated hills, which occur in the vicinity of Chillicothe and Lancaster, are due to the presence of these hard layers of sandstone. North of Lancaster the western border of the hilly country lies well within the glaciated region, and the hills here have been more or less rounded by the action of the ice, so that they are not so abrupt as farther south, although a considerable amount of hard sandstone or conglomerate is found in the country northeast of Mount Vernon and around Doylestown, Akron, and Chardon. Little Mountain, in Geauga County, is the most northern extension of the conglomerate in the State, and owes its presence to the hard, resistant character of this rock, which was able to withstand even the grinding action of the ice.

The plains country.—Approximately three-fourths of the State, including the western and northern sections, consists of level to rolling plains, strikingly different from the hilly southeastern section. In general the surface is a plain, the product of erosion through a long period of time—an old plain modified slightly by a veneer of glacial deposits and the faint scratching by the young streams of a new cycle of development. The young streams have not yet drained all the small lakes and swamps lying on the newly made glacial veneered surface.

As the latest advances of the ice did not extend over the southwestern part of the State, the topography in this section is more mature than in any other portion covered by the ice. The presence of the Ohio, Miami, and Little Miami Rivers has also been favorable to a more rapid erosion in this section, and, therefore, the surface here is more broken and hilly than in almost any other portion of the plains section of the State.

The country along the Ohio River, and extending back from this stream along its principal tributaries, including the Miami and Little Miami Rivers and Whiteoak, Eagle, and Ohio Brush Creeks, is decidedly hilly, much of it being included in the third, and some of it in the fourth, class of topography. The slopes to these streams are usually very steep and broken, but this character of country does not extend so far back from the streams as in the southeastern part of the State.

In parts of Brown, Clermont, Highland, Clinton, and Warren Counties there is a type of topography which is rather peculiar to this section of the State. The surface here was originally level, but the streams have eaten their way into these uplands until at present the country consists of almost dead-level stretches, interrupted by deep, narrow gorges. Looking across the country the surface appears to be level as far as the eye can see, but within less than a mile there may be encountered a narrow, steep-sided valley 100 or even 200 feet in depth. This peculiar character of topography is practically confined to the section covered by the Illinois glaciation and is not found within the limits of the Wisconsin, except where the streams have cut deep channels across the level plains bordering Lake Erie.

In the section of the country between and including Butler and Logan Counties the character of the topography is in marked contrast to that of the section just described. This section comprises a series of terminal moraines, which give the surface a decidedly rolling or billowy appearance. In Logan County, where the glacial material rests upon a remnant of the Allegheny Plateau which occupies the southeastern part of the State, the topography is quite hilly and in some places rough, and this is also true of much of But-

ler County, as well as parts of the intermediate counties, particularly the sections situated near the larger streams. As a rule, however, the topography through this morainic section is made up of long, gentle slopes and rounded hills, giving a billowy surface. In southern Logan County there is a small area of typical kame and kettle topography, consisting of sharply rounded hills and deep, undrained, kettlelike depressions.

Another area of morainic topography is found in the section between Canton and Massillon and extending northward between Akron and Ravenna almost to Chardon. The country here is decidedly rolling and hilly, with many areas of rounded knolls and basins without outlets. A number of small lakes also occur in this section.

A number of other moraines occur throughout the plains section of the State, as can be seen by reference to the glacial map facing page 26, but none of these are as pronounced as those in the two areas just mentioned.

The largest area of level country occurs in the northwestern part of the State, in the section constituting the old lake bed. Over most of Ottawa, Lucas, Fulton, Henry, Defiance, Paulding, Van Wert, Putnam, Wood, Sandusky, and Erie Counties the surface is level, the change in elevation sometimes being no more than 1 foot in a mile. An arm of this level lake-bed country, from 5 to 15 miles in width, stretches eastward along the south shore of Lake Erie as far as the Pennsylvania line. From Cleveland eastward, and in some cases west of this point, there is a sharp rise from the lake plains to the uplands to the south. In the main portion of the old lake bed to the west there is very little broken land along the streams, but going eastward the valleys become deeper and the streams are bordered by belts of thoroughly and sharply dissected country.

There are many smaller areas of level country outside of the old lake bed, as indicated on the map. Such areas occur in the northeastern part of the State and in the section southwest of Cleveland, as well as in the central and western parts. On the whole, these areas outside of the old lake bed are not so uniformly level as the country within, the plane surface being interrupted by gentle swells or undulations. As a rule, the areas occupied by the Clyde soils, the Clermont silt loam, the Volusia and Trumbull clay loams, and the alluvial soils constitute the most level portions of the State.

A very large percentage of the northern and western parts of the State consist of gently rolling plains with just enough change in elevation to give good drainage. Such surface features exist over practically all of the State included in the second topographic class.

Bottom lands.—Throughout most of the hilly country, as well as in the plains section of the State, are found strips of bottom land, but in only a few cases are they as wide as one would expect from the

size of the streams. This is due to the fact that nearly all of the streams, in both the glaciated and unglaciated sections, flow in valleys which have been formed or greatly deepened since the advance of the ice. Nearly all of the streams are, therefore, cutting their channels deeper instead of winding around—making their valleys broader. Because of this fact, very few of the streams have much bottom land along them. Many of them have deep and gorgelike valleys. The Ohio River, for example, although one of the largest streams in the country, has very narrow bottoms along it, the greatest width seldom being as much as a mile. The usual width is very much less, and there are many stretches where the river occupies practically the entire valley. The bottom lands along the Scioto, especially south of Chillicothe, and along the Miami, are wider than those along the Ohio, but this is hardly true of the Hocking. The Tuscarawas has wider bottoms than the Muskingum, due to its occupying a preglacial or interglacial valley. In most cases, however, the alluvial bottom lands are so narrow that it was not practicable to indicate them on the soil map, and those shown are often exaggerated. Most of the streams entering Lake Erie flow in canyonlike valleys with very little, if any, overflow lands along them.

Although the modern alluvial bottoms—those lying along existing streams and subject to occasional overflow—are in most cases very narrow, there are much broader belts of old alluvial valleys in many parts of the State. They are often more than a mile in width and extend across the country for long distances. They are preglacial or interglacial valleys and constitute interesting physiographic features in the State. In some cases they are followed by streams and in other cases not. Occasionally the existing drainage is in a direction opposite to what it was when the valley was formed. Seldom does any existing stream occupy one of these valleys in any other than a misfit way. They are, therefore, called abandoned valleys. One of the most conspicuous of these valleys lies in the eastern part of Lawrence and Pike Counties. It is from 1 mile to 1½ miles in width, and from 100 to 300 feet below the level of the bordering hills, although elevated about 150 feet above the present level of the Ohio and Scioto Rivers. The lower level of these streams has caused some sections of this valley to be rather deeply eroded by streams which have developed since it was abandoned. A number of similar, though smaller, valleys occur through the unglaciated portion of the State. They are occupied principally by the Holston silt loam and Tyler silt loam, so that their location may be determined by reference to the soil map.

Many abandoned valleys also occur along the border of the drift in the section of country between Chillicothe and Canton, and also in the southwestern part of the State, particularly in the section

FIG. 1.—FIVE-YEAR ROTATION FERTILIZER EXPERIMENTS ON WOOSTER SILT LOAM, OHIO EXPERIMENT STATION, WOOSTER.

FIG. 2.—VARIETY FIELDS, OHIO EXPERIMENT STATION.

WHEAT ON CHENANGO SILT LOAM IN FOREGROUND (NO. 1 TOPOGRAPHY) AND WOOSTER SILT LOAM IN BACKGROUND, KNOX COUNTY (NO. 2 TOPOGRAPHY).

between Bellefontaine and Cincinnati. In the glaciated section, or where the streams flow out of the glaciated region, these abandoned valleys are occupied by the Fox, Chenango or the recent alluvial soils, and their course can be readily traced on the soil map.

All of the larger streams, particularly those flowing out of the glacial region, as well as many of their tributaries, have well-defined terraces. Sometimes several different terraces are developed, the highest being 50 to 75 feet above the first, or overflow land. These terraces are usually spoken of as second, third, or fourth bottoms, as the case may be. Each terrace is practically level, but the rise from one to another is usually very abrupt. The most extensive terraces are along the Miami River, where they sometimes have a width of 3 or 4 miles.

REGIONAL DRAINAGE.

Being situated upon the divide between the Great Lakes and the Gulf of Mexico, the drainage of the State of Ohio is effected through the Ohio River and its tributaries, and through streams flowing into Lake Erie. The divide between these two great continental drainage systems is followed rather closely by the Erie Railroad in its course across the State. Of the total area of the State, about 12,000 square miles is drained into Lake Erie, while the drainage of the remaining 30,000 is into the Ohio River or some of its numerous tributaries. Of the streams flowing into Lake Erie, those in the western part of the State are longer, larger, and have a more gentle fall than those farther east.

It will be noted that some of these streams change the direction of their course in a peculiar manner, forming an elbow and flowing off almost at a right angle to their former course. For example, the Grand River flows almost directly northward until within about 10 miles of the lake, where it makes a sharp turn to the west and continues in this direction for a distance of more than 25 miles before it enters the lake near Painesville. From its source, only a few miles south of Lake Erie, the Cuyahoga River flows southwestward for nearly 50 miles to Cuyahoga Falls, where it turns abruptly northwestward, entering the lake at Cleveland. Similar bends will be noticed in nearly all of the streams flowing northward into Lake Erie, and also to a certain extent in those running southward into the Ohio. The diversion of the waters westward was caused by morainic ridges, the presence of which forced the northward-flowing streams to turn westward until they finally broke through and found an entrance into the lake. This can be more easily understood by reference to the glacial map facing page 26.

Practically five-sevenths of the area of the State is drained southward into the Ohio River, which forms the entire southern, and more than half of the eastern, boundary of the State. Of the Ohio tributaries the Miami, Scioto, and Muskingum are the only ones whose headwaters reach back as far as the divide between the Ohio River and Lake Erie. The Wabash and Mahoning Rivers have their source within this State, but reach the Ohio through Indiana or Pennsylvania.

The Muskingum River drains the largest territory of any of the tributaries of the Ohio in this State. In its upper portion it has many branches and is formed by the junction at Coshocton of the largest of these, the Tuscarawas and Walhonding Rivers. South of Zanesville it has no tributaries of any importance, this part of its course being in a postglacial channel.

The Scioto and Miami Rivers, both of which have a number of important tributaries, also drain large sections of the State. These two streams have their headwaters in eastern Auglaize County within a few miles of each other. The Scioto flows eastward through Marion County and thence southward by Columbus to the Ohio at Portsmouth. The Miami flows in a general southwestward direction and enters the Ohio at the extreme southwestern part of the State. It is interesting to note that the Auglaize River, which drains into Lake Erie, also has its headwaters near those of the Scioto and Miami, while the Wabash River has its source only a few miles farther west.

CLIMATE.

Plants must have a suitable environment in order to grow and fruit. This environment consists of two parts—an above ground or climatic and an underground or soil. These two factors control the character of the vegetation on any part of the earth. From a broad, world-wide viewpoint, the climate has a greater influence upon plants than the soil. In Ohio the climatic conditions are fairly uniform over the entire State, while there are marked variations in the character of the soil. For this reason variations in the soil are probably more important in determining dissimilarities in vegetation in this State than the slight differences in climate. While the general climatic conditions are such that practically all crops common to the Temperate Zone may be successfully grown, the weather varies sufficiently to produce decided contrasts in the yields.

The principal climatic factors that influence the growth of crops are temperature, rainfall, and sunshine. Of these, rainfall is the most important in determining crop yields, because the proper amount of moisture in the soil at critical periods is necessary to the largest production. While the temperature and sunshine seldom vary from

the normal sufficiently to affect plant growth to any great extent in this State, there may be a decided deficiency or excess in moisture. A few crops, however, particularly potatoes and tobacco, are influenced by summer temperatures, and fruits and vegetables may be greatly injured or destroyed by early or late frosts or very cold winters. The percentage of sugar in the sugar beet also depends to a large extent upon the temperature and length of the days during the growing season.

GENERAL CLIMATIC CONDITIONS.

The general climatic conditions of the State have been well summarized by Mr. Smith in a recent bulletin of the Ohio Experiment Station, from which the following is taken:[1]

Ohio is in the path of a large part of the general low-pressure or storm areas which move across the United States from west to east. These areas move at an average speed of 600 miles in 24 hours and are preceded by southerly winds and higher temperature and followed by northerly winds and lower temperature. They are usually accompanied by cloudy weather and precipitation and each storm causes an average of from one to two rainy days at each place as they pass across our State.

As there is an average of two of these storm areas each week with fair weather periods between them, it follows that the change in weather conditions is rather rapid. One or two days of stormy weather preceded by higher and followed by lower temperatures, succeeded by one or two days of fair weather preceded by lower and higher temperatures, to be repeated in turn, makes up the usual routine for the week.

Yet Ohio is far enough from the coast so that the damaging Gulf and Atlantic storms lose very much of their severity before reaching our borders. The northwestern cold waves pass across the State with sufficient intensity to ventilate and invigorate the towns and cities and send their health-giving winds into all parts of the State, and yet the cold waves are not so severe in Ohio as in corresponding latitudes in the Mississippi and Missouri Valleys.

TEMPERATURE.

The average annual temperature of Ohio for the period from 1883 to 1910, inclusive, is 50.7°, the highest annual mean temperature being 52.4° in 1894, and the lowest 48° in 1885. The average temperature for July, the warmest month, is 73.1°, and for January, the coldest, 27.7°. There is, however, only 0.5° difference between January and February, and the latter month is quite often colder than the former. June and August are also sometimes warmer than July. The highest temperature recorded in the above period is 113° and the lowest —39°, which gives an extreme range of 152°. Each month from November to March, inclusive, had zero tempera-

[1] The statistical data given in this chapter on Climate, as well as much of the discussion, are taken from "Climate of Ohio," by J. Warren Smith, Bul. 235, Ohio Agricultural Experiment Station.

tures, and every month except July and August had temperatures as low as freezing.

The coolest sections of the State are in the northeastern and the northwestern districts, while the warmest are in the extreme southern and southwestern counties.

The average annual temperature for the coolest section is 48° and for the warmest, 55°, showing a variation of about 7° between the extreme northern and extreme southern portions of the State. As already stated, this is not sufficient to produce any marked effect upon the distribution of the principal farm crops, except oats, which are practically confined to the northern half of the State. Temperature and soil conditions practically restrict the sugar beet to the northwestern part of the State. Serious loss sometimes results from the winterkilling of wheat, which is due to other conditions than extreme cold. The formation of ice over the fields is perhaps most

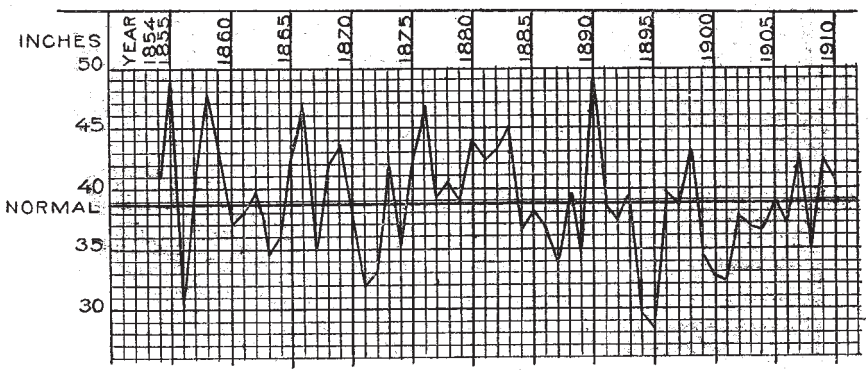


FIG. 2.—Diagram showing annual and normal precipitation for Ohio.

destructive, but alternate freezing and thawing sometimes causes loss by forcing the plants out of the ground.

Lake Erie undoubtedly has a decided influence upon the climate in the section immediately along its shore line, particularly the dates of the last killing frost in spring and the first killing frost in autumn.

The average date of the last killing frost in the spring ranges in different parts of the State from April 15 to May 15. The latest frosts occur in the northeastern part of the State, some distance from the lake. A few places along the lake average as early as April 15, or a little earlier than the average for the extreme southern portion of the State, which is about April 20.

The average date of the first killing frost in the fall ranges from September 20 in the northern part at points some distance from the lake to October 30 near the lake and October 25 in the extreme southwestern part of the State.

The average number of days in the crop-growing season varies from 134 in Portage County to 195 at Sandusky, 194 at Cincinnati,

and 193 at Cleveland. The average for the greater part of the State, however, is between 150 and 170 days.

PRECIPITATION.

The average annual precipitation for the State is 38.89 inches. The amount which may fall in any one calendar year varies consid-

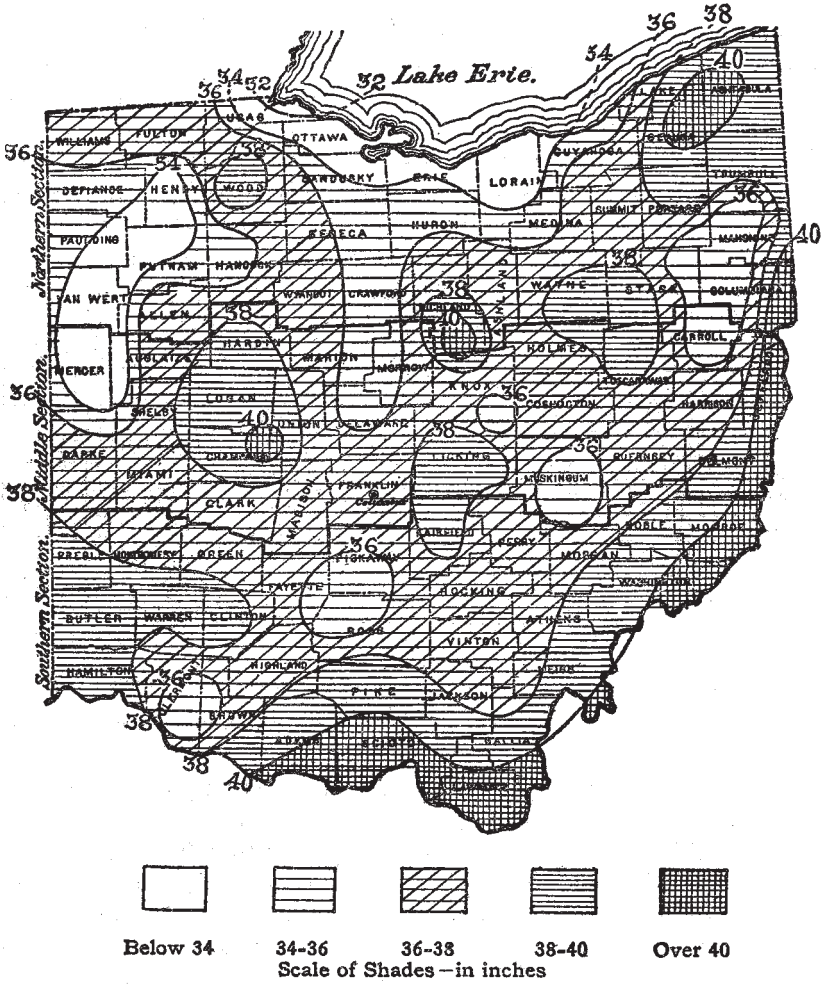


FIG. 3.—Map showing average annual precipitation.

erably, 50.33 inches being reported in 1890 and 20.2 inches in 1856. Figure 2 shows the annual precipitation from 1854 to 1910, as well as the normal for this period.

While the average annual precipitation is fairly uniform over the State, there are some variations in different sections, as indicated by figure 3, in which the differences in precipitation are shown graphi-

cally, areas having approximately the same amount of precipitation being given the same shading.

The precipitation is rather evenly distributed throughout the year, June, the wettest month, having an average of 4.13 inches, and October, the driest month, 2.52 inches.

During the winter months much of the precipitation is in the form of snow, especially in the northern part of the State. The greatest average annual snowfall is in the northeastern part of the State, where it amounts to as much as 50 inches per year. In the extreme southern portion the amount is somewhat less than 20 inches.

For the State the average number of days with 0.01 inch or more of precipitation is 122, the highest number out of 19 well-distributed stations being 159 at Cleveland and the lowest 79 at New Bremen.

SUNSHINE.

The average amount of possible sunshine for the State is 52 per cent. The northern portion has the lowest and the southern the highest percentage. Cleveland has 45 per cent, Toledo 52 per cent, Columbus 54 per cent, and Cincinnati 56 per cent. The amount of winter sunshine, especially in the lake region and along the Ohio River, is very low, the average for November to February, inclusive, at Cleveland being only 26 per cent and at Toledo 36 per cent, Columbus 37.5 per cent, and Cincinnati 30.5 per cent. The latter is lower than Columbus probably because of river fogs. In other words, the sun is obscured by clouds during three-fourths of the day on an average at Cleveland from November 1 to March 1, and almost as much at some other points. This cloudy condition may possibly account for the difficulty experienced in the growing of head lettuce in the lake region.

SOILS.

GENERAL CHARACTERISTICS AND COMPOSITION.

A study of the land surface of the earth will show that it consists almost everywhere of a relatively thin mantle of unconsolidated material, composed of rock débris mixed more or less with the remains of plant and animal life. This superficial covering, which furnishes a suitable medium for the growth of plants, we call "the soil," in the broad use of this term. In a more restrictive sense, however, the term "soil" is used to designate the surface few inches, which has usually been darkened or changed in color by organic matter and weathering, while the stratum below is termed the "subsoil."

The soil material has been formed by the breaking down of the rocks through the action of certain agencies, mainly changes of

temperature and solution, while it has been distributed to the places where it now lies by moving water, ice, and air, or has accumulated where formed.

Although the soil material has been formed by the degeneration of the rocks, and consists very largely of mineral matter, the soil is not mere unconsolidated rock material, but consists of this material together with a varying amount of organic matter, both inorganic and organic matter having been changed by weathering agencies during the evolution from mere soil material to soil.

Lime carbonate.—In the progress of the survey hundreds of litmus-paper and hydrochloric-acid tests were made in all parts of the State. These tests showed that the surface soils over practically all of the State are deficient in lime carbonate. Very few cases were found where the amount of lime in the surface 18 inches was sufficient to effervesce with hydrochloric acid. However, a reddening of blue litmus paper was very common and, in fact, almost always took place, except in the black soils of the Clyde series, especially the clay loam and clay, which seldom gave a decided reddening, and the Brush clay, which, however, effervesced quite freely.

More striking variations were noticed in the subsoils. In the western half of the State, where the drift consists largely of ground-up limestone, the subsoils below 2 feet, and not infrequently nearer the surface, effervesced quite freely with acid in a large majority of cases, showing the presence of an abundant supply of lime carbonate. In the northeastern part of the State, where the drift is composed largely of shale and sandstone material, a decided reddening of the litmus paper was noted, although many of the road cuts, and sometimes a 3-foot boring, would give an effervescence, particularly where the subsoils had a heavy texture. Sandy or gravelly subsoils seldom effervesced within 3 feet of the surface, except in cases where limestone gravel was encountered before this depth was reached.

Many limestone concretions were seen in the road cuts in the glaciated shale and sandstone section, which was not the case where the drift is composed very largely of limestone.

During the progress of these studies it was observed that the subsoils which contained iron concretions, brown iron stains, or white mottling did not effervesce. The presence of these may, therefore, be taken as an indication of a lack of lime, as may also a very light gray or white color where intermittent wet and dry conditions have existed.

Only small areas of soils composed almost entirely of sand occur in the State, while the area of clay soils is not large and is confined almost entirely to the section of the old lake bed west of Defiance. The percentage of silt is usually high, and probably averages as much

as one-half of the surface soil. The subsoil usually has less silt and more clay, the latter generally running from 30 to 40 per cent. By far the great majority of the soils of Ohio should be classed as of medium texture, including loam, silt loam, and clay loam.

Most important constituents.—Of the various constituents that go to make up the composition of the soil, all of which are of greater or less importance, the three which dominate are humus, lime carbonate, and clay. The percentage of these ingredients determines more than anything else the relation of the soil to plant growth. If soils differ materially in the percentage of humus, lime carbonate, or clay, their properties will necessarily be diverse and their crop adaptation and methods of soil management different. Therefore an idea of the approximate amount of these constituents present is essential to an understanding of the character of the soil.

UNDERLYING GEOLOGICAL FORMATIONS.

Limestones.—From a geological viewpoint, practically all of the country west of a line drawn through Sandusky, Columbus, and the eastern part of Adams County is underlain with limestone, the exception being a small area in the extreme northwestern section of the State and a part of the high area in Logan County. Of these rocks the State geologist has this to say:

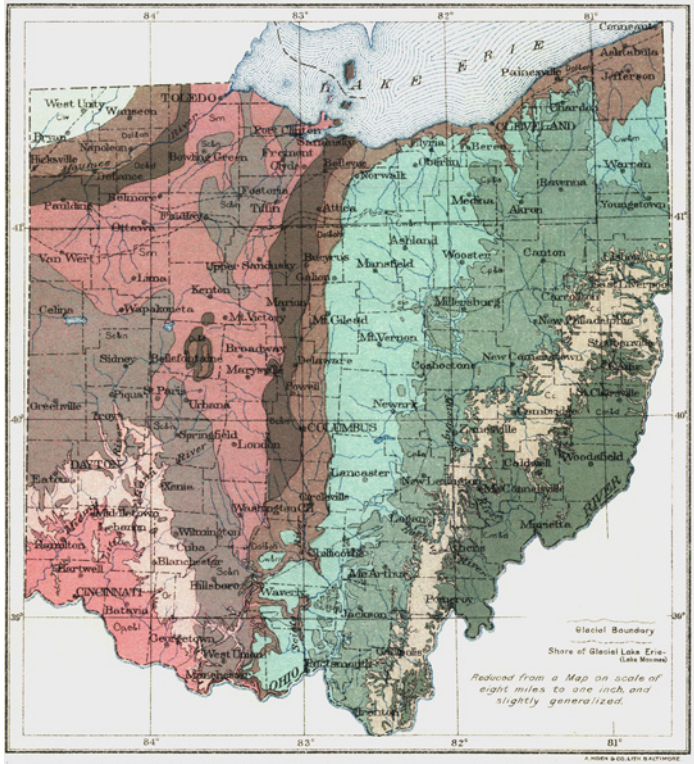
> These western deposits are generally massive, crystalline, light-colored stones of remarkable purity. The clay or sand or iron coloring matter falls below 2 per cent in hundreds of places. The composition, however, is generally dolomitic—i. e., the stone is a mixture of carbonate of calcium and carbonate of magnesium, the proportions often becoming those of the mineral, dolomite, itself, which contains 56 per cent of calcium carbonate and 44 per cent of magnesium carbonate.[1]

Some limestones are also found in the Carboniferous formations which occupy the southeastern part of the State, particularly in the section between Steubenville and Athens, or the portion shown on the soil map as the Westmoreland series. The same authority, discussing these formations, says:

> These Carboniferous limestones are generally under 10 feet in thickness, often only 1 or 2 feet being found. They are very hard, dense rocks, even in spite of their solubility in carbonated waters, lasting longer than the sandstones and shales with which they are intercalated. They generally are blue or dark in color, conchoidal in fracture, fossiliferous, and exceedingly persistent or regular over large areas of country. On this account they have been of infinite service to the stratigraphical geologist, serving as the key to the rocks above and below them. In the largest portion of the coal measure areas, comprising roughly one-third of the State, there are from two to five separate lime-

[1] Bul. 4, Ohio Geological Survey, p. 24.

Report of the Bureau of Soils, U. S. Dept. Agr., 1912 Plate B.



GEOLOGICAL MAP OF OHIO, BY J. A. BOWNOCKER, STATE GEOLOGIST, 1909

stone horizons represented in the same territory. These naturally overlap each other, so that an ascent of one hill will often bring three or four limestone horizons to view. But these beds are generally 5 feet or less in thickness. * * *[1]

Sandstones and shales.—While some limestones are found in the eastern half of the State, the formations consist mainly of sandstones and shales, with some conglomerate, especially in the lower Carboniferous.

The color of the greater proportion of these shales and sandstones is some shade of gray, but occasionally layers which are almost black are found. This is especially true in the Olentangy and Ohio shales of the Devonian. The upper portion of the Conemaugh and the Monongahela and Dunkard formations, which occupy the country between the Ohio River and a line drawn through Steubenville, Cadiz, Athens, and Carpenter, are made up of a series of alternating beds of red, greenish, or gray shales and gray sandstones, which give rise to the Meigs soils. Practically no red shales occur in the Allegheny or Pottsville formations or the Waverly group. In some cases the shales are calcareous, and this seems to be particularly true of the red more than of the gray or yellow shales. However, when associated with the limestones, the nonred shales are often calcareous.

Plate B shows the distribution of the underlying rock formations, and the reader is referred to this for further details.

GLACIAL AND ALLUVIAL FORMATIONS.

Extent of glaciation.—In its advance the ice did not cover all of the State, the southeastern section, or approximately one-fourth, being unglaciated. The line marking its farthest advance enters the State from Pennsylvania near Negley, extends almost due west through Lisbon to Canton, where it turns southwest to Millersburg. From this point it runs slightly northwest, almost to the western boundary of Holmes County, and then turns at a right angle southward, in which direction it extends almost to New Lexington; from there it follows a southwest course, running just south of Chillicothe to the Ohio River near Ripley, in Brown County.

Direction of ice movement.—The general direction of the ice movement, as shown by the arrows on the map which represent striations on the underlying rocks, was from the north or northeast to the south or southwest. This is essentially parallel to the strike of the underlying rocks. The result of this is that the local glacial material in the eastern or sandstone and shale part of the State is almost ex-

[1] Bul. 4, Ohio Geological Survey, p. 23.

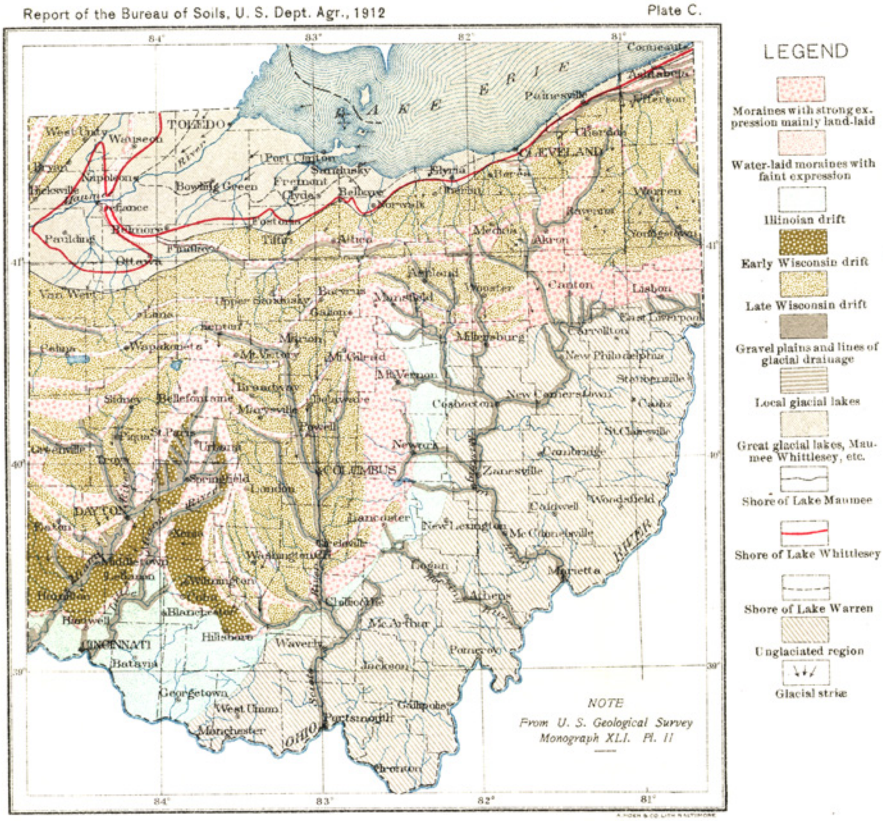
clusively sandstone and shale, while that in the western or limestone part of the State is limestone. There was very little mixing of local material by the ice. However, considerable variation in the direction of the ice movement, due to the elevation and contour of the underlying rock surface, took place. This can best be understood by observing the curve of the moraines on the glacial map. (See Pl. C.)

It will be noted that the broadest moraines are found in the section of the country leading southward from the areas of higher lands. This is due to the fact that the currents of ice which flowed around these higher lands tended to come together again, the movement being outward from the center of the lobe. The junction of these northwest and northeast currents checked the advance of the ice and caused the deposition of a large amount of morainic material along the line of contact. This offers an explanation for the hilly character of the country between Canton, Akron, and Chardon, and also around and southward from Bellefontaine. This direction of the ice movement is a matter of considerable importance, because of the influence which it had in determining the character of the glacial deposits, as is brought out more fully later.

Depth of drift.—The mantle of glacial material left by the ice is not uniform. In some small spots no deposition at all took place, while in others the drift has a thickness of slightly over 500 feet.

In the section between Columbus, Marysville, Wapakoneta, Greenville, Springfield, Washington Courthouse, and Circleville the deposit of drift is usually more than 100 feet in thickness. An arm of this deeper material extends eastward along the old valley to Newark, where it separates, one branch extending northwestward to beyond Mount Vernon, the other northeastward by Coshocton, New Philadelphia, Massillon, and Akron, to the lake at Cleveland. Another area more than 100 feet in thickness covers the northwestern part of the State. The old valley extending from Youngstown north westward by Warren and then northward to the lake just west of Ashtabula is also filled with a deep deposit of glacial drift. Likewise, the deposits in the Miami Valley are usually more than 100 feet in thickness.

In general, the thinnest portion of the drift occurs along the southeastern border of the glaciated area, especially in the section covered only by the Illinois glaciation. Much of this country, as well as a strip several miles wide extending east from Mansfield to the Pennsylvania line, has less than 25 feet of drift. Another area, where the mantle of drift is very thin, occurs along the lake from Elyria eastward to Pennsylvania. This area includes most of the country along the Cuyahoga River and also the high land on the west side of the Grand River Valley. Over most of the rest of the



GLACIAL MAP OF OHIO. FROM SURVEYS BY FRANK LEVERETT, 1900

Scale
10 0 10 20 30 40 50 Miles

State, comprising considerably more than one-half its area, the drift is from 25 to 75 feet in depth, although there are many small areas where the rock is only a few feet below the surface.

Character of deposits.—Glacial deposits are usually characterized by a very heterogeneous mixture of materials picked up by the ice in the country over which it has moved. Some of the material is of local origin, while other portions may have been transported hundreds of miles. The percentage of local material is usually greatest where the drift is thinnest. All the crystalline bowlders in the State, and doubtless much of the finer material of the drift, were brought from the Canadian regions far beyond Lake Erie.

In the discussion of the underlying rock formations it was brought out that in practically all of the country west of the line drawn from Sandusky to Columbus the rocks consist of limestone, while east of this line they are composed almost entirely of sandstone and shale. For this reason the glacial material in the western half of the State is composed very largely of ground-up limestone, while that in the eastern part is made up chiefly of ground-up shale and sandstone. From Bellefontaine and Wapakoneta northward the limestone fragments are less in evidence than to the south. These fragments are especially prominent in the Miami Valley and in the morainic country extending from Bellefontaine southward by Urbana and Springfield. In this southwest section of the State particularly no sandstone or shale fragments are noticed, but east of the moraines, in the Darby Plains, the drift has apparently been influenced to some extent by an inclusion of some ground-up shale material with the limestone.

In the entire northeastern part of the State and extending as an arm southward as far as Chillicothe the drift is composed very largely of ground-up shale and sandstone, with an addition of some crystalline rocks. The shales were usually soft and easily ground up, and are therefore not much in evidence, while sandstone fragments are quite common over much of this section. This is especially true in the country east of Wooster and Medina, particularly in the moraines running northward from Massillon. This may be due to the fact that in the eastern portion of the State the movement of the ice was almost at right angles to the outcrop of the rock, which would tend to cause the ice to gouge up the projecting ledges of sandstone and mix them with the drift, while to the southwest the movement of the ice was almost parallel to the line of outcrop.

The loess.—Although the southwestern part of the State was covered by the ice, very little of the soil here is derived directly from the drift, because this has been covered by a thin layer of silty material

known geologically as loess, but sometimes referred to as the "white clay." This layer is practically confined to the section of the State occupied by the older or Illinois glaciation. However, it extends eastward beyond the line of glaciation, its exact limit being very difficult to determine. While no areas have been definitely located within the Wisconsin glaciation, unless it be in Highland County, there are places where a thin silty layer is found which may possibly have been formed in the same way.

Glacial lakes.—In the melting and retreating northward of the ice a large number of glacial lakes, some of which are still in existence, were formed. The largest of these lakes, which might be considered simply as an extension of the present Lake Erie, was formed in the northwestern part of the State and covered a very large proportion of this section. East of Elyria this lake did not extend many miles farther southward than the present Lake Erie, but west of this point the waters covered a large area of country, extending westward almost to Fort Wayne, Ind. The drainage of this lake was effected through a southwest channel which can now be seen at the latter place.

There were several stages in the receding of the waters, as is shown by the presence of several beach lines, to which different names have been given, each representing the extension of the lake during these different stages. The stage of greatest extent is known as Lake Maumee, while Lake Whittlesey and Lake Warren are names applied to the later stages. The outline and the extension of this lake can be best understood by reference to the glacial map (Pl. C).

During the early history of Lake Maumee east of Findlay the ice probably extended almost as far southward as the highest beach line, but west of this point the ice lobe reached only as far as Leipsic, Defiance, and Wauseon. The tongue of country extending west from Findlay to Leipsic and the rolling country north of Wauseon represent the terminal moraine. Between Leipsic and Wauseon the material deposited by the ice was not sufficient to raise the country above the level of the lake, and the moraine in this section is believed to have been laid down under water, but its course is easily traced by the presence of the beaches.

While these lakes were in existence material was carried into them by the streams, just as is being done into Lake Erie to-day. The coarser particles were laid down as delta deposits near the mouths of the streams, or thrown up as beaches by the waves along the shore. The finer particles were carried into the deeper, more quiet portions of the lake. With the exception of the country west of Defiance, only small areas show evidence of the deposition of any considerable

amount of fine material. West of Defiance there is a deposit of lacustrine material apparently several feet in thickness, but east of this point one can nearly always bore into material containing pebbles or fragments of rock within 3 feet of the surface, except where sandy deposits occur. In much of the country south of Toledo the limestone rock is in many places very near the surface, or even outcrops, proving that very little material was deposited in the lake at these points. The extremely level character of the surface, however, indicates that some reworking of the surface material has probably taken place, for ice-laid deposits are seldom, if ever, so uniformly level as is this section of the State.

The character of the material carried into the lake depended very largely upon the nature of the glacial formations in the uplands through which the streams flowed. As the underlying rocks and glacial deposits east of Milan consist largely of sandstones and shales, while those west are composed principally of limestone, the character of the lacustrine material east of this point is somewhat different from that to the west, and a division of the lake soils is necessary.

A part of the material which was thrown up by the waves along the shores was taken up and redeposited by the wind, giving rise to large areas of sand, which are mapped with the Dunkirk sand.

Terraces.—Most of the streams which drain into the Ohio, rather than into Lake Erie, are bordered by a series of more or less continuous terraces. In some places only one terrace is present, while in others as many as four or five may be seen. These terraces were formed by a filling of the valleys with material deposited by the streams. Where the streams flow through or issue from the glaciated portion of the State, the terraces are composed very largely of sand and gravel, with a thin layer of heavier material at the surface, but where the streams are entirely in the unglaciated section of the State the terraces consist mainly of silt and clay, with very little sand or gravel. In other words, the gravel terraces represent glacial outwash, while the other terraces are built-up with material from another source. Even in the unglaciated portion of the State large streams like the Ohio, Muskingum, and Hocking, with their headwaters in the glacial region, have gravel terraces along them, but the terraces along their tributaries have no gravel beneath. Evidently the streams having their rise outside of the glacial region carried very little or no gravel. The Muskingum and Little Muskingum Rivers, at their mouth, near Marietta, furnish an excellent illustration of the differences in character of material brought down by streams coming from the glaciated and the unglaciated section.

There is much uniformity in the character of the material making up the terraces which are not underlain with gravel, because the streams have flowed through a region of sandstones and shales, but the gravel terraces show considerable variation. Where the streams have flowed out of the glaciated sandstone and shale region the gravel consists largely of these rocks, with an admixture of some crystallines, but where the country was underlain with limestone the gravel is largely limestone, with some crystalline rocks included. All the streams in the western part of the State, extending eastward and including the Scioto, belong to the latter group, while those of the eastern part fall in the former.

Alluvial deposits.—Along nearly all the streams in the State are deposits of alluvial material, which represent the youngest geological formation of the State. As these alluvial deposits consist of actual soils which have been washed off the uplands and laid down as such by the streams, no further description is given here, but they are discussed later in this report in connection with alluvial soils.

CLASSIFICATION.

Soils must be classified or grouped according to their relationships. There are many ways to do this, depending upon the relative importance given to the various soil characteristics. In this report they are classified according to texture, structure, color, and source of the material, the agencies by which it was accumulated, and differences due to variation in the processes of weathering since the material has been laid down. On the basis of texture they are classified into sands, sandy loams, loams, silt loams, clays, and clay loams. The members of any one of these classes are further divided into groups according as they differ in some one or more of the other characteristics mentioned above. These groups are called series, and they are designated by giving them locality names, such as Miami soils or Clyde soils. A soil unit is called a soil type. It is uniform in all the above characteristics in all places where it is found. The Miami sandy loam, for example, should be the same in Wisconsin or Minnesota as in Ohio.

All areas of soil which are practically the same in essential characteristics and properties are included in the same type. Variations in productiveness due to differences in treatment are not considered as type differences, because they may be readily eliminated. A differentiation into types must be based upon inherent and practically unchangeable characteristics. The object of this survey was to locate and describe all of the important types in the State.

In order to enable one to grasp more readily the distribution of these different types and their relation to each other, a map showing the occurrence of the principal soils has been constructed. Because of the intimate association of some of the types it is not possible to show each of them by a separate color on the map; in fact, in nearly every case each color represents two or more distinctly different types of soil, as is indicated in the legend. Where the areas shown under one color consist very largely of one or two types the individual type names are given, but where more than two are included the series name is used instead. More detailed study may develop the necessity of further subdivision of some of the types or the presence of others of less importance not recognized in this general survey.

It should also be borne in mind that the change from one type to another is most often not marked by a sharp or distinct boundary, but rather by a gradual transition, sometimes extending over a considerable distance. This condition, and the further fact that in a reconnoissance survey the boundaries can not be actually traced out through their entire distance, makes the boundaries on the map more or less arbitrary. Therefore in using the map these as well as other limitations should be understood and due allowance made.

The following table shows the groups, series, and types which are recognized in the survey, although it is not possible to indicate all of them separately on the map:

Classification of Ohio soils.

Group.	Series.	Type.
Residual limestone soils	Colbert series	Colbert silt loam.
	Hagerstown series	Hagerstown silt loam.
	Brush series	Brush clay.
Residual shale and sandstone soils	Dekalb series	Dekalb sandy loam.
		Dekalb stony loam.
		Dekalb silt loam.
	Upshur series	Upshur clay.
	Meigs series	Meigs series.
Residual shale, sandstone, and limestone soils	Westmoreland series	Westmoreland series.
	Brooke series	Brooke clay loam.
Glacial drift soils (limestone)	Miami series	Miami sandy loam.
		Miami silt loam.
		Miami clay loam.
		Miami clay.
	Bellefontaine series	Bellefontaine gravelly loam.
		Bellefontaine silt loam.
		Bellefontaine clay loam.
		Bellefontaine clay.

Classification of Ohio soils—Continued.

Group.	Series.	Type.
Glacial drift soils (shale and sandstone)	Wooster series	Wooster sandy loam.
		Wooster gravelly loam.
		Wooster loam.
		Wooster silt loam.
	Volusia series	Volusia loam.
		Volusia silt loam.
		Volusia clay loam.
		Volusia silty clay loam.
	Trumbull series	Trumbull loam.
		Trumbull silt loam.
		Trumbull clay loam.
Glacial lake soils	Clyde series	Clyde sand.
		Clyde sandy loam.
		Clyde loam.
		Clyde clay loam.
		Clyde clay.
	Belmore series	Belmore sandy loam.
		Belmore loam.
	Dunkirk series	Dunkirk sand.
		Dunkirk sandy loam.
		Dunkirk gravelly sandy loam.
		Dunkirk loam.
Loess soils	Cincinnati series	Cincinnati silt loam.
	Clermont series	Clermont silt loam.
Terrace soils	Fox series	Fox sandy loam.
		Fox loam.
		Fox silt loam.
	Chenango series	Chenango sand.
		Chenango sandy loam.
		Chenango gravelly loam.
		Chenango silt loam.
	Holston series	Holston silt loam.
	Tyler series	Tyler silt loam.
Alluvial soils	Wabash series	Wabash sandy loam.
		Wabash loam.
		Wabash silt loam.
		Wabash clay loam.
	Papakating series	Papakating loam.
		Papakating silt loam.
		Papakating clay loam.
		Papakating clay.
	Huntington series	Huntington sandy loam.
		Huntington loam.
		Huntington silt loam.
	Holly series	Holly silt loam.
Organic soils		Peat and Muck.
Miscellaneous materials		Rock outcrop and areas of very shallow Residual or Glacial Limestone soils.
		Marsh.

The following table gives the actual and relative extent of the various soils mapped in the State:

FIG. 1.—APPLE ORCHARD ON MEIGS SOILS, GALLIA COUNTY. SHOWING NO. 3 TOPOGRAPHY.

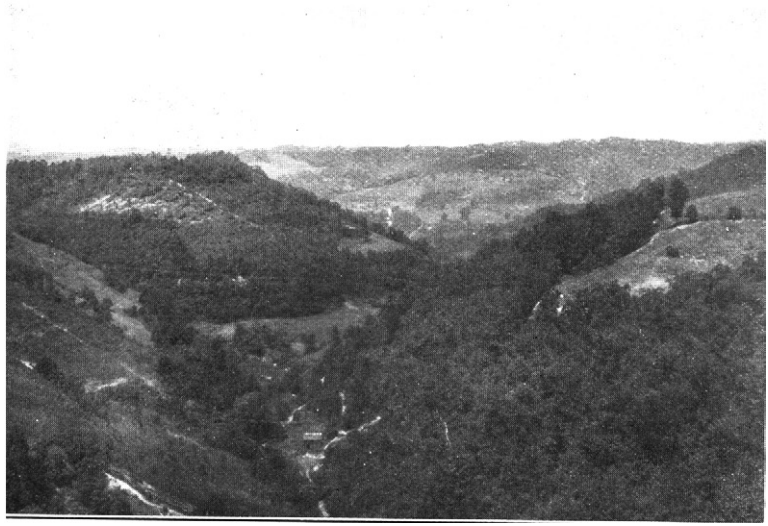


FIG. 2.—ROUGH, BROKEN COUNTRY, MAINLY NO. 4 TOPOGRAPHY.

These very rough areas are best suited to forestry.

FIG. 1.—BADLY ERODED MEIGS SOILS IN WASHINGTON COUNTY.
Sweet clover is very valuable in reclaiming such areas. (See cut below.)

FIG. 2.—BADLY ERODED FIELD RECLAIMED BY USE OF SWEET CLOVER.
Six years ago this field, then absolutely barren and badly washed, was sown to sweet clover; now it is covered with good sod, prevailingly bluegrass.

Areas of different soils.

Soil.	Acres.	Per cent.	Soil.	Acres.	Per cent.
Miami silt loam and clay loam	5,004,288	19.2	Clermont silt loam	352,512	1.4
Dekalb silt loam	4,301,760	16.5	Residual limestone soils	315,136	1.2
Clyde clay loam	2,243,136	8.6	Clyde sandy loam and loam	310,464	1.2
Volusia silt loam and clay loam	1,820,864	7.0	Chenango series	231,104	.9
Alluvial soils	1,652,608	6.3	Dunkirk series	198,464	.8
Meigs series	1,475,200	5.7	Holston silt loam and Tyler silt loam	196,096	.8
Volusia and Trumbull series	1,440,192	5.5	Dunkirk sand	189,056	.7
Wooster silt loam	1,132,096	4.3	Miami clay	178,432	.7
Miami and Bellefontaine series	1,118,080	4.3	Peat and Muck	63,040	.2
Volusia and Trumbull clay loams	968,576	3.7	Belmore sandy loam and loam	37,120	.1
Cincinnati silt loam	802,944	3.1	Marsh	28,032	.1
Westmoreland series	611,584	2.4	Rock outcrop and areas of very shallow residual or glacial limestone soils	20,992	.1
Clyde clay	511,168	1.9	Total	26,073,600	.....
Fox series	459,840	1.7			
Wooster series	410,816	1.6			

RESIDUAL LIMESTONE SOILS.

As most of that part of the State which is underlain by limestone was covered by the ice, only a comparatively small area of residual limestone soils is found, this being confined mainly to Adams County. Practically all of the north-central, central, and southwestern parts of this county, a small area in the southwestern part of Pike County, and the southeastern portions of Brown and Highland Counties have soils belonging to this division. Small areas of limestone soils are also found on nearly all of the steeper slopes in the tier of counties bordering the Ohio River from Adams County westward to the Indiana State line. However, this section was covered by a deposit of loess, and the soils, even on the steepest slopes, are influenced more or less by this material. Sometimes limestone soils occur in the Carboniferous formations which are encountered in the southeastern part of the State, but the areas are usually small and the material more or less mixed with that from the shale, so that it is considered best to describe these in connection with the Westmoreland series.

Although three distinct types of soil, belonging to three different series, were readily recognized in the field, they are so intimately associated that it was not possible to separate them in this survey, and they are therefore all shown in one color on the map, but a separate description of each type is given.[1]

[1]Although two of these types have been correlated with the Colbert silt loam of Alabama and the Hagerstown silt loam of Pennsylvania, there is doubt as to the correctness of these correlations, and the names may be changed later.

In the section of country occupied by this group of soils the surface varies from gently rolling to very hilly and broken. All of the larger streams have cut gorges 100 to 200 feet in depth, making the country along them very hilly and broken. Generally speaking, the roughest part of the country occurs along the Ohio River, where the bluffs are usually too steep for cultivation, but this is also true of most of the country bordering the larger streams. Ridges formed by hard layers of limestone also occur in some sections, as at West Union, giving the country a hilly surface.

The largest section of gently rolling land is in the eastern part, extending from the southwestern corner of Pike County southward to Peebles and Bentonville. Other areas occur between Bentonville and the Ohio River. However, the topography of the larger part of this section is broken, yet it is not by any means as hilly as eastern Adams or western Scioto Counties.

COLBERT SILT LOAM.

The Colbert silt loam consists of a grayish-brown or light yellowish brown, mellow silt loam, with a depth of 8 to 11 inches. The subsoil is a yellow silt loam to silty clay loam grading at about 20 inches into a yellow silty clay, which is often very stiff and plastic in the lower part of the 3-foot section. The upper part of the subsoil is usually yellow, grading at varying depths into a dull yellow, and in places in the lower part to a rather dark yellow or brown. Very frequently, especially in the northeastern part of Adams County, marl or limestone is encountered at depths varying from 20 to 26 inches, and in these areas gritty material is encountered within 3 feet. In some localities there is some grayish mottling in the lower part of the subsoil, and some iron concretions are present. Rarely does the surface soil give an alkaline reaction, although fragments of limestone are frequently found in the soil and on the surface. The subsoil seldom effervesces where the limestone rock is not encountered within 3 feet of the surface.

This type is formed from the weathering of limestone or marl. The surface soil, however, very closely resembles the Cincinnati silt loam in many characteristics, and it is very difficult to draw a boundary between the two. In fact, it seems very probable that the surface soil of a large part of this type is really a thin deposit of loessial material over the limestone. Were it not for the heavier nature of the subsoil and the presence of limestone fragments on the surface, it would be practically impossible to separate the Colbert silt loam from the Cincinnati silt loam, except where the latter has a layer of drift between the loess and the limestone.

The Colbert silt loam occurs throughout the area shown on the map as residual limestone soils, and probably occupies more than

two-thirds of this area. In addition it is found upon nearly all of the steeper slopes along the Ohio River westward to the Indiana line, associated with the Cincinnati silt loam. In this latter section it is especially prominent in the area which has the third class of topography. In Adams, Brown, and Highland Counties it is so intimately associated with the Hagerstown silt loam and Brush clay that it is not possible to differentiate them in this reconnoissance survey, and in fact considerable difficulty would be experienced in separating them even in detailed work.

The Colbert silt loam is a fairly productive soil and when well cultivated gives good yields of general farm crops. The average yield of corn ranges from about 25 to 35 bushes per acre, of wheat from 10 to 15 bushels, hay from 1 to 1½ tons, and oats from 20 to 25 bushels. Considerable tobacco is grown, particularly in Brown and Clermont Counties, where yields of 1,000 to 1,500 pounds per acre are secured. Some areas are devoted to alfalfa, especially on the slopes in Hamilton County.

HAGERSTOWN SILT LOAM.

The Hagerstown silt loam consists of a brown to slightly reddish brown, rather heavy silt loam about 10 inches deep, underlain by reddish-yellow to yellowish-red silty clay loam or clay. The variation in color, however, is usually wide, even within the same field. The slightly reddish brown color of the surface soil may give way to a dull yellow, or dull grayish brown, while the reddish-yellow or yellowish-red subsoil may change to a dull yellow or dull brown within a few feet. Limestone, or disintegrated fragments of this rock, is often encountered within 3 feet of the surface.

The Hagerstown silt loam is probably most extensively developed in Bratton Township in Adams County, but it is found throughout the entire area of limestone soils. It is apparently of more common occurrence in the section underlain by marl than in that underlain by the harder limestone. Very little of it is found west of Adams County, although there are several areas in Highland County, even in the section mapped chiefly as Cincinnati silt loam.

The surface is rolling and sometimes hilly, but some fairly level fields are encountered.

This type is derived from the weathering of limestone and marl, and outcrops of these rocks, especially the former, are quite frequent.

As a whole this is probably the best of the limestone soils. Bluegrass does well upon this type, as upon the Colbert silt loam, and on this account both make good pasture land. The yields of corn range from 20 to 45 bushels and of wheat from 10 to 25 bushels per acre. Hay produces from 1 to 1½ tons per acre, and oats from 20 to 40 bushels, although the latter crop is not extensively grown and

is not considered profitable in this section. Tobacco is grown to some extent and yields from 1,200 to 1,500 pounds per acre. Some fields of alfalfa were seen, and it is believed that this crop can be produced successfully and that its extension would prove profitable.

BRUSH CLAY.

The Brush clay is a dark-gray, sometimes almost black, heavy, sticky clay loam to clay. The depth of the surface soil varies from 2 to 5 inches, but there is no distinct line between this and the subsoil. Many limestone bowlders are scattered over the surface and through the soil. In fact, these are present in sufficient quantities in places to justify calling these areas the Brush stony clay. The subsoil consists of a gray or drab clay of a very greasy and plastic nature. In general the subsoil is lighter in color at a depth of 16 to 20 inches, although in some areas it becomes very much darker at a depth of 30 to 36 inches. Usually, however, the deeper subsoil is light grayish yellow or light gray in color, though sometimes it is a dark yellowish brown. In many cases rock is encountered at 18 to 36 inches. The surface soil sometimes effervesces, and the subsoil nearly always does so. Seldom does either the soil or the subsoil redden blue litmus paper, but the subsoil will nearly always cause red litmus paper to turn blue, and this is also frequently the case in the surface soil.

The Brush clay is derived from shaly limestone and calcareous shales. On this account it might properly be considered as belonging with the group of soils derived from shales, but owing to its intimate association with the other limestone types and its calcareous nature it is best considered with them.

This type is practically confined to the steep slopes. The principal areas occur as narrow strips along Ohio Brush Creek and the Ohio River. The topography is so steep and broken that the type can not well be used for general farming and is best suited for pasture.

RESIDUAL SHALE AND SANDSTONE SOILS.

A very large percentage of the unglaciated portion of the State is underlain by shales and sandstones, which have given rise to two distinctly different soil series, the Dekalb and Upshur.

DEKALB SERIES.

Where the underlying rocks consist almost entirely of grayish or other light-colored shales and sandstones, they have given rise to types having gray or pale yellowish brown surface soils and yellow subsoils, which have been included in the Dekalb series. Several different members of the Dekalb series are developed in the State,

but none of these are of very much importance except the Dekalb silt loam. However, where the rocks are composed largely of sandstone, small areas of the sandy loam are encountered, while in some places the percentage of stones on the surface is sufficient to justify calling the soil a stony loam. The sandy loam seldom occurs in areas of greater extent than a few acres, although a number of such areas are found throughout the section occupied principally by the Dekalb silt loam. The stony loam is developed in considerably larger areas, especially where the topography is rather rough and broken, as in Scioto, Pike, Lawrence, and, to a less extent, in other counties, particularly where the vertical ruling is used. These types are so intimately associated with the Dekalb silt loam and are of such small extent as compared with this type that they are included with it on the map.

DEKALB SANDY LOAM.

The Dekalb sandy loam consists of a grayish-brown medium to fine sandy loam, underlain at about 6 to 8 inches by a yellowish sandy loam of almost the same texture as the surface soil, but usually containing a slightly greater percentage of clay. The texture varies from medium to fine and from a heavy sandy loam to almost a loamy sand. The lighter, more sandy areas usually occur on hilltops and ridges where the sandstone is often encountered within 3 feet of the surface. In dry, plowed fields the surface is a very light gray, but when the soil becomes moist the color changes to a grayish brown or light brown. The amount of organic matter is usually low, and no effervescence was shown by either soil or subsoil, indicating a lack of lime carbonate.

The Dekalb sandy loam is formed by the disintegration of the comparatively thin strata of Carboniferous sandstone. The sandstone layers are in most instances only a few feet in thickness and, therefore, only small areas of this type are found. In many instances the rock is more or less shaly in character, thus causing the resulting soil to have a somewhat heavy texture for a sandy loam. As these sandstone strata usually outcrop on hillsides, there has, in most cases, been more or less mixing of the sandy material derived from the sandstone with the more silty material coming from the shale, making it often difficult to determine, even in the same field, where the sandy loam ends and the silt loam begins. In fact, there is usually a border zone between the two which might more properly be considered the Dekalb loam than either of the other types.

Owing to the very limited occurrence of the sandstone, which gives rise to the Dekalb sandy loam, this type is found in small areas, none of which are of sufficient size to be shown separately on the map. These areas occur throughout the unglaciated section of the State,

but are most common in the area indicated on the map as the Dekalb silt loam. The roads are usually quite sandy where the adjoining fields are of this type, but sometimes the roads are sandy when the fields are not. As this is the only sandy soil in the uplands of the unglaciated portion of the State, it can be readily identified by its sandy texture.

The topography of the type varies considerably. In some cases the surface is gently rolling, while in others it is very rough and hilly. The soil is open and porous, which, combined with its topography, gives ample natural drainage, and the type is not subject to washing and gullying.

In general, the type is not considered a strong soil. It has good natural drainage, warms up early in spring, and is easily cultivated. Where still in forest the chestnut is a very characteristic tree. As this species does not thrive on calcareous soils, it is evident that this type is in need of lime.

DEKALB STONY LOAM.

The characteristic feature of the Dekalb stony loam is the varying quantity of stone fragments which in some places almost entirely cover the surface. Where they are not sufficiently numerous to interfere with cultivation, the soil would not be classed as Dekalb stony loam in a detail survey. The fragments are usually of sandstone or of sandy shale, and vary in size from small chips to large bowlders several feet in diameter. Where the last condition occurs the soil might properly be classed as Rough stony land. Hillsides are often almost entirely covered with irregularly shaped sandstone fragments, broken off from a layer of sandstone which can often be seen outcropping around the hillsides above.

The interstitial material varies considerably in texture, but is most often a loam or silty loam. There are, however, areas where it is a sandy loam or silt loam. In most cases the soil might be considered as Dekalb silt loam, to which there has been added a large number of stones and a small percentage of sand.

The Dekalb stony loam is derived from the sandstone and sandy shales of the Carboniferous formations, and owes its stony character to the hard, resistant nature of the rock, portions of which have withstood the agencies of weathering and been left as fragments on the surface.

Although this type is found throughout the unglaciated section of the State, its most common occurrence is in the area shown on the map as the Dekalb silt loam, particularly where the surface is so hilly that it is indicated by vertical ruling. There are no very large areas of this soil, the most extensive development being in the hilly country between Chillicothe and the Ohio River. While not indi-

cated separately on the map, this type can be easily distinguished in the field by the presence of the stone fragments.

The surface of the Dekalb stony loam is usually quite rough and hilly. For this reason very little of the type is under cultivation. Some areas not too hilly may be used for farming. Most of it, however, is probably best adapted to forestry.

DEKALB SILT LOAM.

The soil of the Dekalb silt loam is a grayish-yellow or light yellowish brown, mealy silt loam, varying in depth from 6 to 12 inches, with an average of about 9 inches. Although the texture of this soil is remarkably uniform for such a large area, there are some variations. Where the underlying rock consists of sandstone, the soil contains a somewhat higher percentage of fine sand than where it is composed largely of shales. As the percentage of sand increases the type grades into the Dekalb sandy loam. The typical soil has a smooth, velvety feel, and is rather mellow and easily tilled, although it has a slight tendency to run together. In cultivated fields the surface soil when dry is usually a very light gray with a pale-yellowish tinge, but when moist, as in freshly plowed fields, the color is more nearly a light yellowish brown. The grayish color of the surface soil is due to the action of organic matter, which has tended to leach out the iron compound to which the yellow color of the subsoil is due.

The subsoil is a yellow to brownish-yellow, rather heavy silt loam or silty clay loam, which carries only a slightly smaller percentage of silt than the soil but a larger percentage of clay. The subsoil attains its heaviest texture at a depth of 18 to 24 inches, below which it becomes gradually more porous as the partly weathered rock is approached. This is especially true in areas where the underlying rock is sandstone. Very rarely is the subsoil heavy or compact, and it is usually not quite plastic enough to appear smooth when rubbed between the fingers.

The depth of the surface soil and subsoil over the sandstones and shales varies widely. On the gently rolling tracts and in the broad valleys, where weathering has taken place rather deeply and the resulting soil has not been removed by erosion, the depth to the unweathered rock is 6 feet or considerably more, but in the more rolling country the fine earth is very shallow, while on most of the steeper slopes very little true soil occurs, the material here consisting of soft, crumbly chips of shale with some fragments of sandstone intermixed. The average depth over the entire area is hardly more than 3 feet. Since the soil is shallow and subject to erosion where not properly protected, it is very important to adopt a system of farming which will reduce the amount of washing to a minimum.

In some areas of this type fragments of shale and sandstone, and in some places small pieces of chert are found in both soil and subsoil. In the deeper, more level areas these fragments are of rare occurrence, so that over entire fields it is difficult to find any stones, but on the extremely rolling land they constitute a large proportion of the soil material and occur in thick masses in the subsoil, increasing in abundance with depth to the unbroken rock.

Where the drainage is poor, brown iron stains and iron concretions are found in considerable quantities. However, as most of the type has good drainage, this condition only occurs locally in valleys and small, nearly level areas.

As a rule the Dekalb silt loam has very little if any lime carbonate present, and over a large part of the area, particularly in the poorly drained places mentioned above, there is undoubtedly a deficiency of this compound, although some of the shales from which this type is formed contain considerable lime. The greater part of the shale is noncalcareous, and even those areas which were highly calcareous have apparently had all the lime leached out of the soil, so that an application of this material is necessary to get the best results with crops.

As already indicated the Dekalb silt loam is a residual soil derived by weathering from shaly sandstones or sandy shales. These rocks belong to the Carboniferous system. In Ohio the Waverly, Pottsville, and Allegheny formations give rise almost entirely to this type in the unglaciated section, while the Conemaugh, Monongahela, and Dunkard formations also give rise to many areas of it, although the proportion of silt loam from these last formations is not nearly so great as from the others.

The Dekalb silt loam is probably the most widely developed type in the State, although the Miami clay loam is comparable with it in area. It occupies an almost continuous belt across the southeastern section of the State. Beginning at the Ohio River in Lawrence, Scioto, and the eastern part of Adams County it follows a nearly northeast direction in a practically unbroken body until it again comes out upon this stream in southern Columbiana and Jefferson Counties. It comprises the principal soil in Carroll, Tuscarawas, Coshocton, Guernsey, Muskingum, Perry, Hocking, Vinton, Jackson, and Scioto Counties, and is a very important type in practically every county in the southeastern part of the State.

Besides the large area, which is indicated on the map as consisting almost entirely of this type, a large proportion of the country included in the Westmoreland and Meigs groups is occupied by the Dekalb silt loam. In these areas, however, it is so closely associated with other soils that it could not well be indicated separately upon the map, although the proportion of this type in these two groups

of soil is probably greater than that of any other. In the Westmoreland group, however, it has been influenced to some extent by the limestone, and, on the whole, is considered a somewhat better soil than where it is not associated with the limestone.

In the hilly section of country which was covered by the ice the deposit of glacial material was often very thin, and in some cases apparently no material was left. Because of this fact, there are areas throughout the hilly glaciated section where the soil is practically or entirely of residual origin, and, therefore, more nearly like the Dekalb silt loam than the Wooster silt loam, which is the most nearly equivalent glacial type. Many areas of Dekalb silt loam are for this reason found throughout the section shown on the map as the Wooster silt loam.

As the Dekalb silt loam is confined to the hilly section of the State, the surface, in general, is rather hilly and broken, consisting of narrow, winding ridges with steep slopes, separated by deep, almost gorgelike stream valleys. Although usually steep, the surface is rather smooth and rounded. The topography varies from nearly level to steeply rolling and hilly. The areas having the nearly level surface are very small and not of sufficient size to indicate in the topographic classification. A number of areas, however, where the surface is rolling, were of sufficient extent to indicate on the map as the second class of topography.

In general, it might be stated that the country is least hilly in the sections which are mapped as No. 2 topography, even though the great majority of it may be included in the third class. The domelike hills of rounded contour occur principally in Licking and Fairfield Counties, where the hills were planed off by the ice. In these areas the soil covering is deep and represents the better areas of the type. Much of the type is too hilly for profitable cultivation. In the badly dissected areas, which more nearly represent the stony loam, only small patches along the streams can be cultivated.

The steeper slopes and more stony areas are forested with oak, maple, chestnut, hickory, and other hardwoods. The land most suitable for cultivation has been farmed for many years, corn, wheat, oats, clover, and timothy being the principal crops. On the better portions of the type good yields are obtained. Corn produces 20 to 40 bushels, wheat 12 to 15 bushels, oats 20 to 30 bushels, and hay about 1 ton per acre. On the thin, hilly land the yields are very much less and there are areas now under cultivation which hardly yield profitable crops. A large proportion of the rough land is used for pasture in connection with a system of general farming. Sheep raising has long been one of the principal industries. There are many excellent orchards on this type, and it is apparently increasing in favor as a fruit soil, especially for apples.

On the whole, the Dekalb silt loam is not considered a very productive soil without fertilization. Experiments conducted on this type at Carpenter by the Ohio experiment station,[1] indicate that a fertilizer containing principally phosphoric acid and potash with a little nitrogen, possibly a 1–10–5 formula, gives the most profitable results. One of the principal needs of this type is organic matter, which may be supplied by the growing and turning under of clover, rye, or other green manuring crop, or by the addition of stable manure, to which this soil gives a ready response. The texture of the subsoil is such that it is retentive of fertilizers, and a permanent improvement of the land may be brought about by proper cultivation and fertilization.

Upshur Series.

The Upshur series includes the residual shale types, which have a brown to purplish-red surface soil and a purplish-red subsoil. They are derived from the red shales of the upper part of the Conemaugh and from the Monongahela and Dunkard formations of the Carboniferous system, some of which are decidedly calcareous. These red shales are usually clayey, and therefore only the types of heavier texture are found, the principal one being the Upshur clay.

The Upshur soils are found throughout the section of the State indicated on the map as the Meigs series. They generally occur in small areas, but are closely associated with the Dekalb soils, from which they can not be satisfactorily separated on the map. In fact, such a differentiation is impracticable even in a detailed survey. It is, therefore, necessary to group these soils with the Dekalb on the map under the name of "Meigs series." However, a description of the Upshur clay, which is the principal type of the Upshur series, is given.

UPSHUR CLAY.

The Upshur clay is known throughout the section where it occurs as "red clay land." The type consists of an Indian-red, purplish-red, or reddish-brown, heavy clay loam to clay, underlain by a red, very heavy, plastic clay which extends to a depth of 3 feet or more. In its typical development there is very little difference between the soil and the subsoil, but there are areas where the red clay is overlain by a thin layer of material which is lighter both in color and texture. The type is very plastic and sticky when wet, but cracks badly upon drying, the cracks varying in width from one-fourth to three-fourths of an inch, and extending in many cases to a depth of a foot.

The Upshur clay is found throughout the section mapped as the Meigs series, and constitutes one of the principal members of this

[1] Bul. No. 182, Ohio Agr. Expt. Sta.

group. It occurs in small, disconnected areas, the largest of which are seldom more than a square mile in extent. One of the largest developments occurs a few miles southeast of Carpenter, in Meigs County.

The topography is generally sharply rolling, although the soil is sometimes found on rather gently rolling hilltops. Most of the areas are rather too steep for general farming.

Many areas of the Upshur clay contain lime concretions, and the subsoil will often effervesce, showing the presence of a considerable amount of lime. Other areas, however, seem to be deficient in lime. Where the subsoil is calcareous good crops of alfalfa are secured, and it would seem advisable to plant a considerably larger proportion of the type to this crop for pasture. The soil erodes easily, and for this reason much damage is done by washing. The use of sweet clover to reclaim eroded land or prevent washing is advisable. On the whole, the type is a rather strong soil and were it not for the steepness of the slopes and the difficulty of cultivation it would be prized very much more highly.

Meigs Series.

The Meigs series has been established to include the undifferentiated soils of the Dekalb and Upshur series, with a gradation and mixture of the various materials from which these two series have been derived. A description of the principal soils of the Dekalb and Upshur series has just been given, but a better idea of the character of the soil in the section included in the Meigs series can be given by discussing the soils together under this head.

Over a large extent of country in the southern and southeastern parts of Ohio alternating strata of sandstone and red shale, thin beds of grayish shale, and occasional beds of limestone outcrop in such narrow, irregular strips, and their weathered products have been so intermingled, that a separation of the different types is impracticable.

It is characteristic of the Meigs series that no type of soil is continuous over any large area. The weathered products of the thin beds of various kinds of rock which occur on the steep hillsides have become so intermingled by wash or by landslides that the soils of the lower slopes are a mixture of various materials with no regularity in regard to the extent of distribution of any of the types. In fact a large part of the area covered by this group is made up of such a mixture of material of distinctly different character that it can hardly be characterized as any definite type, because it is almost impossible to get two borings exactly alike even in the same field. However, where the gray shales and sandstones outcrop over any con-

siderable area, they give rise to typical soils of the Dekalb series, principally the Dekalb silt loam, and, likewise, where the red shales outcrop, they give rise to soils of the Upshur series, principally the Upshur clay.

Probably the most extensive uniform soil in the Meigs series is the Dekalb silt loam, which, on the whole, is rather heavier than the Dekalb silt loam as mapped elsewhere. In fact, there are considerable areas here where the surface soil is a heavy silt loam or even a silty clay loam. On the other hand, where the soil is derived from sandstones, the sand content is greatly increased and small areas of Dekalb sandy loam are found. Next to the Dekalb silt loam the Upshur clay is most frequently encountered in this series, as already stated.

Although the Dekalb silt loam and Upshur clay constitute the two most important soil types in the Meigs series, quite a large proportion of the country represents a gradation between these two types or a mixture of the material constituting the two. In some places as much as 6 inches of silt loam, very similar to the surface soil of the Dekalb silt loam, is underlain by distinctly red clay very similar to the Upshur clay. In other places the red clay overlies lighter colored material derived from the gray shales. Because of the intimate association and mixture of these different soils almost every field has a spotted appearance.

All the soils in the extremely eroded section where this group occurs are shallow, the weathered and partially decomposed material rarely extending to a depth of 36 inches. The Upshur clay probably has a greater average depth than any of the other types. On many of the steeper slopes very little true soil is found, the material consisting largely of only partially decomposed shale or sandstone.

The presence of a large percentage of shale and sandstone fragments is usually a characteristic feature of the Meigs series. In many places these fragments occur in large quantities, and are scattered over the surface and distributed through both soil and subsoil, the proportion increasing with depth as the unweathered rock is approached. As a rule, these rock fragments do not interfere with tillage where the topography is such that cultivation is practicable, but in small areas and on the steeper slopes the material sometimes consists merely of a mass of stone. These areas would be mapped as Rough stony land in a detailed survey.

The Meigs series of soils is confined to the southeastern part of the State, being located in the tier of counties bordering the Ohio River, from Lawrence to Monroe, inclusive. A belt extends northward through the central part of Noble and the eastern part of Guernsey Counties into the northeastern corner of Belmont County.

There are also detached areas in Harrison and other counties, especially those counties near the boundary between this group of soils and the large areas of Dekalb silt loam on the west.

The greater part of the country covered by the Meigs series of soils has a rough and hilly topography, comprising steep hills and ridges with comparatively narrow and deeply cut valleys. The hills often converge in sharp ridges which are in many cases only a few yards wide. Over some comparatively small areas the hills are well rounded, and good-sized farms of tillable land may be found.

The benches along many hillsides, due to the unequal weathering of alternate hard and soft strata, constitute a noticeable feature of the topography of the Meigs series. Landslides, or "slips," are also common where the earth of steep slopes, having been softened by water, has given way and fallen to a lower level.

The roughest part of the Meigs series is found along the Ohio, Hocking, and Muskingum Rivers and a few miles back from these streams along some of their larger tributaries. This broken topography, which is indicated in a general way on the map by vertical rulings, occurs in disconnected areas with little regularity along any given stream.

On account of the rough topography and the tendency of the soil to wash easily on the steep slopes, only a small percentage of the country mapped as the Meigs series is actually under cultivation, although quite a large percentage has been cleared and is used for pasture (see Pl. IV, Figs. 1 and 2). The principal crops are corn, wheat, and hay. The average yields on the two principal types, the Dekalb silt loam and Upshur clay, are given under the description of these soils. There are some excellent apple orchards in this section (see Pl. III, Fig. 1), and the raising of stock, especially sheep, is a profitable industry. The steeper slopes are probably best used for forestry.

RESIDUAL SHALE, SANDSTONE, AND LIMESTONE SOILS.

Westmoreland Series.

Going northward the red shales, from which the Upshur soils of the Meigs series are derived, apparently give way to layers of limestone, so that the northern extensions of these same geological formations give rise to a different group of soils, formed from interbedded shale, sandstone, and limestone. In some places the soils are derived entirely from layers of shale and sandstone and are very similar to the Dekalb soils where they are not associated with the limestone. In other places the layers of limestone are thick enough to give rise to small areas of true limestone soil, which have been called the Brooke clay loam. Over a large part of the area, however, limestone, calcareous shale, and sandstone are so closely associated that no sepa-

ration of the soils is practicable, and they are, therefore, classed as the Westmoreland series.

The most common types of soil found in the Westmoreland series are the Dekalb silt loam and Brooke clay loam. The former has already been described, and a description of the latter follows the general discussion of the Westmoreland series.

While there are many areas throughout the section mapped as the Westmoreland series in which the Dekalb silt loam is typically developed, there are many other places which have been influenced either by the limestone or by the more calcareous nature of the shale from which the soil is derived. The areas of Brooke clay loam, or limestone soil, are usually small or narrow, being limited by the thickness of the beds of limestone, which outcrop on the hills. The peculiar feature of these limestone areas is the irregular nature of their occurrence. The rocks in this section are generally almost horizontal and one would, therefore, expect to find bands of limestone soils outcropping at practically the same elevation around the hills. Though this is true in many cases, there are other cases where one side of the hill is very largely limestone and the other side shows none. This is due, of course, to the lack of continuity, or the lens-like nature of the limestone layers.

Much of the country occupied by the soils of the Westmoreland series really represents a transition between the Dekalb silt loam and the Brooke clay loam. Much of the soil of the calcareous shale section consists of a dark-yellow, rather silty clay loam that changes to dark-yellowish plastic clay at 18 inches below the surface, and at a greater depth becomes more clayey, sticky, and plastic.

The Westmoreland series of soils covers quite an extensive area. They occupy a broad, somewhat broken belt extending from Athens and Morgan Counties to northern Jefferson County. The largest development of this group covers the northern part of Noble, the eastern part of Guernsey, and the western part of Belmont Counties, and extends northeastward through Harrison and Jefferson Counties, terminating in the northern part of the latter, where its most northern occurrence is on the summits of the highest ridges. This area extends southward along the Ohio River to the Monroe-Belmont County line, where it gives way to the Meigs series. In Belmont County the area is somewhat divided by an extension of the Meigs series into the southern part and by the occurrence of an area of Dekalb silt loam in a north and south direction through the center. The Westmoreland series also covers all of the central and northern portion of Morgan County and stretches up into Muskingum County as far as New Concord. From the northwestern part of Noble County a spur extends southeastward through the central part of Noble into Washington County.

Occasionally thin layers of limestone are encountered throughout the area mapped as the Dekalb silt loam or the Meigs series, but they are not of sufficient extent in those sections materially to influence the soils over any considerable area, although there are small areas which might be considered to belong more properly in the Westmoreland series.

The distribution of the different types within the Westmoreland series can not be definitely described. The Brooke clay loam, or limestone soil, is usually distinguished either by the limestone fragments scattered over the surface or by the darker color of the surface soil. In Morgan County the limestone soils are characterized by the outcrops of rock and by the loose limestone bowlders scattered over the surface. However, in the northern extension of these soils there are very few limestone fragments on the surface, though the rock is encountered at shallow depths, as seen in the road cuts.

A peculiar topography characterizes the areas covered by the Westmoreland series. The shales and interbedded limestones weather into rounded hills with long, smooth slopes, giving very pleasing surface features. The entire country is high and sufficiently eroded to be classed as hilly, or sharply rolling, although much of it belongs to the least hilly section, included in the third class of topography. In some sections the typical rounded hills have been worn down by severe erosion, and badly dissected areas have been produced. In other places the hills and ridges are capped by small, sharply rounded knolls, where beds of more resistant limestone have withstood the general degradation of the country.

The country occupied by the Westmoreland series of soils is the most highly esteemed section in the southeastern part of the State. As the calcareous nature of the rocks is everywhere noticeable, it is locally known as "limestone land." Its particular value is due to the fact that it produces bluegrass naturally, making it very valuable as pasture land. On this account the greater part of this section is used for grazing, for sheep as well as cattle. The areas under cultivation produce good crops of hay and corn. Small areas of alfalfa are common. This crop succeeds on the Brooke clay loam and other soils which have more or less limy subsoils. Considerable fruit is grown in this section, and there seems to be no reason why it should not prove as profitable here as in other parts of the hilly section of the State.

BROOKE CLAY LOAM.

The Brooke clay loam consists of a yellowish-brown or dark-brown, rather sticky clay loam, silty clay loam or silty clay, with a depth of 5 or 6 inches, underlain by a grayish-brown, yellowish-brown or drab, plastic silty clay or clay extending to the limestone,

which usually occurs at less than 3 feet from the surface. In some places the clay near the limestone has whitish spots in it which evidently represent pieces of the partly weathered rock. This material effervesces freely, when treated with hydrochloric acid, showing the presence of a large amount of lime carbonate. The yellowish clay subsoil, in borings as well as in roadcuts, often has a greenish tinge or a dull-yellow color. The darker areas of the surface soil are locally known as "black limestone land," and are considered as the most valuable upland soil in the southeastern part of the State.

The Brooke clay loam is derived from the thin strata of limestone which occur interbedded with shales and sandstones in the later formations of the Carboniferous system, principally in the northern extension of the Monongahela and Dunkard formations.

Owing to its limited occurrence it was not possible to separate this type on the map and it was included with the Westmoreland series of soils.

Occurring in the deeply eroded sections of the State, the surface features are hilly, much of the type being rather too steep for cultivation. It is often found capping the tops of narrow ridges with steep slopes.

The Brooke clay loam is a strong, productive soil, and were it not for the hilly character of the surface it would doubtless be considered one of the best types in the State. Where the surface is not too hilly, excellent crops of corn, wheat, and hay are produced. Many areas are devoted to alfalfa, and the type seems well adapted to this crop, doubtless because of the calcareous nature of the subsoil.

GLACIAL DRIFT SOILS.

As approximately three-fourths of the State was covered by the ice, a large proportion of the soils are formed from deposits of glacial drift. In the western half of the State, as has been pointed out, this drift contains a large amount of limestone material, while in the eastern half it is composed largely of shale and sandstone material. Because of this difference in the character of the rocks that have entered into the composition of the drift, the glacial soils may be subdivided into two classes—those derived from limestone material and those derived from shale and sandstone material.

In the underlying geological formations the line of division between the limestone and shale is quite distinct, but in the case of the soil no such sharp line of demarcation can be seen. This is due to the fact that the ice, in passing over both the limestone and shale, grinds them up and mixes the resultant material together, so that instead of a sudden change there is a gradual transition, covering a border zone usually several miles in width. This mixture of material makes it very difficult to draw any boundary between the glacial

FIG. 1.—CORNFIELD ON MIAMI CLAY LOAM AND CLYDE CLAY LOAM.
Leaming corn originated on this farm.

FIG. 2.—A FARM ON THE WOOSTER SILT LOAM, WAYNE COUNTY.

CABBAGE ON CLYDE SOILS, NEAR CLYDE, SANDUSKY COUNTY.

These dark-colored soils are well adapted to this crop.

limestone and the glacial shale and sandstone soils, and any line which is drawn must necessarily be very arbitrary; in fact, it would be very much more nearly correct to indicate on the map a gradual shading off of one color into the other.

The line of separation between these two groups of soils does not coincide exactly with that between the limestone and shale of the underlying formations, because the character of drift does not depend entirely upon that of the underlying rock, but has been influenced by the direction of the ice movement. Where the movement of the ice has been from the limestone toward the shale, fragments of the former will be found in the drift overlying the latter, and vice versa. At Columbus, for example, the Scioto River practically marks the division between the shale and limestone, but the ice has carried some of the limestone material farther east, so that the soil for some distance east of the city is more like the Miami clay loam, a glacial limestone soil, than the Volusia clay loam, a glacial sandstone and shale soil.

The separation of the drift soils into these two large groups, based upon differences in the character of rock content, is justified by the close relation that commonly exists between soils and the included rocks. If the larger particles consist of a certain kind of rock, as shale for example, the finer material is almost certain to be composed largely of the same material, reduced to a finer condition. The separation is also justified, in this case, by the greater productiveness of the glacial limestone soils, as compared with those of sandstone and shale origin. As a rule, the former, especially the subsoils, are more calcareous than the latter, although a considerable amount of lime carbonate is sometimes found in the drift composed largely of shale.

The Glacial Limestone group of soils may be divided into two series, the Miami and the Bellefontaine, of which the former is of much greater importance. The difference in the soils of the two series is primarily due to the better drainage and consequent higher oxidation of the Bellefontaine series, giving them a slightly reddish brown rather than a yellowish or grayish-brown color.

The Glacial Shale and Sandstone group of soils may be divided into three series, the Wooster, Volusia, and Trumbull. The differences between these series are due primarily to drainage, which is affected both by the character of the topography and the nature of the material. Where the surface is rolling and the subsoil more or less gravelly, good drainage conditions exist and give rise to the Wooster soils; where drainage conditions are not so good the Volusia soils are found; and where the surface is level and drainage poor the soils of the Trumbull series are found.

GLACIAL LIMESTONE SOILS.

MIAMI SERIES.

The Miami series includes gray to light-brown surface soils with yellow to mottled gray and yellow subsoils. Four members of this series are recognized, the Miami sandy loam, Miami silt loam, Miami clay loam, and Miami clay. The first and last of these are of very small extent. The other two types are among the most important soils in the State. They are very intimely associated, and have been formed in very much the same way, and the gradation from one to the other is often so imperceptible that their separation on the map is impracticable. The last member of the series, the clay, is derived chiefly from a lacustrine clay, similar to that which gives rise to the Clyde clay, but it is so very much like the other Miami soils that it seems best to group it with them.

MIAMI SANDY LOAM.

The Miami sandy loam consists of a grayish-brown to light-brown sandy loam of medium to fine texture. There is, however, considerable variation in texture, and it is unusual to find an area of uniform soil many acres in extent. The depth varies from about 6 to 12 inches, where the material gradually becomes somewhat lighter in color and contains more yellow. In texture the subsoil varies from almost a sand to a heavy sandy loam. It is underlain at varying depths by a brownish-yellow or mottled gray and yellow clay, which represents the unmodified drift.

The Miami sandy loam is found in the section of country extending from Tiffin southward along the Sandusky River to where this stream breaks through the arm of the old glacial lake near McCutchenville, and thence westward along the north shore of the old lake by Findlay to Leipsic. It is also encountered in Fulton County north of Wauseon, where an island of drift existed when the surrounding country constituted a lake. It occupies only small areas and it was not practicable to separate these on the map, so that it is included with the Miami silt loam and clay loam.

Its occurrence in the sections referred to is an indication of its origin. Along the Sandusky River it represents a slight reworking of the glacial material by this stream during the earliest part of its history and before it had formed any very definite channel. To some extent the sandy material here has been carried to higher levels by the action of the wind. In other sections it represents sandy material which was thrown up along the old beach line and then drifted inward by the wind, mixed to some extent with the heavy material of the drift and left as a thin veneer over it. In some

places the sand has drifted into small mounds, and these areas are very sandy.

The Miami sandy loam is easily cultivated and when properly farmed gives good yields of all the general farm crops grown in this section. It is used to some extent for truck crops and should prove quite valuable for this purpose in sections where most of the soils are rather too heavy for trucking.

MIAMI SILT LOAM AND MIAMI CLAY LOAM.

As the Miami silt loam and Miami clay loam are not only so closely associated that it is not practicable to show them separately on the map, but are also very similar in origin, topography, and drainage, as well as in agricultural value, it is thought best to give a separate description of the soils, but to discuss other features together.

Miami silt loam.—The Miami silt loam usually occurs in three and sometimes in four zones or layers. The upper or surface soil, to a depth of about 8 inches, is a grayish-yellow or light grayish brown silt loam. It has a smooth, velvety feel, although this characteristic is not quite so pronounced as in the Cincinnati silt loam and some other silt types in the State. When dry the plowed fields have a very light gray color with a pale-yellowish cast, but when moist the soil is light brown. The color, however, varies somewhat in different parts of the field even when the moisture conditions are the same. In general the lower, more level areas have a darker color than the more hilly, better drained areas. This is due to the accumulation of organic matter, and these areas really represent a gradation toward the Clyde clay loam. The silt content ranges from 55 to 65 per cent, and the clay from 15 to 20 per cent; proportions that give a loose and friable soil without any decided tendency to bake or run together.

The upper zone of the subsoil, extending to an average depth of about 16 inches, is a yellow, friable heavy silt loam or light silty clay loam. The presence of this friable subsurface layer is one of the most important differences between this type and the Miami clay loam. Below this stratum is found a yellowish-brown or mottled gray and brown, compact clay which is hard and has a tendency to break into cubes when dry, but plastic and sticky when wet. At a depth of about 30 inches, in the better drained localities, there may be another stratum consisting of a yellow, more friable clay containing lime and fragments of limestone. This stratum is highly calcareous and effervesces very freely with acid. In fact, a large percentage of the borings in this type gave an effervescence with acid within 3 feet of the surface, but seldom nearer the surface than 18 inches.

Miami clay loam.—The soil of the Miami clay loam consists of a grayish-yellow to light-brown heavy silt loam to clay loam or silty clay loam, varying in depth from 6 to 12 inches, with an average of about 8 inches. The percentage of clay in this type averages a little higher than that in the Miami silt loam, while the percentage of silt is somewhat less, although it is still rather high in the typical soil. This material often rests directly upon the yellowish-brown or mottled gray and brown clay subsoil, very similar to that of the Miami silt loam, but there is sometimes present a layer 2 to 6 inches in thickness, which is heavier than the surface soil but not quite so heavy as the underlying subsoil. The subsoil is usually quite impervious at 20 to 30 inches, but it generally becomes somewhat lighter in texture before a depth of 36 inches is reached. The deeper subsoil usually contains less yellow or brown than the material nearer the surface, owing to the larger amount of lime present. White spots of lime are frequently encountered, especially in the northwestern part of the State, before a depth of 36 inches is reached. The lower subsoil is more generally mottled in poorly drained localities, and often has iron stains or iron concretions present. Where this condition prevails there is invariably a deficiency of lime. On the more rolling land, where erosion has been rather pronounced, the subsoil is very near the surface and the shallow surface soil is very light colored, indicating a deficiency in organic matter. For this reason it is compact, cold, and less productive than other phases of this type.

The presence of limestone fragments is a characteristic feature of both the Miami silt loam and Miami clay loam. These and the absence of fragments of sandstone and shale constitute one of the most easily recognized differences between the Miami and the Volusia soils. Where the soils of the two series come together there is a broad strip of country in which shale and limestone fragments are found. Such areas really represent a transition between the two series, and the soils here are not typical of either. The limestone fragments are more numerous in the northwestern and southwestern portions of the sections occupied by these types than through the west-central part of the State. In the latter section there are very few rock fragments, even in roadcuts. A large part of the area has an occasional scattering of bowlders over the surface. On the level stretches these are often very scarce, but on the gently rolling line of hills, representing glacial moraines, the rock fragments are more abundant, occurring in some places with masses of bowlders and gravel. The larger bowlders are usually igneous or metamorphic rocks which have been transported to this section from Canada by the ice. Limestone and chert and sometimes sandstone fragments are also present.

The material that enters most largely into the composition of these soils is limestone, such as now underlies the western part of Ohio, which was torn from its original position, ground up, and transported by the ice and redeposited as till. By subsequent weathering this was reduced to its present condition as soil. Considering the large area covered this till is remarkably uniform in composition. In general it seems to be somewhat more clayey in the section of the country south of the old lake bed and extending down the Scioto Valley, possibly due to a larger amount of shale in this section than in the extreme southwestern part of the State. As the movement of the ice was from the northeast, it seems very probable that some shale material was transported southwestward and mixed with ground-up limestone. In the southwestern part of the State the limestone is not only nearer the surface, but the ice, which deposited the drift in this section, had come for a long distance over a country underlain entirely by limestone, which probably accounts for the larger amount of limestone in the drift in this section.

The cause of the difference between the Miami silt loam and clay loam is not entirely clear. It is probably due, however, to the more silty and less clayey nature of the drift in the sections where the Miami silt loam occurs. It is possible that the more silty surface layer represents a thin veneer of loessial material over the drift. The presence of bowlders on the surface indicates that if such deposition took place the layer was very thin.

The Miami silt loam and clay loam cover a very large part of the western half of the State. Most of the country between Sandusky, Chillicothe, Hamilton, and Van Wert is occupied by these two types, which constitute the chief soils in at least one-fourth of the counties in the State. The principal development occurs south of the old lake bed, but a large area, including practically all of Williams County and a part of the adjoining counties, is found in the extreme northwestern part of the State. Strips are also found along most of the streams in the old lake bed, except those west of Defiance, where its place is taken by the Miami clay, but some areas occur here also.

The general location of these soils is indicated on the soil map. However, while they are mapped as covering a vast territory, they must not be considered as occurring in uniform unbroken areas, or as occupying all of the country indicated as these types on the map. In nearly every section there are included small patches of the Clyde clay loam, which are usually only a few acres in extent, and therefore too small to be mapped separately in a general survey. These exceptions are found occasionally in the gently rolling country and rarely in the hilly, morainic regions. On the level portions of the type, however, they are widely and often thickly distributed, so that where the topography is indicated on the map as level, or nearly so,

there will be found numerous areas of the black soil. Likewise in the area mapped as the Clyde clay loam there are many small areas of the Miami clay loam or Miami silt loam, usually the former.

In the morainic section between Bellefontaine and Hamilton these two types of soil are so intimately associated with those of the Bellefontaine series that it is not possible to separate them on the map. As the general character of the country in this section, however, is decidedly different from that in other sections occupied by these types, a different color is used on the map, indicating that these soils occur in that section also.

No attempt is made on the map to show the Miami silt loam and clay loam separately, as it is practically impossible to distinguish between the two types without making an examination in the field. In general, however, the Miami silt loam is much more widely developed in the southern or southwestern part of the area occupied by these soils than in the northern extension. In fact, very little of the silt loam occurs in the northern half of the area occupied by these types. A large part of the area comprises a soil which is almost intermediate between the two types.

The topography of the Miami silt loam and clay loam varies from almost level to sharply rolling and hilly, but the country consists mainly of gently rolling or undulating plains. The more rolling and hilly lands occur largely along the lines of moraines and streams. Some of the streams, especially those flowing southward, have effected extensive erosion, and the country along them is considerably broken and sometimes too steep for general farming. Such areas, however, are comparatively inextensive.

The clayey, close character of the subsoil and the lack of slope render the drainage of these types, particularly the underdrainage, poor. Originally artificial drainage was resorted to only where the natural drainage was very deficient, but it is now generally recognized that tile drainage may be used to advantage over practically the entire country occupied by these soils. As they are naturally cold and wet, tile drainage is advantageous in removing the water in the spring, thus enabling the farmer to begin cultivation several days earlier .

The Miami silt loam and clay loam are among the principal general farming soils of the State. Corn, wheat, oats, and hay are the most important crops grown. Corn is the chief and probably the most profitable crop (see Pl. V, fig. 1). It does not do as well as on the black Clyde clay loam, but the yields are satisfactory, ranging from 25 to 60 bushels, and sometimes as high as 100 bushels to the acre. Wheat is not grown so extensively as formerly. The yield per acre usually ranges from 10 to 25 bushels, with an average of about 15 bushels. Oats produce from 25 to 60 bushels and sometimes

considerably more per acre, but the average is probably about 35 or 40 bushels. They are not grown very extensively south of the latitude of Columbus. Alfalfa is quite extensively grown on these types, especially in Logan, Union, Champaign, Montgomery, Greene, and Madison Counties. It can probably be grown in all sections occupied by these types, but it is sometimes difficult to get a stand to hold over the first year, particularly where the surface soil is deficient in lime. This crop doubtless does best where the soil is well drained and where the subsoil contains considerable gravel and a large amount of lime. Tobacco also is quite extensively grown, particularly in Montgomery, Preble, Darke, and Miami Counties. Both tobacco and alfalfa do better on the silt loam than on the clay loam, although they are grown on both types.

There is apparently no great difference in the agricultural value and crop adaptation of the Miami clay loam and the Miami silt loam. However the silt loam is rather easier to cultivate, does not bake and form clods to as great an extent as the clay loam, is not considered as "cold," and is thus somewhat more desirable. A more careful comparative study, however, is necessary in order to determine the relative value of these types for different crops.

MIAMI CLAY.

The surface soil of the Miami clay consists of a gray, heavy silty clay loam to clay from 4 to 7 inches in depth. The first 2 or 3 inches may be rather silty in nature, but the heavy material is always much nearer the surface than in the Miami clay loam. The color when dry is white or a very light gray, but when moist it becomes darker and in areas adjoining the Clyde clay is a rather dark gray. In some cases it has a slightly yellowish cast.

Beneath the surface soil and extending to a depth of 14 to 16 inches is mottled gray and yellow clay where it changes more to a yellowish-brown color. The subsoil is plastic and impervious and contains very little, if any, grit.

The Miami clay is one of the most difficult soils in the State to manage. If plowed when too wet or too dry clods will form. The amount of organic matter it contains is not sufficient to cause good granulation. Very often the heavier areas check and crack upon drying, causing injury to the roots of the plants. Puddling is easily produced, causing the soil to become very hard and intractable. The impervious nature of the subsoil makes underdrainage somewhat difficult.

Areas of this soil occur along the upper course of the Maumee River and some of its tributaries, including the Auglaize River and streams flowing into the latter. The type has been formed from drift and deposits of lacustrine clay over the drift. The difference

between this type and the Clyde clay is due largely to the accumulation of organic matter in the latter under poor drainage. Being situated near the streams the Miami clay has had better drainage, resulting in the accumulation of much less organic matter, and consequently it has a much lighter color. Corn, oats, wheat, and clover are the principal crops, and the type seems better suited to small grain than corn.

Bellefontaine Series.

The Bellefontaine series includes types having yellowish-brown to reddish-brown surface soils and yellowish to reddish-brown subsoils, which become redder and more gravelly with depth. In some cases beds of stratified gravel are found within a few feet of the surface. The gravel is largely limestone and the subsoil is usually calcareous.

The Bellefontaine series is very closely associated with and related to the Miami series, but is distinguished from it by the redder color, usually more morainic topography, better underdrainage, and generally a larger amount of sand and gravel either within the surface soil or at no great depth below The difference between the two series is apparently due to the better drainage and the consequent higher oxidation and redder color of the Bellefontaine soils. In areas where the Bellefontaine series occurs, the knolls and slopes nearly always have a reddish color, and for this reason the soils are locally known as "chocolate land," "red clay land," or "red sandy loam," depending on the texture of the soil. In other sections it is known as "gravelly land," owing to the fact that gravel is present in the surface soil. Although the soils of the two series are closely associated, the Bellefontaine soils are easily recognized in cultivated fields because of the reddish color which is so noticeable when the land is plowed.

The characteristic surface features of the Bellefontaine soils are of true morainic outline. The topography varies from slightly rolling to very rolling, though rarely rough and broken. In general it occupies the most hilly portion of the State covered by the group of glacial limestone soils. In most places the surface consists of a series of knolls and swells, with intervening sags or depressions. This feature is especially pronounced in Logan County and on the hills southeast of Dayton, and also in portions of Darke County southwest of Greenville.

Like the Miami series, the Bellefontaine series is formed by the weathering of a mantle of glacial limestone drift, but the latter soils are practically confined to terminal moraine deposits, while the former are derived principally from ground moraines. These terminal moraines contain large quantities of gravel, and gravel beds of commercial value frequently occur. In fact, the core of most of

the knolls consists of more or less stratified gravel. The presence of a large amount of gravel in the subsoil and the rolling topography have given better drainage to the Bellefontaine series, to which is probably due the reddish color, since good drainage and aeration are favorable to oxidation. In some places the gravel is encountered at a depth of 3 to 4 feet beneath the surface, but such areas are usually small, and, in most cases, the subsoil is a gravelly till rather than a bed of stratified gravel. In general the more gravelly the subsoil the redder the surface soil, and in such cases the Bellefontaine series closely resembles the Fox series of the gravel terraces.

As shown on the map, the Bellefontaine series occurs principally in the section between Bellefontaine and Hamilton and is practically confined to Logan, Champaign, Clark, Greene, Montgomery, Warren, Preble, and Butler Counties. The Mad River and the Miami, from the mouth of the Mad River at Dayton to Hamilton, run almost through the center of the country in which the Bellefontaine series occurs. However, these soils do not occupy all of this section of the State, part of which consists of the Miami series. The soils of the two series are so intimately associated throughout the region indicated as the two series on the map that it was impracticable to make any separation in the general survey. In general the more rolling and hilly portions of this area are occupied principally by the Bellefontaine series, while the more level tracts comprise the Miami series.

The occurrence of the Bellefontaine series in this particular section of the country is due to the morainic character of the topography which resulted from the tendency of the ice to flow around the highland in Logan County as already explained in the general discussion of the glacial formations.

Although there is no marked difference between the Bellefontaine and Miami series in regard to crop adaptation and productiveness, the former is generally considered slightly more valuable than the latter, when types of similar texture and surface features are compared. About the same crops are grown, but tobacco and alfalfa are more commonly found on the Bellefontaine than the Miami. The greater proportion of these soils are well farmed at present, but it would seem advisable to seed more of the rough, gravelly hills to alfalfa. The limestone gravel furnishes the lime necessary for the thrifty growth of this crop, while its deep root system enables it to withstand drought better than most farmed crops.

While it is not possible to separate the different members of this series on the map, as would be done in a detailed survey, several different types were recognized, including a gravelly or stony loam, silt loam, clay loam, and clay. Of these the silt loam is possibly the most extensively developed.

BELLEFONTAINE GRAVELLY LOAM.

The characteristic feature of the Bellefontaine gravelly loam is the presence of gravel in the surface soil. The quantity varies from only a few scattering pebbles to small areas composed very largely of gravel. The gravel is of all sizes up to that of cobblestones, and in some cases the stones are so large that the type could be called a stony loam rather than a gravelly loam. However, in these areas there is always present a considerable percentage of gravel also, and the difference is not sufficient to justify the establishment of a stony loam type.

The interstitial material varies from a rather heavy loam containing a large percentage of silt to almost a sandy loam, and in fact very small areas of sandy loam do occur. The color of the surface soil usually has a decided reddish cast, and in some places is distinctly a reddish brown. At an average depth of about 7 to 8 inches the surface soil is underlain by a brown or reddish-brown clay loam containing considerable gravel, the quantity increasing with depth. A bed of stratified gravel is usually encountered before a depth of 3 feet is reached.

The Bellefontaine gravelly loam occurs in small areas, usually only a few acres in extent. While such areas may be encountered throughout the entire section in which the Bellefontaine series occurs, the type is more commonly found in Logan County and on the hills southeast of Dayton than elsewhere. It usually occurs in the most hilly and most decidedly morainic sections and often has a typical kame and kettle topography.

BELLEFONTAINE SILT LOAM.

Where typically developed the Bellefontaine silt loam consists of 8 to 12 inches of a friable, slightly reddish to yellowish-brown silt loam, underlain by a yellowish-brown, friable silty clay loam to a depth of 18 inches, and this in turn is underlain to a depth of 36 inches or more by a reddish-brown clay which is lighter in texture and usually more gravelly in the lower 3 or 4 inches. The surface soil in plowed fields has a distinct reddish or brown color, which distinguishes it from the Miami silt loam or clay loam. This reddish color is more noticeable in plowed fields than would be expected from the color of many of the borings made, as these often fail to show very much of a reddish tint. On slopes where erosion has removed the surface soil, thus exposing the heavier subsoil, a more distinct reddish color is seen. The surface soil seldom effervesces with acid, but the deeper subsoil below 30 inches is usually very calcareous and contains a large amount of lime carbonate, much of which is in the form of limestone fragments.

The surface features are rolling to hilly. This gives good surface drainage, while the gravelly subsoil assists materially in providing adequate underdrainage. Because of these conditions this type dries out a little earlier in the spring and after rains and is therefore considered warmer and more easily tilled than the Miami silt loam. Where not too hilly it is an excellent soil for general farming, producing good yields of all crops, especially tobacco and alfalfa.

BELLEFONTAINE CLAY LOAM.

The soil of the Bellefontaine clay loam consists of a light-brown to slightly reddish brown clay loam, in which the percentage of silt is relatively high. In fact, in some cases it could be properly classed as a silty clay loam. This reddish tint is quite noticeable in plowed fields, much more so than when an examination is made with an auger. At an average depth of about 8 inches it is underlain by a hard, compact, brown to slightly reddish brown clay, containing some limestone gravel, the quantity of which increases with depth until at about 30 inches it is very prominent. At about this depth also the color becomes grayer, and the subsoil is very much more calcareous. Beds of stratified gravel sometimes underlie the subsoil. These are uncommon, although the percentage of gravel in the till is rather high.

The surface of this type is rolling to hilly, but less so than that of the gravelly loam. The topography is usually such as to give good surface drainage and the gravel in the subsoil allows the water to pass more readily through it than is commonly the case in the Miami clay loam. The Bellefontaine clay loam is a strong, productive soil, well adapted to the general farm crops grown in this section. In addition, alfalfa and tobacco do well upon it, and the farmed areas, especially of alfalfa, might be increased with profit.

BELLEFONTAINE CLAY.

The Bellefontaine clay is the most distinctive and characteristic type of the Bellefontaine series. The soil consists of 6 to 8 inches of a brown to reddish-brown, plastic, waxy clay, which grades into a brown or slightly reddish brown clay, which is very stiff and sticky. At a depth of about 20 inches, or sometimes less, gravel is found, or else the pebbles in the clay become so numerous that it is impossible to bore deeper with the auger.

While this type does not occur in any large bodies it is rather important, because of its extensive total area. These reddish clay spots are usually found on rounded, gravelly knolls, or where the slope is steep and erosion has been excessive. They represent areas where

the surface soil has been removed, exposing the clay subsoil. Although very difficult to till, because of its waxy, plastic character, this type is considered very fertile, and under favorable conditions gives yields as large as, or even better than any of the other soils of this series.

GLACIAL SHALE AND SANDSTONE SOILS.

Wooster Series.

The Wooster series includes the yellowish-brown glacial shale and sandstone soils, having unmottled brownish-yellow subsoils. When dry, the surface in plowed fields is a light gray, but underneath the surface or when moist the soils are always yellowish or light brown. While generally classed as yellow, the subsoils are more of a brownish yellow, with just a slight tinge of red. Typically they are unmottled, but on level or low places where surface drainage is not good, there may be some gray mottlings in the lower depths. However, these areas represent a gradation toward the Volusia soils, and, in fact, small areas of these are often present, although usually too small to be indicated separately on the map even in a detailed survey.

Both soil and subsoil are lacking in lime carbonate, and even the deeper subsoils, where exposed in cuts, seldom effervesce with acid.

The soils of the Wooster series are derived from a mantle of glacial drift and consist largely of shale and sandstone material. Although deposited by the ice, the material is largely of local origin, especially in the silt loam and toward the south where the underlying rocks are in many places only a few feet below the surface. As the underlying rocks are almost entirely sandstone and shale, the fragments of stone consist largely of these rocks, although pieces of granite or other crystalline rocks are not uncommon, and an occasional piece of limestone may also be found. While the presence of rock fragments is a rather constant feature, the percentage is seldom sufficient to characterize the soil as gravelly or stony. In general, the amount of stone or gravel is greater at a depth of 3 or 4 feet than on the surface, which tends to give good underdrainage, often making artificial drainage unnecessary. This underdrainage and the consequent higher oxidation and unmottled condition of the subsoils is one of the most characteristic differences between the Wooster and Volusia series.

In surface features the series varies from gently rolling to decidedly rolling and hilly. The principal moraines in the glaciated shale and sandstone section of the State are included in this series.

The Wooster series occurs principally as a wide border around the northern extension of the unglaciated or hilly section of the State. These soils occupy a large proportion of the country between

Mount Vernon, Galion, Ashland, Akron, Chardon, Ravenna, Salem, Lisbon, Canton, and Millersburg. Small, scattered areas are also found in other parts of the northeastern section of the State. In general, the Wooster series occupies the morainic and more hilly portions of the glaciated shale and sandstone section of the State, while the more level areas are occupied by the Volusia or Trumbull series.

Four types are recognized as belonging to the Wooster series—a sandy loam, gravelly loam, loam, and silt loam. The sandy loam and gravelly loam are of limited occurrence, but the loam and silt loam occupy rather extensive areas and are among the more important soil types of the State.

WOOSTER SANDY LOAM.

The Wooster sandy loam consists of a yellowish or light-brown sandy loam, varying from 6 to 12 inches, but usually about 7 or 8 inches in depth. The texture varies from a heavy sandy loam, grading into loam, to a light sandy loam or loamy sand. In most cases the sand is of medium texture, but there are areas which might be classed as a coarse sandy loam, while others could be considered as a fine sandy loam. A small percentage of fine gravel and occasional rounded or subangular fragments of stone occur on the surface and in the soil.

The subsoil is a brownish-yellow and sometimes slightly reddish yellow, sandy loam which usually becomes more sandy with depth, and at 3 feet is almost a sand. In some cases, however, a somewhat heavier, rather than a lighter, subsoil is found, especially where the sand has been drifted over deposits of till. Some gravel is frequently encountered in the subsoil, and this usually increases in quantity with depth.

While undoubtedly of glacial origin, the material composing the Wooster sandy loam is not entirely ice laid, but represents material which has been at least partly reworked by water and wind. Its most frequent occurrence along the border of old valleys and around present lakes would indicate that its origin is due largely to the assorting power of water during the melting of the ice. In some cases, as around Burton, in Geauga County, it is apparently due to the presence of sandstone.

The topography varies from almost level to decidedly rolling and hilly. Quite often the surface consists of a succession of knolls with intervening depressions, usually surrounded by higher ridges.

The Wooster sandy loam occurs principally in the section between Akron and Canal Fulton and around Kent, but small areas may be found throughout the morainic section, especially between Akron, Ravenna, and Chardon, one of the largest areas in this section being

around Burton, in Geauga County. The type is also encountered near Leetonia, in Columbiana County, and near Newton Falls, in Trumbull County.

The Wooster sandy loam is a valuable soil for trucking or for fruit growing and general farming. Its sandy nature and good natural drainage cause it to warm up earlier in the spring than the heavier soils, and for this reason it should be used for crops for early markets. Sweet corn, watermelons, tomatoes, early potatoes, and many other vegetables do well. The soil can be improved by the incorporation of organic matter and the application of lime and fertilizers.

WOOSTER GRAVELLY LOAM.

The soil of the Wooster gravelly loam consists of a yellowish or light-brown loam containing from 10 or 15 to as much as 30 or 40 per cent of gravel and small, rounded or subangular stones. The usual depth of the surface soil is about 7 inches. It is underlain by a browish-yellow or slightly reddish yellow gritty loam, containing considerable gravel and usually underlain at less than 3 feet by very gravelly drift, which is sometimes stratified. The stratified material occurs somewhat in pockets and seldom constitutes all of the subsoil in any one knoll. The presence of the gravel, particularly in the deeper subsoil, is one of the main features distinguishing the gravelly loam from the loam. While the amount of gravel on the surface is sometimes not very great, it is always prominent in the subsoil. However, on some of the sharper knolls the surface is literally covered with gravel, so that cultivation is difficult and boring into the subsoil is impossible.

The Wooster gravelly loam is formed from morainic and kame deposits of shale and sandstone material. It is therefore not always entirely ice laid, but has been formed in part through the action of water at the time of the deposition of the material and the melting of the ice.

In surface features the Wooster gravelly loam is very hilly. Most of it consists of high rounded knolls or ridges, with deep depressions or kettle holes in between. This type includes the most hilly portions of the morainic belt. While the slopes are seldom so steep that cultivation is impossible, farming operations over much of the type are carried on only with much difficulty.

No extensive areas of this type are found in the State, its development occurring principally in the morainic section in the western part of Stark and Portage Counties, in the eastern portion of Summit, and extending north into Geauga County. The areas, however, are usually not large, and it is impossible to separate this type from other members of the Wooster series. Some development of the type

occurs between Shreve and Loudonville, also near Beach City, and to a less extent elsewhere along the line of the terminal moraine of the Wisconsin glaciation.

Because of the very hilly character of the surface and its droughty nature this type is not valued very highly for agricultural purposes, although a considerable part of it is under cultivation. It may prove to be a good soil for apples and other fruits, as it has in most cases both good air drainage and underdrainage. In a few cases, as east of Loudonville and north of Beach City, this type occurs in old valleys where there is danger from frost.

WOOSTER LOAM.

The surface soil of the Wooster loam, extending to an average depth of 7 or 8 inches, consists of a yellowish or light-brown loam, usually containing sufficient sand to give it a somewhat gritty feel. The percentage of silt, however, is nearly always rather high for a loam, and in many cases it might be called a silty loam, although the percentage of silt is considerably lower than in the Wooster silt loam. The percentage of sand is sufficient to make it loose and friable and easily cultivated. When moist the soil has a rather rich brown color, but upon drying out after a rain the surface of plowed fields is light gray. Beneath the surface, however, the soil is always brown, rather than gray. The depth of the surface soil varies from 6 to 10 or 12 inches.

This yellowish-brown surface soil is underlain by a brownish-yellow subsoil which usually has a slightly reddish tinge. The subsoil has a solid color and seldom shows any mottling. Areas in which it is mottled really represent a gradation toward Volusia loam. In texture the subsoil is a loam slightly heavier than the surface soil. It usually contains considerable grit and at about 20 to 24 inches becomes more sandy and gr velly, so that it is often difficult to bore below this depth. There is usually some gravel and subangular fragments of stone on the surface, as well as in the subsoil, but the amount seldom exceeds 10 or 15 per cent. However, at a depth of 2 or 3 feet below the surface the percentage of gravel is greater, although deep road cuts through the hills seldom show any stratification. This somewhat sandy and gravelly nature of the till subsoil gives good natural underdrainage, so that the use of tile is usually unnecessary.

The Wooster loam is formed from the drift which was deposited as terminal moraines. During the formation of these terminal moraines there was apparently a slight assorting of the material by water, just enough to remove some of the finer particles, causing such a relative increase in the proportion of sand and gravel as to

create a loam soil. The material is largely of sandstone and shale derivation, but there is also present a considerable amount of granitic and other crystalline rock material, as is evidenced by the occurrence of fragments of these rocks. Some fragments of conglomerate are also present, and some of the gravel consists of rounded white quartz pebbles, doubtless derived from the layers of conglomerate which outcrop in Geauga and some other counties. Good underdrainage has permitted a thorough aeration and a consequent higher oxidation of the subsoil, giving it a slightly reddish color.

The surface features of the Wooster loam are distinctly billowy, being made up of a succession of knolls and intervening depressions. The topography is that of a typical terminal moraine. The hills are usually rather low and rounded, but are sometimes sufficiently steep to offer considerable difficulty to cultivation.

The Wooster loam is most typically developed in the section between Canton and Akron, but occurs throughout the morainic section extending northward into Geauga County. It is rather closely associated with the sandy and gravelly loam and also with the silt loam, so that it is not possible to show it separately on the map. Small areas are found here and there throughout almost the entire northeastern part of the State, even in the sections mapped as the Volusia series.

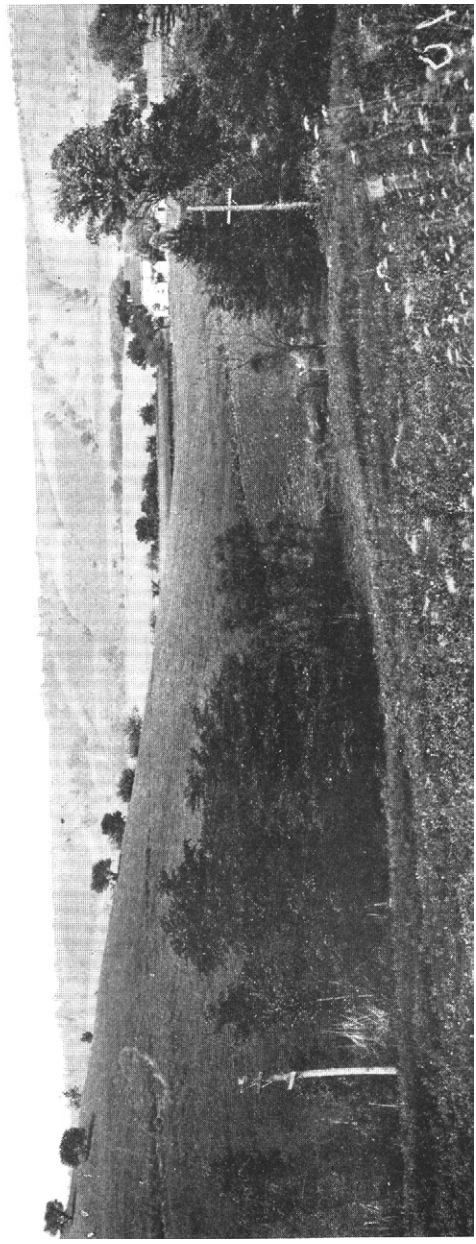
The Wooster loam is considered an excellent soil for general farming and produces good crops of corn, wheat, oats, and clover. Some small areas are devoted to alfalfa, and although not an ideal alfalfa soil, it produces very good crops where limed. Some good orchards were noted. It responds quite readily to fertilization and is capable of being brought to a high state of productiveness.

WOOSTER SILT LOAM.

The Wooster silt loam consists of a yellowish-brown, mealy silt loam underlain by a brownish-yellow, friable silt loam subsoil. The surface soil is distinctly silty and has the mealy, smooth or velvety feel characteristic of all soils having a high percentage of silt. It contains a small percentage of very fine sand, but the coarser grades of sand are absent, and the soil therefore never has a gritty feel like the Wooster loam. As the amount of clay is seldom as much as 20 per cent, it possesses very little or no plasticity, although it has a tendency to run together after a rain. The color of the surface soil is light or yellowish brown, varying considerably with the amount of moisture present. In dry, weather-beaten plowed fields it is a very light gray, but when moist it changes to a rich yellowish brown. The shade also depends to some extent upon the amount of organic matter present, being darker where the supply of humus is greatest.

FIG. 1.—SUGAR BEETS ON CLYDE CLAY, PAULDING COUNTY.

FIG. 2.—ALFALFA ON DUNKIRK SAND, FULTON COUNTY.



VIEW IN MIAMI VALLEY, MONTGOMERY COUNTY.

Fox soils on terraces and Miami and Bellefontaine on uplands.

While the surface soil may vary from 6 to 12 inches in depth, it is usually about 7 or 8 inches deep.

In texture the subsoil does not differ very greatly from the surface soil, although it is usually more compact and slightly heavier. Typically it is friable and inclined to be mealy, and only in the heaviest portions is the amount of clay sufficient to give enough plasticity to rub out smooth between the fingers. In many places there is very little change in the character of the material to a depth of 3 feet or more, but quite often the subsoil becomes somewhat more gritty below a depth of 2 feet. This is especially true in the areas associated with the Wooster loam. Frequently, however, the percentage of clay in the lower subsoil increases, causing it to become somewhat heavier. Such a condition is most often found in the sections where this type grades into the Volusia silt loam.

A small percentage of rock fragments, consisting principally of sandy shale, are a rather constant feature of this type. The proportion is usually greatest upon the slopes and knolls, while upon the more gently rolling areas very few and sometimes no fragments are present. While these fragments consist principally of sandy shale, some granite, as well as other crystalline rocks, occur. At a depth of 3 or 4 feet the amount of stone fragments usually increases considerably, as may be seen by an examination of road cuts, and this provides good underdrainage.

Although the material from which the Wooster silt loam is derived is closely related to the underlying rocks, it has been reworked by the ice, and this type is therefore of glacial origin. As the underlying rocks are usually not very far beneath the surface, the drift is composed largely of local material. However, the imbedding in the drift of crystalline rocks, which must have been brought from Canada, shows that there has been a thorough mingling of the material by the ice.

On the whole the Wooster silt loam represents a thinner deposit of drift than most other types in the area. On the steeper slopes, especially toward the southern border, outcrops of the underlying rocks are much in evidence, and a part of the soil is undoubtedly of residual origin, although it was not possible to show these areas as such on the map. The areas of Dekalb silt loam are especially numerous in the sections of the Wooster silt loam having the third or fourth class of topography on the map, so that a further description of this section is advisable.

Along the outer border of glaciation there is an irregular belt in which the soils are partly of residual and partly of glacial origin, the two being so intermixed that a separation on the map is impracticable. In addition to the difficulty presented by the frequent

occurrence of the two soils in small areas, there is a close similarity between the soils of the outer edge of the glacial area and those of residual origin. As the sandstone and shale material was moved only a short distance by the ice, it is often difficult to determine whether the soil is of residual or glacial origin.

Although all of this section of country was covered by the ice, there are many places where either no material was deposited by the ice or else such as was left has been removed by erosion. A condition often found near the border is the occurrence of drift in the valleys and on the lower slopes, while the hilltops are bare of drift and the soil is of purely residual origin. Where the glacial drift is now absent the soil has all the properties of the Dekalb silt loam, while the soil, in areas where deposits of drift were left, is very similar to the Wooster silt loam. In some places the soil is apparently of glacial origin, while the subsoil is purely residual. Scattering bowlders and fragments of crystalline rocks are found throughout this entire section, even where the soils are entirely of residual origin. Where these are found only upon the surface and not embedded in the underlying material, the soil is considered as residual and correlated with the Dekalb silt loam; but where fragments of crystalline rocks are encountered at 2 or 3 feet below the surface the soil is considered as of glacial origin and classed as the Wooster silt loam.

Throughout the greater part of this section the underlying rocks are within a few feet of the surface. They are frequently encountered at less than 3 or 4 feet. On some of the more level areas and the lower part of the slopes the deposit of glacial material is several feet in thickness. In general, the deposits of glacial drift are more numerous and deeper along the northern and western edges of this more hilly area than toward the southern border, where the deposit of glacial material gradually becomes thinner until it entirely disappears.

Although the outer border of glaciation, throughout almost the entire State, is characterized by a belt of transitional soils, south of Licking County this zone is rather too narrow to indicate on the map. The soils of this section also represent a transition from the Dekalb silt loam to the Volusia silt loam rather than the Wooster silt loam. The largest area of transitional soil occurs in the section between Mount Vernon, Millersburg, and Mansfield, a large part of which was not covered by the Wisconsin glaciation. However, a narrow belt extends on eastward from Millersburg by Canton through Columbiana County to the Pennsylvania State line.

In some respects it might be well to consider this section as belonging to a transitional series rather than classing it with the Dekalb and Wooster series; but considerable trouble is already experienced

in distinguishing between the glacial and residual soils and the introduction of an intermediate series would make it very difficult to distinguish between such a series and the Dekalb on the one hand and the Wooster on the other. Since the greater part belongs with the latter, it is thought best simply to map this section as the Wooster silt loam, and to state that there are included areas of Dekalb silt loam.

In surface features the Wooster silt loam varies from gently rolling to rolling and sometimes very hilly (see Pl. II, fig. 1). While the surface is less billowy than in case of the Wooster loam, owing to the fact that this type does not consist so largely of terminal moraine deposits, it is on the whole more hilly, because of its extension farther southward into the more broken and deeply eroded section of the State. There are, however, large areas, particularly in Wayne and Ashland Counties, which have a gently rolling surface, with some broken country along the streams.

Farther south the surface features may be characterized in general as hilly, although there are some small areas where the topography is gently rolling. Over much of this section it is very sharply rolling and in some places, especially along some of the larger streams, very steep and broken. The general outline of the surface has been determined by erosion, but has been modified to some extent by glacial action. The rounded, rather smooth outline of the hills is one of the most characteristic differences between this section and the typical unglaciated hills farther south. Toward the northern edge, where the soils pass gradually into those of purely glacial origin, the country has a gently rolling contour, characteristic of the more smoothly spread ice-laid deposits, but nearer the limit of extreme glaciation there are considerable areas of rounded hills whose characteristically smooth contours, together with the presence of occasional bowlders of crystalline rocks, furnish the only evidence of glacial action. At the farthest limits of glaciation the hilltops have not been rounded by the ice, but have the sharp outline of a weathered sandstone country, although the valleys and lower slopes have a thin covering of drift. The higher hills and ridges in this section are therefore covered by typical Dekalb silt loam, while the lower slopes are representative of the Wooster silt loam.

Over most of the type the topography is such as to give good natural drainage, but it has been found best in most cases to supplement this with tile, in order to carry off the surplus water. After the melting of the snow and the thawing of the ground in the spring, the soil becomes very soft and somewhat miry, and the use of tile has been found very advantageous in getting this surplus water out of the soil, thus putting it into a condition for earlier plowing.

The Wooster silt loam is one of the most easily washed types of soil in the State, especially in the early spring and during the heavy rains in the summer. The incorporation of organic matter, tile drainage, deep plowing, and leaving the plowed fields somewhat rough, so that the rain will run into the soil rather than off the surface, tend to decrease the damage from erosion. On some of the areas most subject to erosion, terraces might prove valuable. Gullies should be filled with brush, stone, or other material as soon as they start, or much damage will result. In some cases it might be advisable to lay large tile, with inlets at sufficient intervals to admit the surface drainage, in order to prevent the washing of large gullies through the fields. Although no definite determination of the amount of material removed from the surface by erosion has been made, the quantity is undoubtedly large.

The Wooster silt loam is typically developed on the experiment farm at Wooster and occupies quite a large part of the surrounding country, including much of Wayne, Ashland, Richland, Morrow, Knox, Holmes, and Stark Counties. Some smaller areas are found in Summit and Columbiana Counties and to a very small extent in some of the adjoining counties. It constitutes one of the most important soil types in the State. Where it occupies a large continuous area, it is indicated on the map, but there are other areas where it is associated so closely with other soils, principally of the Wooster series, that it is not possible to make a separation from these types.

Wheat, corn, oats, hay, and potatoes are the principal crops grown, and, with proper management, excellent yields are secured (see Pl. V, fig. 2). Where not too hilly the type is well adapted to general farming, as well as to the growing of fruits and vegetables. Alfalfa has been tried with some success, but owing to the deficiency of both soil and subsoil in lime carbonate this type is not particularly adapted to this crop, and the results of the experiments at Wooster make it doubtful whether alfalfa is more profitable on this kind of soil than clover.

While this type would not naturally be considered a strong soil and while it quickly deteriorates under bad management, it can, by the use of proper rotation and treatment, be brought up to a very high state of productiveness, as has been demonstrated on the Experiment Farm at Wooster.[1] The results of these experiments indicate that it is in need of all three fertilizing elements, as well as lime and organic matter, but that a greater percentage of phosphoric acid is required than of either nitrogen or potash. After several years' experiments on one-tenth acre plats, the Ohio Station decided

[1] For a detailed statement of the experiments at Wooster, see Circular 144, Ohio Agricultural Experiment Station, which can be secured free by addressing "Agricultural Experiment Station, Wooster, Ohio."

to put into practice on four 10-acre fields the system of treatment which the results on the smaller plats had indicated would probably prove most profitable. A four-year rotation of corn, oats, wheat, and clover was selected. About 10 tons of manure, to which there has been added about 40 pounds per ton of acid or raw rock phosphate, is applied to the clover sod in the fall and turned under in the spring for corn. About 1 ton of quicklime or 2 tons of ground limestone is then spread over the surface of the plowed field. The corn is followed by oats, with which no fertilizers are used.

The wheat receives a complete fertilizer made up of about 200 pounds steamed bone meal, 100 pounds acid phosphate, and 40 pounds of muriate of potash in the fall, followed by 60 pounds nitrate of soda in the spring, or a total of 400 pounds per acre, having the formula 4–16–5, and costing about $6.60 per acre for the materials.[1]

The wheat is then followed by clover, to which no fertilizer is added.

The outcome of this treatment has been an eight-year average of 77 bushels of corn per acre, followed by 61 bushels of oats, 33 bushels of wheat, and 3⅔ tons of hay.

This shows that it is possible to secure very high average yields on this soil with proper treatment. The yield of oats can doubtless be considerably increased by fertilizing this crop as well as the corn and wheat. When potatoes are substituted for corn and oats in the rotation it is advisable to increase the amount of potash in the fertilizer on this crop until it about equals the percentage of phosphoric acid.

Volusia Series.

The members of the Volusia series have grayish-brown to yellowish-brown surface soils with pale-yellow subsurface and mottled gray and yellow subsoils. While the surface soils, especially in the types of lighter texture and areas of more rolling surface, are almost as yellowish brown as the soils of the Wooster series, in general the soils of this series contain more gray. This is especially true in the types of heavier texture. However, the most distinctive and characteristic difference between the Volusia and the Wooster series is the mottling in the subsoil of the former. The amount of mottling varies with the texture and the topography, the percentage of gray or white always increasing as the surface becomes more level and the drainage more deficient. There is also a tendency toward the formation of an iron "hardpan" in most of the Volusia subsoils and a peculiar imperviousness, which causes a very slow movement of water, much slower than would be expected from the texture. The presence of beech trees is usually characteristic of the Volusia series, while the white oak is more characteristic of the Wooster.

[1] Circular 138, Ohio Agricultural Experiment Station, p. 137.

As a general rule both soil and subsoil are markedly deficient in lime carbonate and will redden litmus paper very quickly. In some cases, however, an effervescence with acid is secured within 3 feet of the surface, but such instances are rare, except in the clay loam and silty clay loam, which frequently give an effervescence. In practically all cases, however, the lime carbonate present is so far below the surface as to have little or no influence upon agriculture, and an application of lime is advisable in practically all areas of the Volusia soils.

The Volusia series is derived from glacial deposits of shale and sandstone material, which cover the northeastern section of Ohio. Bowlders or fragments of crystalline rock are quite common, with occasional pieces of limestone. However, the rock fragments, which are a rather constant feature throughout the entire area covered by these soils, are very largely sandstone or sandy shale. While the greater proportion of the material is undoubtedly true till, there are areas where the till has been modified by water action. In some places the till contains lenses of stratified material, and there are some areas of considerable extent, like the one just north of Alliance, where the absence of stone fragments and the general character of the material indicate a lacustrine origin. As the ice advanced southward it is very probable that at least temporary lakes were formed, in which lacustrine deposits were laid down. The advance of the ice farther southward caused the overriding of these deposits and their mixing with other material in the drift.

Characteristically the surface of the Volusia series forms a gently rolling plain, which in some places, particularly in its northern extension, is dissected by streams having steep, precipitous bluffs and gorgelike channels. The topography, however, varies from undulating to decidedly hilly and broken.

This series covers most of the northeastern part of the State with an arm extending southward through the center.

Owing to differences in texture, four types are recognized as belonging to the Volusia series—a loam, silt loam, clay loam, and silty clay loam. It is not possible, however, to separate these different soils on the map, and, in fact, so closely are they associated with the Trumbull soils that a separation from these, and in some sections from the Wooster, was impracticable. However, some sections are composed largely of two types, and such divisions have been made as seemed most practicable.

VOLUSIA LOAM.

The Volusia loam consists of a grayish-brown to yellowish-brown loam of rather silty nature, but containing a sufficient amount of sand to give it a somewhat gritty feel. While the percentage of silt

is rather high for a loam, it is noticeably lower than in the silt loam, so that this soil does not possess the smooth, velvety feel of the latter type. When dry the color of the surface soil is light gray, but when moist it becomes a light brown, tending in the better drained areas to a yellowish tinge and in the leveler and more poorly drained areas to gray rather than yellow. The surface soil is usually about 7 or 8 inches deep, but in some places it may not be over 6 inches and in others as much as 10 inches in depth.

It is underlain by a yellowish loam, which is rather silty but contains some grit, and is not very different in texture from the surface soil. This material often becomes somewhat more gritty at a depth of about 20 inches, and there is a tendency toward the formation of a "hardpan." The color of the lower subsoil is a yellow mottled with gray or brown iron stains. The degree of mottling depends very largely upon the drainage, being most pronounced where the drainage is poorest.

Fragments of sandstone and shale, with occasional bowlders or fragments of crystalline rock, are characteristic of this type, although the quantity is seldom sufficient to interfere with cultivation.

The Volusia loam is derived from the glacial mantle of sandstone and shale material, and represents areas of lighter or more sandy till. Its lighter texture is due in part to the more sandy nature and nearness to the surface of the underlying rocks in the section where it occurs, and in part to a slight reworking of the drift in the formation of terminal moraines.

The surface of the Volusia loam is rolling. In some places it is undulating and in others hilly. Very seldom, however, is the surface sufficiently hilly to interfere seriously with farming operations.

The Volusia loam is not very extensively developed in northeastern Ohio. Areas of it may be seen around Andover, in Ashtabula County, and southward toward Youngstown, in central and southern Geauga County, and extending southward through Portage into Stark. Much of the country, shown as "Wooster series," in Geauga and northeastern Portage Counties is composed of this type.

Although it has a lower agricultural value than the Wooster loam, the Volusia loam is considered a good soil for general farming. Corn, potatoes, wheat, hay, and buckwheat are the principal crops. It is considered an excellent soil for potatoes and is quite generally used for this crop. Some clover is grown, but the deficiency of the soil in lime carbonate causes some difficulty in securing a stand. The liberal use of lime, the incorporation of organic matter, the application of a fertilizer containing a relatively high percentage of phosphoric acid, and the providing of underdrainage where necessary are among some of the means by which better yields may be secured on this soil.

VOLUSIA SILT LOAM.[1]

The Volusia silt loam consists of a grayish-brown, smooth silt loam, about 7 or 8 inches deep, underlain by a pale-yellow or yellow mottled with gray silt loam, which grades at about 12 to 15 inches into a mottled gray and yellow heavy silty clay loam.

Although the surface soil is considerably like the Wooster silt loam, the tendency is more toward a grayish-brown than a yellowish-brown color, while the subsoil is not only much heavier but is also mottled with gray, as well as with brown iron stains, and there is often a tendency to form a hard, compact layer at a depth of about 20 inches.

The Volusia silt loam is of glacial origin, being formed from a mantle of drift over the underlying shales and sandstones, which are usually not many feet below the surface. The more silty nature of the material, where this type occurs, is probably due to the silty character of the underlying rocks to which the drift is very closely related.

The surface of the Volusia silt loam is rolling to somewhat hilly, and while this provides good surface drainage, the heavy character and rather impervious nature of the subsoil cause this type to be somewhat "cold" and wet for many days after a rain, especially in the spring.

The Volusia silt loam is a rather extensively developed type. It occupies a large proportion of the eastern and southeastern part of Trumbull County, extending northward into Ashtabula and southward into Mahoning and Columbiana and westward into Stark. It is interrupted in Stark by the moraine, which gives the Wooster soils, but some is found again in the western part of the county and extends west through Wayne, Ashland, and Richland, and then southward along the western border of the Wooster or Dekalb silt loam, although its development here is not as typical or extensive as farther east. Its rather intimate association with other Volusia or Trumbull soils made it impractical to separate it on the map, or even throw it all into the same group, and in the eastern part it is included in the "Volusia and Trumbull series" and farther west with the Volusia clay loam. Some is also included with the Wooster silt loam.

Because of its wetter, somewhat springy, and colder nature, the Volusia silt loam is not as highly esteemed as the Wooster silt loam. Thorough underdrainage would undoubtedly bring about an improvement in this soil and make it more nearly equal to the better type. It is used for general farming, corn, oats, potatoes, and hay being

[1] The Volusia silt loam in Ohio is not similar to the type mapped under the same name in New York, as the latter contains a much larger percentage of shale and sandy shale fragments and can therefore be more properly considered as the shale silt loam.

the principal crops grown. The addition of lime, the establishment of thorough underdrainage, the incorporation of organic matter, and the use of a fertilizer containing a relatively high percentage of phosphoric acid, particularly on the wheat crop, are needed in the building up of this soil.

VOLUSIA CLAY LOAM.

To a usual depth of 7 to 9 inches the surface soil of the Volusia clay loam consists of a grayish-brown heavy silty loam to clay loam, which is somewhat sticky and plastic when wet, with a tendency to become hard and compact when dry. When rather silty in character, it contains more sand than the silty clay loam and more clay than the silt loam. However, a very large proportion of the type has a texture almost intermediate between that of a heavy loam or silt loam and a clay loam, although its general characteristics are more nearly those of a clay loam than any other class.

The color of the surface soil is predominately a grayish or very slightly yellowish brown. Weather-beaten plowed fields are light gray in color, but, when moist, the soil becomes a grayish brown, with a tendency toward a yellowish brown in the more rolling and better-drained places and toward a brownish gray in the more nearly level areas.

Usually the subsoil occurs in two rather distinct layers. The upper part is only slightly heavier in texture than the surface soil but the lower portion is decidedly more clayey. To a depth of about 15 to 20 inches the subsoil consists of a pale-yellow, or slightly brownish yellow, heavy clay loam, or silty clay loam, which is seldom plastic but rather has a friable structure and can be readily broken up. Some gray mottlings are not uncommon, particularly in the more gently rolling areas. In exceptional localities it has a compact "hardpan" structure, being somewhat impervious. Below a depth of 15 or 20 inches the subsoil is a compact, rather silty, heavy clay loam or clay, which represents the till in a less weathered condition. The usual color of the lower subsoil is a brownish yellow mottled with gray, the percentage of gray decreasing with depth but usually increasing as the surface becomes more level and the soil more poorly drained. The change between the upper and lower strata is usually rather gradual, both as regards color and texture. Over the greater part of the area iron stains and iron concretions are present in the lower subsoil, as well as in the subsurface, but these, and also the gray mottlings, disappear as soon as a sufficient depth is reached to encounter lime carbonate.

Fragments of sandstone, sandy shale, and igneous or metamorphic rocks occur throughout both soil and subsoil, but seldom constitute

more than 10 or 15 per cent of the material. As a rule, the bowlders are more abundant over the morainic hills where they were deposited along the front and sides of the glacier. Occasional fragments of limestone are also found throughout most of this type, and these increase gradually toward the west until the percentage becomes sufficiently large to justify classing the soil as the Miami clay loam instead of the Volusia clay loam.

The surface soil is usually deficient in lime carbonate. The percentage in the subsoil is seldom sufficient to cause effervescence with acid at a less depth than 30 inches, and sometimes no effervescence can be secured within 3 feet of the surface. Below this depth lime is usually quite abundant, and lime concretions are very common in road cuts.

The Volusia clay loam has been formed by the weathering of sandstone and shale material which was deposited by the ice. In the western part of the type the movement of the ice was to a certain extent from the northwest, and this tended to bring in a larger proportion of limestone material than is found farther eastward. The till, in areas where this type occurs, is usually many feet thick, and the underlying rocks, therefore, farther below the surface than is usually the case where the lighter members of the series are found. In the section between Warren, Ravenna, and Alliance the drift, from which the Volusia clay loam has been formed, has apparently been influenced by an inclusion of some lacustrine material, which causes this type here to grade toward the silty clay loam.

In general the surface is rolling, but there are areas where it is only gently undulating, while in other places it is decidedly rolling and hilly. The latter condition is especially true along the streams where erosion has been active, also along the line of the more prominent moraines, and in the highlands in Geauga and some of the adjoining counties. Practically all of this type is in need of underdrainage. Considerable tile drainage has been installed, principally in the more nearly level areas or swales, but there is still a large acreage where tile could be used with profit. There are very few figures obtainable as to comparative crop yields with and without tiling, but it is believed that the use of more tile would prove profitable in nearly all parts of the area occupied by this type.

The Volusia clay loam constitutes the most extensive soil type of northeastern Ohio and also extends southward into the center of the State. Beginning in Ashtabula County it occupies an increasingly large proportion of a broad belt of country extending westward to Crawford County and then southward practically to Chillicothe. Because of its close association with other members of the Volusia and the Trumbull series, it was not possible to indicate it separately upon the map. In fact, because of its association with different

soils in different parts of the State, it was deemed best to include it in different groups. It occupies nearly all of the northern and western portions of the area shown on the map as the "Volusia silt loam and clay loam," the latter being confined largely to the eastern and southern parts. In the "Volusia and Trumbull clay loams" group it occupies much the larger proportion. Here it covers nearly all of the country indicated as rolling, as well as a large part of that indicated as level. It is also one of the most important types in the section shown as "Volusia and Trumbull series," its importance probably being least in the eastern and southeastern parts of this area, particularly in eastern Trumbull County.

In most cases the western border lies east of the eastern extension of the underlying limestone, the distance depending upon the direction and flow of the ice sheet. Where the movement was more directly east from the exposure of the limestone, fragments of that material were carried some distance eastward and the Miami clay loam was continued, but where the flow was parallel to the line of contact between the limestone and shale the Volusia clay loam approaches the line between the underlying rocks. There is naturally a very gradual change between the Volusia clay loam and the Miami clay loam, and this has made it necessary to draw a more or less arbitrary line between the two, with various degrees of accuracy between different points of contact. In Fairfield County the arbitrary line is drawn for a long distance with a possible error of not more than one-half mile, but toward the north the line is more difficult to determine, as the shale and limestone materials are mixed in varying proportions across the transitional belt many miles wide.

General farming is the type of agriculture commonly practiced upon this type, the principal crops being corn, oats, wheat, clover, timothy, potatoes, and rye. On the whole this type is very well adapted to the crops grown, although the yields are not as high as upon some other soils in the State. Wheat was at one time more extensively grown than at present, the low yields obtained for several years causing a decrease in acreage. A larger acreage is now probably devoted to oats than to wheat. Some alfalfa is grown, but this type is not naturally a good alfalfa soil. By the liberal use of lime and stable manure the crop may be started and, if good surface and underdrainage is provided, it can be successfully grown. The best results can undoubtedly be obtained in the more calcareous portions along the western border and in those areas having the best surface and natural underdrainage. Buckwheat forms a rather important crop in the more northeastern section. It is rather heavy for potatoes and is not as well suited to this crop as the lighter types. The soil is somewhat difficult to cultivate and is considered as rather

"cold," but drainage tends to bring about an improvement in the latter condition.

Dairying is common over all parts of this type, and stock farming is practiced to a considerable extent. This soil type is especially well suited to dairying, where market facilities are favorable, because of its adaptability to the production of hay and forage crops.

Truck is grown where the market facilities make it profitable, but the texture is too heavy for the best development of this industry, except the late and heavier truck crops. Of late years the railroads, trolley lines, and automobile trucks have greatly increased the profits of this industry in sections near the larger cities. Near Lake Erie grapes are grown quite extensively on this type.

The soil is deficient in lime, as is indicated by the rapid reddening of litmus paper, as well as by the growth of sorrel and other vegetation commonly found where soil is acid. The absence of limestone in this section of the State has tended to retard the use of lime upon this type as extensively and liberally as the conditions demand. Very little tile drainage has been used, though practically all of the type is in need of underdrainage. The soil is also in need of phosphorus. The use of potash, especially on potatoes, would also doubtless prove profitable, but it is believed that the supply of this element in the soil is quite large. While this type is generally not considered as among the more productive soils of the State, it can be very much improved by proper methods of treatment.

VOLUSIA SILTY CLAY LOAM.

The Volusia silty clay loam consists of a grayish brown or pale yellowish gray heavy silt loam to silty clay loam, underlain at about 8 inches by a pale-yellow, often mottled with gray, friable silty clay loam, which changes at about 15 to 18 inches into a greasy, heavy plastic clay having a peculiar brownish yellow or olive-drab color with very little or no mottling. White lime spots are found below a depth of about 30 inches, and this lower subsoil is always very calcareous and lime concretions are very common in road cuts.

The texture of the surface soil is distinctly silty, and in this respect it is like the silt loam; however, the percentage of clay is greater than in the silt loam and the soil is therefore heavier, more difficult to work, and more liable to bake and become hard after rains. The most characteristic feature of the type is the heavy, greasy, plastic nature of the lower subsoil and its peculiar olive-drab color. Bluish gray spots, which are frequently found, are particularly unctuous. This subsoil shows up very prominently in the road cuts where it cracks very badly and has a rather peculiar grayish color. Rock fragments very seldom occur in either soil or subsoil.

The Volusia silty clay loam is of glacial origin, but the drift in these sections is believed to be composed very largely of lacustrine material, which was picked up by the ice in its movement southward. It may possibly be due to the heavier character of the underlying shales, but, since these are in some cases at least 100 feet below the surface and as this type is confined to sections in which there were undoubtedly at one time glacial lakes, as is evidenced by places where the clay shows stratification, it seems more probable that this material is of lacustrine origin, although modified and redeposited by glacial action.

The Volusia silty clay loam is practically confined to that portion of the Mahoning River Valley where the stream flows in a northeastern direction, although some of it is found as far down this stream as Niles. The principal areas are found in northeastern Stark County, southeastern and eastern Portage County, and western Trumbull County, particularly in Southington Township.

The topography of the type is gently rolling, although there are some areas which are rather heavily rolling or hilly.

This soil is generally recognized by the farmers as probably the least desirable type in the sections where it occurs. Its heavy, rather intractable nature makes it difficult to cultivate, and the moisture conditions under which it can be plowed are restricted to a rather narrow range. Corn, oats, wheat, and hay are the principal crops. Of these, it is probably best suited to hay and least to corn. The calcareous nature of the subsoil suggests the possibility of growing alfalfa, if the surface soil, which is decidedly acid, is given a heavy application of lime.

Trumbull Series.

The Trumbull series consists of gray surface soils, underlain by light-gray, or gray mottled with yellow, subsoils, which, at an average depth of about 18 inches, become a mottled gray and yellow. The subsoils are usually mottled to a depth of 3 feet or more, and no effervescence was noted within the 3-foot section, even in the heavier types, although it is probable that the till underneath contains lime carbonate, since this is usually found in the surrounding Volusia soils.

The surface soils of the Trumbull series lack the yellow, which is always present in the Wooster and, to a less extent, in the Volusia soils. When dry these soils are a very light gray, in fact almost white, but when moist they become a light grayish brown, or brownish gray, and in some of the most poorly drained areas a rather dark gray, due to the larger amount of organic matter present. However, the most distinctive characteristic of this series is the very light-gray color of the subsurface soil, which in most typical areas has

very little if any yellow mottlings present, although ocherous-yellow or brown iron stains are common and, where the surface has a slight slope, some yellow mottlings are also found. The dividing line between this series and the Volusia has been drawn chiefly upon the color of the subsurface. Where this material is gray, or where it has more gray than yellow, the soils have been classed with the Trumbull, but where more yellow is present than gray they have been thrown with the Volusia.

Another characteristic feature of the Trumbull soils is the level character of the surface, which is always flat, or very nearly so, as only a slight rise will give sufficiently good drainage to produce the Volusia soils.

The Trumbull series owes its origin to changes which have been brought about as the result of poor drainage. In the absence of lime carbonate the organic matter has apparently attacked the iron compounds in the soil, which give the yellow color, causing them to be reduced and leached out, or concentrated in the form of iron concretions or brown iron stains. This action has been most pronounced in the surface and subsurface soils and diminishes with depth, which explains the yellow mottling of the lower subsoil.

Although found more or less throughout the entire northeastern part of the State, the most important developments of this series are in Trumbull, Ashtabula, Cuyahoga, Lorain, and Huron Counties.

The Trumbull soils are usually considered less desirable than the corresponding members of the Volusia series and much less so than those of the Wooster.

Three members of this series—a loam, silt loam, and clay loam—were found. Of these the clay loam is most extensive and the loam least.

TRUMBULL LOAM.

The Trumbull loam consists of a gray, or brownish gray loam, underlain at about 7 or 8 inches by a gray loam, sometimes mottled with yellow, which at a depth of about 18 inches grades into a mottled gray and yellow heavy loam to clay loam.

In dry plowed fields the surface soil looks almost white, but when moist becomes more of a brownish gray. The subsurface is typically a light gray, but ocherous-yellow or brown iron stains are quite frequent and some mottling with yellow is not uncommon. However, the distinctly mottled gray and yellow subsoil does not usually begin until a depth of 15 to 20 inches is reached, although this depth varies, being shallowest where the drainage is best.

The texture of the surface soil varies considerably, ranging from a gritty, somewhat sandy loam to a fine loam in which the percentage of silt is rather high. However, it is distinctly more gritty than the silt loam. The texture of the subsoil is not always uniform,

even in the same section, as pockets or lenses of sandy or clayey material are often interbedded with the loam.

The textural difference between the Trumbull loam and other members of this series is due to the larger amount of sand which is found in the drift in areas where this soil occurs. This is in most cases due to the presence of sandstone only a few feet below the surface, which causes the drift in these areas to contain more sand. In some cases, however, the larger proportion of sand is apparently due to some reworking of the drift by water action or the deposition of coarser material by the same agency.

The surface of the Trumbull loam is flat, with only very slight variations from a dead level. The drainage is, therefore, poor and has to be improved before much success can be obtained in crop production. So far most of the drainage is surface drainage. There are some areas, still in forest, which are too wet for cultivation.

The Trumbull loam is not extensively developed. Although several small areas occur in the northeastern part of the State, the most important are in the southwestern part of Trumbull County, particularly north and east of Warren and between Lordstown and Newton Falls.

The Trumbull loam is used for general farming and is considered a fair soil for the general crops grown in this section. Drainage and the use of lime are two of the most important things to be considered in connection with its improvement.

TRUMBULL SILT LOAM.

The Trumbull silt loam consists of a gray silt loam, underlain at about 8 inches by a light-gray, heavy silt loam to silty clay loam, sometimes mottled with yellow or brown iron stains. At about 18 or 20 inches this grades into a mottled gray and yellow heavy clay loam or silty clay loam.

The surface in plowed fields is a very light gray, in fact almost white; but the moist soil below is a gray or brownish gray, which often has some brown iron stains present, particularly in areas which have never been cultivated. The subsurface is a light gray, usually containing brown or ocherous-yellow iron stains and quite often somewhat mottled with yellow. The percentage of yellow usually increases with depth, until the lower subsoil becomes a mottled gray and yellow. Frequently ocherous-yellow or brown iron spots, and in some cases bog iron ore, occur, usually below 30 inches, although they sometimes appear nearer the surface.

The texture of the surface soil, while usually having the smooth, velvety feel, characteristic of a silt loam, quite often contains a considerable percentage of very fine sand, giving to these areas the texture of a silty loam rather than a distinct silt loam. In these areas

the subsoil also contains more very fine sand than is found in the more typical silt areas. While the lower subsoil often contains some grit, due undoubtedly in part at least to iron concretions rather than sand grains, there is usually enough clay present to give it considerable plasticity when wet and to make it somewhat impervious.

The Trumbull silt loam is derived from the same character of drift as the Volusia silt loam, with which it is closely associated. The difference between the two has resulted from the poor drainage conditions existing where the Trumbull silt loam is found.

Like other members of the Trumbull series, the surface of the silt loam is level and the drainage poor. Water usually remains after rains until evaporated, unless artificial drainage, either surface or underdrainage, has been provided.

Although the Trumbull silt loam is not one of the extensive soil types of the State, it occupies some areas of considerable importance, particularly in eastern and southern Trumbull County, and to a less extent in Ashtabula, Mahoning, and possibly some other counties in the northeastern part of the State. However, very little if any occurs in Stark, Portage, Geauga, or Lake Counties.

Some of the type is still in timber, but a large proportion is under cultivation. Corn, oats, wheat, and hay are the principal crops. The hay crop is very largely timothy, although other grasses as well as some clover are grown. Although not considered as good a soil as the Volusia silt loam, it will, when drained, limed, and well cultivated, give good yields of the crops grown, especially hay.

TRUMBULL CLAY LOAM.

The Trumbull clay loam consists of a gray or brownish gray heavy silty loam or clay loam, underlain at about 8 inches by a light-gray heavy clay loam to silty clay loam, often slightly mottled with yellow, which grades at an average depth of about 18 inches into a mottled gray or bluish-gray and yellow clay.

Like other members of the Trumbull series, the surface soil of the clay loam is, when dry, a very light gray, but when moist it is more of a brownish gray, although there is not even a suggestion of either red or yellow. However, there is quite a little variation in the color of the surface, due principally to differences in drainage and a consequent variation in the amount of organic matter present. In the most poorly drained spots organic matter has accumulated, and these areas are a rather dark gray when wet and are sometimes spoken of by the farmers as "black land." These areas represent a gradation toward the Papakating soils. More often, however, the type is referred to as "white clay land."

The subsurface is a very light gray or white, in which there are found some brown iron stains or, in the better-drained areas, some

yellow mottlings. The depth at which the most apparent change in the color of the subsoil takes place usually follows rather closely the change in texture. In some places it may not be more than 12 or 15 inches. Usually the bluish-gray parts of the subsoil are very heavy and plastic, while the brown or yellow parts are more friable and may contain some grit, possibly largely iron cementations. No effervescence was noted within the 3-foot section, but lime carbonate is undoubtedly present in the underlying till, since it is usually found in the deeper subsoil of the Volusia clay loam with which this type is closely associated.

The Trumbull clay loam is derived from the same character of drift material as the Volusia clay loam, the difference between the two types being due to the macerating processes which have gone on in the absence of lime carbonate under poor drainage conditions. In most cases the underlying rocks are many feet below the surface, but in some areas they are within 10 feet or even nearer. Such is the case on the experiment farm at Strongsville, part of which is composed of a phase of this type. The nearness of the rocks here has not only modified somewhat the character of the drift material but also tended to cause seepage, resulting in rather grayer soils than would be expected from the topography. Some shale and sandstone fragments are found in the soil on this farm, as well as in most other places, although the percentage is usually small.

The surface of the type is level, with often not enough slope to carry off the surface water. The heavy, rather impervious nature of the subsoil makes underdrainage difficult, and very little tile has been used. The plowing of the fields in narrow lands, in order that the surface water may be carried off in the dead furrows, is a common practice on this type and also to a less extent on other members of the Trumbull series.

The Trumbull clay loam occupies some rather extensive areas, particularly in Trumbull and Ashtabula Counties and in the section of country from Cleveland southwestward into Huron County. In the latter section it was not possible to separate this type from the Volusia clay loam, while in parts of the northeastern section of the State it had to be grouped with other members of the Trumbull and Volusia series. The more important areas, where this soil and the Volusia clay loam occupy practically all of the country, have been indicated as these types on the map, but small areas are found throughout the section, occupied by the Glacial Sandstone and Shale soils, except in that portion which is covered by the Wooster soils.

Because of its poor natural drainage, much of this type is still in timber, although the larger proportion is under cultivation. However, it is not considered a desirable soil by most farmers. Its heavy,

rather sticky nature makes it difficult to handle. Corn, oats, wheat, and hay are the principal crops and of these hay is by far the most important. The experiments at Strongsville indicate that drainage, liming, and the use of phosphorus are three very essential and important things in the upbuilding of this type.

GLACIAL LAKE SOILS.

Primarily this group includes soils formed from glacial material which has been reworked by water and deposited in former lakes, or thrown up as beaches around their borders by the waves, and sometimes further modified by the action of the wind. However, it is often very difficult, and in some cases practically impossible, to determine just how much reworking of the material has been effected by the lake waters. Where the deposit was gravelly or sandy, as is the case in the beaches or deltas, the evidences of reworking are usually very distinct, because practically none of the ice-laid material is of this texture, but where there is no such difference in texture, as in the clay loam, it is sometimes impossible to say whether the formation is entirely water laid or ice laid or partly both. Instances were noted where the surface material to a depth of a few inches has undoubtedly been reworked, while that below shows unmistakable evidences of having been deposited by the ice. Over a large part of the old lake bed very little deposition or reworking of the material has taken place, while along most of the streams such material as was reworked has been removed by erosion, and the soils here are derived entirely from drift. Because of these conditions soils belonging in the same series, and even the same types, are found both within and without the old lake bed, and the line of distinction between the glacial lake and glacial drift soils is necessarily more or less arbitrary.

In determining to which group a series or type belongs, the character of the soil itself, as well as its origin, is taken into consideration, and therefore some areas which were never true lakes, but only swampy, are included in the former, while others, which represent at least partly lacustrine material, have been placed in the latter group. In such instances the type is included in a certain series because of its close similarity to other members of this series, while the series is placed in the group with which, as a whole, it most properly belongs.

It has already been pointed out that the drift in the western half of the State is composed largely of limestone, while that in the northeastern part is made up almost entirely of sandstone and shale. This is likewise true, to a large extent, of the glacial lake deposits, and this has had a very important part in determining the character of the soil and, together with other factors, has caused the formation

of several different series. Where poor drainage conditions have existed in the limestone section there has been an accumulation of organic matter, giving rise to the dark-colored soils of the Clyde series, but where drainage conditions have been better or the soils deficient in lime carbonate, the amount of organic matter is much less and the color much lighter. In the northwestern part of the State, where the drift is composed very largely of ground-up limestone, the material of the old beaches also contains a large proportion of limestone, while east of Norwalk it consists very largely of sandstone and shale. Because of this difference in the amount of limestone present, the soils derived from the calcareous deposits have been included in the Belmore series, while those from the sandstones and shales have been correlated with the Dunkirk. Although almost all of the lime has been leached out of the surface soils, the difference in the deeper subsoils is quite marked and is sufficient to justify a separation into two different series.

Clyde Series.

In the Clyde series are included the dark grayish brown to black soils formed from the reworking or partial reworking of glacial drift material. With the exception of the clay loam, all of the soils of this series are derived from deposits laid down in the old glacial lake, but, while much of the clay loam occurs in the old lake bed, very little reworking of the material has taken place. The series is characterized by the presence of a comparatively large amount of organic matter, to which the dark color is due. This organic matter has accumulated under swampy conditions. The amount of lime in the subsoil is not very large, as an effervescence with acid is not often obtained within 3 feet of the surface. This is due, in part of course, to the fact that the reworking of material tends toward the removal of the lime carbonate.

The Clyde series is practically confined to the western half of the State, its most extensive development being in the old lake bed in the northwestern section. The series is more nearly complete than any other series found in the State, the texture ranging from sand to clay. The principal types are the sand, sandy loam, loam, clay loam, and clay. As there is apparently little difference in agricultural value between the different-textured sands or sandy loams, no separation into medium and fine grades was made, and these are described simply as the Clyde sand and Clyde sandy loam.

Clyde sand.

The Clyde sand consists of a dark-brown to black, rather loamy sand, which contains a large amount of organic matter, giving it its dark color. The texture of the sand varies from medium or slightly

coarse to fine, the greater proportion probably being of the fine grade. The dark surface soil varies in depth from about 6 to 15 inches and is underlain by a gray or mottled yellow and gray sand of practically the same texture as the surface soil, although it is less loamy, because of the smaller amount of organic matter which it contains.

The Clyde sand is derived from sandy lake deposits, which were sorted by the waves and more or less modified by the wind. The material of this type and the Dunkirk sand were originally identical, the difference from the latter type being due to poor drainage conditions, which have resulted in the accumulation of organic matter in rather large quantities. Much of the type is poorly drained, especially in the section known as the "Oak Openings," west of Toledo.

This type occurs only in small areas, none of which are of sufficient size to indicate separately on the map. It is closely associated with the Dunkirk sand and the Clyde sandy loam, and is most commonly found in depressions surrounded by areas of light-colored Dunkirk sand. It is locally known as "black sand," although this term is often extended to include the Clyde sandy loam.

Owing to its poor drainage, very little of the Clyde sand is under cultivation. Where properly drained it is a good soil for trucking and produces good yields of corn and other general farm crops, although it is not so well adapted to these as to truck. It is probable that fertilizing with phosphoric acid and potash, in about equal proportion, would prove profitable on this soil.

CLYDE SANDY LOAM.

The surface soil of the Clyde sandy loam consists of a dark-brown to black medium to fine sandy loam extending to an average depth of about 8 inches. The depth varies, however, from 6 to 12 inches. The subsoil is generally a gray and yellow mottled medium to fine sandy loam, which grades into either a sandy or silty clay containing considerable grit. In Ballville Township, Sandusky County, the lower subsoil is nearly always a silty clay with some sand. In Lucas County very little clay subsoil is encountered, but there is instead a tendency toward a coarser grade of sand. The type is spoken of locally as "black sandy soil" or "black sand." There is present a considerable amount of organic matter, the percentage varying with the drainage. Where the drainage is poor the amount is so high that a more or less mucky condition exists, but in the better drained areas the percentage is very much lower and, in fact, is sometimes so small that the soil is hardly dark enough in color to be classed as the Clyde.

The Clyde sandy loam is derived from the sandy material laid down in the old glacial lakes, either as deltas or other shallow-water deposits. It therefore represents material which has been entirely

reworked by water, and on this account the amount of lime present is not as great as in some of the deposits which have not been so extensively reworked.

The surface is level to very gently undulating. The natural drainage is poor, because the slope is usually so gradual that water stands for long periods after rains. The country is so nearly level that large dredge ditches are necessary to drain it properly. Much of the large area west of Toledo is insufficiently drained. Its open, porous nature, however, makes drainage very easy, and it is not necessary in installing tile drains to place the drains very close together.

This type is best developed in Lucas, Fulton, and Henry Counties, with some small areas in Wood and Sandusky Counties, especially in the vicinity of the second beach, which is low and very obscure in many places. The principal areas are indicated upon the map in connection with the Clyde loam, from which it is not differentiated.

This soil is very easy to cultivate and, when well drained, is an admirable trucking soil. Corn, wheat, oats, and hay are grown, although the yields are not so large for these crops as on some of the heavier types. Sugar beets are grown to some extent. Potatoes are quite an important crop, and in quality are said to be superior to those of the heavier soils, being less watery.

CLYDE LOAM.

The Clyde loam is intermediate in texture between the Clyde sandy loam on the one hand and the Clyde clay loam on the other. The surface soil consists of a dark-gray or dark-brown to black loam varying in depth from 6 to 14 inches. Underlying this surface soil there is a somewhat variable subsoil, consisting of a yellow and gray to gray mottled with yellow sandy to silty clay. In most places, however, there is a sufficient amount of coarse sand present to give the subsoil a somewhat gritty feel. There is not a very close relation between the texture of the surface soil and the subsoil. The heaviest portion of the surface soil may be underlain by the lightest parts of the subsoil. In general, however, the type is heaviest in texture where it borders the Clyde clay loam, and lightest where it adjoins the Clyde sandy loam or sand. In some cases the subsoil apparently consists of lenses of sand surrounded by heavier material, or heavier material may occur surrounded by that of a sandy nature. The subsoil is frequently a sandy clay to a depth of 24 to 27 inches, where a change to a silty clay takes place. Gravel is quite common in the lower depths as well as on the surface southeast of Bowling Green, in Montgomery Township, and also in the southern part of Sandusky County and in the northern portion of Seneca County, especially near Kansas.

This type is confined to the old lake-bed region in the northwestern part of the State. It is so intimately associated with the Clyde sandy loam that it is not possible to separate the two types on the map. It is not very extensively developed, covering perhaps not more than one-fourth of the area mapped as this type and the Clyde sandy loam. The more nearly level and lower lying areas are usually occupied by this type. Probably one of the most typical developments is in the country south and east of Napoleon. It most frequently occurs as a rather narrow band between the Clyde sandy loam and the clay loam.

The topography is level to very gently undulating. In fact, the surface is usually so nearly level that swampy conditions formerly existed. Natural drainage is, therefore, not very good, and in most cases the type is drained by large ditches along the roads, into which the tile drains from the fields are led. Having a somewhat more porous nature than the clay loam its drainage is more easily effected, and it is not necessary to put the tile so close together as in the heavier types. A large area in the northwestern part of Lucas County, just north of the Lake Shore Railroad, is being reclaimed. Some of the more nearly level areas near Swanton and Delta are in need of drainage.

The Clyde loam is derived largely from material deposited in the old glacial lake. It represents a mixture of the more sandy material brought in by the stream with that of a somewhat heavier character. In some places the deeper subsoil is undoubtedly derived from the drift, which doubtless accounts for the heavier material sometimes present at a depth of about 30 inches or less.

Although the heavier parts of the type crack somewhat on drying this soil is usually very easy to cultivate and a good tilth can be readily secured and maintained. The rather large amount of organic matter present causes it to granulate and break up into a mellow condition. Because of the ease of cultivation and its high productive power it is esteemed as one of the best soils in the State for general farming. All of the general farm crops are grown, and large yields are secured. Sugar beets do well and are becoming an important crop in many sections. Some areas in the vicinity of the larger towns, like Toledo, are quite extensively used for trucking.

CLYDE CLAY LOAM.

The Clyde clay loam consists of a dark-colored, rather silty clay loam soil, underlain by a mottled gray and yellow heavy clay loam to clay subsoil, also containing a large amount of silt.

In general, the texture of the surface soil is remarkably uniform, considering the large areas covered. It varies, however, from a light clay loam to a heavy clay loam, and, in some cases, almost a silty

clay. The lighter textured areas occur in those sections where the type is associated with the Clyde loam or sandy loam, and represent a gradation toward these types. The heavier areas occur in sections where it is associated with the Clyde clay and in depressions, where there has been a tendency for the finer particles from the surrounding, slightly higher lying areas to accumulate. Except in areas associated with the sandier types only a small percentage of sand is present, the soil consisting principally of silt and clay. This causes it to have a rather smooth feel, while the percentage of clay and humus makes it rather sticky and plastic when wet. The percentage of silt is probably somewhat higher in the areas found in the southwestern part of the State than in those in the northwestern section, due, probably, to the somewhat more silty nature of the drift in the former section. Although the percentages of silt and clay are sufficiently high to make it somewhat sticky when wet, the soil possesses the power of granulation in such a marked degree as to cause the surface soil to form in crumbs and to be very loose and easily kept in good tilth.

The color of the surface soil is popularly known as "black," but varies from a drab or dark gray to dark brown or black, depending upon the amount of organic matter present. The largest percentage of organic matter is usually in the lower lying areas, where the water remains longest after rains. For this reason such areas have the darkest color. In the large areas in the northern part of the State the color is rather uniformly a dark gray, but the soil becomes almost black when wet. Over the scattered areas to the south the smaller spots are usually dark gray, but in the larger areas there are occasional bodies of black soil, which carry such large amounts of black organic matter as to be almost mucky. This condition is also seen in narrow strips around the border of the Muck beds. Good examples of the very dark areas may be seen in the northern part of Madison County, southeast of Plain City, where they occur in numerous small bodies in the larger tracts having a dark-gray color. The average color of the old lake-bed soil is probably a little lighter than the areas elsewhere, due probably to the fact that the surface is more uniformly level, with only very slight depressions. Outside of the old lake bed, however, this type is found in the low-lying areas having poor natural drainage and receiving much of the run-off from the surrounding higher lying Miami clay loam.

The depth of the surface soil varies with the color. In some of the lighter colored areas it is not much more than 6 or 8 inches, while in the black areas it may be as much as 18 inches or even 2 feet. The deeper areas are more common outside the old lake bed than within. The average depth is probably not far from 12 inches.

In general, the subsoil may be described as a mottled gray and yellow heavy clay loam or clay in which there is present a large percentage of silt. There is, however, considerable variation, especially in color. Where drainage has been very poor, the upper subsoil to a depth of 18 to 24 inches is a grayish-drab or blue color, in some places more or less mottled with yellow, but where drainage has been better much more yellow is present, even in the upper subsoil. Below this stratum the subsoil gradually changes from a gray mottled with yellow to a yellow mottled with gray. At a depth of 3 feet, especially in the northwestern part of the State, the subsoil is usually quite yellow or brownish yellow. Over much of the old lake bed, and to a less extent elsewhere, the upper stratum of grayer subsoil is absent and the surface soil grades directly into the mottled gray and yellow subsoil. Brown iron stains and iron concretions are frequently encountered in the subsoil, and sometimes an effervescence with acid is obtained within 3 feet of the surface. As a rule there is no great change in texture or structure with depth, but in rare instances the lower subsoil may become more open and porous. While the subsoil is rather heavy, there is a noticeable difference between the texture of the Clyde clay loam and the Clyde clay, the latter being heavier, more compact, and more impervious.

The Clyde clay loam represents an accumulation of organic matter in the slightly reworked glacial limestone drift material. In the case of all other members of the Clyde series the material constituting both soil and subsoil has been reworked and redeposited by water, but in the case of the clay loam very little reworking has taken place. It is impossible in most cases to determine the exact amount of reworking; but usually it is clear that the subsoil has been formed from unmodified drift, because the main ditches along the roads nearly always show cuts of typical till in which bowlders are quite often imbedded. The extremely level character of the deposit in the old lake bed, however, indicates that some reworking of the surface material has taken place. Where the type occurs as depressions in the Miami soils, there has doubtless been some washing in of material from the surrounding areas; but the amount has not been sufficient to have any marked effect, and the difference between this type and the Miami clay loam must be attributed primarily to the accumulation of organic matter under poor drainage conditions.

On account of the moist conditions necessary to its formation, the Clyde clay loam is confined to level or depressed areas, which in past time have been subjected to very poor drainage. The surface is everywhere either level or very slightly undulating. A very slight rise, however, is usually sufficient to remove the water, prevent the accumulation of organic matter, and cause the formation of the Miami clay loam instead of the Clyde clay loam. In the north-

western part of the State, and also northeast of Marion, the low, rounded knolls and ridges may be covered by the darker soil.

The most extensive development of the Clyde clay loam occurs in the northwestern part of the State, where it occupies the larger portion of what was known as the "Great Black Swamp." This type covers the greater part of Ottawa, Henry, Wood, and Sandusky Counties, and constitutes the principal soil in Fulton, Erie, and Van Wert Counties, and also a very important one in nearly every other county in the western half of the State, except those in the extreme southern part. Outside of the area formerly covered by Lake Maumee, the largest total acreage is found in Fayette, Madison, Union, Clark, and Marion Counties.

As it occurs in large, uniform areas in the old lake bed, it is possible to indicate this type on the soil map with considerable accuracy, except in sections where it is associated with the Clyde sandy loam or loam. Many small areas are included with the two latter soils on the map and, likewise, small areas of these types are included with the Clyde clay loam. Outside of the old lake bed the soil is rarely uniform over any large areas, and in most places where shown on the map it is difficult to find more than a few acres in one continuous body. In the central and western parts of the State there are included in the areas mapped as this type numerous small patches of Miami clay loam or silt loam. In many cases, as in the large areas northeast of Marion, the Clyde clay loam and Miami clay loam are so intricately intermixed that it is difficult to decide which type should be indicated on the map where it is not possible to make a separation of the two. This condition prevails to a lesser extent in a few other localities, particularly in Delaware, Union, and Madison Counties. As a rule, in the areas mapped as Clyde clay loam this is the prevalent type, and the small patches of other soils are local exceptions of minor importance.

In a like manner there are many small bodies of the Clyde clay loam included within extensive areas of Miami clay loam and silt loam which are not of sufficient size to be indicated on the map. These black spots are particularly numerous where the surface is indicated as level and least numerous where it is rolling and hilly. There is scarcely a farm on the more level portions of the Miami clay loam that does not include small patches of Clyde clay loam. Although the individual areas may be of small extent, their aggregate acreage, their wide distribution, and their productiveness make them an important factor in the agriculture of those sections.

It will be noted on the map that some areas of the Clyde clay loam are shown in association with the Volusia silt loam and clay loam, although these latter soils are formed principally from drift, composed

most largely of shale and sandstone. However, the areas where the black clay loam occurs contain some limestone also, and the soil here is so nearly like that found farther west, where the drift is composed principally of limestone, that it is considered best to include it with the Clyde clay loam.

Two rather unusual occurrences of the Clyde clay loam are shown in the old valleys in the southwestern part of the State, southeast of Hamilton and Middletown. These areas apparently represent deposits of till in the old valleys, and the soils are therefore more like the Clyde clay loam than any other type. Evidently these valleys did not form lines of discharge for the waters caused by the melting of the ice of the Wisconsin glaciation, in which case there would have been a heavier deposit of gravel in them, as is found along the Miami River and south of the line of the Wisconsin glaciation.

At the time of the first settlement nearly all of the areas of the Clyde clay loam were in a swampy condition, and artificial drainage has been necessary for their reclamation. In some cases the removal of the dense forest that originally covered the greater proportion of the type allowed the soil to dry out sufficiently to permit cultivation. In other areas, particularly the larger bodies, it was necessary to provide large drainage outlets for the surface water by straightening and deepening the drainage channels or by the construction of dredge ditches. In the lake basin in the northwestern part of the State the establishment of extensive drainage systems was required before the land could be reclaimed. Detailed drainage has been greatly improved during late years by the use of tile.

The greater part of the Clyde clay loam is under cultivation. Except in a few localities where special crops are grown, this type is used for general farm crops, of which corn is the most important. It is considered one of the best corn soils in the country, and yields of 40 to 100 bushels per acre can readily be secured where the type is well drained and a good system of farming is practiced. Wheat does only fairly well, as the soil is not especially adapted to this crop. Owing to the level topography and moist conditions, the crop is likely to be damaged by heaving or by the formation of a layer of ice over the surface. The growth of straw is rank, frequently causing the grain to lodge. Oats are more extensively grown in the northern section than wheat, and good yields are secured. The climatic conditions in the southern portion of the State, however, are not favorable to the best development of this crop. Much hay, including clover and timothy, is grown, and excellent yields are secured. The native grasses make a good growth, but they are often supplemented with timothy.

The greatest value of the Clyde clay loam is in its adaptability to certain special crops, the most important of which are celery, onions,

cabbage, and sugar beets. Onions are grown on the type in Hardin County, bordering the track of Muck land, and, to a limited extent, in Marion County, as well as in the section around Toledo. Celery, though not extensively grown, has proved profitable at several points in the northwestern part of the State. For this crop it is necessary to have a thorough control of both drainage and irrigation, but when these conditions are favorable the Clyde clay loam is said to surpass any other type in the State in the quality of its product. Cabbage is grown extensively for home use and occasionally for market (see Pl. VI). Near all the larger towns the areas of this type are utilized for market garden crops, which do well on soil of this character, and of which cabbage, beets, and lettuce are the most common. Within recent years a considerable acreage has been devoted to sugar beets, principally in the northwestern part of the State. This type and the Clyde clay are the two principal soils upon which sugar beets are grown in this State.

CLYDE CLAY.

The Clyde clay to a depth of 4 to 10 inches is a dark-gray or dark-brown to almost black, heavy silty clay to clay. In general, the soil is remarkably uniform in texture, but there is considerable variation in color, which depends upon the amount of organic matter present and the drainage conditions. Where drainage is poor, organic matter has accumulated and the soil is darker. The greater part of the type is probably best described as a dark gray, which frequently tends toward drab. This type possesses the property of granulation in a marked degree. In fact, the surface soil usually becomes so loose that within an inch or two of the surface it is easily pushed about with the foot. As the soil dries after a rain large cracks are frequently formed to a depth of as much as a foot and sometimes much more.

Below the surface soil a bluish-gray or drab, tenacious clay occurs, and this is usually mottled with yellow before a depth of 3 feet is reached. This subsoil never carries any grit, and no stones or rock fragments are found, a feature which helps to distinguish it from the Clyde clay loam. An effervescence with acid is seldom obtained.

The Clyde clay is one of the heaviest and most difficult soils to handle in the State. It is very sticky when wet, and must be cultivated when in exactly the proper condition of moisture. If plowed too wet, hard clods are formed, although the decided power of granulation tends to cause these to crumble and break down again when moistened by rain. If allowed to become too dry it is so hard that plowing is very difficult. The surface soil apparently becomes more loamy and easy to cultivate after it has been thoroughly drained and farmed for several years.

Naturally the type is poorly drained. The heavy, rather impervious nature of the subsoil renders artificial drainage difficult, but this can be accomplished by placing the tile rather close together.

This type occurs in an almost solid body, occupying the western portion of what was formerly known as "the Black Swamp." It covers a very large part of Defiance, Paulding, Van Wert, and Putnam Counties. The line of separation between this type and the Clyde clay loam is more or less arbitrary, because of the gradation of one into the other, and in some sections it is rather difficult to say with which type certain areas should be mapped. This is especially true near the outer borders of the old lake bed, especially in the section near Van Wert and Delphos. The reason for this can be better understood after a discussion of the method of formation.

It was explained in the discussion of the geology of this section that the entire country occupied by this type was once covered by a glacial lake. At one stage the ice extended only as far west as Findlay, Defiance, and Wauseon, and during this advance the entire country to the west, occupied by this type, constituted a lake, in some places probably as much as 75 feet in depth. In the quiet waters of this lake was laid down the heavy clay from which this type of soil has been formed. Near the outer borders of the lake where its depth was not great, very little if any material was deposited, and areas occur where the subsoil at least is undoubtedly derived from the drift. In these places a somewhat lighter, less impervious soil, which is recognized as the Clyde clay loam, has been formed. East of Defiance practically all of the country is of this character, but only a relatively small proportion is found in the section indicated on the map as the Clyde clay.

Although one of the most difficult soils in the State to handle, the Clyde clay is highly esteemed for general farming. Corn, oats, and hay are the principal crops grown, and excellent yields are secured. Considerable wheat is also grown, but the heaving of the soil in winter often causes injury to this crop. Within recent years sugar beets have been introduced and are being grown quite extensively (see Pl. VII, fig. 1). The type is apparently well adapted to this crop. Alfalfa is also being grown with success. The Clyde clay is one of the strongest, most productive, and highest priced soils in the State.

Belmore Series.

In the Belmore series are included the grayish brown to slightly reddish brown surface soils with yellowish brown to slightly reddish brown subsoils, usually overlying a substratum of calcareous sand and gravel.

As the Belmore soils represent old beach lines they occur as long, narrow ridges, seldom more than 100 yards in width or 15 feet

in height. It was therefore necessary in practically every case to exaggerate their width in order to indicate them on the map. However, the marked difference in the character of the soil of these beaches and their topographic prominence made this justifiable.

Throughout almost their entire extent these beaches are occupied by roads, along which there are usually many houses. This fact greatly reduces their use for general cultivation, but they are used quite extensively for gardens, orchards, and to a less extent for general farming.

Considerable variation in texture occurs, but the greater part consists of a sandy loam or loam containing a greater or less percentage of gravel. Two principal members of the series can, therefore, be recognized—the Belmore sandy loam and Belmore loam.

BELMORE SANDY LOAM.

The Belmore sandy loam consists of a grayish brown or slightly reddish brown sandy loam with an average depth of probably 10 inches and a variation from 6 to 15 inches. The texture is medium to fine, although small areas of coarse sandy loam may be found. Some gravel is nearly always present on the surface and in local areas constitutes a considerable percentage of the soil. The subsoil consists of a brown or slightly reddish brown sandy loam containing considerable clay, which acts as a cement or matrix holding together the sand and fine gravel. Calcareous sand and gravel is usually encountered at a depth of about 3 feet, but very seldom was there any effervescence much nearer the surface, due to the lime having been leached out.

Areas of the sandy loam may be found in all sections where the beach lines occur, but are apparently more numerous and extensive toward the eastern limit of the series than farther west.

The Belmore sandy loam is a good, productive soil, well suited to rather early truck and market garden crops, fruits and potatoes, as well as to general farming. Both surface and under drainage are excellent and this, combined with the calcareous nature of the deeper subsoil, makes it well suited to the growth of alfalfa.

BELMORE LOAM.

The surface soil of the Belmore loam consists of a brown or slightly reddish brown loam sometimes containing almost enough silt to make it a silt loam. At a depth of about 10 or 12 inches the material becomes somewhat lighter in color and heavier in texture and, at about 18 inches, changes to a brown gravelly clay loam. This continues to about 3 feet, where it is underlain by calcareous sand and gravel, with which there is sometimes mixed quite a considerable

percentage of clay. There is usually some gravel present in both soil and subsoil and, in some cases, the amount on the surface increases until it constitutes a considerable percentage of the soil mass. Sometimes the subsoil is more nearly a gravelly sandy clay than a heavy loam or clay loam.

While the loam occurs throughout the section occupied by the Belmore series, it probably constitutes a larger percentage of the series in Van Wert and Allen Counties than elsewhere. However, its total area is not large, and as much of it is utilized as sites for farm houses, it is not of very great importance agriculturally. Much of that under cultivation is used for gardening and the growing of fruits. Like the sandy loam, it is well suited to alfalfa, and several small areas of this crop were seen.

Dunkirk Series.

The Dunkirk series includes types with light-brown surface soils and yellowish-brown or yellow subsoils. They have been formed from the sediment deposited on the bottom of a lake or from such material thrown up by the waves in the form of beaches along the shore, with further assorting and drifting by the wind. The material is of glacial origin, but has been reworked by streams, waves, and to a less extent by wind.

The Dunkirk soils represent glacial lake deposits. They occur principally along the line of the old beaches and where the larger streams entered the old lake and deposited their load. Three separate beach lines occur. The highest of these has an elevation of about 780 feet. The second has an elevation of about 730 feet, and the third an elevation of about 680 feet. These beaches are usually spoken of as ridges, the lower being known as the "north ridge" and the higher as the "south ridge," while the one between is termed the "middle ridge." In some places, especially at an elevation of about 760 feet, more than three ridges are found. The ridges are usually narrow, seldom being more than 250 yards in width. While they are more or less continuous throughout the entire lake plain, they are so narrow that their total area is not great. The most extensive development of the Dunkirk series is where the largest streams, like the Conneaut, Ashtabula, Grand, Chagrin, Cuyahoga, and Rocky Rivers cross the lake plain. This is due, of course, to the deposition of material in the lake by these streams.

While there is considerable variation in the character of the Dunkirk material, it is usually of a sandy or gravelly nature. Apparently very little if any material heavier in texture than a loam was deposited in the lake, the heavy material upon the lake plains being almost entirely a product of ice deposition. Several different types are recognized in the field, including the sand, sandy loam, gravelly

sandy loam, and loam. While gravel is found in many places in the beaches, the percentage on the surface in this State is not nearly so large as farther east, in Pennsylvania and New York, owing largely to the fact that the amount of rock fragments in the upland soils is not nearly so great in Ohio as farther east and probably also to the fact that the fall of the streams here is less rapid. It is not practicable to separate the different types on the map east of Norwalk, and they are shown as the Dunkirk series. West of this point only the sand occurs and is mapped as such.

DUNKIRK SAND.

The Dunkirk sand consists of a grayish to yellowish-gray sand from 4 to 6 inches deep underlain by yellow sand extending to a depth of more than 3 feet. When drifted about by the wind the surface soil becomes very light gray, and in some cases almost white, but the subsoil nearly always has a golden-yellow color. This type contains only a small percentage of organic matter and is so loose and incoherent that it is easily drifted where not covered by vegetation. It is very open, porous, and leachy, and practically never effervesces, except possibly at a depth of several feet. It is composed very largely of quartz, but a number of other minerals can be seen upon a close examination. The size of the sand particles varies considerably in different parts of the area. The greater proportion is a fine sand, although areas of both coarse and medium sand occur. No attempt, however, was made to separate these different grades, as there is apparently very little difference in their agricultural value.

A number of different agencies have been instrumental in the formation of this soil. The material was washed from the glacial uplands into the old glacial lake, where it was assorted by wave action, piled up along the shores, and later drifted in by the wind, just as is taking place along the shores of Lake Erie in many places at the present time. In some cases the material has undoubtedly been transported for a considerable distance by the wind, as areas are found several miles outside of the old lake bottom. Such areas occur north of Wauseon and around Bellevue.

In topography the surface varies from gently rolling to rolling or dunelike. The type occurs as low ridges, rounded hills, and knolls from 2 feet to more than 30 feet in height.

While there are areas in which this soil covers practically all of the country for several square miles, it is often found on small knolls surrounded by the Clyde sandy loam or sand, or associated with other members of the Dunkirk series. Quite an extensive development is found in Fulton County between Wauseon and the Michigan State line. Much of this section constituted an island at the time

of the greatest extension of the lake. The sand was carried onto this higher land by the wind and deposited over the glacial drift. In some places the sand is many feet deep and in others it is shallow and gradually passes into the Miami clay loam. There is often, however, a strip of Miami sandy loam, usually rather narrow, between the sand and the clay loam.

The most extensive development of the Dunkirk sand is in the section around Sylvania and extending southwestward to Liberty Center and, in small patches, as far as Napoleon. From the latter point its extension is eastward along the old beach line, but its development is rather in small, isolated areas. Much of the country between Bowling Green and Weston consists of this type. Scattered areas occur east and south of Bowling Green, and a considerable development is found southwest of Clyde and eastward to Bellevue and Monroeville, and south of Castalia. Much of the country around Norwalk, Milan, and Berlin Heights is also covered by this type. There are a few small areas farther eastward along the beach lines, but these are not of sufficient extent to indicate separately on the map.

All of the larger areas of the type are shown on the map, but there are many other small areas which it would be difficult to show even in a detailed survey. It should also be understood that most of the areas shown on the map simply represent the areas in which the sand predominates over other types. The lower lying areas, or depressions between the sand hills, are usually occupied by some member of the Clyde series, principally the sandy loam, but sometimes the sand or loam. Much of the area around Milan, shown as the Dunkirk series, is rather level, and the surface soil is darker, approaching in character that of the Clyde series, while the area south of Castalia, where the sand has been blown upon the Miami clay loam uplands, includes some of the Miami clay loam or Miami sandy loam.

Because of its open, porous nature and thorough drainage, this type warms up early in the spring and is therefore well suited to trucking, and a large acreage is devoted to this industry. The soil is also well adapted to fruit, and some of the largest orchards, especially of peaches, in the northern section of the State are located upon it. Many different kinds of small fruit also are successfully grown. Some good fields of alfalfa are seen. (See Pl. VII, fig. 2.) Corn, oats, and wheat are grown to some extent, but this soil is not suited to these crops, especially the small grains, and can in most cases be more profitably devoted to special crops.

Fertilizer tests were conducted for several years by the Ohio Agricultural Experiment Station on this type near Neapolis in a rotation

of potatoes, wheat, and clover, but, on account of the drifting of the sand, they were not entirely satisfactory. However, the results secured indicate that this type responds to all three elements—nitrogen, phosphorus, and potassium—and that it is relatively more responsive to potassium than almost any other type of soil which has been experimented upon in the State.

The experiments also brought out the fact that a different method of soil management must be employed upon this loose sandy type than upon the heavier soils, because of the ease with which it drifts. The experiments were begun upon virgin soil, but cultivation caused the rapid depletion of the organic matter and the consequent loosening of the soil, so that it became more and more subject to drifting, causing damage to the crops, especially in the case of wheat. Drifting is one of the most serious problems in the handling of this type. The incorporation of large quantities of organic matter, plowing at right angles to the direction of the wind, and trampling, when possible, by stock, will lessen the injury from this source.

DUNKIRK SANDY LOAM.

The Dunkirk sandy loam consists of a brown sandy loam, with an average depth of about 9 inches but varying from 6 to 12 inches. When dry the surface is gray to grayish brown; but below the immediate surface the material is yellowish brown to brown, and this is the color of the surface soil when moist. The texture ranges from medium to fine, with an occasional small area of rather coarse sandy loam. However, the greater proportion of this soil may be classed as a fine sandy loam. The percentage of silt and clay also varies, giving a range of texture from a heavy sandy loam to a light sandy loam, grading into a loamy sand. The soil is loose and mellow and easily cultivated.

The subsoil is not very different in texture from the surface soil. It is, however, more compact and in some cases contains enough clay to be sticky. In other places it is lighter in texture than the surface soil, consisting of a loamy sand. The color of the subsoil is brownish yellow to slightly reddish brown, rarely with any mottling. At a depth of 3 or 4 feet the subsoil is usually more sandy, and sometimes gravelly, the latter condition being most often encountered on the ridges.

The Dunkirk sandy loam is formed from beach and delta deposits, more often the latter. In some cases the material was probably laid down by the stream, with little or no modification by wave action, while in others it has been entirely reworked by the latter agency and modified to some extent by the wind. The latter is especially true in the more sandy areas of the type.

The surface features vary from level to rolling, the greater part of the type comprising gentle undulations or low ridges. Combined with the sandy nature of the deeper subsoil, the topography is such as to give good drainage, although there are some areas between the ridges where the deposit of sandy material is rather thin which are in need of underdrainage.

The Dunkirk sandy loam is found in all sections indicated as the Dunkirk series on the map and constitutes a larger part of this area than any other type of the series. It was encountered in the detailed survey of both the Ashtabula and Cleveland areas. It is easily recognized in the field by its brown color and sandy loam texture.

Because of its sandy texture, porous structure, free drainage, early warmth, ease of cultivation, and favorable climatic situation near the lake, this soil is well suited to trucking, especially early truck, and is quite extensively used for this purpose near the towns. It is a very desirable soil for early vegetables and a large acreage is devoted to early potatoes, peas, beans, sweet corn, cucumbers, asparagus, etc. It is also well suited to peaches and small fruits, and is used for grapes.

DUNKIRK GRAVELLY SANDY LOAM.

The fine-earth material of the Dunkirk gravelly sandy loam is very similar in character to that of the Dunkirk sandy loam, and the principal difference from that type consists in the presence of gravel. The gravel in the surface soil usually constitutes less than 25 or 30 per cent, but in some local areas it may run much higher, and small areas are found which are little more than a bed of gravel. The subsoil is usually more gravelly than the surface soil and most often grades into a bed of gravel and coarse sand at a depth of 2 or 3 feet. The gravel consists principally of small pieces of shale and sandstone, with some crystalline rock. It is suited to practically the same crops as the sandy loam, but is somewhat more subject to drought.

DUNKIRK LOAM.

The surface soil of the Dunkirk loam consists of a yellowish-brown to slightly reddish brown loam, varying in texture from a gritty, slightly sandy loam to a rather smooth silty loam. The greater proportion, however, is a true loam of a friable, granular structure. The surface in dry, weather-beaten plowed fields is light gray, but immediately underneath, or when moist, the material is a yellowish brown, with just a slight suggestion of red, and in general might be characterized as a rich brown.

At a depth of about 8 inches, but varying from 6 to 12 inches, a marked change of color takes place, owing to a decrease in the

amount of organic matter present and its action upon the surface material, with which it has been thoroughly mixed by plowing. The yellow and red colors become pronounced and the subsoil is a brownish or slightly reddish yellow. The texture is not very different from that of the surface soil, but the structure is a little closer although friable and easily penetrated by the roots of plants. At a depth of about 18 inches to 3 feet the subsoil is usually more gritty, owing to an increase in the percentage of sand and fine gravel; and at a depth of 3 or 4 feet, and sometimes nearer the surface, it consists largely of sand and gravel, which, however, usually contains enough clay to make it somewhat sticky. The gravel consists largely of fragments of sandstone and sandy shale, although some crystalline rocks and occasional pieces of limestone are also present. A small percentage of gravel is quite common in the surface soil and in the upper part of the subsoil, and, in some cases, the amount is sufficient to justify the classifying of these areas as a gravelly loam.

The Dunkirk loam has been formed from material brought into the lake by streams from glaciated shale and sandstone uplands, and deposited as deltas or reworked by wave action and thrown up as beaches along the shore. In areas where the loam occurs the currents were not as swift as where the areas of sandy loam are found, and, therefore, a larger proportion of finer material was deposited.

The surface of the Dunkirk loam is gently undulating and is seldom sufficiently level to cause water to stand upon it. Quite often the type occurs as long, narrow beaches, some 10 or 15 feet higher than the surrounding land. The undulating character of the surface and the underlying layer of sand and gravel give to this type excellent drainage, so that underdrains are seldom necessary.

Owing to the occurrence of this type in rather small or narrow areas and its close association with other members of the Dunkirk series, it is not practicable to show it separately on the soil map. It is therefore included in the Dunkirk series and constitutes one of the most important types in the section shown as such on the map. Being of lacustrine origin and composed largely of sandstone and shale material, it is confined to the counties bordering Lake Erie, where these rocks constitute the underlying formation.

Because of its proximity to Lake Erie and its mellow, easily cultivated, and well-drained condition, the Dunkirk loam is highly prized for the growing of grapes, truck crops, and fruit, as well as for general farming. Alfalfa is grown successfully, but since the type is deficient in lime carbonate, the liberal application of lime is necessary where this crop is sown. By the use of lime, the incorporation of organic matter in the form of barnyard manure or green manure crops, and the use of fertilizers, particularly phosphates, it is pos-

sible to bring this type to a very high state of productiveness and make it one of the most valuable soils in the State.

LOESS SOILS

Closely related to both the glacial drift and glacial lake soils are those formed from the deposit of silty material known geologically as the loess. It is not derived directly from ice-laid material like the former nor from lacustrine deposits like the latter. Instead the loess is believed to represent fine-ground rock material which has been distributed over the uplands by the wind.

The loess soils are confined to the southwestern part of the State, or to the section of country covered by the Illinois glaciation, but not by the later or Wisconsin. A portion of Highland County, which has been considered by Leverett [1] as belonging to the Wisconsin glaciation, is included with the loess because the material is apparently more like the loess than like the Wisconsin drift farther north. The drift in this section is very thin, or in places entirely absent, with frequent outcrops of the underlying limestone, and is also covered by a silty, loesslike layer 2 to 3 feet in thickness, except where this has been removed by erosion.

When laid down by the wind, the deposit of loess was doubtless extremely uniform in character, and if the drainage conditions had been the same over the entire area of its occurrence only one type of soil would have been formed. But a difference in drainage conditions, with the consequent difference in the processes of weathering, has given rise to two distinctly different types of loess soil with all stages of gradation between them. These types are the Cincinnati silt loam and the Clermont silt loam.

Cincinnati silt loam.

The Cincinnati silt loam consists of 8 to 12 inches of grayish-yellow or light yellowish brown silt loam, having a characteristic mealy or velvety feel. But little change in the character of the material takes place within 36 inches, the difference being a slightly brighter yellow color and a heavier texture, the material becoming a silty clay loam in many places. Even where this is true, the subsoil is never hard, compact, or plastic, but is usually rather soft and friable. Where the drainage is exceptionally good, oxidation has been more pronounced and the soil has a faint-reddish color, but where the surface is more nearly level, the type approaches the Clermont silt loam, the surface soil becoming rather yellowish gray and the subsoil mottled gray and yellow. This condition is found on the

[1] Monograph 41, U. S. Geological Survey.

divides which are too narrow to develop the typical Clermont silt loam.

The Cincinnati silt loam is very friable and easy to cultivate, and a good tilth can be readily secured and maintained, although there is a slight tendency to run together and bake after a rain. The type is usually low in organic matter, and the incorporation of large quantities of this material is beneficial in improving the tilth and increasing the productiveness of the soil.

The Cincinnati silt loam is derived from the weathering of the loess under good drainage conditions. The rolling topography prevents water from standing on the surface and causing a water-logged condition. Under these conditions there is good aeration, and oxidation is practically the same throughout the soil mass, giving a solid and uniform color.

Owing to the conditions under which it is formed, the topography of this type varies from rolling to very rolling and sometimes steep and broken. It is never typically developed on level areas, because the drainage conditions there would give rise to the Clermont silt loam instead. The rough and broken topography, however, is not typical of this soil, for where such surface features exist the mantle of loess has been largely washed away and the limestone, or drift, has been exposed, giving rise to residual limestone or glacial rather than loessial soils.

The Cincinnati silt loam covers nearly all of Hamilton County and portions of Clermont, Brown, Warren, Highland, and Adams Counties. Its general distribution is indicated upon the map; but there are included many small areas of the Clermont silt loam and, upon the slopes, of the limestone soils. Likewise many small areas of this type are found in the section indicated on the map as the Clermont silt loam and to a less extent in the area of residual limestone soils. The boundary between the Cincinnati silt loam and the Miami series is usually rather distinct and can be definitely located within less than a mile. However, east of Lebanon in Warren County and in Highland County no distinct division occurs, and the location of the boundary on the map is almost entirely arbitrary. This is also true of the line between the Cincinnati silt loam and the residual limestone soils.

In the section of Highland County around and east of Hillsboro, mapped with the Cincinnati silt loam, the soil consists of such a mixture of the loess, drift, and limestone that it is often impossible to determine definitely its origin. The least rolling portions have a soil very much like the Cincinnati silt loam, except that some grit is usually encountered in the subsoil below 24 to 30 inches. On the slopes limestone outcrops and small spots of red limestone clay occur

with a gradation between the yellowish-brown silt loam and the red clay. Because of this mixture the soil here is somewhat different from that found elsewhere in the State. Farther west the reddish color gives way to yellowish brown and the difference in Highland County is apparently due to the presence here of deposits of limestone which give the reddish soils rather than the yellow.

The Cincinnati silt loam, under present conditions, probably produces slightly larger crops than the Clermont silt loam, but the yields on this type are low and a large part of it is not under cultivation. Corn and hay are the principal crops grown, the acreage in oats and wheat being very small. In Brown County considerable tobacco is grown, not as a rule on the typical development of this soil, but rather on the eroded slopes where the soils are affected by the limestone and are probably more nearly like the limestone soils. Clover is not grown to any great extent, and there is very little alfalfa, although the slopes where the limestone outcrops include many good fields of this crop. The true Cincinnati silt loam is probably too low in lime to give the best results with alfalfa without an application of lime before seeding.

One of the first essentials in the improvement of this soil is thorough underdrainage. Some farmers have an idea that this type can not be drained, but there are a sufficient number of fields where tile drains are being used to demonstrate that tile drainage is both possible and profitable. The type is also in need of organic matter and every opportunity to increase this, either by turning under green manure, or by the addition of stable manure, should be taken advantage of. The use of lime and a fertilizer high in phosphorus is also beneficial.

CLERMONT SILT LOAM.

The surface soil of the Clermont silt loam consists of 7 to 12 inches of light-gray or nearly white silt loam. Where typically developed it is very ashy, and on the flattest, most poorly drained areas iron concretions are frequently scattered over the surface. When dry this soil appears to be white, or nearly so, in the cultivated fields, although where the drainage is better and the soil approaches the Cincinnati silt loam the color is more nearly a yellowish gray. The soil contains a very high percentage of silt, with a small amount of clay, and very little sand, except that of the finest grade. The subsoil contains more clay than the surface soil, with almost no sand. The subsoil is a gray, slightly mottled with yellow, heavy silt loam, or silty clay loam, which usually becomes drab or bluish drab in color within 3 feet of the surface. On the most level areas, which really represent the most typical development of the soil, a subsurface layer almost always occurs between depths of 8 and 16 inches, consisting

of an almost white, floury, and mealy silt loam. Where this subsurface layer occurs the subsoil below is usually a drab or bluish-gray silty clay, which is plastic and apparently almost impervious, but not hard and compact.

Under proper moisture conditions this type is easily cultivated, and a good mellow seed bed can be prepared. But the soil is easily beaten together by the rain and packs badly when wet, causing some difficulty in obtaining a good tilth. It possesses practically no power of granulation, and therefore runs together and packs much worse than would be expected with a soil of this texture. The type has many characteristics in common with the Marion silt loam in southern Illinois, but is distinguished from it by the less impervious and compact nature of the subsoil. Both soil and subsoil practically always give a decided reddening of litmus paper, indicating a deficiency of lime carbonate. The amount of organic matter is also very low.

Within the area shown as the Clermont silt loam occur several areas of soil of a darker color, due to the accumulation of organic matter. These areas are usually spoken of locally as "black land" or "maple swamp." The soil is not a true black, but rather a gray to dark gray which seems black in comparison with the surrounding almost white Clermont silt loam. The soil, as well as being darker in color, is also somewhat heavier in texture, and is more nearly a silty clay loam than a silt loam. There is usually 8 to 12 inches of dark-gray heavy silt loam or silty clay loam soil underlain by a bluish-drab, plastic clay. This is really a distinct type rather than a variation of the Clermont silt loam, but the areas were too small to map separately.

The largest area of this dark soil is in Jackson Township, Clermont County, where it covers most of 2 or 3 square miles between Blowville and Owensville. Other areas occur in Brown County north of Hamersville in Clark Township, and in Pike and Washington Townships. Besides the areas given numerous smaller ones are scattered throughout the more level portion of the Clermont silt loam.

The Clermont silt loam is practically confined to five counties, Clermont, Brown, Highland, Clinton, and Warren. In addition small areas occur in Adams and Hamilton Counties, although these are too small to be indicated on the map. In general the type is encountered throughout the loessial area wherever the surface is so nearly level as to permit water to stand for any length of time.

One of the most distinctive features of the Clermont silt loam is the level character of the topography. In fact, it is formed only where the surface is so nearly level that the water remains for a number of days after a rain. It occupies some of the most level portions of the State.

Owing to the level character of the surface and the more or less impervious nature of the subsoil, natural drainage is very deficient and artificial drainage is somewhat difficult. Many farmers consider that drainage is not practicable, but the results obtained on a few farms where tile drains have been installed indicate that it can be satisfactorily established. Although the surface is practically level, there is usually enough slope to give sufficient fall, or it is usually possible to lead the drains into one of the deep gullies which have been cut back into the upland, without having to go any great distance. To insure perfect drainage it is necessary to lay the tile lines rather close together and to exercise care not to lay them too deep.

The Clermont silt loam is derived from the weathering of the loess under conditions of deficient drainage. The covering of loess in this section is shallow, ranging in thickness from 5 to 10 feet, but the underlying material has practically no influence upon the formation of this soil, because the topography is so uniformly level and the drainage so deficient that there has been no erosion to carry away the surface material and expose the formations beneath. The difference between this soil and the Cincinnati silt loam is due entirely to differences in drainage. The water, standing on the level surface of this type, sometimes for several days after a rain, prevents aeration, so that the natural processes are entirely different from those which are active where the surface is rolling and the soil aerated. Under these intermittent wet and dry conditions organic acids are formed, which, according to Hilgard,[1] "reduce the ferric hydrate to ferrous salts, oxidizing away the humus, and accumulating in the form of inert concretions most or all of the lime, iron, and phosphoric acid of the soil mass."

Under present conditions the Clermont silt loam gives rather low yields and is rated as a poor soil. Corn is the most extensively grown of any of the farm crops and average yields of about 20 to 25 bushels per acre are secured. Very small acreages of oats and wheat are grown. The climatic conditions are unsuited to oats, and because of the undrained condition of the soil the wheat is subject to heaving and winterkilling. A large percentage of the type is kept in mowing lands, the hay being sold. Timothy and redtop are the grasses usually grown. Clover is not grown extensively, because it is almost impossible to get a stand, probably because of a lack of lime, as this type always gives an acid reaction in both soil and subsoil.

Any system of improvement in this type must include thorough drainage by means of tiles. Furrows to carry off excess surface water are advantageous. After drainage, the application of lime and

[1] "Soils," by E. W. Hilgard, p. 285.

the turning under of green manure and other organic matter are beneficial.

While this type is recognized as being below the average for the State in productiveness, it is capable of being greatly improved. On one or two farms, where the soil is thoroughly underdrained, 50 or 60 bushels of corn per acre are produced. With the adoption of proper methods of soil management, it is believed that the yields on this soil can be materially increased.

TERRACE SOILS.

A large number of the streams of the State are bordered by more or less continuous strips of terrace or bench lands. Sometimes as many as four or five distinct terraces are present, but usually the number is smaller. Their formation and character have already been referred to in the discussion of the geology of the region, but it might be stated here that they are remnants of stream flood plains formed when the streams flowed at a higher level than that at which they now lie. Some of them are made up largely of sand and gravel; others of finer material. The material of the gravel terraces consists very largely of reworked glacial drift, while that of the silt and clay terraces contains very little, if any, glacial material. The former might, therefore, be designated as glacial terraces and the latter as nonglacial.

Since the material composing the glacial terraces has come very largely from the drift, its rock composition corresponds very closely to that of the drift from which it is derived. In the western half of the State, where the drift deposits consist largely of limestone material, the terrace gravel is largely limestone; but in the eastern half, where the drift-included rocks are principally shale and sandstone, the gravel consists mainly of these rocks. Because of this difference in the character of the rock material, the glacial or gravel terrace soils have been divided into two series, the Fox series and the Chenango series, the former representing the limestone gravel terraces and the latter the sandstone and shale terraces.

The nonglacial, or silt and clay terraces, are composed almost entirely of material washed from the shale and sandstone uplands, occupied chiefly by the Dekalb silt loam. A few small areas, where the wash is from the residual limestone soils, occur in Adams County, principally along Ohio Brush Creek, but elsewhere these terraces consist almost entirely of reworked sandstone and shale material.

The presence, or absence, of the gravel has had a very marked effect upon the drainage. In the case of the gravel terraces, the underdrainage is usually excessive, but the nongravel terraces often have insufficient drainage. This lack of drainage on the silt and clay

terraces has resulted in the development of two distinct series of soil. Where the surface is level and water stands for several days after a rain the soils are white, and are included in the Tyler series. Where the drainage conditions are better the soils are not so white, and are included in the Holston series.

Fox Series.

The Fox series consists of brown to reddish-brown surface soils with somewhat lighter brown subsoils, underlain at 2 to 5 feet by sand and gravel, consisting largely of limestone. The typical soils occurring along the terraces have a distinctly reddish cast, very similar to that of the Bellefontaine series, to which they are closely related. They also resemble the soils of the Chenango series, from which they are distinguished by their slightly redder color and more calcareous nature, both of which seem to be due to the large proportion of limestone present in the Fox series.

The most extensive development of these soils is along the Miami and Scioto Rivers and their larger tributaries. (See Pl. VIII.) Their general location is shown upon the soil map, but many areas are too small to be shown separately, and in many cases some exaggeration of those shown is necessary. In a number of places the bottoms are so narrow that it is not possible to separate the terrace and alluvial soils, and therefore some alluvial soils are included with the terrace soils on the map.

The reason for their extensive occurrence along the Miami and Scioto Rivers is the fact that these streams formed the principal channels of discharge in this section of the State for the glacial waters. By reference to the glacial map it will be seen that much of the area through which the Miami River flows was not covered by the late Wisconsin glaciation and, being uncovered by the ice, received the waters from the section to the northwest over which the ice advanced and melted. The Miami River thus served as a line of discharge for the water from the melting of the ice of the Miami glacial lobe, while the Scioto furnished a similar channel for the waters from the Scioto lobe. Practically no limestone is present in the uplands along the Scioto River south of Chillicothe, but the flooded waters carried the limestone gravel southward to the Ohio.

The surface of the terrace soils of the Fox series is in all cases almost level, the only exceptions being small areas where streams have cut across the terraces and carved out narrow valleys. Although the surface is almost level, drainage is thorough.

The Fox soils have been under cultivation for a longer time than any other soils in the sections where they occur, because at the time of early settlement, before the uplands were improved, they were considered the best grain soils.

All the general farm crops of this region are grown on these soils, and good yields are usually secured. Wheat is not grown as extensively as in former years, because the average yields have been rather low, especially on the sandy loam and loam. Corn, oats, rye, tobacco, and alfalfa are grown. The Fox soils give good yields of alfalfa, because the drainage and the presence of an abundance of lime in the subsoil are very favorable for the growing of this crop. Where the Fox soils occur near the larger cities, they are extensively utilized for market gardening. The excellent subdrainage afforded by the gravelly substratum enables these soils to dispose of excess moisture readily and causes them to warm up early in the spring, thus making them especially well adapted to trucking or market gardening.

The market-garden crops grown with success include sweet corn, potatoes, beans, tomatoes, peas, melons, lettuce, and cabbage. The production of sweet corn is a special industry of increasing importance, and is one of the most profitable uses to which these soils can be put. While the supply of moisture is sufficient for the needs of crops during ordinary years, in unusually dry seasons the crops, especially field corn, suffer for lack of moisture. The thorough drainage, however, causes the soils to warm up early in the spring, and the sweet corn not only matures earlier than on the heavier soils, but can usually be harvested before the drier summer weather sets in. For these reasons this crop does particularly well on these soils, and is extensively grown, especially in the sections between Dayton, Hamilton, and the mouth of the Miami River. Cincinnati offers a ready market for the product.

There is considerable variation in the percentage of sand, silt, and clay present in different parts of the terraces occupied by these soils, and at least three different types of the Fox series are recognized, a sandy loam, loam, and silt loam. In many small areas the percentage of gravel in the surface soil is sufficient to justify the use of the term "gravelly loam." The change in texture from one type to another is generally very gradual, though sometimes sharp and distinct. It is not possible in this survey to make any separation of these types, and all are shown together on the map, a brief description of each being given.

FOX SANDY LOAM.

The Fox sandy loam consists of a brown to reddish brown sandy loam, having a rather gritty feel. This is due to the presence of particles of coarse sand or fine gravel which, though usually not present in large quantities, are very evident to the feel. These coarser particles, however, may be entirely absent and the sand present be almost all of the finer grade, giving the texture of a fine sandy loam.

No large areas of this type are found, and for this reason it is not of very much importance. Its decidedly sandy character and brown color enable one to readily recognize it in the field.

FOX LOAM.

The Fox loam consists of a brown to reddish brown loam about 8 or 9 inches deep, underlain by brown or reddish brown loam or clay loam, which is usually underlain at a depth of 2 to 3 feet by a bed of limestone gravel. There is usually enough sand present to give it a slightly gritty feel, but it is distinctly heavier than the sandy loam. A small percentage of gravel is often found in the surface soil, but the amount is seldom sufficient to justify calling it a gravelly loam. The principal areas are along the slopes to the streams or along the rise from one terrace to another. It is easily worked, is fairly retentive of moisture, and in many respects a very desirable soil. It occurs in considerable areas and occupies a large proportion of the area mapped as the Fox series.

FOX SILT LOAM.

The Fox silt loam consists of a slightly reddish brown, friable silt loam with an average depth of about 10 inches, underlain by friable yellow brown or slightly reddish brown silty clay loam, which at a depth of about 20 to 22 inches grades into a reddish brown clay usually containing coarse sand. In nearly every portion of the area where this type is found gravel and coarse sand is encountered at a depth of 3 to 5 feet, which is usually held together at first by a sticky clay or sticky clay loam, but before a depth of many feet is reached generally becomes little more than a mass of sand and gravel.

CHENANGO SERIES.

In the eastern half of the State, where the gravel terraces consist largely of sandstone and shale, with very little, if any, limestone, the soils are included in the Chenango series. This series comprises yellowish-brown to slightly reddish brown surface soils, with brown or yellowish subsoils, which are underlain at a depth of 2 to 5 feet or more by sand and gravel. While the depth to the underlying gravel varies in places within the same field, it is generally nearer the surface in the glaciated portion of the State, and the overlying layer of heavier material gradually becomes deeper and the gravel finer as the streams flow farther and farther from the glaciated region.

Although the Chenango soils occur principally along streams entirely outside of the glaciated regions, the material composing them is very largely glacial outwash. This is proven by the fact that

these soils are never found along any of the streams in the unglaciated sections, except those, like the Ohio, Muskingum, and Hocking, which have their headwaters in the glaciated region. All of the tributaries of the Muskingum, which are entirely within the unglaciated section, have silt and clay instead of gravel terraces along them. Where such tributaries enter valleys which embrace gravel terraces, a very sharp and distinct change in the soils occurs. The glacial outwash was carried down the Muskingum and Hocking Rivers to the Ohio. Going down the Ohio the percentage of local material increases until only scattering beds of gravel are found by the time the mouth of the Scioto River is reached. If the gravel is present within 5 feet of the surface, it can usually be detected by the brown rather than gray color of the surface soil.

The soils of the Chenango series occur on terraces along the streams flowing out of the glaciated portions of the State where the covering of glacial drift is composed principally of sandstone and shale material. Only a few exceptional areas are encountered along the streams flowing northward into Lake Erie. The most extensive development is along the upper Muskingum and its tributaries, especially the Tuscarawas River. Most of the terraces are narrow and scattered. The Ohio and Hocking Rivers also have remnants of the terraces along them, but in most cases they are so narrow that it is impossible to show them on the map, without great exaggeration, and only the larger areas, usually situated in the bends of the streams, are shown. In Fairfield and Licking Counties there are terracelike formations covered by a silty soil where the gravel is so far below the surface, if present at all, that it is difficult to determine whether they are true gravel terraces or ancient valleys filled with drift, but they are in most cases mapped with the Chenango series.

The terraces usually occur in long strips, varying in width from a few rods to a mile or more. The surface of these terraces is level to gently undulating. Occurring as they do principally in the hilly section of the State, they constitute very prominent topographic features.

Differences in the velocity of the current which deposited the terrace material resulted in a considerable variation in its texture, and several different members of the series are recognized, although it is not possible to separate them on the map. Areas of sand, sandy loam, gravelly loam, and silt loam, which could be separated in a detailed survey, are encountered.

CHENANGO SAND.

The Chenango sand consists of about 10 to 12 inches of a brown, loose sand of medium to fine texture, underlain by a uniformly brownish-yellow sand similar in texture to the surface soil.

This type is of minor importance, and occurs in only a few small areas, the most important being in Meigs County. While consisting largely of glacial outwash material, this has been modified to some extent by the action of the wind. It is an early, easily cultivated soil, well suited to fruits and early vegetables.

CHENANGO SANDY LOAM.

The Chenango sandy loam consists of a light-brown to chocolate-brown sandy loam, underlain at about 8 to 10 inches by a brownish-yellow sandy loam which is only slightly heavier in texture than the surface soil. At a depth of 2 or 3 feet the subsoil is usually more sandy, while the deeper subsoil consists almost entirely of sand and fine gravel. The texture of the soil material is usually medium to fine, although there are some areas of rather coarse sandy loam. The type occurs in scattered areas throughout the entire area occupied by the Chenango soils, but it usually has a comparatively small development. It is a good soil, well suited to fruits and vegetables and to general farming.

CHENANGO GRAVELLY LOAM.

The Chenango gravelly loam consists of a brown loam ranging in texture in different parts of the area from a coarse, rather sticky loam to a silty loam. The subsoil, which is encountered at a depth of about 10 inches, is usually a brownish-yellow gravelly loam. The characteristic feature of the type is the presence in the surface soil of waterworn gravel, the quantity of which may vary from a few scattering pebbles to such proportions that the value of the land is greatly impaired. By far the greater part of the type, however, has a small percentage of gravel present, in most cases only a sufficient amount to give the soil the characteristics of a true gravelly loam. The proportion of gravel in the subsoil is usually in excess of that in the surface soil. Over a large part of the type a mass of material in which the gravel content ranges from 30 to 60 per cent and in some cases even more is encountered at less than 3 feet. The gravel ranges in size from very small to more than an inch in diameter, and in the glaciated section stones as large as cobbles are sometimes present. The gravel consists of shale and sandstone with a small proportion of granite, quartz or quartzite, or chert.

The Chenango gravelly loam is one of the most extensively developed members of the Chenango series, and occupies quite a large proportion of the area mapped as this series. The type is in many respects very much like the Wooster gravelly loam, and where the moraines occur in the valleys, as at Justus and south of Jeromesville, it is rather difficult to distinguish between the two. The greatest

difference is in the more rolling or undulating character of the Wooster soil.

Where the underlying bed of gravel is not too near the surface the Chenango gravelly loam is considered an excellent soil for general farming as well as for fruits and vegetables.

CHENANGO SILT LOAM.

The surface soil of the Chenango silt loam consists of a yellowish-brown to chocolate-brown mellow silt loam from 9 to 12 inches deep, underlain by a brownish-yellow, compact but friable silt loam which gradually becomes more compact and heavier as depth increases. Gravel occurs at a depth varying from 3 to 5 feet and sometimes even deeper. As the depth to the underlying gravel increases the soil gradually becomes more like that of the Holston silt loam. Where the gravel is nearest the surface a slight but distinct increase in the amount of grit occurs in the lower part of the subsoil. In some small areas slight mottlings of gray with a few iron stains occur in the lower subsoil, which represent areas where the underdrainage is somewhat deficient. However these areas are not large, because the gravelly subsoil usually furnishes excellent underdrainage.

The Chenango silt loam is found throughout the areas mapped as the Chenango series and occupies more of such areas than all the other types combined. Its most extensive development is along the Tuscarawas and Ohio Rivers.

A broad area of terrace soils northwest of Newark, in Licking County, which are classed with this series, closely resembles the upland silt loam, and in many places it is difficult to determine whether the terrace is purely glacial material or has been reworked by streams. The soil here consists of a light-gray or grayish-yellow silt loam, underlain by rather compact silty clay loam.

The Chenango silt loam is well adapted to general farming and is in all respects the most valuable member of the series. It yields as well as, and in most cases better than, the best of the upland silt loam types. Wheat, corn, oats, hay, and potatoes are the principal crops grown, and the yields secured are considerably above the average for the State (see Pl. II, fig. 1). Some trucking is done near the large cities and, while this soil is not as early as the sandy loam, good returns are secured, especially with the later truck crops.

HOLSTON SILT LOAM AND TYLER SILT LOAM.

Under this classification are included the terrace soils of the unglaciated section of the State, which have been built up by the deposition of silt and clay washed from the residual sandstone and shale

soils of the uplands. Unlike the gravel or glacial terraces, these non-glacial terraces are very uniform in texture and practically the entire area occupied by them consists of silt loam. Owing to differences in drainage, however, two different series are recognized, the Holston and Tyler. The Holston silt loam and Tyler silt loam are very intimately associated, are derived from the same material, and their general features can, therefore, best be discussed together.

The Holston and Tyler silt loams are confined to the eastern and southeastern part of the State, the most important development being in the latter section. They occur as narrow strips along the present streams or in old abandoned valleys. The largest and most important body of these soils occurs in the old channel of the Kanawha River, particularly in the abandoned portion between Wheelersburg and Waverly. Between Huntington, W. Va., and Wheelersburg, and also between Waverly and Richmond Dale, most of the deposits of the old Kanawha River have been removed by the Ohio and Scioto, but remnants are still visible at an elevation of about 150 feet above the present streams. Between Richmond Dale and Chillicothe, where the Scioto found a new channel, a considerable development of these soils occurs in a bend of the old river channel. Some of the terraces along the Ohio, which are 50 to 75 feet below those formed by the Kanawha River, are occupied by soils which are more like the Holston than the Huntington, and are, therefore, mapped with the Holston, although they are somewhat better soils than those found on the higher terraces. However, in most other areas along the Ohio, the higher terraces consist of the Chenango series instead of the Holston or Tyler.

In addition to the large area just mentioned, narrower strips of these soils are found along most of the smaller streams in the unglaciated sections, especially along those which now, or formerly, flowed northward. These areas are particularly numerous in Jackson, southern Vinton, and western Gallia Counties, between McArthur, Jackson, Oak Hill, and Bidwell. The largest development in Washington County occurs along the lower course of Duck Creek and the Little Muskingum River and on the higher terraces in the bends along the Ohio. The largest areas in Guernsey County are on Wills Creek and in Muskingum County, on Moxahala Creek. Only the larger areas could be indicated upon the map, but many other small strips of detached areas occur along the streams in the unglaciated region. It is well to mention in this connection that practically no areas of these soils occur along the Scioto, Hocking, Muskingum, and Ohio Rivers, or any other streams flowing through or out of the glaciated portion of the State. A few scattered areas are encountered along the Scioto, but these were undoubtedly formed when the drainage was northward.

Holston silt loam.—The Holston silt loam consists of a grayish-yellow or light yellowish brown, friable silt loam, grading at 5 to 11 inches into a yellow, friable but compact, heavy silt loam. In places the subsoil may be as heavy as a silty clay loam or even a clay. At 24 to 30 inches there is often a slight mottling with gray, which continues through the lower subsoil and really represents a gradation toward the Tyler silt loam. Where the terrace covering over the underlying rock is thin, the material in places is somewhat sandy and carries sandy shale fragments. On some of the more sloping terraces the soil near the border of the hill has been modified to a slight extent by wash from the upland. In general characteristics the Holston silt loam resembles the more level portions of the Dekalb silt loam, and the change from one to the other is, in many places, so gradual that it is very difficult to draw a line between them. In the same manner this type gradually merges into the Tyler silt loam.

Good surface drainage is an essential characteristic of the Holston silt loam, since conditions of poor drainage give rise to the Tyler silt loam. The surface, therefore, varies from almost level to gently rolling and in some places to hilly. It must be borne in mind, however, that where it has been eroded so thoroughly as to produce a hilly topography the soil on the hill slopes really belongs to some other type, usually the Dekalb silt loam.

While the streams have in some cases carved out deep gorges in the former terrace, the uniform elevation at which the disconnected, almost level areas occur indicates very clearly that these areas were at one time parts of a continuous terrace.

The Holston silt loam is a soil of moderate productiveness and the greater part of it is under cultivation. Where it follows the streams or abandoned valleys in the eroded, hilly country it constitutes the most valuable soil of that section. The principal crops are corn, wheat, hay, and potatoes. Considerable difficulty has been experienced in many fields in the growing of clover, which is probably due to the acid condition of the soil. In nearly every case where this type was tested with litmus paper it gave an acid reaction, indicating the need of lime. Tile drainage and the liberal application of lime are among the first requirements in the improvement of this soil.

Tyler silt loam.—The surface soil of the Tyler silt loam consists of a light-gray to almost white, floury silt loam of a close, rather compact structure. In some places, which really represent a gradation toward the Holston silt loam, it has a light, slightly yellowish brown color, but in the typical areas, particularly when dry, it is almost white. It contains a small percentage of organic matter and has practically no tendency to form crumbs or granules, but runs together after rains and remains in a close, compact condition, which gives very poor aeration.

At a depth of about 7 inches the soil grades into a light-gray or mottled gray and yellow, heavy, compact silt loam, which becomes heavier with depth, until at 18 to 24 inches it may be classed as a silty clay loam. Like the surface soil, the subsoil has very little power of granulation and is therefore close and rather impervious.

The Tyler silt loam has many characteristics in common with the Clermont silt loam of loessial origin, the Trumbull silt loam of glacial origin, and the Holly silt loam of alluvial origin. Like these soils, it is the result of intermittent wet and dry conditions in the absence of lime carbonate. The water-logged condition of the soil has resulted in certain macerating processes which have given to the material a light-gray or almost white appearance, and has caused the accumulation of iron in the form of brown iron stains or concretions.

As poor drainage conditions are essential to the formation of this soil, it is only found where the surface is practically level. The slope is usually hardly sufficient to carry off the surface water, and underdrainage is deficient.

Owing to its close association with the Holston silt loam, the Tyler silt loam can not be shown separately on the soil map. It occupies the level parts of the terraces and is most extensive upon the level divides, where the present streams have not developed sufficiently to give good drainage. In general it is not as extensive a type as the Holston silt loam.

On account of its poor natural drainage and rather low productiveness, the Tyler silt loam is not considered a very desirable soil. It is used chiefly for general farming, particularly in the production of corn and hay, but the yields secured are not as good as upon some of the other types. It is deficient in lime and organic matter.

ALLUVIAL SOILS.

Along all of the streams in Ohio there are more or less continuous strips of bottom-land soils, which have been formed by deposition from the streams during times of overflow. All soils so formed are termed "alluvial." They represent the most recent soils in the State and, in fact, are in process of formation at the present time, an addition, or in some cases a removal, of material taking place during each successive overflow.

Since the alluvial soils have been formed by stream action, they are in the strictest sense transported. They differ, however, from all other transported soils in that they are deposited as actual soils and do not need to be acted upon by the agencies of weathering before they are capable of producing good crops. In fact, they represent material which had already been subjected to these processes and changed into true soil before it was washed from the uplands. Because of this fact, the alluvial soils are often many feet in depth,

show no marked difference between soil and subsoil, and as a rule really have no true subsoil like that found under older soils. The amount of organic matter is usually higher than is found in the soils from which they have been derived, especially below the first foot. The contrast between soil and subsoil is greatest where the bottom land is situated at a considerable elevation above the stream and is not subject to frequent overflow. On the higher terraces the difference is so pronounced that these soils are best not considered as alluvial.

The material composing the alluvial soils not only consists almost entirely of reworked upland surface soils, with the addition of organic matter from various sources, but it also contains much soluble material which has been leached out of the upland soils. These facts, together with the renewal of fertility at each successive overflow, make the alluvial soils usually much above the average in productiveness.

The higher position and more sandy nature of the soils along the banks than farther back from the streams are characteristic features of the alluvial bottom lands. This is due to the checking of the current upon leaving the main channel, which causes the coarser particles to be deposited first, while the clay, silt, and finer sand are carried farther back and laid down in the more quiet waters.

In general, alluvial soils represent a mixture of material from a great variety of sources. Such must necessarily be true in the case of a large stream like the Ohio, but less so as the drainage area becomes more restricted and the upland soils more uniform, until along many of the smaller streams the alluvial material is derived almost entirely from a single upland soil type.

In the discussion of the geology it was brought out that the soils in the eastern half of the State consist largely of shale and sandstone material, while those in the western half contain a very large proportion of limestone. This difference in the character of the soil material in the uplands is reflected in the larger amount of lime and organic matter in the alluvial soils of the latter as compared with the former, although the contrast, at least agriculturally, is not so great as in the original material. This difference in the amount of lime and organic matter is the most important factor in the separation of the alluvial soils into different series, and, since the color is rather closely related to both of these, it furnishes the most obvious means of distinguishing between them in the field.

Four important alluvial soil series are recognized in this State, and there are one or two others of very restricted occurrence. The dark-brown to black soils are included in the Wabash and Papakating series, the former representing those washed from glacial limestone soils and the latter largely those from glacial shale and sand-

stone soils. The light or yellowish-brown soils are classed as the Huntington and the light-gray or white soils as the Holly. In the section where the red Upshur soils constitute a large percentage of the uplands the soils along some of the smaller streams have a distinctly reddish-brown or purplish-red color, and, in the detailed surveys in Pennsylvania and West Virginia, have been mapped as the Moshannon series. They constitute a very small area in this State, being confined to the section shown on the map as the Meigs series.

Usually no distinct division exists between the soils of the different alluvial series, and it is often difficult to decide in which series the soils should be placed. Along the Scioto River, for example, most of the soils are colored more like the Huntington than the Wabash, but the percentage of lime is higher than is usually found in the former. On the whole, it is considered best to class all, except the darker areas along this stream, with the Huntington and consider them as not typical of this series. but rather as representing a gradation toward the Wabash. Along probably a majority of the streams the soils all belong to the same series, and in some cases to the same type, but the not infrequent occurrence along the same stream of soils belonging to more than one series, combined with the narrow strips in which the alluvial soils are found, renders any separation of them on the map impracticable.

While the assorting power of water has caused a wide range in texture in the alluvial soils, thus giving rise in most cases to several different members or types in each of the above series, this variation is not as important agriculturally as is usually the case in the adjoining upland soils, owing principally to the much shallower depth of the water table and the relatively larger amount of organic matter. Both of these factors tend to diminish the effect of differences in texture upon the moisture relations of the soil. Although a brief description of practically all the more important members of the different series is given in connection with that of the series themselves, it is not practicable to make all of these separations even in detailed surveys. And since each overflow usually causes changes in texture, the making of fine textural distinctions and close separations is not justified.

Wabash Series.

Where the alluvial material has been washed from the glacial limestone soils of the uplands it contains a sufficient quantity of organic matter to give the soils a dark-brown to black color. Below 10 to 18 inches the color gradually becomes lighter and changes to light brown, yellowish brown, or drab, the latter color being most frequently encountered in the heavier areas. While these dark soils

are not entirely typical of the Wabash series as found in the black prairie regions farther west, the difference is not very great, and, in fact, there are many places, especially in the northwestern part of the State, where the soils of the two sections are similar, and it therefore seems best to correlate them with this series.

The typical Wabash soils are not underlain by gravel, and where the drainage is northward toward Lake Erie very little is present, but along the southward flowing streams gravel or sand occurs quite frequently within 3 or 4 feet of the surface. This is especially pronounced along the Mad River in Champaign County and may necessitate the recognition of another series in a detailed survey.

The Wabash series is confined to overflow bottom land in the western half of the State. All of the alluvial soils in this section can not be included in this series, however, as some of those of lighter color are really more like the Huntington than the Wabash. Their most typical development is probably along the streams in the old lake bed. This is partly due to the fact that these streams, which flow into Lake Erie, have less fall than those flowing southward and therefore afford poorer drainage and more favorable conditions for the accumulation of organic matter, and, in part, to the fact that the greater proportion of the material deposited by them has been washed from the dark-colored soils of the Clyde series.

Being of alluvial origin, the texture of the Wabash soils depends upon the strength of the current at the time of the deposition of the material. Almost all gradations of texture between sand and clay are found, but the most common classes or types are the sandy loam, loam, silt loam, and clay loam, their rank in importance being practically the reverse of the order in which they are named. Although it is impossible even in a detailed survey to separate these types on a map, a brief description of each is given as an aid to their identification in the field.

WABASH SANDY LOAM.

The Wabash sandy loam to a depth of about 10 inches consists of a dark-brown sandy loam, which in some places has a slightly reddish tinge. The subsoil is more variable than the surface soil, but is usually a brown heavy sandy loam or sandy clay loam. There is often a small amount of gravel present in both soil and subsoil, which has been derived from the adjacent gravel terraces.

The type is not very extensively developed, although it occurs in large areas along the Scioto and Miami Rivers. It is considered valuable farming land and the general farm crops of the section are grown upon it. The better drained portions are well adapted to alfalfa and are also used to some extent for trucking.

WABASH LOAM.

The Wabash loam consists of a dark-brown to almost black loam, containing enough sand to make it somewhat gritty to the feel. At a depth of about 10 inches the color is a lighter brown, although in many cases there is very little difference to a depth of more than 3 feet.

The type is not extensively developed, but small areas are found along many of the streams in the western part of the State. It is a very strong, productive soil, especially well suited to the growing of corn. It is closely related to the Wabash silt loam and from an agricultural standpoint differs very little from this type.

WABASH SILT LOAM.

The Wabash silt loam consists of a dark-brown to black silt loam, which at a depth of about 10 inches gradually becomes lighter in color, changing to a drab, or yellow and drab, mottled heavy silt loam or clay loam. A small amount of fine sand is usually present, and scattering gravel may be found throughout the soil and subsoil along some of the streams. The type contains a large amount of organic matter, which gives it a loose, granular structure and makes it easy to secure a good tilth.

This type is widely distributed over the western half of the State, and is a very strong, productive soil, well suited to general farm crops and to alfalfa where the type is properly drained.

WABASH CLAY LOAM.

The soil of the Wabash clay loam is a dark-brown to almost black heavy clay loam, containing a large amount of silt. The dark color is due to the large amount of black organic matter present, which in some places is sufficient in quantity to impart a mucky character to the surface soil. No sharp line between the surface soil and subsoil exists, but at a depth of 10 to 18 inches the color is usually lighter, often being a bluish drab. Although rather sticky when wet, its marked power of granulation causes clods to break down rather easily, and makes it possible to secure an excellent seed bed. In some places the texture is almost a clay, and small areas of the Wabash clay are doubtless associated with this type. Practically no gravel is found except in Champaign County, where the soil is underlain by beds of gravel often within 3 feet of the surface.

The type is found principally in the northwestern part of the State and in Champaign and Clark Counties, but smaller areas occur throughout the western part of the State. In some cases, where the stream valleys are very shallow, this type grades into the Clyde clay loam, and it is difficult to distinguish between the two.

The Wabash clay loam is one of the most productive soils in the State. Large yields of corn and other crops are secured where the type is properly drained and the crops are not damaged by overflow.

Papakating Series.

The Papakating series includes the dark-brown to black alluvial soils consisting of reworked sandstone and shale material. They closely resemble the soils of the Wabash series, but differ from them in being made up principally of shale and sandstone material and in containing on an average a smaller amount of lime. In many cases they are deficient in lime carbonate, as is evidenced by the reddening of blue litmus paper. They are also closely related to the soils of the Huntington series, but differ from them in carrying a much larger percentage of organic matter and also in having a much darker color. The larger amount of organic matter in the Papakating series, as compared with the Huntington, is due to poorer drainage, which has caused its accumulation in these soils. Because of this necessary condition of origin, these soils naturally have poor drainage, for where such is not the case the yellowish-brown soils of the Huntington series have been formed instead.

The Papakating series is practically confined to the northeastern part of the State, where it shares the first-bottom lands with the Huntington. Its almost exclusive occurrence in this section is due principally to the existence of areas of naturally wet lands, resulting chiefly from changes in the streams brought about by the ice. These soils are very common in old valleys.

Where the surface is sufficiently level to give poor natural drainage, the velocity of the stream is not sufficient in most cases to carry very coarse particles, and therefore only small areas of the sandy members of the Papakating series are found; and it is not necessary in this report to more than mention their existence. Although the total area occupied by the heavier members of the series amounts to only a few square miles, a brief description of each is given.

Papakating loam.

The Papakating loam consists of a dark-brown to black loam, which at a depth of 10 or 12 inches grades into a lighter colored loam to clay loam, often mottled with yellow, gray, or brown iron stains.

The type usually occurs in the sections where a considerable amount of sand is found in the upland soils. When drained this is a good, productive soil, giving large yields of corn and other general farm crops.

PAPAKATING SILT LOAM.

The surface soil of the Papakating silt loam is a dark-brown to black, friable silt loam, containing very little sand. It gradually becomes lighter in color with depth, and at about 12 inches is a mottled yellow, gray, and brown heavy silt loam or clay loam, which sometimes contains lenses of sand.

This type occurs only in small areas, and where drained it is classed as a strong, productive soil.

PAPAKATING CLAY LOAM.

The surface soil of the Papakating clay loam consists of a dark-brown or black clay loam, usually containing a large amount of silt. It gradually changes with depth into a dark-drab or mottled yellow and gray heavy clay loam to clay. This soil is very similar in appearance to the silt loam, but is heavier in texture and therefore more difficult to cultivate.

Areas of the clay loam are usually found in the old valleys whose channels were occupied by larger streams before glaciation. When drained it is an excellent soil for corn, hay, and other farm crops.

PAPAKATING CLAY.

The Papakating clay consists of a dark-brown to black, granular, sticky clay, which at a depth of 10 or 12 inches gradually becomes lighter in color and changes into a drab or "blue," plastic clay, sometimes mottled with yellow or stained brown with iron. It occupies very level or slightly depressed areas, which were doubtless formerly occupied by small lakes.

Like the clay loam, this type occurs in the old abandoned valleys, one of the best developments being along Killbuck Creek, just west of Wooster. It sometimes occurs as a border around areas of Peat, the amount of organic matter increasing until the soil changes to Muck or Peat. Although somewhat difficult to handle, it is a very fertile soil, and is well adapted to general farming.

HUNTINGTON SERIES.

In the Huntington series are included the light-yellowish or "rich"-brown alluvial soils, with somewhat lighter and more yellowish-brown subsoils. There is usually present less lime and organic matter than in the Wabash, but more of both of these elements than in the Holly. The amount of lime is probably about the same as in the Papakating, but the percentage of organic matter is much lower.

The Huntington series is composed principally of reworked shale and sandstone material, with usually a slight addition from crystal-

line rocks and limestone. In its most typical development it represents a mixture of glacial and residual material, such as occurs along the Ohio River, but may be composed of material derived entirely from either source. As the underlying sandstone and shale formations in the glacial and residual sections are similar, no great difference would be expected between the alluvial soils. However, where composed entirely of residual wash, the soils are usually a little lighter in color, somewhat lower in lime and organic matter, less productive, and grade toward, or into, the Holly soils. This is especially true where no limestone layers occur in the uplands. In some cases the soils washed from glacial limestone drift are more like the Huntington than the Wabash, but these must be considered rather as a gradation toward the latter than as typical of the series. In the glacial sandstone and shale sections they grade into the Papakating. In other words, the Huntington series represents a condition intermediate between the dark-colored Wabash and Papakating soils on the one hand and the almost white Holly soils on the other. However, as the Huntington soils are very productive, they are in agricultural value much nearer the first two than the last.

The Huntington series is more extensive and more widely distributed than any other alluvial series in the State. It occurs as rather narrow, almost continuous strips, seldom more than a mile in width, principally along the Ohio, Muskingum, Hocking, and Scioto Rivers and their tributaries. However, along the Scioto the soils are not entirely typical, but contain more lime and represent a gradation toward the Wabash, which is also true of all areas in the western half of the State. Most of the soils along the Scioto north of Chillicothe are best classed with the Wabash series. In the northeastern part of the State the Huntington series is associated with the Papakating and occupies the better drained portions of the bottom lands.

In texture the Huntington soils vary from sand to almost a clay. The silt loam is the most extensive type of the series, with the sandy loam and loam next in importance. The areas of sand and clay loam are not of sufficient size to justify more than mention in this connection, although much of the silt loam approaches the clay loam very closely in texture. A description of the three most important members of the series is given.

HUNTINGTON SANDY LOAM.

The soil of the Huntington sandy loam consists of a brown or yellowish-brown sandy loam of medium to fine texture, gradually changing at about 10 or 12 inches into a slightly lighter colored sandy loam of about the same texture as the surface soil. Both soil and subsoil often contain layers of more sandy or heavier material,

and in a few cases gravel is also present. Along the Ohio and other large streams the texture is usually a fine sandy loam, but along the smaller streams it is often a medium or even coarse sandy loam. This difference is, of course, due to the greater velocity of the smaller streams.

The most common occurrence of the Huntington sandy loam is as narrow strips along the banks of the streams, especially in the bends, where it usually occupies a slightly higher elevation than the heavier soils. However, it may be found anywhere in the bottom land, where the current has been sufficiently strong to deposit sandy material. Its ease of cultivation, higher elevation, good drainage, and natural productiveness make it a very desirable soil.

HUNTINGTON LOAM.

The Huntington loam consists of a yellowish-brown mellow loam, containing a sufficient amount of sand to give it a somewhat gritty feel. At a depth of 12 inches it gradually becomes lighter and more yellowish in color, although there is not much change in texture. It is not uncommon, however, to find layers of sandy loam or clay loam interstratified with the loam in the subsoil.

The type occurs in rather small areas, more often along the smaller than the larger streams, and is more common in the sections where there is considerable sand in the upland soils. There is usually a narrow band of this type between the areas of sandy loam and silt loam. It is an excellent soil, and where well drained and crops are not subject to damage from overflow it is very highly prized as farm land.

HUNTINGTON SILT LOAM.

The soil of the Huntington silt loam consists of a brown to dark yellowish brown silt loam, which is usually loose and friable and easily cultivated. In some places, however, where it is heavier and grades toward the clay loam, there is some tendency to clod. Quite frequently this character of material extends to a depth of several feet, but more often at about 9 to 14 inches the color gradually becomes lighter and changes to a light or yellowish brown, while the texture is a silt loam or clay loam, which may vary considerably at lower depths as layers of lighter or heavier material are encountered. In areas where this type has been derived entirely from the Dekalb silt loam the color is somewhat lighter, approaching that of the Holly silt loam. This variation is rather general along the smaller creeks which flow through the area shown on the map as the Dekalb silt loam.

The Huntington silt loam is the most extensively developed alluvial soil in the State. It is found principally in the eastern and

southern sections, where it usually constitutes the chief soil along nearly all of the streams. It is used mainly for the production of corn, because it gives large yields and because this crop can usually be planted after danger from the spring floods is past. As most of it is subject to overflow almost every year, the need of crop rotation is not so great as upon the upland soils.

Holly Series.

Where the alluvial material has been washed almost or entirely from degenerated sandstones and shales containing little or no lime the soils are much lighter in color, more acid, lower in humus, and naturally less productive. This is especially true where the fall of the streams has not been sufficient to prevent wet, marshy conditions, which, in the absence of lime, bring about marked differences in the character of the soils, as indicated in preceding pages. These light-gray to almost white soils, which are underlain by mottled gray and yellow subsoils, constitute the Holly series, and are the alluvial counterpart of the Clermont, the Trumbull, and the Tyler series.

Holly silt loam.

The Holly silt loam ranges in texture from a light to heavy silt loam, and in color from light gray to almost white. When wet it is browish gray or drab. The subsoil is quite variable in color. It is generally drab, mottled with yellow or brown, but in some localities the drab predominates, with only slight traces of yellow. There is usually a tendency for the proportion of yellow to increase as a depth of 3 feet is approached. In texture the subsoil is most commonly a heavy silt loam, gradually changing at lower depths to a silty clay loam or clay, which is usually plastic though not very tenacious. Where associated with the Huntington silt loam, the color gradually becomes browner or more yellowish until the soil grades into this type.

The Holly silt loam is an alluvial soil, made up principally of material collected by streams flowing through areas of residual soils weathered from sandstones and shales. It is probable that the original material was deficient in lime, but, if not, such deficiency has been brought about by leaching in the process of reworking. In the absence of lime, poor drainage conditions have resulted in the formation of this white soil because of its failure to accumulate humus under such acid conditions.

As a lack of lime and poor drainage are essential conditions for the formation of this soil, its development is restricted to those areas where practically no limestone occurs in the uplands and where the streams are sluggish. Such conditions are most often found along the streams which flow northward into the Tuscarawas or Muskingum

Rivers, probably due to the changes in drainage which took place as a result of the ice invasion. Although rather widely distributed in small patches over the first bottoms in the southeastern part of the State, this soil constitutes an important type in only a few counties. In Harrison County it is found along the Stillwater and Conotton Creeks and also along the former stream in Belmont County. In all localities it is closely associated with the lighter colored variations of the Huntington silt loam.

On account of the undrained condition of the greater part of this type, it is largely used for pasture. Where drainage has been accomplished by ditching or tiling, fair crops of corn and oats have been secured. Obviously the primary requirements for its improvement are a liberal application of lime, the incorporation of organic matter by plowing under legumes and stable manure, and good drainage.

ORGANIC SOILS.

PEAT AND MUCK.

Over most of the glacial portion of Ohio there are many, though usually small, areas where conditions have been favorable for the accumulation of plant remains. Where such accumulations are shallow, the decayed product is only sufficient to give a dark color to the surface soil, as in the case of the Clyde clay loam and other members of this series, but where the deposits are deeper, the remains consist very largely of organic matter, and beds of Peat and Muck occur.

Considerable difference and confusion exists in the use of the terms "Peat" and "Muck" and no strict line of distinction separates the two. Both represent accumulations of plant remains in different stages of decay. The term "Peat" is generally used to designate the coarser, less decomposed remains that have not lost the cellular, fibrous structure of the original plant tissue, and which usually have mosses and coarse grasses incorporated in the beds, only slightly changed by decay, while "Muck" indicates organic remains in the more advanced stages of decomposition. In the case of Muck, the cellular structure of the original plant has been lost, the accumulations have been reduced to a soft, finely divided condition, and some silt, clay, and very fine sand have usually been washed or blown into the depressions during the processes of formation. In other words, Muck might be considered as representing a gradation between the almost entirely undecomposed areas of peat and the black soils which usually occur as a border around the Peat and Muck areas.

While the above represents the usual distinction made between Peat and Muck, from an agricultural standpoint, the term "peat" is often used, especially in geological reports, to include not only muck

but sometimes even areas where the amount of organic matter is little more than enough to give a black color to the surface soil. In a recent report on the "Peat Deposits of Ohio" Dachnowski[1] uses the term "peat" in the broader sense to include all accumulations of plant remains, as may be seen from the following quotation in regard to the varieties of peat:

> In any undrained or partly drained water basin of Ohio where peat is accumulating, two varieties of the material may be readily distinguished. One is coarsely fibrous and matted, containing the roots, rhizomes, and aerial parts of plants from which the organic matter is derived. It has a light-brown color, definite physical and chemical properties, and often lies as a floating mat near open water on account of its low specific gravity. The outer covering of the plant material is more or less strongly cuticularized, disintegrates very slowly, and hence is still in the early stages of partial decay. The other variety is a dark-brown, almost black, well-decomposed, compact peat, which is usually found near the outer margin of the deposit and above the ground-water level. The fibrous structure is less apparent, for it has disappeared through decay, and the larger part of the annual peat increment is made up of leaves and disintegrating woody parts of trees and shrubs. Between these two varieties peat samples collected from a horizontal or vertical cross section are found in various intermediate stages of disintegration. This is indicated in most deposits by a progressive change in color from light to darker shades and in texture from coarse, loose, and matted to fine, plastic, and often more liquid peat, which results largely by the gradual falling of material from the under side of the floating and strongly matted variety. The chemical composition, the biological soil processes, and the physiological properties of the different varieties and types of peat also vary.

The two varieties of peat as described in the preceding quotation are so very markedly different, from an agricultural standpoint, that it seems best to confine the term *peat* to the brown, fibrous material, while the black, thoroughly decomposed portions are termed *muck*, and it is in this sense that these words are used throughout this report.

In Ohio Peat and Muck are very closely associated, and there is usually a gradual change from one to the other. The Peat usually occurs in small patches throughout the larger areas of Muck, and a separation of the two on the map was therefore impracticable. A large proportion of the Muck has not reached a very advanced stage of decomposition, but in most cases there has been sufficient modification to make it a true soil and admit of its being classed as Muck.

As already stated, Peat and Muck are composed largely of organic matter, the percentage of ash or mineral matter in some of the pure varieties of Peat being less than 5 per cent. In the true Peat the amount of ash probably seldom exceeds 15 per cent, but in the Muck it may run as high as 25 per cent or constitute even a much larger

[1] Peat Deposits of Ohio, by Alfred Dachnowski, Geological Survey of Ohio, 4th series, Bulletin 16, p. 18.

proportion. In fact, material containing as much as 25 or 30 per cent of organic matter would be decidedly mucky in character.

Being composed so largely of organic matter, Peat and Muck are very retentive of moisture, the amount present when air-dried ranging from 5 to 15 per cent.

The color of the Peat and Muck deposits ranges from brown to black, and is usually dependent upon the stage of decomposition. The true Peat areas are usually brown, though sometimes almost black, while the areas of Muck are always black. This difference in color forms one of the most obvious distinctions between Peat and Muck.

The depth of the deposits of Peat and Muck in Ohio varies from a few inches to as much as 20 or 25 feet. In general the deposits of Peat are deeper than those of Muck. Most of the areas of Muck are believed to be between 12 inches and 5 feet in depth. Beneath the deposits of Peat and Muck are usually found layers of blue or drab clay, but in a number of cases they are underlain by deposits of marl. These beds of marl usually contain quite a large percentage of lime carbonate, and may prove very valuable sources of lime for use on the upland soils.

The condition essential to the formation of Peat and Muck is a constant and abundant moisture supply, such as is found in or around the border of lakes or ponds. Unless the remains of the plants are kept practically covered with water all the time, their destruction will take place almost as rapidly as the production by growth, and the accumulation will not be sufficiently rapid to form beds of these materials. A vigorous vegetal growth, constant saturation and consequent lack of aeration, and low temperature are the conditions most favorable for the accumulation of beds of Peat and Muck.

As poor drainage is essential to the formation of Peat and Muck, their occurrence is practically limited to depressions which were formerly and in some cases are still occupied by lakes. Such depressions are rather common in glacial regions, especially the portions occupied by terminal moraines, because the deposition of material by the ice naturally leaves a somewhat uneven surface, made up of swells and depressions, and because the time which has elapsed since the glacial period has not been sufficient for these depressions to be drained by erosion. Another factor which causes glacial regions to be favorable to the formation of areas of Peat and Muck is the change in drainage which is often caused by the ice. Old valleys have been abandoned by the streams and in them have been formed finger lakes, in which the growth of aquatic vegetation has resulted in the accumulation of deposits of plant remains. Some of

the largest areas of Peat and Muck in Ohio are found in such old valleys.

As Peat and Muck have been formed under water, the surface is invariably level, except where slight depressions have been made by burning. Artificial drainage is necessary in reclaiming these areas. In large tracts, like the Scioto Marsh, extensive systems of drainage through cooperation of the landowners are necessary, and ditches several miles in length have been constructed. On many of the smaller tracts also drainage has in some cases been established more or less effectively, only a small amount of ditching and tiling being needed. In some cases, however, the areas occupy such deep depressions that it is necessary to cut a ditch many feet deep through the surrounding rim in order to drain them. Muck and Peat, however, must not be overdrained, as too deep and thorough drying reduces their productivity and causes great danger from loss by fire. It is very common, therefore, to find the subsoil saturated with water within a short distance of the surface. Not only is there danger from fire when too thoroughly dried, but much damage may result from blowing by the wind. Neither danger can be entirely eliminated, but both may be reduced by not draining too deeply.

Peat and Muck do not occur in broad, extensive areas covering wide stretches of country, but rather in numerous small, isolated spots. Many of the areas are only an acre or so in extent, but there are a few tracts of as much as several thousand acres. The largest single area in Ohio is found over what is known as the Scioto Marsh in the western part of Hardin County. Another rather extensive area is found in Washington Township in the northern part of the same county Both of these areas are surrounded by wide strips of Clyde clay loam, which closely approaches the Muck in character and crop value. A large area is found in the southwestern part of Seneca County and extends westward for several miles into Hancock. The second largest area of Peat and Muck in the State occurs in the southwestern part of Huron, the northeastern part of Crawford, and the northwestern part of Richland County, the largest part of the area being in Huron County. Other quite extensive areas are encountered south of Lodi, in Medina County, east of Clinton and Hartville, in Stark County, in the corner of Geauga, Cuyahoga, Portage, and Summit Counties and extending southward for many miles along the boundary between the last two, in northwestern Trumbull County and reaching northward into southern Ashtabula County, and northeast of Dayton in northwestern Greene County. In addition to these larger areas, many smaller ones, most of which are too small to show on the map, occur throughout the glacial region, particularly in the morainic sections between Canton, Akron, Chardon, and Ravenna, and around Bellefontaine. In general the areas of Peat and Muck

are most numerous on the divide between the Ohio River and Lake Erie. Very few areas are found in the Darby plains around Columbus, in the southwestern part of the State or in the old lake bed, except in the portions occupied by sandy soils.

While the areas of Peat and Muck are not very extensive, the largest one in Hardin County probably comprising less than 15,000 acres, the total area of these soils amounts to many thousand acres. Davis[1] has estimated the total acreage of "Peat" lands in Ohio at 155,047 acres, which is more than twice as much as that mapped as Peat and Muck in this report, the remainder being included in other highly organic soil types.

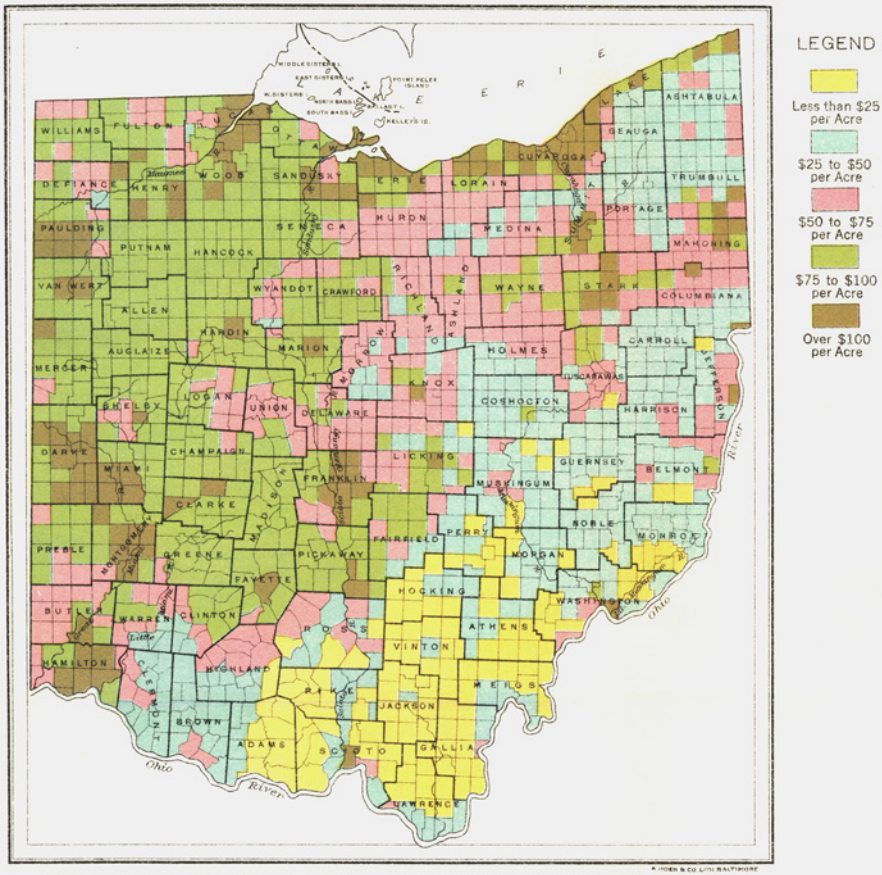
Although there are still many areas of Peat and Muck in Ohio which have not been reclaimed, quite a large proportion has been brought under cultivation and constitutes some of the highest priced land in the State. In the areas of brown Peat the material is not sufficiently decomposed to make good farming land, but the Muck is, where properly drained, very highly prized; more, however, for special crops than for general farming.

The general farm crops grown on the Peat and Muck areas are corn, oats, hay, and potatoes. Corn is not generally found on the Peat and deeper Muck areas, but does well where there is an admixture of silt and clay. Oats yield well but there is danger of lodging from too rank a growth of straw. Of the grasses, timothy seems best suited to the Muck, and is one of the most profitable general farm crops that can be grown on the shallow areas.

Muck and Peat in Ohio have their highest value for certain special crops, of which onions and celery are most extensively grown. Onions are found on nearly every cultivated area of these lands in the State. In the larger areas, like the Scioto Marsh in Hardin County and Garden Isle south of Lodi in Medina County, onions are grown on a very extensive scale and when average prices prevail prove very profitable. Celery is widely grown on the Peat and Muck soils, especially in the western part of the State, although not nearly so extensively as onions. A large proportion of the areas near Lodi and east of Hartville, as well as elsewhere in the northeastern part of the State, is devoted to the growth of celery, and an excellent quality is produced. The crop is most profitable where the moisture conditions are fairly well under control. It is likely that the acreage will be largely extended as new areas of Muck and Peat are brought under cultivation.

The largest areas of Muck and Peat soils have been cultivated only a short time, and their capacity has not yet been fully tested. The results, as a whole, have not been entirely satisfactory, particu-

[1] Davis, P. A., "Peat Resources of the United States, Exclusive of Alaska," Bul. 394, U. S. Geol. Sur. (1909).



MAP OF OHIO, SHOWING AVERAGE ASSESSED VALUE OF FARM LAND, 1911

Scale
10 0 10 20 30 40 50 Miles

larly in the western part of the State. This is doubtless due, in part at least, to a lack of familiarity with the methods of handling and the needs of these peculiar soils. Peat and Muck are often deficient in the mineral constituents, especially potash. This is particularly true where the material consists almost entirely of organic matter and is several feet in depth. Where the deposits are shallow and a large amount of mineral matter is mixed with the organic matter the necessity for mineral fertilizers is less pronounced. Fertilizers of mixed formulas have been generally used, so that no definite conclusion can be drawn from the results, but it is probable that potash is lacking in all of the deeper deposits and that an addition of phosphoric acid is also needed. The turning under of straw or other coarse organic matter has proven very beneficial upon similar soils in Indiana and in some other States.

MISCELLANEOUS MATERIAL.

ROCK OUTCROP AND AREAS OF VERY SHALLOW RESIDUAL OR GLACIAL LIMESTONE SOILS.

There are no very large areas of bare rock in the State. Throughout the more hilly sections there are outcrops of sandstone and limestone in the form of ledges, but the area of these is so small that they can not be indicated upon the map. However, in the northwestern part of the State there are many small areas where the movement of the ice across the limestone carried away practically all of the surface soil and deposited very little, if any, material in its place. In some places the limestone outcrops at the surface, but in most cases there is a thin covering of soil over the limestone, although this covering is frequently so thin that the areas are practically unfit for agricultural purposes and support only a scanty growth of grass and sometimes a few trees. In dry weather the lack of moisture causes practically all vegetation upon these shallow areas to die, although there are many pockets, or places where the soil covering is deeper, which are used to some extent for agriculture. Since the shallow areas are unfit for agricultural purposes, it is thought best to indicate them on the map, although it is sometimes necessary to exaggerate their size in order to do so, and although the areas so shown may include some small areas of good Miami clay loam. In addition to the areas indicated on the map there are many areas entirely too small to be shown on a map of this scale.

There is considerable variation in the soil of these areas. In some cases it is very similar to the Miami clay loam, except that the limestone is encountered within 3 feet of the surface, but in other areas apparently no glacial material was left, and the thin covering of soil is apparently of residual origin. In such areas the soil is usually a

brown to reddish-brown clay loam, containing many flat pieces of limestone.

The area just north of Castalia, in northwestern Erie County, is entirely different from those found elsewhere. This area is underlain by a soft limestone or marl, which is found within a few inches of the surface. The surface soil here consists of a very black, rather mucky, clay loam, somewhat like the Clyde clay loam, but usually containing more organic matter. Owing to the shallow depth of the surface soil, this area is of very little value for agriculture, although its appearance gives one the impression of excellent land. This area supports a characteristic prairie vegetation.

MARSH.

The term Marsh has been applied to strips of low-lying water-logged land occurring along Lake Erie between Toledo and Sandusky. The soil varies from loose sand to heavy clays. Most of it, however, is Clyde clay loam, with occasional areas of Muck.

The elevation above Lake Erie is so slight that the land can be drained only by constructing dikes along the lake and pumping plants to remove seepage water and rainfall. This has been done on a small scale, but is profitable only for the production of high-priced special crops. At present the greater portion has no agricultural value and is not likely to be utilized in the near future. The native vegetation consists of rushes, cat-tails, and other water-loving plants and grasses. The soil when drained is especially adapted to growing celery, cabbage, and onions.

RELATION OF SOILS TO LAND VALUES.

While there are many factors which have an influence upon the value of land for agricultural purposes, the character of the soil is undoubtedly one of the most important. In order to bring out any relation which might exist between the character of the soil and the value of the land, a map (Pl. D), showing by townships the "average value per acre as fixed by the Tax Commission, exclusive of unincorporated villages, manufacturing plants, and minerals," has been prepared.

On this map the townships have been grouped in divisions of $25 differences in value, with the exception that all land having a value of over $100 an acre is shown in one division, although in several cases the value is more than $200 an acre and in a few cases over $300. However, these high values are always near the larger cities and are therefore due to location rather than soil. The lines of division are necessarily arbitrary, and two townships, one above, the other just below a division figure, may fall in different groups although the land has almost exactly the same value.

The law in Ohio requires that land shall be assessed at its true value in money, which is usually considered the price which the property would bring at a forced sale. As this is usually somewhat lower than the price at which the land would sell under ordinary conditions, and as the price of farm lands is on the increase, the values as given on the map are probably something like 25 per cent less than the selling price at the present time. The average value for the entire State, as fixed by the Tax Commission in 1911, is $63.78 an acre, as compared with $53.34 as given by the Census Bureau in 1910. The important thing, however, in a study of this kind, is the relative rather than actual values.

A comparison of the map of land values (Plate D) with the general soil survey map brings out some very interesting relations between the value of the land and the character of the soil, some of the more important of which will be pointed out; but the maps themselves should be studied by anyone interested in this question.

It will be seen that nearly all of the residual soils of the State fall below $50 in value, and that a very large proportion, covering most of their southern extension, are valued at less than $25. The lowest valuations in the State are in western Scioto and eastern Adams Counties, where some townships fall below $10.

While the lower valuation in the southeastern part of the State is due in a large measure to the more hilly nature of the country, the effect of differences in soils within this section is also quite evident. The influence of limestone (Westmoreland soils) in the country north of Athens County is clearly shown by the higher value of the land, some townships in the limestone sections of Jefferson, Harrison, and Belmont Counties including land above $50 in value, while very few townships where the Westmoreland series occurs drop below $25.

A much better indication of the influence of the soil upon the value of the land may be had by comparing the different soils in the glacial section, where differences in topography may be practically eliminated. In general it will be seen that the land in most of the Glacial Limestone section of the State has an assessed value of $75 to $100 an acre, some of it going higher than the latter figure, while the value of the greater proportion in the Glacial Shale and Sandstone section is less than $75, much of it being less than $50. The line between these two great groups of soils corresponds rather closely with that which separates the $50 and $75 land.

In the Glacial Shale and Sandstone section the Wooster soils are of higher value than the Volusia, although the topography of the Wooster is decidedly more rolling, or even hilly, than the lower priced Volusia. The lower value of the Volusia and Trumbull areas

as compared with the Wooster areas must certainly be due to the character of the soil.

In the Glacial Limestone section the presence of the black Clyde soils tends to raise the valuation, as is evidenced by the occurrence of several townships valued above $100, particularly in Paulding and Darke Counties.

Another striking illustration of the influence of the soil upon the land values may be noted in the contrast between the Miami and the Loess soils (Clermont and Cincinnati silt loams) in Highland, Clinton, and Warren Counties. In Hamilton County the proximity of the city of Cincinnati causes an increase which offsets the difference due to the soils.

Some of the highest-priced lands in the State occur along Lake Erie, but this is due more to the climatic influence of the lake and the desirability of this section for residence purposes than to the character of the soils.

SUMMARY.

This report represents the results of a reconnoissance soil survey of the entire State of Ohio, covering a total area of 40,740 square miles.

The altitude of the State varies from about 500 to 1,500 feet, considerably more than one-half of its area being less than 1,000 feet above sea level.

The southeastern part of the State is decidedly hilly, while other sections consist very largely of gently rolling plains, with some extensive stretches of level land, particularly in the northwestern part. The bottoms are usually narrow, and many streams have very little alluvial land along their courses.

Practically five-sevenths of the State drains southward into the Ohio, while the drainage of the remainder is into Lake Erie. Many changes in drainage resulted from the advance of the ice, and very few streams now occupy preglacial channels. Many of the changes were probably *interglacial* rather than *preglacial*.

The average annual temperature for the extreme northern section of the State is 48° and for the extreme southern section 55°, giving a difference of only 7° F. Lake Erie has a decided influence upon the climate in the section immediately along its shore. The average annual precipitation is 38.89 inches and is rather uniformly distributed throughout the year.

The western half of the State is underlain by limestone and the eastern half by shales and sandstones, with only a few thin beds of limestone. As three-fourths of the State was glaciated, only the southeastern section has residual soils, while those in other sections are transported.

The most important residual soil is the Dekalb silt loam, derived from nonred shales and fine-grained sandstones. The red shales give rise to the Upshur clay, which can not be separated on the soil map from the Dekalb, and the Meigs soils represent undifferentiated Dekalb and Upshur material with all gradations between. Where limestone is interbedded with the nonred shales and sandstones, the soils are classed as the Westmoreland. A small area of residual limestone soil occurs principally in western Adams County.

The transported soils can be subdivided into glacial drift, glacial lake, terrace, loess, and alluvial soils.

In the western half of the State the drift consists largely of ground-up limestone, and the soils may be termed glacial limestone soils. The two principal types are the Miami silt loam and clay loam. The slightly reddish brown morainic soils have been included in the Bellefontaine series.

East of Sandusky and Columbus the drift consists largely of shale and sandstone and gives rise to three soil series—the Wooster, Volusia, and Trumbull. The Wooster loam and silt loam, the Volusia loam, silt loam, and clay loam, and the Trumbull silt loam and clay loam are the most important types in these series.

Three series of glacial lake soils are recognized. The dark-brown to black soils are included in the Clyde series, of which the clay loam and clay are the most important members. Where the light-colored beach soils are composed largely of limestone they are classed as the Belmore series, while those consisting largely of shales and sandstones are mapped as the Dunkirk. In these two series the Dunkirk sand and sandy loam are the two most important types.

The loess soils are found only in the southwestern part of the State and consist of two types, the Cincinnati silt loam and the Clermont silt loam.

The river terraces are divided into glacial or gravel terraces and nonglacial terraces without gravel. The gravel terraces may be further divided into those composed largely of limestone (Fox series) and those consisting chiefly of sandstone and shale (Chenango series). The silt loams are probably the most important types in each case. The nongravel terraces are occupied by the Holston and Tyler silt loams.

Ohio does not have a large area of alluvial soils, as the bottoms are usually narrow. Four series of such soils, the Wabash, Papakating, Huntington, and Holly, are recognized. The Wabash clay loam and Huntington silt loam are the most important types.

Many small areas of Peat and Muck occur in the State, principally on the divide between Lake Erie and the Ohio River.

Texturally the soils of Ohio consist principally of silt loams and clay loams, sands and clays constituting only a small proportion.

Excepting the black soils, found throughout the western half of the State, but most extensively in the northwestern, old lake bed section, most of the soils are light colored and rather low in organic matter.

In the eastern half of the State both soil and subsoil are practically everywhere deficient in lime carbonate, except the deeper subsoils of Volusia clay loam and silty clay loam, but in the western half most of the subsoils are well supplied with lime, although it has been very largely leached out of the surface soils and upper subsoil. Often, even in the western part, the application of lime is beneficial.

Some very striking relations exist between the soils and the value of the land, as may be seen by comparing the soil and assessed land value maps.

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