Indiana Soil Types.

CHAS. W. SHANNON.

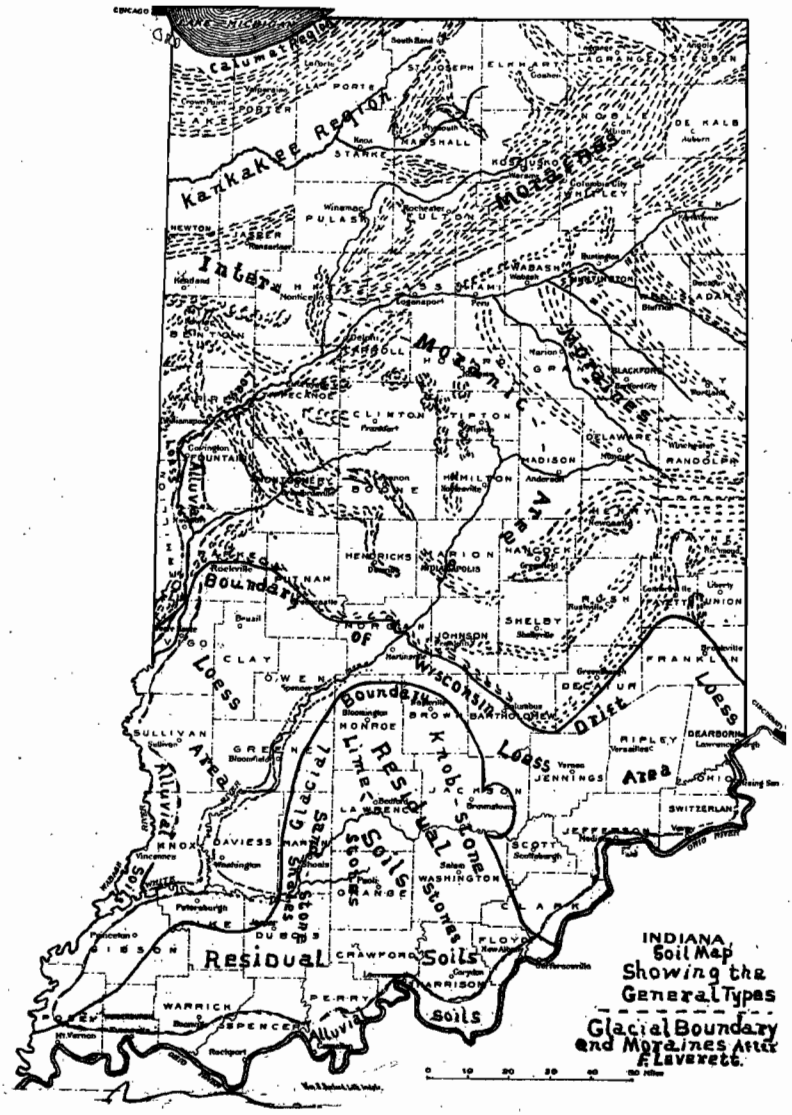
The excellent showing which Indiana makes among the States of the Union, in the production of wheat, corn, hay, oats, etc., and in the value of her live stock, is due chiefly to three things: First, the great variety of soil types adapted to the growing of numerous crops; second, the high average fertility of the soils; third, the degree of intelligence manifested by the farming population in the care and cultivation of the soils.

As a basis of classification the soils of Indiana may be divided into three great groups, viz., drift soils, residual soils, and alluvial soils.

The fundamental unit in mapping and classifying soils is the type. The most important things to be considered in the determination of a type are the texture, which deals with the size of the particles; the structure, which deals with the arrangement; the organic matter content, origin, color, depth, drainage, topography, native vegetation, and natural productiveness—all factors that influence the relation of soil to crops must be taken into consideration.

The grouping known as the soil class is based on texture. All soils are made up of particles of different sizes and by means of mechanical analysis the particles are separated into different grades and the various percentage relationships determine the class of soil, as sand, sandy loam, clay, etc.; and if in addition to the fine earth the soil contains particles of larger size it is called gravel, and if larger are called stones, so that it is possible to have gravelly or stony members of the various classes—as a gravelly loam or a stony clay. A set of soil classes may be so related through source of material, method of formation, topographical position, and coloration that the different types constitute merely a gradation in the texture of an otherwise uniform material. Soils, of different classes thus related constitute a series. Soils may, however, be very similar in origin and texture but may occupy so entirely different topographic positions that their relation to crop

production is entirely changed, and this fact would be recognized by another serial name. Many of the soil types in any area have



been formed by the same general processes, and necessarily grade into one another in respect to all characteristics.

The names given to the various soil types in the description and on the maps which accompany this report will be correlated

so far as possible with established names in Indiana Geology, in relation to the different geological formations and agencies to which they are due, and to their topographic position; and with the common terms of agriculture, in relation to crop production, native vegetation and general characteristics of texture, structure, color, drainage, etc. There will be found in nearly all areas soils of local origin and of exceptional characteristics which will necessarily be given local names, but such soils encountered will be placed as much as possible under the general types, but described as to their importance, peculiar qualities, and their behavior under cultivation.

(a) DRIFT SOILS.

The drift soils of Indiana cover approximately three-fourths of the State. Extending from the north boundary to the southern limit of the Wisconsin drift, the glacial material is on an average more than 100 feet in thickness, with a maximum thickness of about 500 feet. South of this limit about one-half of the area has a comparatively thin covering of drift due to earlier ice invasions.

"In Indiana, the glacial deposits and scorings have been recognized from the earliest days of settlement; indeed, it is in this State that we find about the first recognitions in America of the boulders as erratics and of striae as products of ice action. So long ago as 1828, granite and other rocks of distant derivation were observed by geologists near New Harmony, in the southwestern part of the State. At nearly as early a date (1842), striae were noted near Richmond, in the eastern part of the State.

"Notwithstanding the early date at which observations of glacial action began, very little attention was given to the drift, here or elsewhere, until within the past twenty years. It was commonly passed over in geological reports, much as the soil is even today, with some casual remark concerning its presence in great or small amount. Within the past twenty years interest in these deposits, because of the varied history which they reveal, has been so aroused, that many geologists, both in America and Europe, are making a systematic study of them.

"In Indiana these deposits are engaging the attention of both the State and the United States Survey. The study of general features and a comparative study of the drift of Indiana and neighboring states has been undertaken by the United States Survey, while the detailed examination of deposits has been entered upon by the State Survey.

"*First Ice Invasion.*—This State was invaded by ice which had as its center of dispersion the elevated districts to the east and south of Hudson Bay. There was a movement from the region north of Lake Huron in a course west of south over the Lake Michigan basin, Illinois and Western Indiana. There was also a southward movement from the same region across Lakes Huron and Erie, Western Ohio and Eastern Indiana. It is not known whether these movements were independent and of different dates, or whether there was simply a radiation in movement of a single ice accumulation. It should not be taken for granted that even within the State of Indiana the ice-sheet was occupying the glacial boundry completely at any one time.

"The ice deposited but little drift near its extreme limits, either in Indiana or the states to the west. There is not, as a rule, a well-defined ridge or thick belt of drift along the glacial boundary, such as characterizes the southern limit of some of the later drift-sheets, though occasional ridging of drift is to be seen, as in the Chestnut Ridge in Jackson County, and a similar ridge in Southern Morgan County. The boundary of the drift in Indiana is usually so vague and ill-defined that it is only approximately known.

"If we may judge of the deposit over the State from the outlying portions, south of deposits made by later invasions, the deposits of the first are of much less volume than those of the later invasions. They appear to include not more than 30 to the 130 feet which the writer estimates the State to carry. In the portion of the State which was glaciated but once the thickness is usually less than the 25 feet, but filled valleys will probably give it an average of somewhat above that amount. What is true of the drift of the earliest invasion in Southern Indiana is also true of the same drift of Southern Illinois and Southern Ohio. This invasion seems, therefore, to be quite widely characterized by a lighter deposition than that of the later invasion.

"*First Interglacial Interval.*—After reaching the line marked by the glacial boundary, the ice melted away and left the drift exposed to atmospheric agencies. How far to the north the land became uncovered is not known. At this time a black soil was formed, which is now concealed beneath deposits of silt, termed loess, in Southern Indiana, and beneath later deposits of till in the northern portion of the State. This soil is found at the base of the loess at various points over the southern portions of the State, but is best developed on flat tracts. It may be seen beneath the

loess in the flat districts east and south of Terre Haute at a depth of from six to eight feet. The vegetable matter appears to have accumulated there just as it does on the present surface of poorly drained tracts in northern latitudes, where decay is slower than accumulation. In Western Indiana, from Parke to Vermillion counties northward, the soil is found below a later sheet of till at depths varing from twenty feet up to one hundred feet or more. Numerous references to the soil below till in this portion of the State are to be found in the 'Indiana Geological Reports.' It has not been observed in Eastern Indiana, so far as the writer is aware, but it may be present, for few valleys there reach low enough to expose it. It seems not to be so conspicuous, however, as in Western Indiana, otherwise it would have been brought to notice in well-borings.

"No conclusions have been reached concerning the length of time involved in the formation of this soil. The land at that time seems to have been so low or so flat in Indiana, that drainage lines were not so well developed in the drift surface, and we are thus deprived of one important means of estimating the work accomplished."

"*Main Loess Depositing Stage.*—For explanation and description of this period see 'Loess Covered Areas.'

"*Interglacial Stage Following the Loess Deposition.*—Between the main deposition of loess and the invasion of Northern Indiana by a later ice-sheet, considerable time elapsed; for we find that the drainage lines have reached a much more advanced stage on the loess-covered districts south of the deposit of the later ice-sheets than they have upon those deposits. It is found that large valleys had been opened in the loess and the underlying drift before the streams from the later ice-sheet brought their deposits into the valleys. This interval of valley-erosion is thought by several who have had opportunity to study it, including the present writer, to be longer than the time which has elapsed since the ice-sheet last occupied Northern Indiana.

"The question has been raised, whether the greater amount of erosion outside the later drift may not have been due to streams of large volume which accompanied the later ice invasion. That this is only a minor influence, is shown by the fact that valleys in Southern Illinois which lie entirely outside the reach of such waters are much larger than valleys of similar drainage areas within the limits of the later drift-sheet.

"It can not be urged that the region with the smaller valleys is

less favored by slopes or stream gradients than the region with well-developed valleys, for the reverse is the case. There are large areas within the loess-covered districts which do not possess the reliefs and other conditions favorable for the rapid development of drainage lines which appear in much of the newer drift. In short, there appears no escape from the view that the interval between the loess deposition and the later ice invasion was a long one.

"*The Wisconsin Stage of Glaciation.*—After the interglacial interval just mentioned, there occurred one of the most important stages of glaciation in the entire glacial period. It is marked by heavier deposits of drift than those made at any other invasion. Throughout much of its southern boundary in the United States, a prominent ridge of drift is to be seen rising in places to a height of 100 feet or more above the outlying districts on the south, and merging into plains of drift on the north, which are nearly as elevated as its crest.

"The southern border of this drift sheet is less conspicuous in Indiana than in the states on the east and west. The ridge on its southern border in Western Indiana rises scarcely twenty feet above the outer border tract, and it is no more conspicuous in Central Indiana. Indeed, from near Greencastle to the vicinity of Columbus there is not a well-defined ridging of drift along the border; the limits there being determined by the concealment of the loess beneath a thin sheet of bouldering drift. From the east border of East White River a few miles below Columbus, northeastward to Whitewater Valley at Alpine in Southern Fayette County, there is a sharply defined ridge of drift standing twenty feet to forty feet above outer border tracts. Upon crossing Whitewater, where the border leads southeastward, it is not so well defined as west of the river, though there is usually a ridge about twenty feet in height.

"Although not conspicuous in Indiana by its relief, this border is about as clearly defined as anywhere in the United States. Within the space of a half dozen steps one will pass from loess-covered tracts of earlier drift to the bouldary drift of this later invasion. Accompanying the change from loess to bouldary drift, there is a change in the color of the soil, from a pale yellowish or ashy color to a rich black. This line is one of great agricultural importance. The distinct lying to the north is finely adapted to corn and timothy, while that to the south seems poorly adapted to these crops. The southern district when uncultivated, soon becomes thickly covered with briers, a feature which is not com-

mon to the black soil of the bouldary drift. In this connection we would remark, that while the loess has great fertility, the compact loess of Southeastern Indiana is adapted only to certain products. It seems as well adapted to wheat, orchards and small fruits as the black soil, and there appears to be an appreciation on the part of the residents of this restricted adaptability."—Frank Leverett, United States Geological Survey. See Studies in Ind. Geography, Dryer, pp. 29-40.

The glacial drift is for the most part a very productive and permanent soil. The drift deposits of the State are varied in the arrangement of clay, gravel and sand, so that what is true in one area may be entirely different in another. But in general it consists of a confused mass of material from various primary and igneous rock, and is usually rich in all the necessary constituents of plant food.

The various types of the drift soils of the State are described under the following divisions:

1. The Calumet Region.

The Calumet River rises in Laporte County, near the Porter County line. It is a meandering stream, with sluggish waters, and without definite banks, except in places where they rise a little above the water level, but seldom more than 10 feet. Near its source it flows in an almost straight course and has the appearance of an artificial ditch rather than a natural stream. After flowing across the counties of Porter and Lake, it crosses the State line but three miles south of the line of its entry into Porter County, and almost due west of its source. From the State line it flows in a northwesterly direction for about seven miles, and then at Blue Island, Illinois, it makes a sharp curve, then flows northeast, then southeast and again crosses into Lake County about three miles north of its first line; then continuing eastward for 14 miles it empties into Lake Michigan, but two and one-half miles northwest of where it first entered Lake County. The area included in this great meander consists of slightly elevated morainic belt, sandy beaches and marshes.

The principal part of the Calumet area occupies that part of Indiana included in the glacial lake known in geological literature as "Lake Chicago." The area extends from the present shore line of Lake Michigan as far as Dyer, 15 miles south of Chicago, and reaching to the east to a point of crossing Deep River 2½

miles south of Hobart, thence to the northeast in a rather regular line, with arms including the present stream of Salt Creek and the head waters of the Calumet, and then at a point opposite the mouth of Salt Creek continues to the northeast in a strip two to three miles wide to the Indiana-Michigan line.

The general physiography of the area under consideration, will show the presence of a variety of soil types and on our basis of classification it will be seen that we have there an area of beaches, sand dunes, marshes and morainic ridges. A large part of this region is physically unfavorable from an agricultural standpoint, but we find a dense population, due to the influence of Chicago.

1. *Area of Beaches.*—This area includes three distinct lines of beaches. The first known as the Glenwood Beach, enters Indiana at Dyer. It extends east for four miles as a ridge and then for a distance of two miles and one-half is broken and finally lost. Then rising again, stretches out to the northeast and into the second beach. The crest of the ridge rises 20.45 feet above the marshes to the north and from 80 to 95 feet above the present level of Lake Michigan. The crest is practically level and from 40 to 70 feet wide, the base is from 40 to 60 rods wide, and with the south slope much more gradual than the north. This beach represents the first stage of Lake Chicago.

The second or Calumet Beach lies between Glenwood Beach and the Calumet River. It extends eastward about a mile and a half south of the river and along the north edge of Cady Marsh, until it joins the Glenwood Beach northeast of Ross. In general it is about the same in width and elevation as the first beach.

The third or Tolleston Beach, lies between the Little Calumet and the Grand Calumet River. Through Lake County the beach is composed of a broken ridge of sand dunes, varying in height from 20 to 30 feet. In Porter County it is largely covered with the sands from the present lake, and the original beach can not be easily distinguished.

In many places these beaches are spread out over considerable distance and are composed of several small ridges with intervening depressions. The beaches consist of a fine sand with a mixture of rather coarse gravel some distance below the surface. The vegetation consists of small, scrubby, black oak, thickets of crab-apple and other trees, and shrubs and grasses peculiar to a sandy soil. The wooded crests stand out in sharp contrast to the treeless swamp intervening. When vegetation is plentiful the ridges are less broken, since the vegetation protects from the wind. On the

crest and slopes of many of the higher ridges wild grapes grow abundantly, and the fruit is large and well developed. Wild berries also grow luxuriantly. The huckleberry appears to be especially adapted to the sandy ridges, and is one of the most prolific and highly esteemed of the wild summer fruits. Wherever wild berries and wild grapes thrive tame ones can be successfully cultivated. Within recent years the growing of strawberries has been carried on quite successfully, especially in the vicinity of Furnessville. This fruit is adapted to sandy soil and hundreds of acres in the Calumet region which now produce nothing but weeds and shrubs, would be suited to strawberry culture. The sand contains sufficient calcareous and organic matter to furnish a plentiful food supply. To produce a good yield of berries there should not be an excess of vegetable matter in the soil. The raising of raspberries has also been successful in the vicinity of Furnessville, as well as on the sandy land farther south. Tame grapes are grown successfully, peach and cherry trees thrive and give a fair yield. Plum trees would doubtless grow well, since many wild plums grow on the sand ridges. The more level tracts of the sand areas, when first cultivated, produce excellent sweet potatoes, watermelons and pumpkins. But in order to obtain a good yield, year after year, a careful system of fertilization is required. Even as a result of such a system abundant yields of vegetables have been obtained from land thought to be barren. The raising of small fruit and vegetables should be encouraged, since all produce will find a ready market in Chicago.

2. *The Sand Dune Area.*—All the area lying between Tollesten Beach and the present shore line of Lake Michigan, is covered with sand. It is a series of low beaches, sand ridges and high isolated sand dunes, due partly to a former extension of the lake and partly to present wind action. The highest of these hills reach a height of 150-200 feet above the level of the lake. In some places the ridges are for long distances without vegetation. In many places the drifting sands have wholly or partly covered tall trees, and when the dead tops are projecting a few feet above the crest of the ridge they have the appearance of dwarfed trees and shrubbery, and one may rest in the top limbs of a tree whose trunk and main branches are buried in the sands. Back some distance from the lake the dunes are often covered with black oak, northern scrub pine, stunted white pine and many shrubs, grasses and other plants peculiar to a sandy soil. The sand is held in place by the network of roots from the vegetation, but if this network is

destroyed the wind storms begin to carry the sand about and entire dunes are swept away and the sands are built up into new ridges or hills farther inland. But very few forms of animal life are found among these dunes; even insect life is rare and the sound of a bird is seldom heard. The entire area is of very little agricultural value, but in places where the sand ridges may be protected and in the lower areas, fruit growing may be carried on to some extent. The chief value of the dunes is in the sale of the sand for elevating the beds of railways, filling lots, brick manufactories, etc. Thousands of trainloads of sand are annually shipped from the dunes, but the supply is continually increased by the waves and wind.

3. *Marshes.*—Throughout the greater part of its course in Indiana, the Calumet River in the summer season has a very slight current. In places the waters spread out a mile or more and the channel is so obstructed with the water-lily and other aquatic plants, that it is almost impossible to even pass down the stream in a boat. "But in the late winter or early spring time, when the melting snow and heavy rainfalls fill to the brim the low banks, the overflow covers a large amount of the surface, justifying the expression of the early geographers that 'the country around the extreme south bay of Lake Michigan has the appearance of the sea marshes of Louisiana.' It is then that the marshes of the Calumet become the temporary home of thousands of water fowl and the paradise of sportsmen."*

A very large part of the land adjacent to the Calumet River is marsh, but the largest and most important of these areas are known as Cady Marsh, lying between Glenwood and Calumet Beach; the Grand Calumet Marsh, between Tolleston Beach and the low beaches and sand dunes; the Furnessville Marsh, and McDonald's Marsh, southeast of Furnessville.

The marshes are covered with a growth of grasses, bulrushes, reeds, wild rice and other moisture-loving plants. Much of the area is too wet to even allow passing over it. Other parts have been sufficiently drained to allow the cutting of marsh hay. In the marshes wild cranberries grow and excellent crops are produced. With a little care and cultivation, the largest, best flavored and highest-priced berries can be grown on much of the marsh land now uncultivated. Large areas now uncultivated will also produce paying crops of peppermint and celery, both of which require rich, moist soil to be successfully grown.

*22d Annual Report Department of Geology, p. 42.

The soil of the marshes is a dark sandy loam, rich in organic matter. It is porous and retains large quantities of water; below the surface is a darker colored sand and below this is gravel and blue clay of the older glacial till. A noticeable feature of this area is the treeless marsh, bordered by the wooded crests of the beaches.

These marshes contain some peat, valuable as fuel. Several beds are found in the Cady Marsh and several years ago some of these were worked with profit. That of the Grand Calumet area is shallow and loose, and of a poor quality, but may be burned in its crude condition. In the marsh north of Furnessville, peat of a fine quality is found in abundance. Beneath the peat in these marshes is usually found quantities of limonite or bog ore.

Public roads are built through these marshes with difficulty, and the railways which cross over them have trouble in keeping the roadbed in suitable condition.

4. *Morainic Area.*—This includes the slightly elevated area now mostly covered with the lake sand. West of Hobart is a strip of moraine rising out of the southern limit of Chicago, and also between Furnessville and the eastern part of the Little Calumet a practically level area rises above the arm of the ancient lake and the low beaches of the present lake. These higher areas are covered with glacial till, which is also found in a strip one-fourth of a mile to three miles wide, bordering a very large part of the outer margin of the old glacial lake. These tracts will be included in the description of the great morainic belt lying between the Calumet River region and the Kankakee River area.

The Calumet River region is traversed by a dozen lines of the great railway systems, and five great belt railways connecting these roads for transferring freight from one great trunk line to another, cross and intersect the Calumet region, giving to that area the most excellent shipping facilities. In the past few years promoters and capitalists have availed themselves of the opportunity offered by their facilities and about Hammond, East Chicago, Whiting, Hobart, Porter, Chesterton and Gary, have been located some of the largest and most flourishing factories in Indiana. Hammond at present ranks next to Indianapolis as a manufacturing center. The union of cheap coal and iron has attracted to the shores of Lake Michigan, at the new industrial city of Gary, Ind., what will eventually be the largest and most complete iron and steel manufacturing plant in the world. In fact, the Calumet region, with its many railways, its waterways, afford shipping

facilities unrivalled in the world; its close proximity to Chicago, the cheap price at which factory sites can be secured within its bounds, now mark this once little valued region as one of the future great manufacturing districts of the world.

2. The Kankakee Region.

The Kankakee River rises in a large marsh about three miles southwest of South Bend in St. Joseph County. It flows in a southwesterly direction to the Laporte County line, from which point it forms the boundary between the counties of Laporte, Porter and Lake on the north, and Starke, Jasper and Newton on the south. It crosses the State line almost thirty miles south of the point where the Little Calumet crosses. From the State line it flows southwest until it joins with the Iroquois River and then turns to the northwest, where it unites with the Des Plaines, the two forming the Illinois River. The Kankakee is noted for its low banks, the sluggish motion of its waters and the peculiar direction of its [redacted]. From its source to the State line is about 75 miles. Within this distance the stream is said to make 2,000 bends and to flow over a total length of 240 miles, and according to the survey of Dr. J. L. Campbell, in 1882, the difference in level of the two points is but 97.3 feet, showing a fall of but 1.3 feet to the mile. The bed of the river is composed mainly of sand and fine gravel, but in a few places contains rather coarse gravel and large boulders.

The Kankakee marshes comprise the most extensive body of swamp land in Indiana. In the seven counties drained by the Kankakee, the original area of the marsh was almost a half million acres. In many places wild rice, rushes, water-lilies and grasses grow so abundantly in the channel as to cause the flooding of the marshes even during a summer freshet. In former years the river could scarcely be approached, but now more than a dozen railways cross the stream and numerous public highways bridge its waters. In 1872 Rev. T. H. Bell of Crown Point wrote of that portion of the Kankakee bordering on Lake County: "A river is known to be there. The blue line of trees marking its course can be discerned from the prairie heights; but only occasionally in midwinter or in a time of great drought can one come near its water channel. So far as any ordinary access to it from this county is concerned, it is like a fabulous river, or one the existence of which we 'take on trust.' Now within Lake County five north and south

roads reach its borders through the marshes, while three wagon and two railway bridges span its waters. In Porter County six roads lead to it, and one railway and three wagon bridges cross it.

"The surface of this marsh land is for the most part a great treeless plain, with an average slope of about 1.2 feet to the mile in a westerly direction. On the immediate border of the river there is a strip ranging in width from a fourth to one and one-half miles, which is heavily timbered. In the southeastern corner of Lake and on adjacent territory in Porter County this timbered area widens and comprises about ten square miles. The only other timber is found on the so-called 'islands' or 'groves,' whose surfaces rise 10 to 20 feet above the general level of the marsh. All were once covered with a heavy growth of oak, hickory, black gum and other timber, the best of which was long ago removed by the early settlers along the northern border of the marsh. The surface of these islands, when cleared, becomes fair grazing lands, but the soil is in general too sandy for cultivation. On the majority of the 'islands' are houses, in which dwell the owners or renters of the surrounding marsh lands.

"*Vegetation of the Marshes.*—The open marsh is covered with a rank growth of wild grasses, bullrushes, sedges, reeds, wild rice and semi-aquatic vegetation. Over a large area which has been sufficiently drained much of this growth is annually cut, either for bedding or marsh hay. In other places the surface is either too rough, being cut up with sloughs and bogs, or never dries sufficiently to allow teams to pass over it. Oftentimes, after a long drouth, thousands of acres are burned over by a fire which sweeps along with great rapidity, consuming everything in its path.

"Between the woodland bordering the river bank and the marsh, as well as around the margin of most of the islands, there are dense thickets of elbow brush, willows, swamp dogwoods, soft and red maples and other swamp-loving shrubs. These grow so densely that a person has no little difficulty in forcing his way among them. In some places * * * large areas of land, whose soil is a rich, sandy loam, rise above the surrounding swamps. These areas were less heavily timbered than the islands above mentioned, and comprise valuable farming lands.

"*Soil of the Marshes.*—In general the soil of the marsh is a dark, sandy loam, very rich in organic matter. For century upon century a thick mass of vegetation has fallen and decayed, and mingled with its remains have been the particles of sand and clay brought down as sediment by the overflowing waters. No richer

soil occurs in the State, and its depth in many places is from three to five, and even six feet. Like all soils composed of similar materials, it is very porous and has the power of taking up and retaining large quantities of water. Beneath the soil is a sand, darker colored and containing a greater mixture of calcareous and earthy matter than that found near the shores of Lake Michigan. When thrown up by the dredge it packs and becomes hard, forming excellent roadbeds wherever it has been put to that use. Below the sand are layers of fine gravel and below that the omnipresent blue clay of the older glacial tills next above the surface rock.

"*Origin of Kankakee Valley.*—All of the materials lying between the blue clay and the soil are the sedimentary deposits of a post-glacial river, for the valley itself doubtless owes its origin to the flow of waters which followed the melting of one of the later retreating ice sheets. This flow was at first sufficient in volume and velocity to erode the present valley to quite a depth through the underlying clay. Later, on account of a diminution in the supply of water, as well as the gentleness of the slope, the current became too sluggish to erode much deeper or to carry coarse material, and only the finer sediment was brought down. From a still farther diminution in the water supply, as well as by the building up of a sedimentary dam near the western end of the valley, the water for a long period ceased to flow, and a lake of shallow depth resulted. Where the waves or currents of this lake washed against the higher portions of its bed, or its shores, accumulations of sand and mud were thrown up from its bottom. These increased in size, and, rising above the water, became covered with trees. The surface of the 'sand islands' has ever since remained above the flow of waters and, as a consequence, their soil lacks those rich organic constituents formed by the decay of aquatic plants, which are possessed by the soils of the surrounding marsh.

"Again, by a new accession of water from the northwest, the barrier at the foot of the valley was washed away and the river of the present had its beginning. At first the waters flowed the full width of the valley, but in time their volume decreased and a portion of the river's bed became bare in summer. Over this a vegetation sprang up and decayed. A soil was started above the sands and was added to each year by the decay of the summer's vegetation and the sediment brought down by the overflow in the spring. The main current of the stream was thus gradually narrowed until it reached its present size. The annual overflow is yet sufficient to

cover the porous soil and fill its every interstice with water, which, on account of the gentle slope, can not flow rapidly away after the subsidence of the flood. Thus the valley remains a marsh, and will so remain until a complete system of drainage furnishes a more rapid outlet for the waters which are absorbed during the annual overflow." *

The entire region of the Kankakee is commonly known over the State as the "Swamp" or "Marshes." But within this region there are several distinct soil types, grading from the richest to that which is at present absolutely worthless. Yet it is the general opinion that the area is such a worthless tract that at its best nothing more can be gained than the cutting of some marsh hay, or the use to some extent for pasture. It is necessary to make a distinction between the swamps and the marshes, which have a much wider area. We then have the following types in the region: swamp, marsh, island, peat and muck.

1. *Swamp.*—The classification of swamp is based upon topographic position and drainage conditions rather than upon the physical character of the materials of which it is composed. The term designates areas too wet for any crop and covered with standing water for the greater part or all the time. Variation in texture and in organic matter may occur even in small areas. Much swamp land is capable of drainage, and when this is accomplished they constitute lands of high agricultural value.

The swamp area of the Kankakee comprises a strip along the river from one-eighth to two miles in width. It is low-lying and generally level, though more or less broken by old stream channels and lagoons and is under water most of the year. During dry weather some areas become dry enough to allow the cutting of hay and for pasturage. The soil varies from a light sandy soil to a heavy clay loam. The color is very dark on account of the large amount of organic matter that has been added through the growth of a heavy vegetation. The area is practically covered with a heavy growth of water-lilies, wild grasses, sedges, rushes, reeds, wild rice and other water loving plants. On the immediate border of the river is a dense growth of brush, oak, poplar and willow, elbow brush, swamp dogwood, and soft and red maples. A very few acres of the swamp area has been drained sufficiently to admit of cultivation, but under present conditions it can not be drained economically.

2. *Marsh.*—This term designates low, wet, treeless areas, cov-

*W. S. Blatchley *in* 22d Annual Report State Geologist, 1897, 56-59.

ered with water much or all of the time, and supporting a growth of wild grasses, rushes, etc. The marsh area of the Kankakee occupies a broad valley between the borders of the moraines—the Valparaiso moraine on the north and the Iroquois on the south—and the swamp area adjacent to the channel of the river. For at least four months of the year hundreds of thousands of acres are covered with water and during half the remainder of the year much of this area is an immense bog or quagmire. In general, the soil of the marsh is a dark sandy loam, rich in organic matter. For hundreds of years a heavy growth of vegetation has fallen and decayed and become mixed with the sand and clay. The soils may be divided into two distinct classes which gradually merge into each other. The first, a dark gray to black, medium to fine sand is the prevailing type; at varying depths from 6 to 24 inches, the soil grades into a subsoil having about the same texture as the surface soil, but containing much less organic matter. The color ranges from a gray and yellow mottled to a reddish yellow or brown in areas where considerable iron is found. In other areas the subsoil consists of a coarse, fibrous peat, which is underlain by a dark-colored sand containing a high percentage of organic matter. On the average the surface soil of the fine sand areas contains about 60 per cent fine sand, 12 per cent silt and about 6 per cent clay. The subsoil contains about 70 per cent fine sand, 6 per cent silt and about 6 per cent clay.

The second type is a heavy clay loam, of a black color, due to a large amount of organic matter. The subsoil contains more sand but constitutes a sort of "semi-muck," due to the high clay content, which is rather impervious. It checks into cubical blocks upon exposure. In some areas this subsoil is underlaid by a layer of peat, which is underlaid by an impure marl of varying thickness. Usually the soil of this second type grades gradually into the sandy soil and in other areas the line is well defined.

Both of these soils are low lying, wet, practically level, with only a slight fall toward the stream, and hence the first and important question concerning these lands is that of drainage. Can they be drained economically?

A large acreage of the marshes has been partially reclaimed by large ditches, either dredged by private enterprise or by assessment against the adjacent land. The main ditches are cut 20 feet or more across the top and usually with considerable slope toward the bottom, the depth being on the average from 5 to 8 feet. The work is done chiefly by the use of a steam dredge. Leading into

these main channels, laterals are cut, and branching off from these are minor, secondary channels or ditches. Where the banks are left too straight, freezing causes the sides to slough off and partially fill the ditch; the sand and material washed in by subordinate ditches also accumulates in the ditches, so that it is necessary to have them redredged.

Dr. J. L. Campbell in 1881-1882, by authority of an act of the Legislature, prepared a report on the drainage of the Kankakee Marsh. In part he says: "The drainage and recovery of the Kankakee marshes will include: First, the construction of a better main channel than now exists, for the flow of the river; second, the straightening and deepening of the beds of the streams which empty into the main stream; and third, the digging of a large number of lateral ditches through the swamps to the improved channels.

"The Kankakee River below the mouth of Mill Creek (in Laporte County) has a belt of timber along its banks which would make the cost of straightening the river very great.

"The great deflection of the river from the general direction of the valley makes it important to shorten the distance by a new channel.

"The line proposed for the improvement lies in a remarkable part of the valley. The line will be clear from timber obstruction, except about one and one-half miles at the lower end, where it passes through the belt of river bank timber into the old channel. The line lies for the most part in a series of deep marshes, now impassable, and well known in the neighborhood as a deep slough, sand channel, etc."

(For line of proposed channel see map in State Geologist's Report 1897.)

"At Grand Junction, the new channel or the Upper Kankakee, the old channel or the Yellow River section, and Crooked Creek, unite their waters and form the enlarged lower river.

"From Grand Junction to the State line, and to Momence, Illinois, there is plenty of water for the purpose of navigation and it is desirable that the improvement below Grand Junction should be made with reference both to drainage and navigation.

"In addition to the cost of construction, the question of maintenance of the new channel requires consideration. The same causes which produced the present crooked river will in a less degree afflict the straightened stream, and continued care will be required to preserve an unobstructed flow.

"If we assume that the river has an approximately stable bed, the result mainly of the free action of mutual forces on the sandy soil, it is evident that any increase of velocity will affect this stability and introduce a disturbing element which will require special attention.

"The banks of the new channel will likewise deliver quantities of sand into the current until they assume their proper angle of rest and are protected by grass or other vegetable growth.

"The lateral ditches will also bring down masses of sand, which will, if left uncared for, form bars where these ditches empty into the river.

"To meet these difficulties it will be necessary to keep at work one or two dredging machines until the new channel has assumed a partially stable condition.

"Grasses grow most luxuriantly in all parts of the Kankakee Valley, and from this cause we may expect that the banks will be covered very rapidly. After the drainage has been once accomplished and the lands brought under cultivation, there will be a great diminution of the volume of water to be carried off.

"The absorbent power of the reclaimed lands and the evaporating surface will be increased, and the quantity of surplus water will be proportionately diminished.

"The diminished volume will give a relative increased capacity, with less depth, and thus by degrees the new channel will become stable, while at the same time it fulfils all requirements for complete drainage."

The cost of constructing a comprehensive drainage system will be necessarily large; but the land if properly managed, should yield a profitable return on the investment. According to Dr. Campbell, the cost of the improvements for the drainage system west of Mill Creek would be not less than $294,015, and the maximum $390,450. But when we take into consideration the large area to be benefited the cost would be small when estimated by the acre.

The agricultural and crop value of the fine sand areas varies in different areas, depending largely upon the amount of organic matter contained. Areas in which the organic content is small are used chiefly for pasture when sufficiently drained. This type in some places forms dunes, the higher parts of which are either without vegetation or only a sparse growth of bunch grass. In the areas containing a greater percentage of organic matter the staple crops grow and produce fairly well, but as the organic mat-

ter is consumed the average yield decreases from year to year. The average yield of corn which a few years ago was as high as 50 bushels, is now estimated much lower. Oats average about 25 bushels. Timothy makes a fair growth but is usually coarse. The soil is not suited for clover and very little is sown. Some rye is grown, and on well drained areas blue grass grows well. The soil is very suitable for truck farming and for the growing of small fruit. The successful growing of potatoes, however, in this region, depends much upon the season and the drainage conditions, as the crop is often water-killed or rots before coming up. Some stable manure is used as fertilizer, but very rarely has any commercial fertilizer been used. This is a very fairly good grass land and on account of its decrease in organic content when cultivation begins, its value as a grain soil depends very much upon the organic matter added through the application of stable manure or changes to grass.

The U. S. Department of Agriculture, Bureau of Soils, have made examination of a sample of soil from this type, in order to obtain an idea of the manurial requirements, the result of which "by the wire-basket method indicate that stable manure has a moderate effect in increasing the growth of crops; that nitrate of soda and sulphate of potash give a small increase, and that nitrate of soda, sulphate of potash, acid phosphate, or lime used alone or in combination (except as above), have little or no effect. These results were obtained under favorable climatic conditions for the crop and by having the soil in the best possible physical condition, and, while held to be strictly applicable only to the field from which the sample was taken, they substantiate the general farm practice on this type of soil in Newton County, where considerable barnyard manure is applied to the fields with beneficial results and practically no mineral fertilizers are used."

In the heavy clay loam areas a large percentage has already been partially reclaimed and most of such areas can be successfully and economically drained. This soil is very productive and is well adapted to corn, the yield averaging from 40-50 bushels; oats, with a yield of about 35-40 bushels; rye, timothy, clover and blue grass.

In the sandy area sugar beets were formerly raised in a limited way, and produced fairly well, but at present very little attention is given to their production. The soil seems well adapted to their growth and, since they must be rotated with other crops, the beet sugar industry would certainly prove a paying industry for this

area. The beet tops, and refuse beets, are also of value for feeding farm animals, and the improved condition in which land is put by beet cultivation, for better and larger yields to the crops which follow beets, is an advantage to be considered as additional money value.

"Taking into consideration their proximity to Chicago and the excellence of their soil, there is little doubt but that these lands, if permanently drained, would command from $40 to $60 per acre. It would seem, therefore, that private enterprise would have long since provided for their drainage. But in this instance private enterprise has been waiting for State aid, which has been granted only to the extent of partially removing the barrier of rock at Momence. If the State would appropriate $300,000 for straightening the river and reclaiming the lands, it would be only a loan of money soon to be repaid, for the increase in the taxable value of those lands would soon bring back to her coffers far more than the amount expended. The principal reason why such an appropriation is not made doubtless lies in the fact that the lands are, for the most part, owned in tracts of from one to ten thousand acres, instead of by many individuals. The people of the State do not believe in increasing the wealth of these speculative owners by temporarily taxing themselves. Still, as a business enterprise, the State would in time be largely the gainer, and a portion of her area now practically valueless would soon be known as the garden spot of northern Indiana."—W. S. Blatchley in State Geologist's Report for 1897, 64.

3. *Island.*—The "islands" or "groves" rise on an average 10 to 20 feet above the general level of the marsh. They vary in area from a few acres to about four square miles in extent. The surface is very irregular, consisting of slight elevations, rounded hills, and ridges, in a few cases rising to considerable height. The soil consists of a loose, medium to fine sand, varying in color from light brown to yellow, according to the amount of organic material. On the more elevated areas the organic content is very low, the sand loose and drifting, and vegetation often suffers from lack of moisture. The native growth of timber is chiefly a heavy growth of scrub, white and black oaks, hickory, black gum, hazel, sumac and a few quaking aspens. The best of this timber has been removed by the early settlers along the borders of the marshes. The surface of these islands when cleared becomes fair grazing land, but on account of the loose, open character of the soil, and the drifting nature of the sand, it has little agricultural value. Blue

grass grows well on the lower areas. Sorghum is grown to some extent for home use, and melons and early potatoes do fairly well. The growing of fruit has been tried to a limited extent and from results it seems that these areas would be well adapted to fruit. In some places this soil grades into a rich sandy loam, which is less heavily timbered and a more valuable farming land.

4. *Peat.*—The peat areas of Indiana may be divided into two groups: The deposits found within the marsh regions along the Calumet and Kankakee rivers, and the marsh areas in the region of morainic lakes. But wherever found the general characteristics are the same, and their soils may be described as one type. Peat consists of vegetable matter in various stages of decomposition occurring as turf or bog, in low situations, always more or less saturated with water, and representing an advanced stage of swamp, with drainage partially established. Within the region of the Kankakee some extensive peat deposits are found. The soil varies from a coarse, fibrous peat through all stages of decomposition to that of muck. The subsoil varies from a medium to fine sand, in which there is but a small percentage of organic matter, to a light blue clay and in some areas to an impure marl.

As has been the experience in most peaty soils, the farmers have found that the soils of this area produce fairly well for a few years after having been reclaimed, when the productiveness has begun to decline, which shows that the productions of the peat is correlated in some way with the state of the organic matter present, and that as soon as the marsh sod, leaves, trash, etc., plowed under, become thoroughly decayed or consumed the yield of the crops cease to be profitable. The results obtained on an experimental plot of peat soil in McClellan Township, Newton County, under the direction of the Indiana experiment station, show that "two plots upon which muriate of potash and sulphate of potash were applied, respectively, produced at the rate of 48.9 bushels and 40.5 bushels of corn per acre. Where no fertilizer was added the yield was 36.4 bushels. Another plot, where one ton of coarse straw was applied, produced at the rate of 58.5 bushels per acre, or about ten bushels more than the plot fertilized with murate of potash.

"It would seem from these results, together with the generally observed fact that these soils produce well until the marsh sod, etc., is destroyed, that the peat of the area is not lacking in plant food, and that the low yields are due to some unfavorable condition, which was alleviated by the addition of the coarse straw. While

potash improves these soils it seems quite probable that the beneficial results are not due to the plant food thus added, but to some other effect it has upon the soil.''

Corn is grown more extensively upon these soils than any other crop, but the corn is usually of poor quality. Timothy and blue grass may be grown where drainage conditions are good. The soil is adapted to special crops and considerable experimental work is being carried on in these areas. For further description and importance of peat soils, see under ''Peat'' in Morainic Areas.

5. *Muck.*—This type of soil is less extensive in the area under consideration than any other type discussed. The muck occurs around the outer margin of the peat deposits. It may be considered an advanced stage of peat, in which the vegetable decomposition is more complete, and in addition varying amounts of mineral matter have been added. The muck soil does not extend to as great depth as the peat, and is of a finer texture and closer structure.

In accordance with experiments as to manurial requirements of muck soils in this area, it has been found that stable manure and green manure are both very beneficial. Sulphate of potash gave a large increase in growth, but lime, nitrate of soda and acid phosphate had little or no effect. For further discussion of muck soils see under ''Muck'' in Morainic Areas.

3. Morainic Areas.

A study of the form and arrangement of the moraines of Indiana will show a somewhat regular series of crescentric ridges, parallel, in the main, with each other, but in places curved, twisted and crowded together so that there seems to be no general arrangement, and in some cases so inconspicuous that they cannot be traced accurately.

''When the glacier covered most of Indiana the ice was at least 500 or 600 feet deep over the present site of Terre Haute, and nearly as deep over that of Indianapolis, and it thickened gradually northward. If an observer could have stood on one of the hills in Brown County at that time he would have seen to the east of him the great wall of the ice front extending south towards Kentucky, while to the west it would have been seen in the distance stretching away towards the southwest. For hundreds of miles to the east and west, and for 2,000 miles or more to the north, the glaring white desert of snow-covered ice like that seen in the in-

terior of Greenland by Nansen and Peary, would have appeared, stretching away out of sight with not a thing under the sun to relieve the cold monotony. It is hard to think of Indiana and her neighboring sister states as being clothed in such a shroud-like mantle as this. But it was in large part this same ice sheet, coming four or five times in succession, that covered the State with the inexhaustible soil of the drift, and made Indiana the fertile agricultural State that she is today.

"Three glacier lobes, corresponding to as many basins toward the north, entered Indiana; the Erie (with which was combined the lobe from Lake Huron) covered the eastern part of the State, and the Saginaw and Michigan lobes combined to cover the northern and western parts. The combined effect of the extent, relative strength, oscillations, conflicts and the relative positions of these lobes was the prime factor in shaping the topography of the northern half of the State. With the probable exception of the Wabash below Attica, every stream in this area had its course determined or largely modified by the features of the drift, and especially by the moraines. If the lake basins had been absent or differently located, or if the ice had advanced from a different direction, the drainage systems and the general arrangement of the physical features of this part of Indiana would have been entirely different." *

"Whenever a glacier has reached the limit of its advance and there halted a sufficient length of time to deposit a large amount of debris, such an accumulation is called a terminal moraine. This moraine does not consist, as is often supposed, of numerous large bowlders, which have been dropped on the surface in more or less regular concentric lines. Such bowlders are only an accompaniment, and constitute but a very small fraction of the moraine proper. The main portion usually consists of a thick bed of compacted tough clay, in which are many pebbles and bowlders of small size, and often pockets of gravel and sand. Such a moraine may be a number of miles in width and consist of many small parallel ridges, or it may have been a number of subordinate ridges branching off in every direction from the main one. These 'unite, interlock, separate, appear and disappear in an intricate manner. Several of these subordinate ridges are often plainly discernible. It is usually between them and occupying depressions caused by their divergence that most of the larger lakes embraced in the moraine are found. * * * The component ridges are them-

*B. F. Taylor, Studies in Indiana Geography, 1897, 97, 102.

selves exceedingly irregular in height and breadth, being often much broken and interrupted.' When very complex, the term 'morainic system' is often given to a terminal moraine.''*

The great rugged and massive morainic belts are ''hills of accumulation'' formed by the excessive dumping and heaping up of drift along the margins and between the lobes of the melting ice-sheet. The more rugged part consist of dome shaped hills as steep as the material will lie, and in many cases reaching to a considerable height. The best examples of this type are found in Steuben, Lagrange, Noble and Kosciusko counties. There are many morainic ridges of slight elevation and gentle slopes, which are scarcely noticeable except for their influence upon streams. In addition to these are the long, narrow, curving strips thickly covered with large bowlders—known as ''bowlder belts.''

The principal morainic belts are, (a) *Valparaiso Moraine,* separating the basins of the Kankakee and Calumet rivers. It is about fifteen miles in width and is due to the last advance of the great Michigan lobe. The surface of this moraine to the north and northeast is more broken and irregular than farther to the south. The soil overlies a thick bed of clay, in which are imbedded many pebbles and small bowlders, and becomes quite gravely to the east.

The crest is a wooded ridge intersected toward the north by numerous other ridges composed mainly of stiff, yellowish white clay containing many pebbles and fragments of limestone.

Extending across from Illinois on either side of the main crest a high rolling prairie sets in and extends to Cedar Lake, where a wooded table land begins stretching eastward for six or seven miles, when the rich prairie again comes in on the south of the crest and extends to the vicinity of Hebron, where it is again interrupted with the timbered areas; then, again, north of Hebron, a prairie again rises until it reaches the region of high ridges and morainic lakes.

The soil of the prairie is a rich black loam, from one to three feet in thickness, overlying the clay till of the moraine. This clay varies in thickness from 40 to 65 feet, beneath which is a layer of sand of varying thickness, which furnishes a good supply of water. The soil of the wooded tract and the broken ridges to the northeast is of a yellowish white clay, far less rich and productive than that of the prairie. In the more broken parts, bowlders of large size are very plentiful. With the exception of the Calumet and Kankakee rivers, all the principal streams which drain this area have their

*W. S. Blatchley, State Geologist's Report, 1897, 31.

sources on or near the crest of the moraine, except a few tributaries which flow through breaks in the crest.

(b) *Moraines of Erie-Wabash Region.*—This region extends from the west end of Lake Erie southwestward across Ohio to Central Indiana. There are in northeastern Indiana massive moraines twenty-five miles in width, extending from Steuben County to Cass, with arms making broad, sweeping curves to the southeast, to the south of the Wabash River. This massive morainic belt consists of a part of four or five great moraines. The part covering Steuben, Lagrange, Noble, Kosciusco, Whitley, and on to the southwest through Cass, is a typical terminal moraine in all its phases. The surface is a confused series of irregular valleys and narrow, winding ridges, consisting of clay, sand and gravel and bowlders piled together, and in many places rising 200 feet or more with the slopes as steep as the material will lie. But in general the greater part of the area the slopes are more gentle and the tops of the ridges are broad, yet there is very little level ground. Throughout this morainic region the depressions are occupied by marshes or lakes ranging in area from the fraction of an acre to several square miles and numbering more than a thousand within the State. Within this region is a great variety of soils. Underlying all is the stiff, gravelly clay, similar to the great mass of drift, and forming the surface soil over the greater part of the area, but containing in places great heaps of sand, gravel and bowlders. Many shallow lakes have been entirely or partly filled with heavy growth of vegetation and converted into marshes or muck lands, much fine material has been washed into the old valleys, producing a fertile soil of fine texture.

"The whole region was originally covered with a heavy growth of hardwood forest, except the marshes, or so-called 'wet prairies,' and a few small tracts of genuine dry prairie in the northwest. No equal area has furnished more valuable timber, oak, walnut, beech, maple, ash, elm, sycamore, poplar, hickory, locust, cherry and others. For unknown centuries before the advent of the white man, the Indian hunted in the forests and fished in the lakes. The Maumee-Wabash was an important route of canoe travel between the Great Lakes and the Ohio. The carry or portage from the head of the Maumee over to the little stream which now occupies the Erie-Wabash channel was short and easy, and in 1680 LaSalle found there an Indian village and fur-trading post. Here was a favorite congregating place for men, savage and civilized, at the forks of four water-ways, and the spot was naturally predestined to

be the site of an important town. It has passed through all the regular stages characteristic of so many American towns, Indian village and portage, trading post, military fort, modern city. It was as easy a route for the canal boat as for the canoe, and as early as 1834 the Wabash and Erie canal was constructed through it, having its summit level in the abandoned glacial drainage channel, and fed with water from the St. Joseph. Towns sprang up all along its course and Defiance, Fort Wayne, Huntington, Wabash and Peru owe their early start and substantial growth to their situation upon this line of communication.

"Twenty years after the canal, the Wabash Railroad followed the same route and now three east and west trunk lines avail themselves of the Fort Wayne gap to pass through the highlands. At the same time the Maumee Lake bottom, known as 'the black swamp,' with its tenacious soil, poor drainage, and absence of road-making materials, offered a serious obstacle to immigration by wagon from the east, delaying the settlement of the country until long after that of Southern Indiana. The tide of immigration did not come in until the decade 1840-50. The heavy forest was but an indication of the fertility of the soil. The pioneers had the strength and courage to attack, and with incredible labor to clear it away. Their reward was the rich farms which now form the greater part of the wealth of the region. Many of the marshes have been drained, among the rest the Erie-Wabash channel itself, thus adding to the health and productiveness of the country. The hills and lakes remain, and render the region of the higher moraines among the most picturesque and beautiful under the sun. The Maumee Lake bottom has been last to come under the hand of man, and within the last year many square miles of virgin soil have been cleared, drained and brought under profitable cultivation. Every feature of the Erie-Wabash region, natural or artificial, marsh, lake and hill, forest and farm, lonely cabin and prosperous city—is, in a real sense, the gift to man from the Erie lobe of the North American ice-sheet."*

Other Moraines.—Numerous arms of the chief moraines branch in every direction, and the remnants of other moraines are found scattered over the entire area as far south as the boundary of the Wisconsin drift. Some of these are several miles in width and rise to a considerable elevation above the surrounding country, and are decidedly undulatory and rolling; others are almost inconspicuous except their presence is shown by their influence upon drainage.

*Charles R. Dryer, in Studies in Indiana Geography, 1897, pp. 51, 52.

In general the texture of the soils is a yellow clay, mixed with sand and gravel, and frequently grading into a fine sandy loam.

In the morainic region the various kinds of soil may be included under the following types: fine sand, sandy loam, black clay loam, silt loam, peat, muck and meadow. Of these general types many divisions might be made by one type grading into another, giving a difference in fineness, color, etc.

1. *Fine Sand.*—This soil is found chiefly in the low hills and ridges and probably represent deposits of glacial outwash made during the recession of the ice-sheets, and has since been modified to some extent by the wind action. The soil consists of a medium fine sand, grading from light to dark brown, due to the amount of organic matter contained. The subsoil is about the same texture as the surface, except in places it becomes more gravelly. Drainage conditions are well developed and crops often suffer from the effects of drought, hence the wet seasons are more favorable for this type. Corn, oats, rye and timothy are the principal crops, and the yields are only fair. The soil is well adapted to vegetables and melons, but very little attention has been given to such crops.

2. *Sandy Loam.*—The surface of the area covered by this type is for the most part undulating and rolling. The soil is a medium to fine sandy loam, and contains a high percentage of organic matter, giving to the soil a very dark color. The subsoil underlying this type varies greatly in different areas. It consists of clay sand and gravel in varying proportions, usually becoming more gravelly with depth. In some small areas the surface soil becomes quite gravelly and some large bowlders are found scattered over the surface. Natural drainage is good, but artificial drainage increases the productiveness of the soil. This type in general is a productive soil and is adapted to a great variety of crops; corn and oats are the chief crops. Timothy and clover are grown, but it is usually difficult to obtain a good stand of clover on account of the dry summer weather. Blue grass is grown for pasture and wheat is grown to some extent, but its yield is uncertain. Some fruit is grown and the soil seems fairly well adapted to the growing of fruit.

3. *Black Clay Loam.*—This is a heavy clay loam, carrying about equal proportions of clay and silt and a considerable percentage of fine sand. The color is due to the organic content and this type varies in color from black to yellow. The soil when wet is often of a mucky nature, and if worked when in this condition large clods are formed, which become very hard and can scarcely be pulverized until moistened again by rain. The subsoil is a mucky, yel-

low colored clay, almost impervious, and causes the natural drainage to be very poor. This type occupies the basin-like depressions between the hills and ridges and the surface is generally level. The fine texture of this soil has been increased by the washings of fine particles from higher elevations. Corn is the principal crop of this soil, and yields on an average about 45 bushels per acre. Oats yield from 30-40 bushels per acre, but often lodge badly and the crop is uncertain. Timothy yields well and the better drained areas are well adapted to the production of clover.

4. *Silt Loam.*—This type is found chiefly occupying the upland along the Wabash River, and belongs both to the morainic and intermorainic region. It is due to the deposition of loess over glacial drift. The greater part of the surface is level, but in places is somewhat broken. On the level areas the soil is much deeper than on the rolling tracts. It grades in color from a brown to black loam, and contains a very high percentage of silt. Large amounts of organic matter have been added to the level areas and shallow depressions, while in the more elevated parts organic matter is almost lacking and the soil is of a very light color and far less productive. The principal part of the area comprises the typical prairie lands of this section with the heavy nature growth of grasses and other prairie vegetation. Along the streams and in the more hilly parts are found forest growths of oak, ash, walnut, maple and hickory. In general the natural drainage is good, but artificial drainage is necessary in the lower areas. Corn, oats, wheat and clover are the chief crops produced. The average yield of corn is about 45 bushels, oats about 50 bushels, wheat about 20 bushels per acre, and clover about two tons per acre. Wheat does better on the lighter areas, and corn produces better on the heavy, dark areas. The hilly tracts are used principally for pasture and fruit. The subsoil grades from a sandy silt or clay to a medium gravel, and contains a considerable number of iron concretions, which impart a rusty yellow color to the soil. From experiment as to the manurial requirements of this soil, the Indiana Experiment Station has found that an excellent increase in production may be obtained by the use of stable manure; that nitrate of soda, with either sulphate of potash or acid phosphate, will give a large increase, and that cowpeas and lime, acid phosphate alone, or nitrate of soda alone, will give a fair increase. Sulphate of potash or lime gave only a small increase. The samples were taken from a field that had been planted to corn most of the time for 20 years, and no fertilizer of any kind had been used, and the average yield was about 30 to 35

bushels per acre. In the tests wheat plants were used as an indicator, and the results were not held to be applicable to other and unrelated crops, or to fields which have received treatments essentially different from that from which the sample was taken.

5. *Peat.*—Peat is found to some extent in all parts of the areas covered by the Wisconsin drift, but the large areas found in the three northern tiers of counties. These areas are the site of old glacial lakes, bayous and sand-dune lake basins. The soil is of a brownish color and varies from a coarse, raw fibrous peat, in which the percentage of combustible matter is extremely high, through all stages of decomposition to that of muck. The peat is usually much deeper than the muck, generally extending to a depth of 8 to 12 feet. The subsoil varies from a medium to fine sand, containing a very low percentage of organic matter. In some places the subsoil is a light blue or gray sandy clay, and in some small areas the subsoil is a marl. The peat deposits have been found by the gradual accumulation of organic remains in low situations, with a very slight fall toward the drainage. These areas are always more or less saturated with water, representing an advanced stage of swamp with drainage partly established. In the spring of the year large amounts of water accumulate, both from melting snow and spring rains, so that practically the whole areas are under water. The drainage of these areas is of very great importance to the State and especially to the land owners of these sections. Large areas have been fairly well drained by a system of dredged ditches, but these have not proven satisfactory; the cost has been great and the desired results have not been obtained. The ditches are difficult to keep open on account of the slight fall. The tile drains become choked with fiber and sand. An economic drainage would mean millions to this part of the State. In most cases the peat land produces fairly well for two or three years after it has been drained, and then begins to decline, but it is believed that the soil will gradually improve with careful cultivation, and may be especially adapted for special crops. Considerable corn is grown upon this soil, giving for the first few years a fair yield, but of a rather poor, chaffy quality. Grasses may be grown on reasonably well drained areas, but with little profit. Some areas are adapted to truck farming, but to the present time but little has been undertaken. When the peat is reclaimed it should be well adapted to corn, rape, grasses, potatoes, onions, celery, cranberries and similar crops in small fruit and truck. From investigations of the experiment stations of Illinois, Wisconsin and Indiana, on these and similar soils, it has been

found that they are in need of potash, and in some cases potash, phosphoric acid and stable manure should be applied to make them productive. But in many cases it has been found that where coarse straw was applied the yield was greater than where muriate of potash was used. In the areas under these conditions it would appear that the peat is not lacking in plant food, and that the low yields were due to some unfavorable condition which was overcome by the addition of coarse straw. Both stable manure and green manure are beneficial on these soils. These soils contain a high percentage of nitrogen, which would make it peculiarly adapted to corn, rape, grasses, etc., mentioned above. Aside from the condition already given, the chief difficulties in farming peat soil are great amounts of water in spring, danger of frost and the accumulation of nitrates. Even under the best condition, the soils are often too wet to admit early spring sowing, and crops are often planted two or three times before a successful stand is secured. This shortens the growing season and frost often comes before the crops mature. The presence of nitrates stimulate stalk and leaf growth, and being in excess, the grain crops fall badly.

Peaty soils and all those containing large amounts of humus are liable to visible shrinkage. When passing from the wet to dry conditions, but in their texture being loose and porous, such shrinkage does not usually cause cracks in the soil or injure the roots, as is the case in heavy clay lands. The entire mass of the soil shrinks downward, but rarely cracks on the surface. From these observations it shows that the introduction of "humus" into heavy clay soils is among the best means of improving their tilling qualities.

6. *Muck.*—The "muck" areas of Indiana occur most extensively in the four northern tiers of counties and especially in the localities where the peat deposits are largest and most numerous. This type is composed of a more or less thoroughly decomposed vegetable mould occupying low, wet places, with little or no natural drainage, and are locally known as "marshes." The surface soil is usually of a very black color, grading into a reddish brown down from the surface as the depth increases. The muck varies in depth from 1 to 3 feet or more. The muck is an advanced stage of peat decomposition, with the addition of mineral matter, brought in by water and wind. A white sand or sandy clay usually underlies the muck. This type is found in areas of a few acres up to 2 and 3 miles in extent. The muck areas are almost level and are supposed at one time to have been shallow lakes or ponds. In some cases muck is

found entirely surrounding a lake; it is also found in streams in narrow strips. The vegetation consists of swamp grasses, coarse sedges, mosses, golden-rod, willow, huckleberry bushes, cottonwood, alder and birch, with a very few larger trees around the edges.

Artificial drainage is necessary before the areas can be used, except for pasture and for marsh and timothy hay, which are generally of a poor quality, but yielding from 1 to 3 tons per acre. When drained, muck is very productive and well adapted to corn, potatoes, cabbage, onions, celery, peppermint, etc.

Much has been accomplished in drainage by the large open ditches which are made by the steam dredge; the tile drains empty into the larger ditches. But at the present time more than three-fourths of the area remains undrained.

In recent years the muck lands, which were formerly considered of very little value, are becoming valuable and some of them, where truck farming is carried on, sell as high as $150 per acre. Without fertilizer, the yield is less. The improvement of the muck is brought about by mixing it with clay, sand, manure, or straw, by adding fertilizer and by bringing several inches off the surface in the thicker beds. The plowing under of the fertilizer, such as straw and manure, not only enrich the muck by supplying potash, but also interferes with the capillary rising of the water level, and thus permits the soil to dry out. In general the clayey subsoil is preferred to that of underlying sand.

"Chemical analysis of the muck by the Agricultural Station of Indiana, shows a typical muck soil of Indiana, when dry, to contain about three-tenths per cent of potash, the same amount of phosphoric acid, and from three and one-half to four per cent of nitrogen; while a clay subsoil of the State has about two per cent of potash and one-tenth per cent each of phosphoric acid and nitrogen. This indicates that the muck runs very low in potash and high in nitrogen, while the clay has a fair amount of potash, but becomes in a few years deficient in nitrogen. Sand runs much higher in potash and lower in nitrogen than the muck; and straw and barnyard manure contain considerable amounts of potash.

"When muck is added to clay or sand, the improvement of the soil may result from the power of the muck to absorb and retain water, thus, to some extent, replacing the dry condition by a moist one and influencing the temperature of the soil. The various organic acids attack the complex silicates, breaking them down through solution into the more simple forms. Solution and weath

ering brings on disintegration, which produces a more comminuted form of the material. Ammonia is added, which gives nitrogen to the soil.

"The effect of mixing muck, clay and sand is very well illustrated in Allen County, on the farm of Thomas Elliston, in the southeast quarter of section 26, the southwest of 25, the northwest of 36, and northern half of 35 (30 N. 11 E.). Here, where Lost Creek empties into Little River, 200 acres are composed of a mixture of muck, clay and sand. This association resulted from the fact that Lost Creek has a fall of 7½ feet to the mile, while Little River has only 1½ feet. At times of flood the steeper grade developed a strong current in Lost Creek, which, upon meeting the more quiet waters of Little River, slackened its rate and deposited sand and silt upon the muck beds that fill the river valley. Corn crops raised on this mixed soil are reputed to average at least 70 bushels to the acre, while the adjacent land, composed of either muck or sand, will scarcely yield 47 bushels to the acre. This seems to indicate that none of these soils alone contain all of the constituents necessary for plant growth, but the combination furnishes the necessary food. Numerous other cases were brought to the writer's notice, where the farmers would haul sand or clay onto the muck, or vice versa. In all of these instances, the results are said to have been very good.

"Although the burning of the surface in order that the inorganic material contained by the muck may be concentrated, is frequently resorted to with good results, yet the waste of fuel is enormous, and the improvement in the soil will not begin to recompense for the loss of peat. Mr. H. Fancher, whose farm is located five miles west and one mile north of Hamlet, Starke County, experimented by turning 1½ acres to a depth of 6 inches. Afterward he put on 300 pounds of Armour's High Grade Potato Grower Fertilizer, which is said to contain 8 per cent of potash. The yield on this 1½ acres was 1,030 bushels of onions, while on ground adjacent to it that was not burned, but was treated with the same amount of fertilizer, the crop was less than 400 bushels to the acre.

"In section 30 (33 N. 13 E.) of Dekalb County, about 4 inches of muck was added to a clay soil that was very cloggy. During the first season the muck dried out and did not mix with the clay, the clogs remained and the production was lower than previously. But when the fall rains came on, followed by the freezing and thawing of the winter, and then the spring rains, the muck and

clay became well mixed. The clogs disappeared and the annual yield was decidedly increased. The kernel of the potato, instead of being mealy and thick shelled, like that raised on the pure muck in this vicinity, was firm and large like that produced on a clay soil.

"Farmers who have both sand and clay underlying their muck, say, in general, that they prefer the clayey subsoil. Where the land has been drained the muck overlying the clay requires less fertilizer to keep it in a good condition, and seems to improve with age. The writer will suggest two possibilities that may account in part for this improvement. It is to be noted, where the muck beds do not exceed 2½ or 3 feet, that the crayfish carry up the clay to the surface much more than they do the sand. This permits a more thorough mixing of the muck and clay than of the muck and sand, and consequently a greater addition of potash to the former than to the latter.

"Charles Fairfield, whose farm lies several miles northwest of Ft. Wayne, experimented by putting the muck on a sandy soil, which previously had grown twelve bushels to the acre. The same soil, after manuring, yielded 35 bushels to the acre. The first year after putting on several inches of muck and plowing it in, the production was less than 12 bushels. The muck did not seem to dry out and become well mixed with the sand. The next year there was a great improvement in the soil and a yield of 35 bushels to the acre, and for several succeeding years the crops were no smaller."*

Undrained muck land sells at an average of about $25 per acre, and when drained the value is more than double, often selling for $75 and upwards. Corn in the drained areas yields from 40-75 bushels per acre. At present the greater part of this type is used for pasture and hay.

7. *"Meadow."*—The term meadow is used to designate low-lying, flat, poorly drained land, in areas adjacent to water courses, or subjected to overflow or seepage, such as may occur in any soil type. The term represents a condition, irrespective of soil texture or vegetation. Soils of this type are used chiefly for pasture or forestry, and can in most cases, when cleared and drained, be made tillable land, of high value for the production of various general farm crops. The soils of this type frequently vary in texture, even in very small areas, and being subject to overflow, the character of the soil at any point may be changed, and does not permit of detailed mapping as distinct types.

*A. E. Taylor, State Geologist's Report, 1906, p. 286.

4. Intermorainic Area.

Lying between the morainic belts are large areas comprising the most fertile agricultural tracts within the State. This area extends as far south as the limit of the Wisconsin drift. While the limit is not marked by a well-defined ridging of drift along the border, the limit is determined by the concealment of the loess beneath a thin sheet of bowldery drift. Within a very short distance one will pass from loess covered tracts of earlier drift to the bowldery drift of the latter invasion. The change is also marked by color of the soil from a pale yellowish or ashy color, to a rich black. It is this rich black soil which is the prevailing type within the intermorainic area, and that which gives to it its great agricultural importance. It is this soil, especially, that places Indiana in the front rank as a great corn producing State. It is not to be understood that this is the only type within this area, but there are numerous types—sandy loam, silt loam, gravel areas, peat, muck, meadow and various kinds of clay loam grading through all colors, containing varying proportions of organic matter, and variously adapted from an agricultural standpoint. The silt loam, peat, muck and meadow areas of other areas have been described in the foregoing pages, and need here only be mentioned as occurring within the area under consideration, since these types, wherever found, are of the same general characteristics and crop values.

1. *Sandy Loam.*—The soil of the sandy loam type generally occurs on a rolling topography. The soil or the higher elevations being a light-brown sandy loam, underlain by a yellow sandy clay or gravelly clay. The depressions have a black sandy loam of greater depth and containing less gravel than the higher elevations, and the subsoil in general is a heavy, bluish gray, sandy loam. Near the streams both the soil and subsoil contain considerable gravel. Several bowlders are found scattered over the surface. Small areas of this type are found scattered through the other types of this region. The sandy loam is especially adapted to truck farming and the growing of small fruits. Corn yields from 25 to 60 bushels, wheat from 10 to 20 bushels. Clover and timothy give fair yields.

2. *Gravel Areas.*—Small areas of gravelly soil occur within the other types. These grade from a coarse sand containing large pebbles to a coarse gravel in which are found numerous large bowlders. These gravelly areas frequently occur as the subsoil of other types. In the sandy loam areas on the higher tracts are spots

which are quite gravelly. These spots of coarse sand and gravel are clearly defined during the growing season, as the crops upon them frequently suffer from lack of moisture. Corn, clover, oats and wheat are the principal crops. The yields are best when the rainfall is quite evenly distributed throughout the growing season.

3. *White Clay Loam.*—This type is found in small areas usually bordering muck areas. The soil is somewhat silty in character and contains a large proportion of fine sand. It is of little agricultural value, yet in the better parts it produces a fair yield of corn and wheat, and is well suited for pasture land.

4. *Yellow Clay Loam.*—This soil is of a brown color when wet or newly plowed, but becomes light yellow when dry. It contains considerable coarse sand, and a relatively high percentage of silt. Many small pebbles are found in the surface of this soil and a few small bowlders, but not in sufficeint quantity to interfere with cultivation. When dry the soil is light and easily tilled, but when wet becomes quite sticky; in general it contains a small amount of organic matter. The subsoil is a heavy, tenacious clay of mottled yellow color, grading into a gravelly, sandy loam. The natural drainage conditions are only fair and artificial drainage is necessary for the best results. Corn is the principal crop and yields on the average from 35 to 45 bushels; wheat will, in favorable seasons, yield 20 bushels, and oats yield about 40 bushels.

4. *Black Clay Loam.*—The soils under this heading consist of two or three distinct types. The chief divisions are the timbered areas of central and eastern Indiana, and the prairie tracts of the central western part of the State.

The native forest growth of the first division consists chiefly of red and white oak, walnut, beech, ash, wild cherry, hickory, elm, etc. The soil consists of a dark brown or black loam of fine texture, and very rich in organic matter. The areas are practically level, but are low lying in reference to surrounding types. In some places where the drainage is bad the soil is of a heavy nature and is apt to form large, hard clods when plowed. The entire area of this type must be well drained by artificial ditches in order to be in proper condition for successful tillage. The depth of the soil varies from 6 to 24 inches. The subsoil varies from a heavy loam to a medium to fine gravel, mixed with some clay. All the grain crops are grown successfully on this type, but corn gives the best yield, often producing as high as 75 bushels per acre, but averaging about 40 bushels. When the season is not too wet oats grow well and give

a good yield, as in former years; it now averages about 12-15 bushels per acre. Much of the wheat in the past few years has been winter-killed, and the acreage grown to wheat is becoming less each year, and more oats are sown. The oats are used largely as a nurse crop for clover and timothy, both of which yield well in this area.

The soil of the second division, the black loam of the prairie tracts, is designated by the United States Bureau of Soils as the Marshall loam, which, by the mechanical analysis, shows about 24 per cent clay, 37 per cent silt and 21 per cent fine sand. The area covered by this type is mainly a level plain sloping gently toward the drainage channels. The surface is sometimes broken by small, shallow depressions and slight knolls and ridges. The surface soil is a black or dark brown loam, varying in depth from 8 to 24 inches. In places this soil has the characteristics of a silt loam. On the low knolls and ridges the soil is more sandy than the typical loam. Below the surface the soil becomes lighter colored, and at an average depth of 12-18 inches the subsoil grades into a yellow clay loam, which, as depth increases, becomes more sandy and in some areas becomes coarse gravel. Some gravel and a large number of bowlders occur on the surface. Most of these have been picked from the fields and piled along the fences, and in some places have been constructed of these large bowlders. They are also used for foundation stone for buildings. The dark color of the soil is due to the large amount of organic matter which has been added by the decay of a heavy growth of prairie vegetation, and as the organic content decreases on the more elevated tracts and in the subsoil the color becomes lighter. The clay subsoil is often a mottled yellow, due to the presence of irony concretions.

In the more rolling parts natural drainage conditions are well developed, but in the level areas tile drainage is necessary to insure productions of good crops. A large proportion has been tiled, but there yet remains much to be done before the largest yields can be expected.

The soil of this type is especially adapted to the production of corn and oats and has been used almost exclusively for these crops. This continual cropping system has caused the productiveness of the soil to decline, so that the average yield is considerably lower than 15 or 20 years ago. The average for corn is about 35-40 bushels per acre. Some wheat is grown, but does not give a good yield. Clover and timothy are grown to some extent, but it is often difficult to get a stand of these crops. Blue grass and white clover

are sown together for pasture. Fruit and vegetables are grown for home use. They produce well on this soil, but as yet very little attention has been given to their cultivation.

"There are a number of unproductive spots in the Marshall loam that are locally called 'alkali spots.' Their unproductiveness, however, is not due to the presence of alkali salts. Before this part of the county was drained these areas, which occupy depressions too small to be shown on the map, were known as 'sink holes' or 'quicksand' areas, and the soil is now generally somewhat more sandy than the neighboring productive lands, while the subsoil is largely composed of sand. Liberal applications of stable manure increase the productiveness, and large quantities of straw have been burned on them with good results.

"A test was made to determine the manurial requirements of this type, using a large sample collected about 1½ miles west of Goodland. The soil here consists of a dark brown to black, heavy silt loam, and the sample was taken to a depth of six inches. The land has been in cultivation for from twenty to thirty years, the chief crops being corn and oats, with some grass. Moderate applications of stable manure are used, but no other fertilizers. Yields of both corn and oats average about 40 bushels per acre, while hay averages about 1½ tons per acre.

"The results of the examination of this sample by the wire-basket method indicate that stable manure has a large effect in increasing the growth of the crop. Results obtained with nitrate of soda, sulphate of potash, acid phosphate, and lime, used separately and in various combinations with each other, were small, and were no greater when two or more of these substances were used in combination than when one is used by itself.

"These results are held to be applicable only to the field from which the sample was taken, but it may be stated that they agree well with the experience of farmers upon this type of soil."*

5. Loess Covered Areas.

The line between the loess covered areas and the bowldery drift is one of great agricultural importance. There is a notable difference of topography, soil, vegetation and general improvement. The soil changes from the rich black, so well adapted to corn and oats and hay, and many special crops, to that of the loess covered area, with its pale yellow color, and producing only fair yields of the

*Field Operation, Bureau of Soils, 1905, pages 16-18.

staple crops, with the exception of wheat, which is usually above the average; but the soil is somewhat well suited to the growing of fruit, and special crops, when care and intelligence are manifested in cultivation. The loess of Indiana is more compact, and less uniform in texture and of less fertility than soils usually described as typical loess. These soils contain about 75 per cent silt and 18 per cent clay, and a small percentage of medium and fine sand.

"Loess is a term applied to a fine-grained, yellowish silt or loam, which overspreads the southern portion of the glacial drift in North America and extends thence southward on the borders of the Mississippi Valley to the shores of the Gulf of Mexico. The term was originally applied to deposits of this character on the Rhine, which have extensive development in the German lowlands and bordering districts in Northern Europe. Microscopical analysis shows it to consist principally of quartz grains, but it usually has a variety of other minerals such as occur in the glacial drift. It is apparently derived from the drift, either by the action of the water or wind. In many places, especially the borders of the large valleys, the loess is charged with calcareous matter which partially cements it. When excavations are made in it the banks will stand for years and will retain inscriptions nearly as well as the more solid rock formations. It has a strong tendency to vertical cleavage, and usually presents nearly perpendicular banks on the borders of streams which erode it. It often contains concretions of irregular nodules of lime and of iron and manganese oxides. It is also often highly fossileferous. The fossils are usually land and fresh-water mollusks, but occasionally insects and bones of mammals are found.

"There is in Western Indiana along the Wabash, a loess of more recent date than the main deposit, but it is confined to low altitudes, seldom appearing more than one hundred feet above the river level. In Western Illinois, a loess has been found which is older than the main deposits, but it has been seen in only a few places and is apparently a thin and patchy deposit. It is thought by Professor Salisbury that the loess of the lower Mississippi was deposited at two distinct stages. Loess is, therefore, a deposit which, like sand or gravel, may be laid down whenever conditions are favorable, but the great bulk of it having been deposited at a definite stage of the glacial period, it seems proper to refer to that stage as the loess stage.

"In Southern Indiana, and in bordering portions of Southern Ohio and Southern Illinois, there is a continuous sheet of pale silt, locally termed 'white clay,' which is thought to be a phase of the

loess. It covers the interfluvial tracts as far north as the limits of a later sheet of drift and has been discovered at a few places below that later drift. It probably extended much farther north than its present exposed limits, for the ice-sheet appears to have receded far to the north at the main loess depositing stage, thus leaving the surface free to receive these deposits. The northern limit of the exposed portion in Indiana is marked by the 'Wisconsin boundary.' This deposit is usually but a few feet in thickness, seldom exceeding eight feet. Along the Wabash, however, where it becomes a typical loess, it often reaches a thickness of twenty to twenty-five feet It may be readily distinguished from the underlying till by texture and color. It contains only very minute rock fragments, while the till is thickly set with stones of all sizes. In color it is a paler yellow than the till. There is usually also a weathered zone at the top of the till and sometimes a black soil, making still more clear the line of contact.

"The loess and its associated silts is found at all altitudes in Southern Indiana; from the low tracts near the Wabash, scarcely 400 feet A. T., up to the most elevated tracts in Southeastern Indiana, which in places exceed 1,000 feet A. T. The great range in altitude is one of the most puzzling features of the loess. The same perplexing distribution is found in Europe as in America. As yet no satisfactory solution for the problem of its deposition at such widely different altitudes has been found."*

Large areas within the limits of the region here described belong to the alluvial soils, and will be presented under that heading. The silty loess material has contributed considerable material to some of the alluvial types. Some areas of peat are also found and large marshes are numerous, especially in the southwestern part of the State. In Knox County about 4,000 acres have been reclaimed in the vicinity of Decker by the completion of the Plass ditch. The ditch runs through six miles of what has been the least valuable land in Knox County. About 25,000 acres near the swamp will also be increased in value by this ditch. The ditch will cost the owners of the land affected about $60,000. The improvement will result in the value of Knox County real estate being raised at least $200,000. In addition to the draining of the large tract of land the ditch robbed the Wabash River of one of its tributaries, the Du-Chien River. Before the ditch was constructed this river emptied into Wabash River a few miles above Mt. Carmel, Illinois. Now

*Frank Leverett. United States Geological Survey. See Dryer's Studies in Indiana Geography, pp. 35–36.

the stream empties into White River, using the ditch as its channel for six miles of its course. Before the completion of the ditch the Du Chien River was the only outlet for these swamp lands; but the river never did its work and the swamp spread out over a wide area.

The loess soils are easily cultivated. Much of the surface of a well tilled field is frequently a loose floury dust and the small clods are easily broken. It may be plowed when rather wet and yet easily be worked to a loose, pliable condition. There is a marked deficiency of organic matter in the virgin soil and as this amount becomes less the soils get in a poor physical condition and are sometimes difficult to manage. A large amount of commercial fertilizer is used, but a systematic rotation of crops and good application of stable manure and straw are necessary to keep the soils in a good state of cultivation.

The average yield of corn is about 40 bushels, but the yield varies greatly, even on adjoining farms. Oats average less than 30 bushels and the yield is very dependent on the season. Wheat averages about 15 bushels. Timothy and clover yield about one and a quarter tons per acre. A large acreage has been sown in alfalfa during the past few years. Potatoes average from 50-80 bushels. In some of the counties melons are grown extensively, and much small fruit is raised for the market. Much of the land is used for pasture, but when left uncultivated for a few years the ground becomes covered with a growth of wild briers.

Considerable tracts in Indiana which have been included in various writings as loess covered, will be found to represent soils in places, and their origin can be clearly traced to the underlying formations.

(b) Residual Soils.

The great mass of soils has been produced by the weathering and disintegration of rock under atmospheric influence; and it is generally found in the place where formed. Every species of rock has produced its soil; but the older formations, from their greater hardness and power of resistance to atmospheric action, produce in proportion to their exposed surface, less soil than do the secondary and tertiary groups. Any weathering rock surface shows us the process of soil making and the mosses and lichens that grow on the rock surface and aid in the deepening and enriching the soil. In some places the soil is thick and in others it is thin. In the level regions or those of gentle slope the soils have considerable

depth; on the steeper slopes the soil is thin; and on the steepest slopes the rocks are laid bare and we have a region of waste, in which but little vegetation can find a foothold. To be valuable soils must have depth and must contain more or less organic matter. Residual soils usually have a rusty red color, varying from a reddish yellow to a deep dark red. A vertical section of a soil in place from the surface to the decomposing rock will show a series of soil characteristics. The surface for a few inches is usually of a dark yellow to black soil of fine texture and containing a high percentage of organic remains; immediately beneath this layer is a mass of earth in which very little trace of vegetable matter is found, the color assumes more of the rusty red color which increases with depth, the particles are less finely divided and small fragments of the parent rock are found, and at a depth of a few feet we find the weathered surface of the rock mass and a little farther below we come to the solid rock. The line between soil and subsoil is usually well dfined.

The residual soils of Indiana cover a part of 20 counties of the central southern part of the State lying south of the glacial boundary, and in several other counties of southern Indiana the geological formations are responsible to a considerable degree for the character and fertility of various soil types. These soils have less fertility than the drift and alluvial soils because of the limited variety of materials entering into their composition.

The various limestones, sandstones and shales with their resulting soils are of special interest and importance, both from a geological and an agricultural standpoint, and many questions arise as to origin, composition, requirements, adaptability, and general value.

It is an old saying that "a lime country is a rich country," and the limestone soils, such as are found in Kentucky and Tennessee, are famous for their fertility and richness. In the soils of Indiana derived from the limestone formations, while they have a marked degree of fertility, the lime content is low. In most cases these soils are "acid" or "sour." At first thought it would appear that soils produced from formations containing about 98 per cent lime carbonate would be strongly calcareous. But since this lime carbonate is highly soluble, the penetrating roots and heavy rainfall have leached these soils of the lime, and one of the things necessary for high productions is the application of lime on the surface. In the presence of high lime content relatively low percentages of phosphoric acid and potash prove adequate; while the same or even

higher amounts, in the absence of satisfactory lime percentage, prove insufficient for good production. It has been found by observation and numerous analysis that the higher the clay content of a soil, the more lime carbonate it must contain to have the value of a lime soil; and that while in sandy lands lime growth may follow the presence of only .10 per cent lime, in heavy clay soils not less than about .6 per cent should be present to bring about the same result. The dark tinted humus characteristics of calcareous lands do not appear in clay soils until the lime percentages rise to nearly 1 per cent, while in sandy lands a much smaller amount, or about .2 per cent, will produce this effect. In heavy clay soils where the lime content falls below .5 per cent, lime vegetation is lacking and a growth of black jack and post oaks is found, which indicate soils too poor for profitable cultivation, while phosphoric acid, potash and nitrogen are the leading plant foods; lime is an important factor in soil fertility and exerts a wide influence upon plant distribution.

The analyses of limestone soils of Indiana show in the surface soil about .50 per cent calcium oxide, and .35 per cent potassium oxide and .15 per cent phosphoric acid anhyd. The first foot below the surface soil shows an average of about .55 per cent calcium oxide, .45 per cent potassium oxide and .18 per cent phosphoric acid anhyd. The third foot down to the rock mass shows an average of about 1.5 per cent calcium oxide, .60 per cent potassium oxide and .17 per cent phosphoric acid anhyd. We see from the above that the lime content is lower than that of true calcareous soil, the amounts of total phosphoric acid and potassium oxide are low and that the amount contained within these percentages of readily obtainable material would be very small, and these soils are likely to call for early fertilization. By careful investigations less than one-fourth of one per cent of potash is likely to constitute a deficiency. One-fourth of one per cent is usually high for phosphoric acid content. One-tenth of 1 per cent of P^2O^5 may prove adequate, but soils showing between .1 per cent and .05 per cent are weak and are liable to need phosphate fertilization very early. In soils with a weak phosphoric acid content a high percentage of lime carbonate or the presence of a large supply of humus often produce good results by bringing about greater availability of the phosphates. In the absence of lime carbonate, ferric hydrates may render phosphoric acid inert by the formation of insoluble ferric phosphate. The nitrogen content in soils is variable, and the amount necessary for plant growth depends largely upon

other soil conditions, as moisture, etc., and upon the nitrification of the organic matter of the soil.

The soil types in the residual soils are varied and numerous. The limestone soils grade from a reddish yellow to a dark red; the ferruginous sandstones and shales produce a variety of colors in their soils; the purer sandstones and shales break down into yellow soils. In passing from east to west over the residual soils, the topography is varied, on account of the succession of hard and soft strata, with their different rates of disintegration. The shales weather faster than the limestones, and the limestones more rapidly than the massive sandstones.

1. Knobstone Group.*

General Description.—The Knobstone Group, consisting of a series of shales, sandstones, and patchy, thin-bedded limestones, is so called because "these siliceous strata weather into peculiar conical knobs or hills." The Knobstone Group is the surface formation of a strip extending from the south of New Albany to near Crawfordsville. This strip reaches its maximum width in Jackson, Monroe, Brown and Bartholomew, where the belt is from 25 to 35 miles in width. To the north of Monroe and Brown the formation is more or less covered with glacial material, and has but very little relation to the soil, and the same is also true to the east of an irregular line extending from the northwest corner of Bartholomew County to the outlying knobs of the Guiena Hills at the south side of Scott County, along which line the glacial debris laps up against the foot-hills of the "Knobs"; within these limits there are considerable areas over which some glacial material is scattered, but in such small amounts that the soils will be classed as residual soils of the knobstones. In addition to the counties named, this group comprises large areas in Lawrence, Washington, Clark and Floyd Counties.

The thin, rather persistent bed of limestone at the base of the formation is known as the Rockford Goniatite limestone. It varies in thickness from a few inches to about two feet, and usually contains a large number of crinoid stems. The other limestone mentioned is near the top of the formation and is not so persistent as

*The discussion of the soils of the Ordovician, Silurian, and Devonian formations, the oldest rocks exposed in Indiana, has been omitted from the general discussion of the soil types; but in so far as these formations have produced soils of their own or influenced other soils they will be taken up by Messrs. Ward and Ellis in their description of soils of Southeastern Indiana in which area they have made special investigations.

the first. It is very thin bedded, and on weathered edge is shown to be an impure, porous limestone.

Overlying the basal limestone is a thick bed of greenish-colored shale known as the "New Providence Shale." This shale has a maximum thickness of about 120 feet. Imbedded with this are several thin layers of iron carbonate, fragments of which may be seen very plentiful along the streams and sides of ravines, but not in sufficient quantity to be of any economic value, although in 1835-40 preparations were made to erect a furnace near Henryville to smelt this ore.

The Knobstone Group is capped with the Knob Sandstone. It is not a single, massive sandstone, but is a series of rather pure, soft sandstones separated by layers of sand shales. The upper layers of the sandstone are somewhat ferruginous. The total maximum thickness of the Knobstone Group is over 500 feet.

Topography.—The hills resulting from the erosion of the Knobstones present the most important topographic feature of southern Indiana. These hills or knobs rise from 150 to 500 feet above the drainage level of the surrounding country. The sandstones predominate in the greater part of the region. These sandstones and alternating shales have not been affected by erosion as early as have the areas farther south, where the shale predominates and where the sandstones are found only at the top of the group, and the soft shales are thus worn away as rapidly as they are exposed by the removal of the overlying sandstones. A topographical map of the knobstone area would show lines with somewhat regular curves along the broken ridges, others would show knobs almost isolated, and in every case the lines would be very close together.

The scenery is very attractive, varied by the undulating uplands and round topped hills, among which many streams wind their way, through valleys now wide and again so narrow that scarcely a roadway can be made at the side of the stream. From the higher points magnificent birds-eye views of the surrounding country may be seen in all their beauty. The local names that have been given to various ridges and hills in Brown, Scott, Clark and Floyd Counties will give an idea of the diversified forms and types resulting from the erosion and weathering of the knobstone.

"Weed Patch Hill," in Brown County, is a high ridge forming the divide between two of the main branches of Salt Creek. At its highest point it is more than 1,000 feet in elevation. One of the illustrations gives a view looking northeast from the ridge and gives an idea of the knob topography. "Bear Wallow Hill"

is another high ridge forming part of the divide between the Bean Blossom and Salt Creek. "Guinea Hills" and "Silver Hills" are names given to parts of a continuous line of knobs extending from the Ohio through Floyd and Clark Counties into southeastern Washington and southwestern Scott and forming the divide between the tributaries of the Muscatatuck River and the head waters of Silver Creek; and south of this the waters of Mutton Fork of Blue River and Indian Creek on the west are separated from those of Silver Creek to the east. The early settlers gave the name of "Silver Hills" to the southern part of this ridge and the name "Guinea Hills" has been given to that part extending through northern Clark into Washington and Scott Counties. Some of the names given to other hills within this area are "Pigeon Roost," "Buzzard Roost Point," "Piney Point," "Round Top," "Hay Stack Knobs," "Horse Shoe Range," "Hound's Leap," "Huckleberry Knob," and "Pike's Peak." When we view the landscape from these various points and see the succession of hills and valleys, woodland and cultivated fields, streams and rocks, or look across on the broad valley with its meandering streams, the Ohio is certainly entitled to the name given to it by the French, "La Belle Riviere."

The western dip of the knobstone strata has controlled the initial drainage of this area, and the main drainage lies, with the exception of the lower course of the Muscatatuck and middle course of East Fork of White River. The intricate system of narrow V-shaped valleys running in every direction form the most important topographic characteristic of the knobstone area.

Economic Value.—Until within the past few years the knobstone formations have contributed very little to the economic interest of the State. Considering the formation, the amount of material of commercial value is very low. The sandstones are used to some extent in buildings and for bridge abutments. When first quarried the stone is very soft, but hardens on exposure. Two things especially are against these sandstones for structural purposes: being thin-bedded and irregular, much time and waste is necessary in quarrying; because of their power to absorb water they are easily disintegrated by frost action. But in some places the stone has been found massive for several feet and has proved a durable stone.

From a few localities considerable of the shale is being used in the manufacture of cement, brick and drain tile. It is probable that the knobstone shale in many places will be found suitable for

Portland cement manufacture. Much of the shale is too high in silica to make a good cement. The best deposit contains a large number of iron stone concretions, but these can readily be removed in the quarrying. The limestones are used some for the improvement of the public roads. Some sandstone is also used for this purpose, but stream gravel is the principal road metal through the section. A number of mineral springs rise from the New Providence Shale, and their waters have been used for medicinal purposes, and in the future some developments may be made along this line.

Weathering.—The strata of the Knobstone Group disintegrate very rapidly. The soft sandstones and shales absorb water easily, although they are practically impervious as far as circulating waters are concerned, and they are thus readily disintegrated by frost action. The power of erosion in these soft formations has been shown in the discussion of the topographic features. The knobstone where exposed in bluffs weather largely by exfoliation, and large pieces are often broken loose by frost action. While running water has had a great influence upon the topography, temperature changes are the agencies of greatest importance in the disintegration of these formations, as is evidenced by the broken strata along the bluffs and streams, and in the differential weathering of the hill slopes.

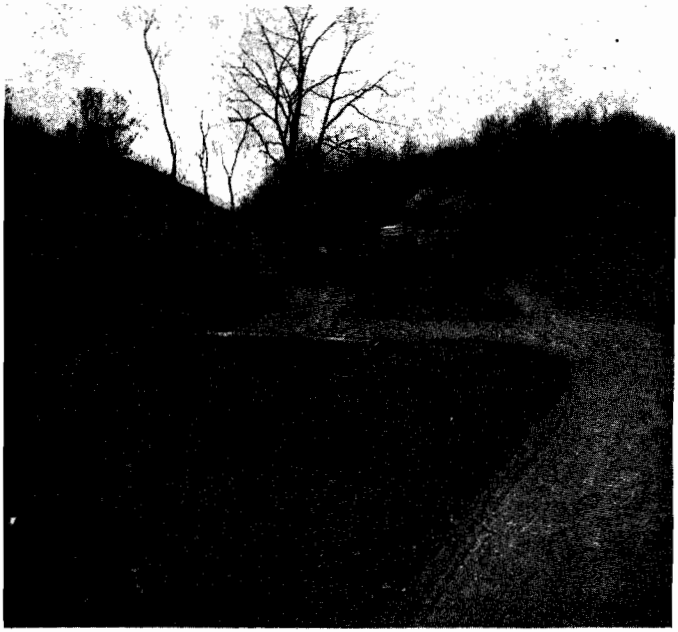
"It is a noticeable fact that throughout the whole Knobstone area where unaffected by glacial material, and where the valley systems are well developed, the south hillsides have gentler slopes than those facing northward, i. e., that erosion is farther advanced on the south-sloping hills that those sloping northward.

"This feature is most noticeable along the east-west valleys. In north-south valleys the gentler slope, when one is gentler than the other, is usually on the east side of the valley, i. e., on the westward sloping hillside. The difference in the angle of slope between east and west hillsides is not so noticeable as that between north and south slopes.

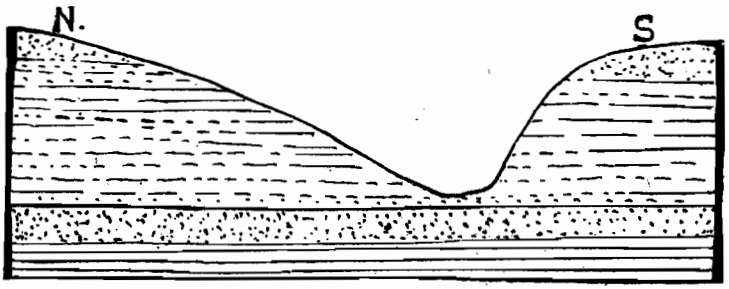
"This differential weathering of the slopes is attributed to the effect of temperature changes, especially of freezing and thawing, upon the rocks. Changes in temperature probably have a more potent effect in breaking up these rocks than has any other agent.

"The south hillsides are exposed to many more changes of temperature in the course of a year, and especially in the winter time, than are the hillsides facing northward. During the winter months in this region the nights are cold, often for weeks at a

time, freezing a crust over the ground, which next day is thawed out on the south-sloping hillsides. The north slopes, however, being sheltered from the sun's rays, are frozen, or covered with snow.



View along Hinkle Creek, Monroe County, in Knobstone area, showing south slopes and manner of weathering.



TYPICAL NORTH-SOUTH VALLEY in the KNOBSTONE.

and remain so almost the whole winter long. Thus, while the rocks of the south slopes will be successively frozen and thawed out many times during the winter, the corresponding north slopes may be frozen and thawed only two or three times.

"One has only to cross this country on a warm winter's day after a cold freezing night, and to see the muddy streams flowing down from the south hill slopes while the north slopes remain solidly frozen, to realize the importance of this process of wearing away of these rocks. Both the climate and the structure of the rocks are peculiarly favorable for this class of erosion.

"There is considerable difference, also, in the quantity of heat that reaches east and west slopes, the westward slopes receiving more heat than those facing eastward, owing to the fact that the afternoon is the warmest part of the day. Because of this the westward slopes are not so noticeably different, however, as are the north and south hillsides.

"These differences can not be due to the gentle south-westward dip of the beds, because if they were so controlled, the westward slopes would certainly be the most gentle of all, as the prevailing dip is westward."*

Soils.—The soils of the Knobstone area are composed of sand and clay in varying proportions, and present several closely related soil types. Clay, sandy and silt loam, sand areas, clay tracts and rough, stony land containing many broken pieces of sandstone are often so plentiful as to prohibit successful cultivation. These knobstone soils are usually of little value, but within the past few years they have begun to attract the attention of fruit and vegetable growers. While as a class these soils do not produce large yields of the staple crops, they are capable of yielding much greater returns than in the past.

Corn yields on an average from 25 to 30 bushels to the acre, wheat averages 10 to 15 bushels, oats average 25 to 40 bushels, clover and timothy yield from one to two tons per acre. Alfalfa has been successfully grown on small areas, and a fair grade of tobacco is also produced on the silt and sandy loam. Tomatoes yield well on the various types and a number of canning factories are being built up within the area, with apparent opportunity for many more to do a successful business. Large yields of peaches and apples are realized from the orchards located on these soils, and from present indications grapes might well be grown with profit for the market.

There is no marked line between the various soil types given above, and several or all of them frequently occur even in the same field. The natural fertility and productiveness is about the same for the various types for general farming, but with some variation

*J. F. Newsom, in Report of State Geologist for 1901-02, 270.

for special cropping. Potatoes yield about 40 bushels to the acre, but experiments have demonstrated that as high as 80 bushels or even more can be grown.

The surface soil is from 10-14 inches in depth, and usually grades from a gray to light brown color and becomes a dark yellow or light red at greater depth. In places small fragments of chert, limestone and sandstone are found, which represent the remains of the upper strata of the Knobstone. Thin layers of hard brown ferruginous shale, such as form the outer layers of the imbedded geodes and iron concretions, frequently occur with the softer shales, or are found scattered over the surface. The characteristic red or yellow or brown color of the soil is due to the oxidation of the large amount of iron contained in the original material.

The soils wash badly on the hill slopes, and the texture of the soil on the slopes varies according to the steepness of the slopes and the amount of erosion that has taken place. Careful management is necessary to keep these soils in a productive state and some system of crop rotation is very important. The turning under once in every two or three years of clover, cowpeas or some other crop that adds a large amount of humus to the soil is very important.

The alluvial soils of this area are composed chiefly of the upland wash, and the material is not far removed from its original location, and shares the same properties of the upland soil except for poor drainage conditions, which in some cases has caused a depleted condition of the soil-reductive masceration.

The general improvement on these soils ranges from poor to fair, but some marked changes for better have been made even in the past few years. Railroad facilities are bringing about improved farm conditions, and this region yet promises to become an important agricultural district, and large tracts are being bought by wide-awake, energetic men who see great possibilities in the knobstone soils. The average price of land at present is from $25 to $50 per acre. The rougher portions of the area offer splendid opportunties for grazing and fruit growing.

Taken as a whole, the area is of value, and with improved methods of agriculture, railroads, improved public roads, rural routes, etc., this area will add much to the wealth of the State. Places which now yield hooppoles, ties and hickory bark will produce grain, fruit and vegetables in abundance, and the sites of one and two-room log cabins will be marked with up-to-date farm homes.

2. The Harrodsburg Limestone Area.

General Description.—The Harrodsburg Limestone lies above the Knobstone, and with it are included the transitional beds of chert, geodes and limestones that lie directly above the knobstones. The masses of chert fragments are very plentiful, and the geodes or "mutton heads," ranging from the size of a pea up to 24 inches in diameter, are found in great quantities. A few geodes are found scattered through the knobstone, but they are confined principally to the lower part of the Harrodsburg. Above the geode layer there is a crystalline, fossiliferous limestone, containing small crystals of pyrites, which give it a greenish tint. In many places the bedding planes are marked by stylolites or crowfeet, and masses of chert are very common. The upper strata of this limestone becomes more massive, and consists chiefly of bryozoa with its lacework effect.

The Harrodsburg limestone is the surface rock over an irregular belt from one to six miles wide, lying between the Knobstone Group and the Oolitic belt. It is from 60 to 90 feet in thickness.

Topography.—The Harrodsburg Limestone is the cap rock protecting the softer knobstone below, and to its influence are due the bold, unbroken escarpment of the knobstone strata. The limestone at its eastern contact outcrops at the tops of steep-sided hills and ridges, whose lower portions are composed of the knobstone. The top of these hills form a more or less even plateau sloping gently to the west. In areas where the Harrodsburg has not cut through to the knobstone the slopes are more gentle, and on the table lands broad rolling tracts stretch out in contrast to the knobs. But upon a map the greater part of the Harrodsburg appears in fringe-like strips branching off from a main continuous belt. It will be seen by noting the drainage that this main belt caps the high ridges and that the sinuous line passes around the heads of the streams.

Economic Value.—The Harrodsburg Limestone is of medium hardness and in places coarsely crystalline, is rather impure from chert, etc., and has but little economic value except as a road metal and for ballast. As such it is second best in this section of the State. Being of medium hardness, it readily wears a smooth surface. The cementing value and the lasting qualities are good except on roads of the heaviest traffic. The stream gravel derived from the chert, geodes and fragments of limestone is a very suitable road metal. The massive bryozoan strata have been quarried to a small degree as marble. On a polished surface the bryozoan

lace work gives a beautiful effect, but on account of the porous nature the stone will not retain a high polish. This stone has little use as a building stone, but is sometimes used in foundations and in bridge construction. It has been used some for the burning of lime, but on account of the high proportions of clay it is less suited for this than other limestone. The purer beds give an analysis which shows this stone to be of value in the making of Portland cement, and especially may it prove of such value when it can be used in connection with the overlying Salem and Mitchell Limestones.

Weathering and Soils.—One of the chief economic values of the Harrodsburg Limestone is the fine, deep, rich soil formed by its decomposition. The soil varies in depth from about three feet to about twenty feet in a few places, with an average depth of five or six feet, except on the steeper slopes, where it is very shallow. The soil in general is stiff, fine-textured clay of a deep red to chocolate brown color. The lower members of the limestones with the geode and chert beds form a soil of a much darker red than that from the upper strata. The line between the surface soil and the subsoil from the lower members contain many chert fragments and geodes, increasing in number until the remnants of the solid rock are reached. In places these are so plentiful that the subsoil may be classed as coarse gravelly. Large areas of soil containing these insoluble rock constituents are found in the transition planes, with no remaining limestone other than fragments at the base. Thus on the soil maps showing the contact between knobstone and Harrodsburg soils, the line will in most cases be farther to the east than the line of contact of the rock outcrop shown on geological maps.

The surface soils from the different strata of the limestone are similar, being a loamy clay of fine texture, and varying in color from a light brown to a dark reddish brown. The various colors are due to the different proportions of organic matter present and to the leaching action of roots. These soils owe their red color chiefly to the large amount of ferric hydrate contained, and where the roots of plants and trees have penetrated these soils, that part of the soil in immediate contact with the roots has lost part of its iron content and the color becomes a dull brown. The surface soil is from 6 to 18 inches in depth. The subsoil derived from the massive strata is a fine clay of uniform texture extending down to the parent rock. In some places, however, it departs from the usual red color and becomes somewhat mottled with white, yellow

and red. This is due partly to the thin-bedded shales and to poor drainage conditions. The clay of the subsoil, when exposed, breaks and crumbles in cubical forms. These little blocks continue to crumble until the clay becomes very finely divided. In general, the natural drainage conditions are good. It may be cultivated when rather wet, without injury since upon drying it readily goes to pieces and does not have the strong adhesive properties of such heavy clays as the Flatwoods and like soils. But upon a roadway, even after a summer shower, this clay works up into the toughest kind of mud.

The native timber growth of the Harrodsburg is such as denotes a good, rich soil—maple, walnut, ash, poplar, hickory, cherry, beech, oak, etc. This soil ranks as second best among the residual soils of the State. The area for the most part is inhabited by a thrifty set of farmers, who have their farms fairly well improved with buildings, fences, etc., so that in appearance the area shows agricultural progress.

Corn, wheat, hay and oats are the principal crops. The soil contains a considerable percentage of humus, and an adequate amount of the essential plant food. But it appears that this plant food is not highly available for some crops. Large amounts of stable manure are used, and in addition commercial fertilizer is used in the wheat and corn. Clover, alfalfa and cowpeas are grown for the crop, and aid greatly in the nitrification of the soils. Corn gives an average yield of 45-50 bushels, and is usually af a fair quality. Wheat grows well and yields from 15-30 bushels per acre. Oats yield about 40 bushels. They usually grow rank but rust badly. Timothy makes a good, heavy growth and yields from one and a half to three tons of hay per acre. Much of the corn is cut into fodder and shredded for feed. Considerable fruit is grown, and the soil seems well adapted to fruit. Vegetables grow well and give good yields. The soil is excellent for blue grass, and large tracts on slopes and rougher portions should be sown to grass, and a greater number of live stock should be kept. In this way all waste places may be utilized.

3. Oolitic Belt.

General Description.—The Indiana or Bedford Oolitic Limestone outcrops in a sinuous belt ranging from a few feet to more than a mile in width and lying between the Harrodsburg and Mitchell Limestones. It lies conformably upon the Harrodsburg Limestone

and varies in thickness from 25 to 100 feet. It is a massive limestone, generally free from lamination, and shows very few bedding planes. It is soft and easily worked when quarried, but hardens upon exposure. It varies in color from a white to a blue or buff. The Oolitic Limestone is a granular limestone in which both the grains and the cementing materials are carbonate of lime. The texture varies from a very even, fine-grained limestone, made of rounded grains mostly of foraminfera and bryozoa and other forms, to a coarse fossiliferous stone in which large forms of gasteropods, brachiopods, bryozoa and other fossils are very abundant and are commonly clustered together. The fine-grained stone is of value from a commercial standpoint. There are slight variations in the hardness of the stone, but only in a few places is it too soft to be of any value, and in no place is it too hard to work.

Topography.—The thickness and width of the Oolitic Limestone is not sufficient to develop a strong topography of its own, but in the broader areas where the topography has been controlled by the limestone the slopes are gentle and the surface slightly rolling. The long, gentle slopes toward the drainage levels and the rolling uplands present the most picturesque farming region in southern Indiana. The topographic features are such that almost any point of the area can be reached by railways at a moderate expense for grading.

Economic Value.—Next to the coal beds of Indiana, the Oolitic Limestone is the most important geological formation in the State from a commercial standpoint. Its chief value is as a building stone. Considerable is used for monuments and bases. Large quantities are used as ballast on railroads. It is used as a road metal, but is not durable for that purpose, yet makes a good, smooth roadway when traffic is light, and is the best material that can be had for roadmaking with the exception of the stream gravel, which is derived principally from the limestone. A large amount is burned for lime, and produces a very white lime of excellent quality. In the past few years this limestone has been used to a considerable extent in the manufacture of Portland cement, and the large amounts of waste about the quarries and the areas unsuited for commercial stone should encourage an extensive use of this limestone. "The tests show the cement to be of the highest quality, and at least equal to any Portland cement manufactured in this country or Europe."

Weathering.—Chemical analysis shows no sufficient percentages of elements that should cause weakness in the stone itself. The

stone is about 98 per cent carbonate of lime, one of the most durable substances under ordinary conditions. In contact with acids, however, it is one of the least stable, and is readily dissolved by any of the acids. On the open outcrops and where the surface soil has been removed from the limestone in quarry stripping it is found to be weathering into numerous fissures, caves, seams and corrugated surfaces. This is caused by the solubility in acids. The rainwater absorbs some acid from the air and more from the soil through which it passes, and acting for long periods of time it leaches away great quantities of stone. This stone is more porous than the average limestone, and great quantities of water are absorbed. The joint planes furnish openings for the ground water, and the effect of solution is very great.

Some of the old quarries of the Oolitic Limestone furnish excellent examples of the weathering process. Large blocks are scarred and furrowed by the action of the rainwater, and in many places the surfaces are honeycombed or pocketed, due o the unequal solubility of the limestone.

Soils.—When the lime carbonate has been dissolved out and carried away there remains a small percentage of unsoluble matter which forms the basis of the deep red soil of the Oolitic belt. In many places the gradation from surface soil to solid rock can be readily observed. Although these soils contains so little lime that it is necessary to apply lime to secure the best results in crop production, the lime percentage increases with depth, but even very near the rock the lime content is very low. The soil finally grades into an earthy limestone which crumbles easily, and this passes gradually into the solid stone.

In color, depth, texture, structure, native vegetation and crop production the soil of the Oolitic limestone is very similiar to that of the Harrodsburg Limestone.

The rolling blue grass pastures, wheat and hay fields afford a most picturesque scenery. Considerable dairying is carried on in this section. The staple crops all produce well, but the chief attention is given to corn, wheat and hay. Corn is of good quality and yields an average of about 45 bushels. Wheat averages about 18 bushels, and in some places the yield has been about 30 bushels. Timothy is grown rather extensively, and yields from 1½ to 3 tons per acre. Clover is grown principally for the hay. Some seed is threshed, but the average yield is low. A large proportion of the hay, both timothy and clover, is sold from the farm. Some fruit is grown, and truck farming is receiving considerable attention.

4. The Mitchell Limestone Area.

General Description.—The Mitchell Limestone is a series of impure limestone, calcareous shales, and fossiliferous limestone, overlying the Oolitic Limestone. This limestone is the surface rock over a large area. In eastern Owen and northwestern Monroe, extending through central Monroe to the southern boundary, the strip of Mitchell Limestone is from one to six miles wide, and in Lawrence County it widens until it is about ten miles from east to west, and continues to widen until in Orange County and Washington County the belt is more than 25 miles in width, and continues in a wide strip to the valley of the Ohio. The eastern outcrop runs in an irregular curving line about the outcrop of the Oolitic. To the western side large areas are made irregular and patchy by the overlying Huron. In general, the limestone has a very white appearance. The lower members are unfossiliferous and of a dirty yellow or gray color. Above this stone comes the thin-bedded shales and heavy dark blue flaggy limestone and the massive gray lithographic limestone.

Topography.—The Mitchell area is in general a fairly level plateau, dotted with a great number of sinkholes. These sinkholes are basin-like or funnel-shaped depressions from a few feet to more than 50 feet deep, and ranging in diameter from a few feet to five hundred feet, with an opening at the bottom which leads to underground water channels which form the true drainage lines of the country. When the underground drainage is well developed there is scarcely any surface drainage. These underground streams produce a great variety of sinkhole caves and Lost River. If the openings in the sinkholes have been closed, the basin is filled with water. These are very common over the area and are utilized by the farmers as source of stock water because of their convenience and since it is difficult to obtain good wells in the formation. In many places streams flow into the sinks and are lost for some distance, and rise again. The best example of this is Lost River in Orange County, which enters the ground two miles southeast of Orleans and again emerges at Orangeville after flowing underground by a winding course for about fifteen miles. In wet weather this stream also occupies a surface channel in a very narrow valley. The stream throughout its course has a very meandering direction and very little valley except as occurs in the meander curves. When the underground channels have been abandoned by the stream, they may be explored great distances, as in Wyandotte Cave and the numerous smaller caves. Many narrow amphitheater-

like valleys have been formed by the falling in of the roof of subterranean caverns. Numerous springs are found along this outcrop of the limestone. This topography in the main has been developed by the solution and erosion of the underground waters.

Economic Value.—The Mitchell Limestone has little value as a building stone. Its chief value in former years was for the manufacture of lime; but recently a large amount has been used as the limestone ingredient in the manufacture of Portland cement. Near the top of the formation is a fine-textured, even-grained, gray lithographic stone, but on account of the many little veins of calcite the stone cannot be secured in pieces large enough to be of value. Large quantities are used as railroad ballast, and as a road metal it stands at the head of the list.

Weathering and Soils.—Surface weathering is less noticeable in the Mitchell Limestone than in either of the above-described limestones. Joint and bedding planes are very plentiful and solution is concentrated along these lines, and being fine-grained, the stone absorbs very little water and the ground water is forced to follow the joints.

As a formation the Mitchell contains a much larger per cent of impurities than the Oolitic. The soil resulting from its decay is a stiff red clay, similar in general appearance to the limestone soils described above, but lacking in the general fertility and agricultural advantages. Throughout the soil, and especially in the subsoil, are found many fragments of chert and fossils.

The soil is of a light yellow to brick-red color, the two colors showing very prominently in patchy areas in the same field when fresh plowed. The red patches occur principally on the more elevated parts and are due to the surface soil being carried to lower levels and leaving the unleached soil exposed. The yellow soils are of a more loamy texture on account of the mechanical action of the roots of plants, and owe their lighter color also to the leaching action of the plant roots. In places the soils become of a darker color, due to the greater amount of organic matter. When in a good state of tilth the surface soil is very fine and contains much flour-like material and also a large amount of fine grit derived from impurities in the limestone and from the sandstone formations which formerly extended over much of the area. The soil varies in depth from 6-18 inches.

The subsoil is a stiff clay of a dark brown or red color, and contains much chert and other impurities and fragments of stone.

The chert beds of the area may in the future prove of some value as rock fertilizers. No analyses have yet been made.

The growths of sassafras and briars are very noticeable on these soils, and fields left for a year or two without cultivation are rapidly covered with these plants. The soils are in need of available potash and phosphoric acid. It has been noticed that when fire has burned the briars over a given area that the amount of potash made available in the ash causes a very thrifty growth of the briar, often becoming much higher than a man's head and more than a half inch in diameter. A large amount of commercial fertilizer is used on these soils. The yield of corn when fertilized is from 40 to 70 bushels. Unfertilized, it is often almost a failure, except in seasons of great rainfall. Because of the system of underground drainage and sink holes, the soil soon dries out and crops often suffer from drought. In some places, especially on the more level uplands, series of shallow sink holes have become clogged, and the standing water gives the appearance of a marsh area and the vegetation is that of a typical marsh.

The Mitchell soils generally produce wheat well, with an average of 12 to 15 bushels per acre, and in many cases it will yield 25 bushels or more. Oats grow fairly well, but seem to rust considerably. It is a good soil for fruit, and does fairly well for vegetables. In the rough parts the soils wash badly, and should be kept in grass as much as possible and used for pasturage. Timothy yields from one and a half to three tons per acre.

The improvements over the area are good, especially in the large, level tracts of the uplands, where there are many large farms of great value. The roads are for the most part in a fair condition, and much has been done in the last three or four years to improve their condition. Some dairying is carried on and sheep raising is becoming an important occupation.

5. The Huron Formation.

General Description, Topography, Etc.—The Huron consists of a series of limestones, sandstones and shales. There are three limestones and two sandstones, and the total thickness of the formation is more than 100 feet. The sandstones of the formation are of fine texture and are usually a buff or gray color. The lower limestone resembles very closely the Mitchell, and all the limestone contains considerable chert and other impurities.

The topography of the Huron is more rugged than that of the

Mitchell. Most of the drainage is subterranean, although well defined drainage lines can be traced through the confused system of hills and valleys.

The limestones are used for the burning of lime, for road metal and for bridge abutments and foundation stone. The sandstones are also used in bridge construction and for foundations, and in Orange County they are quarried to some extent for whetstones.

Soils.—The soils of the Huron vary from sandy areas to stiff, mucky clay. The sandy types are of a reddish-yellow color and are not very productive since they consist of little but quartz and ferric hydrate. A small percentage of these lands are under cultivation. The soils, derived principally from the shales, are tenacious clays with a variety of colors, but chiefly of a white or light yellow color. They retain a large amount of water, but are fairly productive, corn, wheat, oats, clover and timothy being grown successfully. White daisies, briars, sassafras, persimmons and pawpaws are the principal products from uncultivated areas. The soils wash badly, and most careful cultivation is required on the slopes to prevent destruction.

The areas which have for their soil a mixture of the sand, shales and clays of the limestone are the most productive and present the greatest opportunity for agricultural development. Improvements are poor, railroads few, but the public roads are being rapidly improved, and the Huron limestone, which is an excellent road metal, is used principally on this improvement.

6. The Mansfield Sandstone.

General Description, Topography, Etc.—The Mansfield Sandstone lies to the west of the Huron formation. It was formerly designated as the "Millstone grit" and "Conglomerate sandstone." The sandstone has a thickness of about 150 feet, and even more is shown along the bluffs of White River north of Shoals. It varies in texture from a fine-grained stone to a coarse, pebbly conglomerate. It varies from light yellow to dark brown in color. At the base of the sandstone beds of shale with thin veins of coal are rather persistent, varying in thickness from a few inches to fifteen or twenty feet.

The topography of the Mansfield area is very rugged. It is a thoroughly dissected plateau. Steep hills, abrupt cliffs and long, narrow, winding valleys are characteristic of the area. The hill tops are protected by a layer of heavy, hard sandstone, and the

streams have cut down rapidly through the softer beds. The eastern part of the area is far more rugged than the west.

The Mansfield has been used to a small degree as a building stone. Some of the fine-grained parts have been used for whetstones and grindstones, and the conglomerate beds are a source of road material.

Soils.—The soils of the Mansfield sandstone are of a light yellow color and vary from sandy loams to sandy clay loam. The average depth of the soil is from 10-15 inches. At greater depth the soil usually becomes more tenacious and of a reddish color, due to the large amount of iron contained within the original stone. Large areas of these soils are uncultivated, being grown up with second-growth timber and underbrush. The improvements are, as a rule, very poor, and the necessary thrift is lacking to accomplish much in an agricultural line.

Oats grow well, wheat produces from 8 to 20 bushels. Timothy and clover are grown, but the hay is of rather poor quality. Farmers are beginning to use considerable fertilizer and are well repaid.

In some parts the soils have a stiff, clayey texture due chiefly to the overlying shales of the coal measures. Within the Mansfield area is much rough, stony land. It includes the rock outcrop along the streams, the steep, stony hillsides and the land which is intersected with deep ravines so close together that the land is worthless for farming purposes.

The principal timber growth consists of oaks, beech, mulberry and some maple and walnut. Some fruit is grown and the soils seem well adapted for the same. Very few stock are raised for the market; sheep raising and dairying might be engaged in with profit.

There are few railroads through this area, and the public roads are yet in a poor condition. The agricultural products are not much in excess of the local demand.

7. Coal Measures.

General Description.—The coal measures lie unconformably upon the Mansfield and consist of a series of shales, sandstones, coal, fire clay, concretionary iron ores and thin-bedded limestone. The coal measures are of varying thickness and cover a wide strip of country. The topography is usually gently rolling or flat. In the eastern part of the area, where the coal measures occur as remnants on the higher ridges, the ridges are flat topped and pre-

sent some of the most level and productive soils of that part of the area. The coal measures are the chief sources of Indiana coal, fire clays and shales.

Soils.--The soils of the area grade from sandy and silt loam to clay, and usually contain large numbers of iron concretions and fragments of sandstone. The soils are of a light color and as a rule are fairly productive. The staple crops are all grown, and considerable vegetable farming is carried on. In the rougher parts to the east the greatest drawback to development is the high elevations above the surrounding country, and the difficulty thus experienced in marketing produce. In some parts of the level area mining is the chief concern of the people and the soils are neglected.

The chief and most extensive soil type is the silt loam, locally known as "yellow clay." It is high in silt and contains but very little sand. The soil is easily cultivated. If plowed when slightly moist, the surface material crumbles easily into a loose, floury dust. Oats produce well, corn averages about 40 bushels, wheat about 15 bushels in the best season. Considerable fertilizer is used, especially on the wheat. The soil grows good grass, and water is abundant, and dairying and stock raising could be made paying enterprises. Fruit growing should also be encouraged.

Several railroads traverse this area, public roads are being well improved in the level parts and the general improvements are advancing.

8. Alluvial Soils.

Alluvial soils are those deposited along streams, the materials having been gathered along the course of the streams from various sources and carried to some distance before being deposited. The characteristics of the alluvial soils are largely dependent upon the nature of the formation and soils found within the drainage area of the stream, and the relative proportions of the various components is dependent upon the steepness of the slope and the velocity of the current.

The principal alluvial soils in Indiana are those of the White River, Wabash and Ohio valleys. The valleys of Indiana streams are the result of stream erosion, most of them by the streams which now occupy them. During the glacial period they were largely choked with drift, only a small part of which has been removed. Gorges and ravines exist in great numbers along the Whitewater, White and Ohio rivers and all their tributaries. The eastern tribu-

taries of the Wabash in Fountain and Parke counties flow through beautiful canyons cut in massive sandstones, often with overhanging walls. The streams flowing from the glacial area had their valleys flooded with glacial waters and choked with glacial debris. The effects of this are shown by the extensive terraces of sand and gravel which border their present channels and mark the heights at which they were once able to deposit sediment. Between these terraces are the bottom lands or flood plains, large areas of which contain some of the most productive soils to be found anywhere.

The Wabash River valley in the upper two-thirds of its course presents a variety of fine, sandy loams, gravelly, sandy loams, silt loams and clay loams. The lower part of the valley consists chiefly of clay underlain by sand or sandy clay. The clay is of two special types—a brown clay loam containing a small amount of sand, mingled together with a large amount of organic material, and is in a good state of cultivation; the second is a whitish silty loam about six inches in depth, underlain by a stiff clay mottled with yellow and white. Varying amounts of coarse sand and iron concretions are found through the soil. At present a small percentage of this type is under cultivation because of the poor drainage conditions. All along the lower Wabash there are numerous depressions, bayous, sloughs and narrow ponds lying parallel with the course of the river.

The greater part of the soils of the lower Ohio are of the same general types as those of the lower Wabash. Farther up the Ohio the valley becomes much wider, and the soils are usually of a very productive type.

The soils of the lower White River consist of varying proportions of clay, sand and silt, the prevailing type being a silty clay similar to that of the lower Wabash. The soils of the West Fork through its lower and middle course consist of a yellowish-brown silt loam containing considerable fine sand. The remaining timber along the streams consists of walnut, ash, elm, sycamore and poplar. The soil is excellent for corn but the soils are poorly cared for and no cropping system is attempted. The upper course is of clay and sandy loam with considerable coarse gravel.

The soils of the East Fork in its lower course consist of sandy loams of fine texture. This part of the valley is very narrow, in some places being less than a quarter of a mile in width. The upper part of the valley is very wide and affords large areas of the best farming land within the State. The soils are sand, sandy loam and brown clay loam. Along the Muscatatuck, the principal

tributary, are a series of clay mucks, white clays, clay loams and silt loams.

The alluvial area of the State is subject to frequent overflows; each flood leaves a sediment or washes away a part of that already deposited, and thus the surface soil is constantly renewed and altered. Thus a strong, fertile soil is formed, capable of producing good yields of various crops. On account of danger of overflow, however, it is planted almost exclusively to corn.

During the past two years the amount of overflow has exceeded that of former periods, and much change in soil has taken place and great injury been done to growing crops. In the spring of 1907 much bottom land corn was not planted until late in June, but, however, was well matured before killing frost came. In the spring of 1908 the rainfall was very great, and during the month of May was far in excess of that of former years, consequently much bottom land was too wet for plowing, and large areas had not even been plowed up to the first of June, yet it is reported that a much larger acreage will be planted to corn than in 1907.