THIRTY-NINTH ANNUAL REPORT

OF

Department of Geology and Natural Resources

INDIANA

EDWARD BARRETT
State Geologist

1914

INDIANAPOLIS:
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1915

THE STATE OF INDIANA,
EXECUTIVE DEPARTMENT,
June 24, 1915.

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June 24, 1915.

No financial statement.

DALE J. CRITTENBERGER,
Auditor of State.

JUNE 24, 1915.

Returned by the Auditor of State, with above certificate, and transmitted to Secretary of State for publication, upon the order of the Board of Commissioners of Public Printing and Binding.

BERT NEW,
Acting Secretary to the Governor.

JUNE 24, 1915.

Filed in the office of the Secretary of the State of Indiana.

HOMER L. COOK,
Secretary of State.

Received the within report and delivered to the printer, June 25, 1915

ED D. DONNELL,
Clerk Printing Board.

LIST OF ASSISTANTS.

Dr. A. D. Hole	Field Assistant
Dr. J. W. Beede	Field Assistant
E. J. Grimes	Field Assistant
C. H. Orahood	Field Assistant
H. N. Coryell	Field Assistant
R. S. Hesler	Field Assistant
Floyd E. Wright	State Supervisor of Natural Gas
Margaret M. Kirby	Stenographer and Clerk
W. V. Moss	Custodian and Messenger

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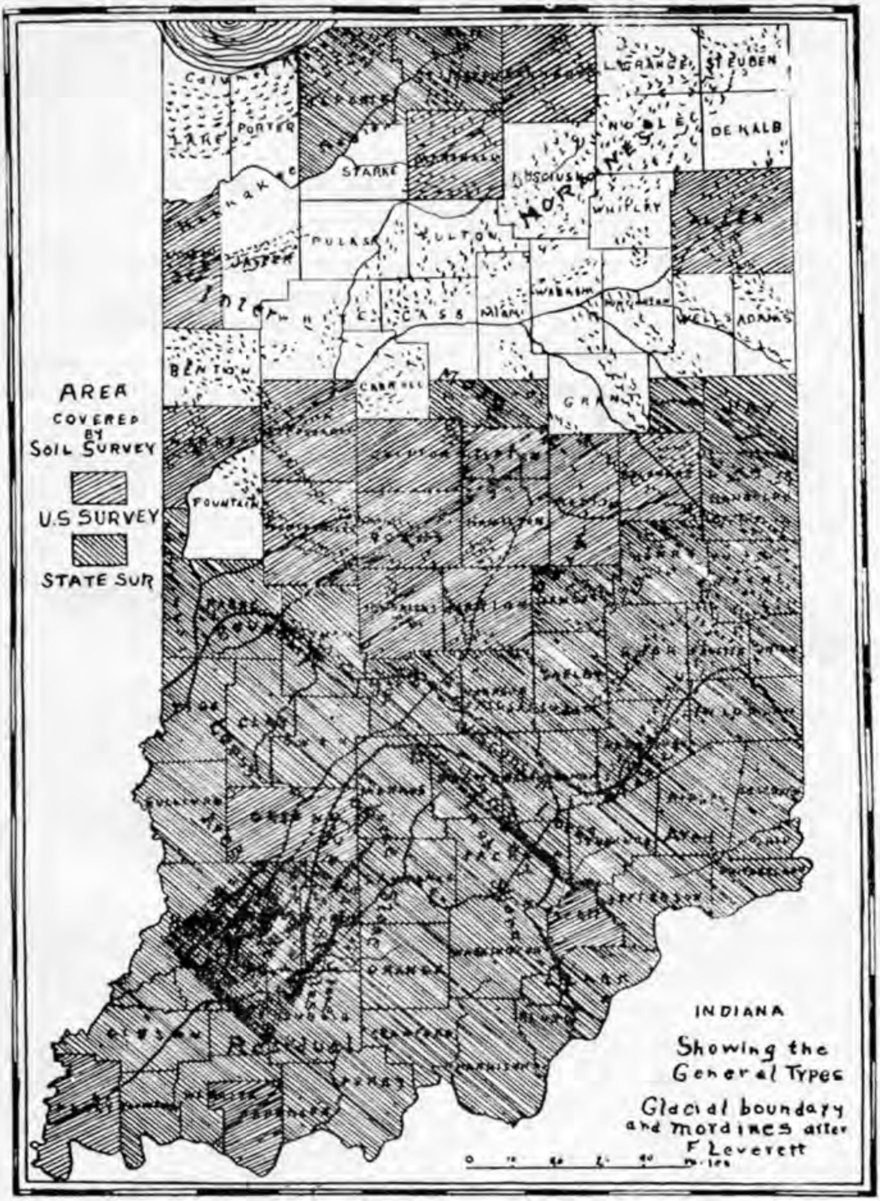
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STATE OF INDIANA,

DEPARTMENT OF GEOLOGY AND NATURAL RESOURCES.

INDIANAPOLIS, IND., June 24, 1915.

Samuel M. Ralston, Governor of Indiana:

MY DEAR SIR—I submit to you today, in accordance with the law, the manuscript of the Thirty-ninth Annual Report of the Department of Geology and Natural Resources.

I am pleased to mention that the co-operative contract with the United States government, continuing the soil survey of the State, has been renewed, and three expert soil men from the United States Bureau of Soils have been assigned to Indiana to work with three of my assistants in the field. This co-operative soil work has been productive of much good, and I have received hundreds of letters from interested farmers concerning this survey.

The submission of this report was delayed several weeks awaiting the inspection of the Soils Correlating Committee of the United States Bureau. Owing to the volume of work before it, this committee could not complete its work on the Indiana soils until a few days ago. Through the courtesy of Milton Whitney, Chief of the Bureau of Soils, the work was hurried on to completion, and our farmers will get the benefit this year of the work done in 1914 under the co-operative contract.

A review of the lines of work pursued by the Department for 1914 will be found in the introduction to this volume.

With the hope that the manuscript herewith submitted will meet your approval, and that the State Printing Board will order its early publication, I am

Very respectfully,

EDWARD BARRETT,
State Geologist.

INTRODUCTION.

By Edward Barrett.

The importance of a detailed soil survey cannot be shown more strongly in figures than by presenting the acreage of land in the United States, and in each of the States, and the total acreage of land in farms, and improved lands in farms.

The total number of acres of land in the United States is 1,903,-289,600, representing 100%; the amount of land in farms is 878,-798,325 acres, or 46.2%; the amount of improved land in farms is 25.1%. It will be seen that less than one-half of the total acreage of the United States is in farms, and slightly more than one-fourth of it is in improved farms.

Below is a table showing the facts in regard to individual States:

Name.	*Total Acreage.*	*Land in Farms.*	*Improved Land in Farms.*
Alabama	32,818,560	20,732,312	9,693,581
	or 100%	or 63.2%	or 29.0%
Arizona	72,838,400	1,246,613	350,173
	or 100%	or 1.7%	or .5%
Arkansas	33,616,000	17,416,075	8,076,254
	or 100%	or 51.8%	or 24.0%
California	99,617,280	27,931,444	11,389,894
	or 100%	or 28.0%	or 11.4%
Colorado	66,341,120	13,532,113	4,302,101
	or 100%	or 20.4%	or 6.5%
Connecticut	3,084,800	2,185,788	988,252
	or 100%	or 70.9%	or 32.0%
Delaware	1,257,600	1,038,866	713,538
	or 100%	or 82.6%	or 56.7%
Florida	25,111,040	5,253,538	1,805,408
	or 100%	or 15.0%	or 5.4%
Georgia	37,584,000	26,584,000	12,298,017
	or 100%	or 71.7%	or 32.7%
Idaho	53,346,560	5,283,604	2,778,740
	or 100%	or 9.9%	or 5.2%
Illinois	35,867,520	32,522,937	28,048,332
	or 100%	or 90.7%	or 78.2%
Indiana	23,068,800	21,299,823	16,931,252
	or 100%	or 92.3%	or 73.4%
Iowa	25,575,040	33,930,688	29,491,199
	or 100%	or 95.4%	or 82.9%

NAME.	*Total Acreage.*	*Land in Farms.*	*Improved Land in Farms.*
Kansas	52,335,360	43,384,799	29,904,067
	or 100%	or 82.9%	or 57.1%
Kentucky	25,715,840	22,189,127	14,354,471
	or 100%	or 86.3%	or 55.8%
Louisiana	29,061,760	10,439,481	5,276,016
	or 100%	or 35.9%	or 18.2%
Maine	19,132,800	6,296,859	2,360,657
	or 100%	or 32.9%	or 12.3%
Maryland	6,362,240	5,057,140	3,354,767
	or 100%	or 79.5%	or 52.7%
Massachusetts	5,144,960	2,875,941	1,164,501
	or 100%	or 55.9%	or 22.6%
Michigan	36,787,200	18,940,614	12,832,078
	or 100%	or 51.5%	or 34.9%
Minnesota	51,749,120	27,675,823	19,643,533
	or 100%	or 53.5%	or 38.0%
Mississippi	29,671,680	18,557,533	9,008,310
	or 100%	or 62.5%	or 30.4%
Missouri	43,985,280	34,591,248	24,581,186
	or 100%	or 78.6%	or 55.9%
Montana	93,568,640	13,545,603	3,640,309
	or 100%	or 14.5%	or 3.9%
Nebraska	49,157,120	38,622,021	24,382,577
	or 100%	or 78.6%	or 49.6%
Nevada	70,285,440	2,714,757	752,117
	or 100%	or 3.9%	or 1.1%
New Hampshire	5,779,840	3,249,458	929,185
	or 100%	or 56.2%	or 16.1%
New Jersey	4,808,960	2,573,857	1,803,336
	or 100%	or 53.5%	or 37.5%
New Mexico	78,401,920	11,270,021	1,467,191
	or 100%	or 14.4%	or 1.8%
New York	30,498,560	22,030,367	14,844,039
	or 100%	or 72.2%	or 48.7%
North Carolina	31,193,600	22,439,129	8,813,056
	or 100%	or 71.9%	or 28.3%
North Dakota	44,917,120	28,426,650	20,455,092
	or 100%	or 63.3%	or 45.5%
Ohio	26,073,600	24,105,708	19,227,969
	or 100%	or 92.5%	or 73.7%
Oklahoma	44,424,960	28,859,353	17,551,337
	or 100%	or 65.0%	or 39.5%
Oregon	61,188,480	11,685,110	4,274,803
	or 100%	or 19.1%	or 7.0%
Pennsylvania	28,692,480	18,586,832	12,673,519
	or 100%	or 64.8%	or 44.2%

NAME.	*Total Acreage.*	*Land in Farms.*	*Improved Land in Farms.*
Rhode Island	682,880	443,308	178,344
	or 100%	or 64.9%	or 26.1%
South Carolina	19,516,800	13,512,028	6,097,999
	or 100%	or 69.2%	or 31.2%
South Dakota	49,195,520	26,016,892	15,827,208
	or 100%	or 52.9%	or 32.2%
Tennessee	26,679,680	20,041,657	10,890,484
	or 100%	or 75.1%	or 40.8%
Texas	167,934,720	112,435,067	27,360,666
	or 100%	or 67.0%	or 16.3%
Utah	52,597,760	3,397,699	1,368,211
	or 100%	or 6.5%	or 2.6%
Vermont	5,839,360	4,663,577	1,633,965
	or 100%	or 79.9%	or 28.0%
Virginia	25,767,680	19,495,636	9,870,058
	or 100%	or 75.7%	or 38.3%
Washington	42,775,040	11,712,235	6,373,311
	or 100%	or 27.4%	or 14.9%
West Virgniia	15,374,080	10,026,442	5,521,757
	or 100%	or 65.2%	or 35.9%
Wisconsin	35,363,840	21,060,066	11,907,606
	or 100%	or 59.6%	or 33.7%
Wyoming	62,460,160	8,543,010	1,256,160
	or 100%	or 13.7%	or 2.0%

It will be seen from the above that Indiana is third as to number of acres of land in farms. This estimate doubtless means land under fence and exclusive of water areas, both stream and lake. In the matter of improved land in farms, Indiana would come fourth, in comparison with her sister States. By improved land in farms is doubtless meant farms in a good state of cultivation and good improvements. Indiana, then, ranks high comparatively in an agricultural point of view.

But when we think that the average yields in most cereals is only one-third to one-fourth as much in this State as in some of the best agrictultural states of Europe, we can see the necessity of added knowledge and more effective methods of soil improvement, not only through experimental and extension work, but through field work from the standpoint of geology. There is no good reason why a survey of the topmost formation in Indiana, the soil and subsoil, is not a proper function of the Department of Geology, and as long as the present incumbent is in charge of the department, it shall be so held.

"The soil survey is recognized as a scientific institution engaged in the accumulation of data bearing upon the soil and its relation to agriculture. The soil survey field man is a scientist and his results are important and his methods are scientific, as much so in his particular field as those of other scientists in their special lines of endeavor, whether working in the field, office, or laboratory. His methods are not the same as those of the laboratory man but his results are just as reliable when he has used his methods just as effectively. He is or should be not merely a getter of facts, but an interpreter of those facts. He must show relationships if he measures up to the opportunties afforded him. He has the opportunity to study soils and agricultural facts and relationships in a more intimate way than has ever been permitted to any one in this or any other country. No other scientific man has ever studied the actual soil and agricultural conditions of any country as closely and in as much detail as does the soil survey field man."

A soil survey from a geologic standpoint would fall largely under the following heads:

Topography and Physiographic Situation.

"While the survey does not attempt to map topography, it is important that the field man should take advantage of all topographic maps and consider topography in its relation to soil mapping. It is particularly important, however, that he give careful attention to the topographic situation, as this will often help him to determine the source of the material and the agencies through which the material has accumulated. It is important, also, in his description of the area and for the proper understanding of the soil relation that the general physiographic features of the area be described, whether in the main or in any part of the area, the surface presents the general features of a valley, a plateau, a plain, or a rough or even mountainous condition. Such information not only leads to correct classification of soil material and of soil types, but it may have much to do with the explanation of the present or future use of the soil type.

Source and Derivation of Material.

"To insure the proper classification of soils it is important to know the derivation of the material. Soil material derived directly from the disintegration of granite, talcose, schist, basalt, and other quartz-free minerals, limestone, and sandstone have essentially different properties, the reason for which may not be well understood though the facts upon which to base the classification may usually be determined. In the case of residual soils derived directly from the weathering and disintegration of solid rocks, the important guides are: Exposures of the rock itself at the surface or in road cuts, the evidence presented by geologic surveys and maps, the physiographic relationships, and the character of the soil material itself. In case of heterogeneous material which has been transported by ice, a study of the rock content of the soil or subsoil will often reveal the main character of the material from which the soil has been derived. Granitic material, sandstone and shale, limestone or basalt fragments will appear in such form and frequency as to give a fairly correct idea of the original source of the material.

"In case of soil material transported by running water or by waves in lakes or oceans, the general source of the material may be obtained by studying the physiographic position with reference to drainage basins and noting the course the material must have followed from its source to its present position.

Agencies Through Which Material Has Accumulated.

"Having determined the source of the material, it remains to determine the principal agencies through which the material has accumulated. The agencies recognized by the survey as essential in the classification of soils are few and in the main are readily determined, though sometimes they are obscure and, particularly along boundary lines, may be difficult to determine. The first of these is: The weathering and disintegration in place of consolidated rocks without material subsequent movement or mixture except through local creep and erosion, giving rise to residual material. The next is the agency of moving ice and the influence of the rushing glacial waters as the ice recedes. The evidence of ice-laid accumulations is usually to be seen in the more or less stony and unsorted character of the soil or subsoil material. The evidence of ice-laid material subsequently acted upon by rushing glacial waters is sometimes more difficult to determine but is usually indicated by a broad separation of coarse residual material, flanked by plains or filled-in valleys of sand with outer zones of silt and clay. The stratification of the material as seen in the vertical section is also an important criterion. The next important agency is the wind, which has a tendency to mix materials from widely separated localities. This influence is felt more or less in all soils, but becomes sufficiently marked to serve as a basis for soil mapping in only a few definite areas. The principal evidence of wind deposition is the great uniformity in the character of the material, the fact that the body covers both hills and valleys with a blanket of comparatively uniform thickness, or that it has the form of dunes or hillocks.

"The remaining agency to be mentioned is water transportation by river and wave action. Water-laid deposits will reveal their manner of accumulation through the stratification of the material, which will be nearly horizontal, and by a smooth and practically level original topography. The stratification of the material can usually not be seen in the upper three feet of the deposit because of the influence and effects of roots of plants, animals, cultivation, and soil creep. Soil material transported through the agency of running water is very different from the same material that has been subjected to the influence of wave action or the distribution and segregation of the different grades of material through ocean or lake currents."

In the prosecution of the soil survey along the lines indicated in the review above, two field parties were maintained in the year 1914, one by the State exclusively, and the other under the co-operative contract with the United States Bureau of Soils.

Messrs. H. N. Coryell and C. M. Rose of the State Survey went carefully over the soils of Howard County, and Mr. Allen D. Hole, with several advanced students of geology from Earlham College, made a detailed survey of the soils of Jay County.

The co-operative work was done in Clinton County by Mr. W. E. Tharp, of the United States Bureau, and Messrs. R. H. Peacock and C. M. Rose of the State Survey.

Grove B. Jones of the United States Bureau, assisted by R. S. Hesler of the State Survey, spent between four and five months going carefully over the soils of Elkhart County.

E. J. Grimes of the Indiana Department of Geology and E. H. Stevens of the United States Bureau of Soils had charge of the work in Warren County, and worked out the soil types with much detail.

A large portion of the present volume is devoted to a geological survey of the Bloomington Quadrangle, the work being based on the map made by the United States Geological Survey on that quadrangle. The State Geologist had general charge of the work, while Prof. J. W. Beede of the State University had immediate direction of the survey in the field. The survey was made under the following heads:

(1) General Geology.
(2) Glacial Geology.
(3) Special Reference to Mitchell Limestone.
(4) Economic Geology, principally under the following heads:
Utilization of by-products of Oolitic limestone.
Waste limestone in the manufacture of lime.

In the report of Mr. Floyd E. Wright, State Supervisor of Natural Gas, the general conditions and outlook of the oil and gas fields of the State are reviewed.

The present volume closes with "A Supplemental Check List of Indiana Mollusca," by Mr. L. E. Daniels. In 1902, Mr. Daniels had published in the Annual Report of the Department a check list of the Indiana Mollusca, with localities. Since the publication of that list, Mr. Daniels has continued his work of collecting and has added about forty species and thirty-six varieties to his first published list.

Much of the State Geologist's time in the year 1914 was devoted to the question of "Good Roads"—a question in which the people of Indiana have become deeply and enthusiastically interested. During the year, the State Geologist delivered some twenty addresses at different points in the State on road construction and on the excellent road materials of Indiana. He also wrote several circulars and magazine articles on the same questions. In addition to the above, he also spent considerable time before farmers' meetings and institutes on geological problems that are closely related to the soils and farming interests of the State. Work along these lines will be continued during the rest of the State Geologist's present term.*

*U. S. Bureau of Soils.

Conditions of Oil Fields and Development in Indiana, 1914.

By Edward Barrett.

The Continental War in Europe has affected the movement of most commercial commodities in this country, and consequently the prices of such commodities, but none perhaps have been as seriously affected as petroleum and its by-products. These products seem to be very sensitive to any curtailing of the export trade of the country, and they respond immediately to fluctuating conditions.

The war has practically shut off oil exportations; as a consequence the supplies of oil in this country exceed the demand. The first effect of the curtailing of the export trade in oil was a lowering of the price from $1.35 per barrel to 75c per barrel, a reduction of practically 45% on the barrel.

With this tremendous reduction in the price of crude oil, investment in oil properties and development in oil territory practically came to a standstill; particularly is this true in untried and untested territory, and also in territory that is believed to be worked out or exhausted to a large extent. A large portion of Indiana would fall under the above conditions. Even in the newest developed field in Indiana, viz., Sullivan County, oil investment and development have been reduced perhaps 50%.

Possibly there has never been a time in the history of oil in this State when as many persons, and as much capital, stood ready to enter the oil business as at the present time, and these are waiting the time when our ports will be open for exportation and the consequent rise in price.

There never was a time, too, when readiness to invest and develop was as *general* over the State as at the present time. The areas awaiting development, as reported to this Department, include the following:

Noble, Lagrange, Pulaski, Jasper, Miami, Wells, Grant, Howard, Fountain, Hamilton, Madison, Delaware, Hancock, Hendricks, Putnam, Vigo, Owen, Shelby, Rush, Decatur, Greene, Sullivan, Knox, Daviess, Martin, Orange, Jackson, Washington, Scott, Clark, Harrison, Perry, Spencer, Dubois, Pike, Gibson, and Posey.

The above list may not include all the counties awaiting investment and development, but they do include all the areas, and they show the widespread interest in oil development. The distribution of these counties shows also that every known oil and gas formation in Indiana is to be exploited. The tendency, too, of oil drillers and operators is toward deeper borings, and this will make all tests more thorough.

In the old Trenton field in the eastern part of the State, borings below the Trenton formation were not necessary, as the strata and conditions for the accumulation of oil and gas below Trenton, offered no inducements. But as we go westward in the State, the number of superincumbent strata increases every few miles, and some of these strata are known oil bearing rocks. To illustrate, some oil and gas are found in the Jeffersonville limestone (Corniferous) and in the Devonian shales (Genesee); again in the Huron limestones and shales; and still farther west in the Mansfield sandstone, and possibly in the Carboniferous limestones and shales. All of these, with the intervening formations, add to the total thickness of the crust as we advance westward in the State, until we reach the Coal Measures. The added thickness probably amounts to a total of from 1,500 to 2,000 feet; and this thickness would have to be added to the old Trenton rock depth in drilling for Trenton rock oil in the western part of the State. As a rule, too, drillings for oil in the several formations mentioned would have to be deeper than in the old Trenton rock field, which averaged about 1,000 feet. The exception to this is found in Sullivan County, where the wells run from 600 to 800 feet in depth.

There have been about 35,000 oil and gas wells drilled in Indiana in the last twenty-five years. Probably 30,000 of these were drilled in the Trenton rock field, and the rest in counties in various parts of the State.

The following is from the Oil City Derrick:

"The development of oil resources back in the early nineties opened at that time a new area of prosperity to the State of Indiana, and it is scarcely an exaggeration to say that petroleum did exceed in value any other industry in the State at the time, helped along by the wonderful gas development that brought many large manufacturing plants from other sections of the country. True, the interest that attaches to an oil well is perhaps lacking in the interest inseparable from other industries, and yet the crude product of the Eocene or Neocene age has not been without its romance in ancient times, and also in modern history. But in these rapid living days the practical side of life is what appeals to the multitude, and any new invention or new development of nature's resources that tends to add to the material strength and capability of the nation may be counted as a factor in the broadening out and development of civilization.

"While the knowledge of the existence of oil in Indiana dates back to a time long anterior to the advent of Gaspar de Portala's little band of missionary friars, and when the Godfrey tribe of Indians were roaming over the territory adjacent to Montpelier, the successful development of these hidden sources of wealth is so recent that the importance of the industry that had sprung into existence was not yet fully developed until early in the Nineteenth century, and was not appreciated during the early nineties.

"Indiana's first oil excitement dates back to 1862, when oil springs were found on Otter Fork and West Fork and along the streams tributary to them, in Crawford County. There were a number of springs from which small quantities of oil could be collected. The oil rock could be found in many places. At one place on Otter Fork the bed of the creek was soft black sandstone, or shale, which contained more than 30 per cent of oil.

"During the oil excitement of 1862-66 when oil springs were found on Otter Fork and West Fork, oil seekers flocked to that county and the excitement ran high. Several wells were drilled, but oil in paying quantities was never found. On the farm of J. J. Clark a well was drilled during the oil excitement, but only a small quantity of oil mixed with salt water was obtained. At 408 feet, in this well natural gas was found, and at 648 feet salt water and a small amount of oil.

"The second oil excitement in the State dates back to 1865, when an artesian well being drilled for water at Terre Haute, Vigo County, found oil at a depth of 1,630 feet. During the following five years three more wells had been drilled in that locality, and all found quantities of sulphur water, with more or less oil. It was not until 1888, however, that this oil development attracted the attention of operators. It was on May 6th of that year that the Phoenix well was drilled in, and for a dozen years yielded an average of 1,000 barrels or more a month. The result of this strike was like that of all similar ones in the history of the oil industry. Hundreds of oil operators from far and near flocked to Terre Haute. Real estate was usually almost doubled in price. Twenty-four new companies were formed, eighteen of which made locations. A dozen or more wells were drilled to the required depth within three miles' radius of the Phoenix well, struck the proper stratum, and, for the most part, found—nothing. Terre Haute never did make an oil field.

"*The Oil Area.*—The great bulk of Indiana's oil is derived from the Trenton rock formation in Wells, Blackford, Jay, Adams, Grant, Huntington, Delaware, Randolph, Madison, Hamilton, Marion, Miami and Wabash counties. The Indiana field is but an extension of the Ohio Trenton rock district, which was discovered several years previous to the Indiana field. The Ohio development was extended rapidly, and test wells drilled to the south and west of the original strikes in Wood, Hancock and Allen counties of Ohio indicated an extension toward the Indiana line, the result being that a test well was drilled at Eaton, Delaware County, in 1885, which resulted in a large gas well, making the beginning of the development of the great Indiana gas and oil field. The Indiana Trenton rock field extends over a large area, commencing with the Ohio line at its eastern boundary, and extending westward approximately 50 miles into the central portion of the State. On the north of the principal oil pools will be found an immense area of territory in which the oil formation has been filled with blue lick water, making it an impossibility for the oil reservoir to contain oil in commercial quantities, except in certain isolated pools, where the terrace structure or slight anticlinal folds may have trapped the oil and gas.

"In the southern part of the field, notably in what is known as the Camden district in Jay County, and also in several of the isolated pools located in the gas area near Alexandria, Marion and Hartford City, the principal pays are found from 80 to 200 feet in the Trenton, the upper portion of the formation in these districts being filled with natural gas at considerable pressure when the field was new. In the eastern end of the field, known as the Geneva district, all of the profitable pays were found located in the upper 60 feet of the Trenton. In the early days of the excitement, gas was so plentiful that it was wasted. Large flambeaux would be seen in all parts of the field, with millions of cubic feet of the natural fuel going to waste daily. At that time it was thought that the supply would always last, but in later years it was discovered that not near enough gas could be found to furnish fuel for the pumping of the wells, and for that reason thousands of wells were pulled out and abandoned that would have been snug fortunes for their owners had there been a supply of gas to handle them cheaply. This great waste of Indiana gas caused other States to adopt the conservation policy of handling it, and many States have profited from the experience in Indiana.

"*First Paying Oil Strike.*—The first real oil well was drilled in Indiana in 1886 and located near Portland, in Jay County, but was abandoned. Numerous wells were drilled in the same vicinity and it was up to Benjamin F. Fulton to start the ball rolling by drilling in a 35-barrel producer. It was at this well that the first real disaster occurred in the Indiana field. Oil was being used for fuel on the James Penn farm, and an explosion caused the death of the driller. The first paying oil well was drilled in Indiana in June, 1890, and was owned by the Northern Indiana Oil Company, and located on the D. A. Bryson farm, in Chester Township, Wells County, near the town of Keystone, north from Montpelier. This well started at 60 barrels a day natural, but within three months had dropped to 25 barrels a day. Then it was given a shot and increased to 90 barrels a day. This same company drilled several wells in the vicinity of the Bryson well without results. The second scene of operation was on the Cory farm, in Nottingham Township, Wells County, where Edward J. Little, a resident of Toledo, Ohio, at the time, but now deceased, drilled in a well that started at 250 barrels.

"The best oil wells found in the Indiana field were located in the heavy gas belt near Camden, Jay County, known as Pennville, and in Penn Township. Wells showing a production above 3,500 barrels were drilled in this pool, but the life of the wells was short as they blew out in a few years, as did the gas in the same field. Another important and productive pool was located in the northwest corner of the same township, and known as the Harris. This pool was void of the big gushers but was a very exciting development, as many wells of the 200 barrel size were drilled in daily. The best well in the pool was the first well drilled, and was located on the southeast corner of the Hannah M. Harris farm, from whence the pool derived its name. This well started at 15 barrels of oil and close to 2,000 barrels of water, but at the expiration of forty days the water had about exhausted and the well produced 1,400 barrels of oil, being one of the remarkable wells of Indiana. This pool was located just at the edge of the Godfrey reserve, known as Indian lands, upon which later some fair wells were found. The Nottingham pool as well as the Muncie and Geneva pools was also rich, but the fading away of the gas supply made all the pools look alike to the oilman.

"Outside of the Trenton rock field and in the western section of the State, the past few years has shown some production in Gibson, Pike, Vigo, Sullivan, Martin and other counties, but nothing like the early wells in the Trenton rock section of the State.

"It is remarkable the number of wells that can be drilled in an oil field within a few years and the great number that can be abandoned. As near as can be gleaned since development work started in the oil fields of the State, there have been 17,164 oil wells abondoned out of a total producing number of 28,279 wells. This does not include the dry holes and gas wells. The greatest number of wells completed in any one year in the Indiana field was in 1902, when a total of 3,914 wells were completed, and the years of 1902-3-4 were the most active in the history of the field.

"The Grant County field was exhausted of its production more rapidly than any other county in the State, as over 5,000 oil wells have been abandoned in the county, with Wells County a close second, although the last named had a great many more wells and produced for some years before Grant County was developed.

"The number of wells completed yearly in the State is of interest to all identified with the past industry in that once active and productive oil field.

"The following table gives the number of wells drilled in the Indiana field each year since 1892 and with the number drilled previous to that year. The figures give the total number of completions with the number that were oil wells and the dry holes and gas wells.

Year.	*Comp.*	*Oil Wells.*	*Dry and Gas.*
Prior to 1892	1,306	405	901
1892	296	220	76
1893	665	519	146
1894	1,808	1,413	295
1895	2,711	1,957	754
1896	1,637	1,185	452
1897	1,041	761	280
1898	1,102	758	344
1899	2,223	1,706	517
1900	2,963	2,323	640
1901	2,586	2,144	442
1902	3,914	3,283	631
1903	3,686	3,310	376
1904	3,766	3,366	400
1905	1,922	1,678	244
1906	1,185	1,043	142
1907	655	529	126
1908	402	317	85
1909	305	219	86
1910	366	300	66
1911	117	82	35
1912	89	65	24
1913	311	225	86
1914	744	471	273
Total	35,800	28,279	7,521

Soil Survey of Howard County.

By H. N. Coryell and C. M. Rose.

DESCRIPTION OF THE AREA.

Howard County lies 96 miles north of Indianapolis and is situated in the central part of Indiana. It is bounded on the north by Cass and Miami, on the east by Grant, on the south by Tipton and Clinton, and on the west by Clinton and Carroll counties. It comprises an area of 295½ square miles, or 189,120 acres. It is approximately a rectangle 27 miles east and west by 11 miles north and south.

The surface is level to rolling. The rolling land lies in a connected district, forming a strip from two to four miles on each side of the large stream that extends almost the entire length of the county. At Phlox, a small country village in the southeast part of the county, the width of the undulating area is no more than a mile, and from this place it gradually widens to two miles at Greentown; while at Kokomo the rolling land of Little Wild Cat Creek extends to that of the principal stream, making the entire area almost seven miles wide. The width increases on going westward by the addition of new streams and new tributaries with their accompanying rolling areas, until the entire distance north and south is greater than that of the county. Thus the county is divided by this wedge into three regions, that one lying to the north being broad flats and very low swells, presenting great similarity to prairie topography, except about Cassville, where a small stream flows out of the county. Fully seven square miles in that vicinity are steeply rolling and hilly.

The southern division has a topography similar to the northern district, but it lies in detached areas east of Hemlock, southeast of Kokomo, and south and east of Russiaville. The surface about Fairfield is very gently undulating, and the extent of broad, flat areas of dark colored soil is very limited.

The northern and southern division contain the prized "corn lands" of Howard County. The soil is black, loose and often mucky, lying in low, broad flats interpolated by very gentle, dark gray swells.

The part of the county lying in and about Russiaville and New

London shows the work of erosion greater than any other. The steep slopes, gullies and deep, narrow ravines are evidences of the great work that it is able to do.

Reclamation becomes a serious and difficult task. The rougher portions are left to the ravages of weathering, to become covered by shrubs, trees and native grasses, or are planted in orchards and small fruit that are proving good investments. Large tracts of blue grass pastures cover many of the slopes that are too steep for the cultivation of tillage crops.

POPULATION.

The number of people in Howard County has steadily increased since 1890. The movement has been a continuous flocking of the laboring class to the large factory center at Kokomo. Every township has decreased in population with the exception of Center. The increase in Center Township is due to the growth of Kokomo city.

TABLE OF POPULATION ESTIMATES.

	1914.	*1910.*	*1900.*	*1890.*
Center Township, including Kokomo	22,500	19,600	12,796	10,388
Kokomo city	20,000	17,010	10,609	8,261
Clay Township	1,000	1,050	1,268	1,466
Ervin Township	1,690	1,706	2,055	2,169
Harrison Township	950	958	1,067	1,110
Alta	50	....	....	....
West Middleton	200	....	....	....
Honey Creek Township	1,130	1,137	1,240	1,210
Russiaville	500	....	....	....
Howard Township	1,050	1,084	1,323	1,324
Cassville	50	....	....	....
Jackson Township	900	909	1,197	1,370
Sycamore	70	....	....	....
Liberty Township	2,700	2,843	3,219	2,432
Greentown	1,100	1,166	1,289	721
Pleona	40	....	....	....
Monroe Township	950	959	1,052	1,135
New London	250	....	....	....
Taylor Township	1,800	1,832	1,919	2,090
Center	350	....	....	....
Hemlock	150	....	....	....
Fairfield	60	....	....	....
Union Township	1,040	1,099	1,439	1,492
Jerome	45	....	....	....
West Liberty	30	....	....	....
Phlox	65	....	....	....
Howard County	35,810	33,177	28,575	26,186

Early History.

Howard County was organized in 1844. For three years it was known as Richardville County in memory of the Miami Indian Chief, Richardville.

The county was formed wholly out of the Miami Indian Reserve. Erwin, Monroe and Honey Creek townships were part of the seven-mile strip sold off of the west side of the reserve and given by the government to the State of Indiana to use the proceeds of the sale of these lands for the completion of the Wabash and Erie Canal. After Indiana had sold this strip, Erwin and Monroe townships had been annexed to Carroll County, which had been organized in 1828, and Honey Creek had been annexed to Clinton County, which had been organized about 1830. The remainder of the county was formed from the final sale of the "Reserve" in 1840. The county was covered with forests of giant poplar, walnut, ash, oak and maple. The first settlements were made along the streams, where water power was used in turning the mills and saws.

In 1847 the name was changed by an act of the Legislature to Howard.

Kokomo.

The location of early Kokomo was donated by Daniel Foster, and at that time the swampy lands were rated at only $2.00 per acre. This donation forms the heart of the city of Kokomo as it is today. Large, three, five and seven-story buildings cover the lots, and splendid paved streets cover the early muddy roadways.

The development of Kokomo dates from 1866, when the first successful gas well was drilled. This caused a flock of various classes of men to Kokomo. The first came for exploitation and drilling; the speculator, for investment in land; and the manufacturer for the utilization of the cheap fuel. From that time on, Kokomo has been a manufacturing city of wide reputation. The recent exhibition staged at the city parks affirms, without doubt, that the manufactured products stand high in the estimation of the consumers.

The following is a complete list of the factories, many of which are among the best known establishments of their sort throughout the State:

Apperson Auto Company.
Armstrong-Landon Milling Company.
Bornique Glass Company.

Buck Handle Company.
Central Closet Manufacturing Company.
Central Indiana Fence and Wire Company.
Chandler Machine Company.
Cloverleaf Creamery Company.
Globe Stove Range Company.
Great Western Pottery Company.
Haynes Auto Company.
Jenkins Glass Company.
Knerr Board and Paper Company.
Kokomo Bale Tie Company.
Kokomo Brass Works.
Kokomo Canning Company.
Kokomo Hoop and Lumber Company.
Kokomo Nail and Brad Company.
Kokomo Paper Company.
Kokomo Rubber Company.
Kokomo Sanitary Manufacturing Company.
Kokomo Sanitary Milk and Ice Cream Company.
Kokomo Steel and Wire Company.
Kokomo Stone Company.
Kokomo Trunk Company.
J. M. Leach Brick Company.
National Mitten Company.
Opalescent Glass Company.
Pittsburg Plate Glass Company.
Rockford Bit Company.
Sailors Packing Company.
Superior Machine Tool Company.
Ulrich Manufacturing Company.
Worth Wire Works.

The school system of Kokomo is one of the best in central Indiana. The completion of the high school building in 1915 will give ample facilities for the higher subjects of the public school work. A new grade building was completed in 1914 in the north part of the city. The several grade buildings are conveniently located in various parts of the city and are known locally by the following names: Central, Willard, Lincoln, Columbia, Meridian, Palmer, Washington, Douglas and St. Francis. Kokomo has some of the largest church buildings in northern Indiana. The splendid stone or brick structures add much to the beauty of the city.

The Kokomo City Park, lying just beyond the corporation limits, on the southwest, is a beautiful place, with streams, ponds, springs, artesian wells, drives, flower and zoological gardens. A part is improved especially for children, and another for games and entertainments. The city golf links and tennis courts lie adjacent.

The Kokomo, Marion and Western Traction Company owns and operates the street railways.

Continuous public improvements are being made, and many new additions have been plotted and added to the city within the last few years. Many people of moderate means have found that Kokomo property is a good investment and that the city is a desirable place to live.

Passenger and shipping facilities over the railways are all that could be desired.

Greentown.

Greentown is eight miles east of Kokomo and is connected with it by the main line of the Cloverleaf and the Kokomo, Marion and Western Traction. It has hourly passenger service over the Traction Company's lines, both to the east and west. It has a population of about 1,100. The decrease is due to the shifting of the business that was formerly done at Greentown to the city of Kokomo.

In 1914 the first brick street was laid.

A new graded school building was constructed in 1913, and facilities were added to give instruction in the vocational courses.

The Traction Company furnishes electric service for street and home lighting.

Other industries are: An ice factory, public water works, canning factory, grain elevator and flour mills. Greentown has a bank and several good retail stores and shops.

One mile west and one-half mile north of Greentown is one of the remaining gas pumping stations. A few houses have been built near, for the employes. The pumps are constantly in motion, but the gas pressure is so very low that the company may discontinue most any time.

Plevna.

Plevna is a small village four miles north of Greentown. It was an early trading post and furnished many supplies to the people of the vicinity before the roads were improved, and travel had assumed its modern aspect. It has a population of about forty

Sycamore.

Sycamore is one mile north and two miles west of Greentown. It is a railroad village and furnishes a market for the products of a portion of the best farming land in the county. A grain elevator and general store are the principal mercantile establishments.

The town is electrically lighted by the I. E. L. and R. R. Co.

Jerome.

Jerome is an old trading center, founded in 1847. It is one and one-half miles east, and two miles south of Greentown. An old dam across Wild Cat Creek marks the place of an early "grist mill" and saw mill. The buildings are mostly of the early styles and many are now empty. A few shops and retail stores constitute its commercial life.

West Liberty.

West Liberty is three and one-half miles east, and three and one-half miles south of Greentown. At present it is a cluster of a little over a dozen houses, including a small retail store. In 1849 a water mill was built near this place, which was of great service to the early settlers. After the beginning of the clearing of the land, the stream became so low that the mill had to be abandoned. The stream at present is intermittent and cannot be depended upon to furnish water for the stock that pasture along its banks.

Phlox.

Phlox is another early trade center developed for the convenience of the people. At present there is a population of about sixty-five. It has two churches and a school building. The retail stores furnish the people ready access for provisional supplies.

Hemlock.

Hemlock is a small railroad town lying on the west edge of a fine farming district. It furnishes a good market for the farm products, over the Pittsburg, Cincinnati, Chicago and St. Louis Railroad. It is six miles southeast of Kokomo. Its business industries can be listed as: Grain elevator, coal yards, and general mercantile shops. It has a population of about one hundred and fifty.

Center.

Center is five miles southeast of Kokomo on the Pittsburg, Cincinnati, Chicago and St. Louis Railroad. Many people who live here are retired farmers who prefer a small town for a home.

A few stores and shops make up its retail portion. A grain elevator offers accommodations to the farmers for shipping of the corn, wheat and oats. The farmland about Center is gently rolling and the Miami series predominates.

Fairfield.

The Union Traction Company of Indiana and the Lake Erie and Western Railway pass through this village. Many of its people do the majority of their shopping at Kokomo because of the hourly service offered by the electric company.

The industries of Fairfield include a grain elevator, machine shops and retail stores.

This town was laid out in 1849 by John Stephen in anticipation of the building of the railroad from Indianapolis to Peru.

It has a population of approximately sixty. Most of its people are owners of and laborers on the farms.

Cassville.

Cassville is four miles north of Kokomo. The prospects of the building of what is now the L. E. & W. Railroad gave impetus to its early growth.

A grain elevator and a few retail stores form the list of its business enterprises.

A splendid country home with aquarium and park is located at Cassville.

Alto.

Alto is one mile west and three and one-half miles south of Kokomo, on the banks of Little Wild Cat Creek. It is an old trading post that was not favored with a railroad. A cluster of two dozen houses occupied by retired farmers and farm laborers makes up its population. A single store and shop are its only business enterprises.

The local church is a live institution. A new school building was completed in 1914.

Electricity is furnished by the I. E. L. and R. R. Co.

West Middleton.

West Middleton is a small town located five and one-half miles southwest of Kokomo. The Kokomo, Marion and Western Traction Company gives hourly service over its lines through this place to Kokomo, or to Frankfort, in Clinton County. One of the officials of the company has a beautiful country home near here, locally known as "Sunny Brook Farm".

West Middleton has a new addition plotted, intended to be sold to those who desire to live in a country town and take advantage of the electric service in going to and from their business interests elsewhere.

The school system is in good condition, though the building is not fully modern.

It has electric lighting service from the I. E. L. and R. R. Company.

Russiaville.

Russiaville is eight miles southwest of Kokomo. The K. M. & W., or Indiana Electric Light and Railway Company's lines, and the Cloverleaf pass through it.

The Howard County fair grounds are located here. The Fair Association is a live institution, and racing forms the chief annual attraction. The building of the electric line has stimulated permanent building and public improvement. Many people with business interest elsewhere make their home at Russiaville. The electric service for the town is furnished by the I. E. L. and R. R. Company. The town has its own public water system. The streets are heavily macadamized.

New London.

New London is one and one-half miles north of Russiaville. It is one of the oldest settlements of Howard County. Its early industries were a water-power flour mill, and sawmill. The stream is not large enough now, throughout the year, to give such services.

There is a splendid graded school building here that was constructed only a few years ago, and ample stable room is furnished for the horses of the students who take advantage of the high school courses.

The retail stores and shops are the principal business enterprises.

The electric service for lighting is furnished by the Indiana Electric Light and Railway Company.

Other Commercial Enterprises.—Approximately one and one-half miles west of New London is located a large tile factory. All sizes of tile and various kinds of porous brick are made from the clay beds near by. The clay beds are under the Miami type of soil, which is the predominant one in this locality. Nearly all of the output is used by local consumers.

Four and one-half miles east of Kokomo on the Toledo, St. Louis and Western Railroad (Cloverleaf) is a large elevator and a few houses. This place is called Vermont, and is one of the large grain shipping stations in eastern Howard County. The old trading station of Vermont was a short distance south and east of the present location. After the construction of the railroad the retail business was moved elsewhere, and the grain elevator erected near the railway took the name of the old settlement.

TRANSPORTATION.

The Early Roads.—The first state road located in the county was the Burlington and Marion. The report on this was made to the commission in June, 1845. The road was one and one-half miles in Carroll County, twenty-nine and one-fourth miles in Richardville (Howard) County, and eleven miles in Grant County. This was a winding road, changing its course sixty-four times in crossing Howard County. In passing through Kokomo it enters at the west end of Sycamore street and passes out at the east end of this street.

The second road was built in 1845 and was known as the Kokomo, Michigantown road. It began at the southwest corner of the square and ran south on Buckeye street to the Wild Cat Bluffs, thence southwesterly to the north banks of Wild Cat Creek, crossing at the rapids and zigzagging back and forth, finally reaching Michigantown.

The third was the Peru and Canton (Tipton) state road, and the fourth the Logansport state road.

The first gravel roads were toll roads. The Kokomo and New London road was the first under the toll law. It was built in 1867—ten miles long, and cost $27,000. It passed through Alto, West Middleton and New London.

The Kokomo-Greentown road was built in 1867. It extended from Kokomo running along the north side of Wild Cat Creek through old Vermont to Greentown and thence to Jerome.

The Petes Run gravel road, built in 1869, left Kokomo at West Jefferson street and forms the principal thoroughfare to the western part of the county. The Sycamore street pike begins at the west end of Sycamore street and runs west along Wild Cat Creek for ten miles.

The Deer Creek road runs north to the Miami County line. The Albright runs south on Home avenue to one mile east of Fairfield. These were completed in 1878.

With these early improved highways Kokomo soon became the center of the commercial life of the county. Road after road has since been improved in the county, so that only a few miles of the six hundred, remain unpaved with gravel or stone.

Lake Erie and Western Railroad.—This road was one of the first to be completed, and was constructed under the name of the Indianapolis and Peru Railway. It crosses the county from north to south, passing through Cassville, Kokomo and Fairfield. Cassville and Fairfield (Oakford) were laid out in anticipation of the building of the railroad. Excellent local passenger service is furnished by the company, and the Indianapolis market is made easy of access.

Pittsburgh, Cincinnati, Chicago and Indianapolis.—The line of this railway company passes through the towns of Kokomo, Center and Hemlock. It makes the Chicago markets available to local shippers. The passenger service over this line is splendid, especially the through trains. This company also gives passenger service over the Lake Erie and Western Railroad from Kokomo to Indianapolis.

The Toledo, St. Louis and Western.—This line, better known as the "Cloverleaf" has more mileage in Howard County than any other. It is the main line of this company from St. Louis to Toledo. The through passenger service is excellent, and the local trains make all stops in the towns through which the line passes. In Howard County the towns along this road are, from west to east: Russiaville, West Middleton, Kokomo, Vermont, Greentown and Sycamore.

Union Traction Company of Indiana.—This electric railway parallels the Lake Erie and Western railroad throughout its entire extent in the county, passing through Cassville, Kokomo and Fairfield. At Kokomo a branch of the electric company parallels the Pittsburgh, Cincinnati, Chicago and St. Louis Railway leading to Logansport. Hourly passenger service is given over the electric line in both directions during the day. The passenger cars carry express. Daily freight service is given between Indianapolis, Logansport and Peru.

Indiana Electric Light and Railway Company.—This company's line passes through Russiaville, West Middleton, Kokomo, Greentown and Sycamore. It parallels the Cloverleaf on the north side of the railroad from Russiaville to West Middleton. One-half mile west of West Middleton, at the "Sunny Brook Farm" the electric car passes under the railroad and from thence it parallels the latter on the south side to Kokomo. From Kokomo to Greentown the electric railway follows the township line, and from Greentown to the Howard County line the Clover Leaf is paralleled, first on the south side as far as Sycamore, then on the north side to the county line.

This company, also known as the Kokomo, Marion and Western, gives hourly passenger service from Frankfort to Marion. The company furnishes the electric power to the following towns and cities in Howard County: Sycamore, Greentown, Kokomo, Alto, West Middleton, Russiaville and New London. Numerous electric cables run to farm communities and give them the accommodations of light and power that are available within a corporation.

AGRICULTURAL NOTES.

Howard County is an agricultural county and produces in abundance wheat, oats, corn, potatoes, rye and hay. Corn is the leading crop. The deep black soil and the abundant rainfall during the growing season is the right combination for a splendid yield. The various grasses furnish abundant hay and pasture. The rolling lands along the streams are excellent grazing areas, and the live stock industry is in most cases limited to that district.

In the pioneer days hard wood forest covered almost the entire county. Native timbers and lumber were used in all buildings and fencing. The oak, poplar, walnut, maple and hickory are almost gone. Only a few small wood lots mark the places where once stood the great forests. The high prices of native timber has compelled the use of pine and cheaper materials. Local sawmills are gone and with them the revenue formerly obtained by lumber shipping. And today there is little waste land on the farms where some years ago much of it was unused.

Howard County has over 95 per cent. of its area in farms. In 1900 there were 2,680 and this number has decreased to 2,461 in 1910 and is still decreasing. The farms are becoming larger and the country population less dense. The greatest number of farms contain from 50 to 100 acres, there being 770. This is the usual size of the average farm. Only one in the county is over 500 acres, and ten less than three acres.

The crop reports for 1910 show the following interesting data:

Corn	acres,	60,158	bushels,	3,115,338
Oats	acres,	22,776	bushels,	782,924
Wheat	acres,	23,355	bushels,	424,458
Barley	acres,	16	bushels,	430
Rye	acres,	296	bushels,	4,950
Clover seed			bushels,	371
Potatoes	acres,	884	bushels,	94,609
Timothy	acres,	9,634	tons,	14,210
Clover	acres,	1,471	tons,	1,791

CLIMATE, DRAINAGE AND CROP NOTES.

Table of Climatical Changes, for a Period of Sixteen Years.

MONTHS.	Mean Monthly Precipitation.	Mean Temperature Fahr'h't°	Maximum Temperature F. °	Minimum Temperature F. °	Average Depth Snow, Inches.	Average Number of Rainy Days.	Average Date of Killing Frost.	Earliest and Latest Killing Frost.
January	2.6	27.1	68	—17	7.2	9	....	....
February	2.03	25.4	65	—20	7.6	9	....	....
March	3.28	40.1	84	— 1	5.2	11	Last	
April	3.2	50.9	92	17	0.5	10	in spring	....
May	4.1	62.7	97	29	Trace.	11	April 26.	Latest
June	3.99	70.8	101	37	....	9	....	June 7.
July	3.39	74.9	104	41	....	9	....	....
August	3.25	72.3	101	40	....	7	....	....
September	2.55	66.1	98	30	Trace.	7	First in	Earliest
October	2.09	63.1	88	18	Trace.	6	autumn	September
November	2.96	40.2	75	4	1.3	8	October1.	14.
December	2.41	30.8	64	— 9	4.6	9	....	....
Annual	35.85	50.9	104	—20	26.4	105	....	....

The recording station at Kokomo is 840 feet above sea level.

The growing season from the average time of killing frost in the spring to the average time of killing frost in the fall is ample for the maturing and harvesting of the staple crops of corn, wheat and oats.

The distribution of the precipitation during the growing season is a vital factor in crop production.

The definiteness of the time of the seeding of corn is governed by the variability of the season and moisture changes. The first or second week in May is the usual time, though later seeding often brings good returns.

Winter wheat is sown from the sixth to the fifteenth of September; however, during a late fall, wheat sown during the last few weeks in September or the first week in October will get sufficient growth to withstand the freezes. In either case a killing frost should visit the wheat land before the sprouts appear above the ground. This would prevent the injury to the growing wheat that is usually done by the noxious insects.

Vetch or some other legume should be sown on the land after the corn is "laid by" in the spring and plowed under as a green manure during the preparation of the seed bed.

Oats are usually sown during the early spring months, as soon as the freeze is out of the ground and the soil becomes sufficiently dry to till. The oats harvest follows the wheat harvest in close succession during the month of July.

Drainage.

The natural surface drainage is good. Wild Cat Creek flows through the entire county from the east to the west. On the south side, Kokomo, Little Wild Cat and Honey creeks flow into Wild Cat Creek and afford outlets for drains for the southern part of the county. On the north side, Lilly, Pipe and Deer Creek drain and afford outlets for drains in that part.

In the early days, Howard County was wet and swampy. The natural drainage depressions were obstructed by fallen timbers and decaying vegetation. These were difficult to keep open so that adequate drainage for crop tillage was possible. Later, large public drain ditches were constructed. They meandered through the farms and rendered not a little land waste. Many of them have since had one or more rows of tile laid within and covered up, so that farm operations are now carried on over them. The soil is black and deep, and the most fertile types in the county. There are no marshy lands so low that they cannot be drained, and, in fact, the county may be said to be without untillable marshes or bogs.

The major part of this black, fertile soil lies in Clay, Howard, Liberty, Jackson and Taylor townships, and is classed as the Clyde and Muck lands.

Drainage has yet another purpose than to remove the surplus surface water. We notice on close examination of the soils practically everywhere they are mottled, at a depth of ten to thirty inches, by brown and whitish colorations. The soil that is in the best of condition will not show such characteristics. It is an indication that the soil has become "heavy", compact, and as a resultant, "sour". Tiling is an important factor in obtaining the needful soil ventilation, in bringing the oxygen into the ground and giving the soil the proper temperature. The more drains placed in the "sour" land, with the idea of aeration in mind, the more productive and fertile the old soils will become. It is not necessary that a tile drain carry water. Much of the upland, though it has a rolling topography, would be benefited by permitting the passage of air through the drains and assist in removing the coldness and compactness of the soil and bring about that condition of deep porosity and pulverization, which enables the plant roots to pierce deeper and reach abundant food before the acidity of the soil kills the growing root tips, and a steady growth would then be insured during the summer months, notwithstanding the presence of insufficient rain.

Vetch and Its Uses.

Vetch is attracting considerable attention, yet its value as a legume is practically unknown to the majority of people. It has been known and cultivated in Indiana for the last decade. The "Sand or Winter Vetch" has become more popular, as its value as a soiling, green-manuring crop is learned. It is especially recommended for poor soils, upon which it thrives luxuriantly. It improves the soil by adding nitrogen and makes phosphoric and potassium compounds available.

As a soil restorer, vetch has few equals. It prevents washing and leaching during the winter months, and makes a rank growth for plowing under in the early spring.

The winter vetch will grow on almost any kind of soil that has reasonably good drainage. No soil should be left uncovered during the winter, and the writer knows of no other plant that can be used at such a great advantage as this one. As a fertilizer, the Department of Agriculture at Washington, D. C., has compared its value as equal to putting into the ground twenty to forty dollars' worth of commercial fertilizer per acre. It is surprising in what a short time the poorest lands can be restored and made to produce crops equal to the best.

Vetch can be sown after every wheat crop and in every maturing corn crop. Then it gives a good coating of green manure to be turned under for the next season. The land, if well drained, will not become sour, nor does it become dry or stunt the growing plants, on turning under the heavy foliage of the vetch.

It makes an excellent hay when grown with rye or wheat to hold it up, but its rank growth and vining habits unfit it for a hay crop alone. Its greatest value is as a pasture, and green manure crop in adding humus to the soil.

The vetch belongs to the same family as the cow-pea and clover, and it resembles the former in growth and general appearance. It grows about three feet high ordinarily, although occasionally on good soil it reaches a height of five or six feet. The greatest drawback at present is the scarcity and high price of the seed, but a small plot will furnish enough seed for several acres. The harvesting of the seed is done in the same way as the harvesting of the cow-pea.

The time has come when a legume must be grown for the benefit of the soil as well as for commercial purposes, and we believe vetch to be one of the greatest soil builders ever discovered. Its roots are the home of nitrogen-gathering bacteria, which bring the nitrogen from the air into the soil and make it into compounds which the growing plants can use. It has the advantage in being grown upon the soil at times when the soil would otherwise be bare. Seeing that it is necessary to add plant food to the soil if we continue to expect crop returns, we are forced to consider the fertility of the soil as a bank account that must be replenished in order that our drafts will be honored, or else we shall find ourselves facing the proposition of reclaiming "abandoned farms".

Rye and Its Uses to Restore Fertility.

Within the central area of Indiana there is perhaps no one who is at all acquainted with the growing farm crops, that does not know the characteristic features of a matured plant of rye. This plant is one of the family of grasses that lives for only two years, and during that period brings within the soil in which it grows abundance of nitrogen and nitrogenous compounds. In utilizing the rye plant for soil fertilization, this is one of the chief factors that makes it profitable.

The seeding of rye is done in the month of September about the same time as the seeding of wheat. The growth obtained in the fall and in the spring, until the time for breaking the ground for corn, should be left untouched and turned under in order to add humus to the soil. The ventilation and friability will be increased also.

By some who have used this method of soil rejuvenation, it is said that if the growth of rye is plowed under about May 1st, the money value added to the soil is from ten to thirty dollars per acre, at an expense of three dollars an acre. Others say that the increased fertility is equal to that produced by the addition of forty loads of good stable manure; yet even if this estimate is considerably too high, we are convinced that the easy method and small expense of producing a growth of rye over large areas would make it a desirable plant for soiling purposes. In addition to this advantage, it is grown at the time of year when much of the soil is unoccupied by other crops.

In order to gain the best results from the rye, for soil fertilization, we believe that the entire crop should be turned under at the spring plowing; yet, in many cases, the occupant of the farm, if the farm is small, would find that he could not care for his stock throughout the period of production of the tillage crop that followed the rye, so we must not fail to emphasize the pasturing advantage of rye in the fall. In all such cases, however, the advantage of the compromise should be made in favor of the soil, so that the hopes of maintaining it in a better state of productivity for an indefinite number of years would be insured.

ARTESIAN WELLS.

Originally, artesian wells and flowing wells were synonymous; but any notably deep well is now called artesian. The artesian well, which does not flow, does not differ greatly from common wells in principle, while the flowing well is really a gushing spring, the opening of which is made by man.

Flowing wells depend upon certain relations of rock structure, water supply, and elevation. Generally speaking, a flowing well is possible in any place underlain by any considerable bed of porous rock, if this rock outcrops at a sufficiently higher level in a region of adequate rainfall and is covered by a layer or bed of impervious, or relatively inpervious rock. The porous rock is the reservoir of the flowing wells. It is usually a stratum of sand or sandstone, and of gravel or conglomerate. The impervious layer must be unbroken and continuous except at the point of catchment, or the place of the outcropping of the water-bearing stratum. This maintains the water head and gives the pressure to the flow from the well.

Many of the deep gas wells of Howard County have passed through conditions favorable to flowing wells. The light, gaseous substance that lay upon the surface of the underground water, that was below the impervious strata, has been removed and now the same openings have become flowing wells of good water.

The majority of the wells that are flowing at present are located in the vicinity of Kokomo and Fairfield. From some, the water is similar to that of the common wells and is quite useful for farm purposes, while from others the mineral constituents are so abundant as to give the water a pungent odor and disagreeable taste. Iron sulphide, hydrogen sulphide, calcium carbonate, calcium sulphate, magnesium sulphate, and included quantities of natural gas are the principal compounds that give that "peculiar" taste to the artesian water of Howard County.

One well-known and often visited flowing well is located in the city park of Kokomo. The water here is strongly sulphuretted, has a pungent odor, and to many people it is a curiosity that has but little fascination.

The continuous flow from the many wells in Howard County has without doubt lessened the water head. The pressure is much less now than it was several years ago, and it may be only a few years until the wells will cease to flow.

Lime and Its Uses.

Lime has long been recognized as a valuable agent in promoting crop production. The earliest forms used as fertilizers were marls, gathered from their native deposits and applied to the soil by sowing broadcast upon the plowed surface and harrowing in. If lime is desired as a fertilizer it makes little difference what sort is used—marl, ground limestome, slacked lime well mixed with dirt or some other filler. Burned lime or caustic lime should not be used until well air or water slacked. Then it would serve the purpose better by using a good filler.

Lime, with a little phosphate or phosphoric acid, usually causes a complete change in the poorest of soils, so that for a time cultivated crops do well. The acidity of the soil is neutralized by the application of lime, and the crop immediately following will be better than the previous ones; yet the depletion of the soil by the chemical action that results does not approve of the continuation of such applications. It is well to use the lime for neutralization of the acid and then further enrichment should be done by growing some legume, as cow-peas, soy-beans, clover, alfalfa, winter vetch or hungarian.

The lime has a tendency to decompose the humus and liberates and reduces the amount of plant food stored in the soil. Because of this property, it can be used to an advantage upon peaty deposits in order to hasten the process of decay.

In choosing a limestone for use in liming soils, the magnesium limestone should be rejected. A method of differentiating it from the purer limestone may be made by noting the fact that it is heavier than the calcium carbonate and will not effervesce vigorously when cold hydrochloric (muriatic) acid is dropped upon its surface, while the effervescence of pure calcium carbonate (limestone) is extremely vigorous.

As a general rule, from one-half to one and one-half tons of lime per acre is sufficient to change the acid soils, but heavier application of two tons would be advisable in case of very acid soils, which are to be seeded to grass and left for several years in pasture or meadow. The practice of applying small amounts of lime at somewhat frequent intervals is being generally accepted as preferable to the use of large amounts at rare intervals. The frequncy of the application depends upon the character of the soil, the number of years involved in crop rotation, the kind of plants grown for cropping, and the kind grown for soiling purposes.

Limestone in the form of ground limestone or marl can be applied in the spring or at any season of the year, but autumn is always the safest time to apply the slacked caustic lime. It is generally considered best to apply the lime to the soil immediately after plowing and then harrow in thoroughly. Lime which is already slacked may be spread upon the soil directly from wagons or by the use of a lime spreader or fertilizer attachment. Lime alone should not be depended upon to maintain the fertility of the soil, for all of the ingredients which plants need must be present in the soil to insure a profitable crop production and consequently must be returned by the addition of humus, as suggested elsewhere in this paper.

The commercial fertilizers may be used as a stimulant to the soil, in starting a crop, but we believe that its constant use with all crops must never be resorted to under any condition. A much better method of restoring worn soils is by growing nitrogenous plants as vetch, rye and cow-peas and giving back to the soil the entire growth between the harvesting and seeding of tillage crops.

SOILS.

Miami Series.

Types:	*Area.*
Miami Silt Loam	131 square miles.
Miami Silt Loam—Flat Phase	36 square miles.
Miami Gravel Loam	2½ square miles.
Miami Loam	2 square miles.

The soils of the Miami series are the most predominant of all the types, and include the various divisions given in the table above. Throughout the county they form the clay uplands or "white lands", as they are often locally known. Everywhere the surface stratum consists of a very fine silt or silty clay varying in depth from a few inches to a foot or more. This thin layer is continuous over the Clyde types also, but is not so distinguishable. On steeper slopes along the streams it has suffered partial, and in places complete erosion, exposing the underlying till.

In structure the upper stratum consists of very fine soil particles and feels like flour. There is little doubt but that this is a wind deposit similar to loess, yet during the process of tillage it has become intermixed with the coarser layer below, so that a great deal of the original characteristics have been lost. In this condition we classify it as a silt loam. The percentage of clay is usually low save where the layer is so thin that the clay from the stratum below has been mingled with it. Usually it does not become sticky when wet or hard when dry, except in those districts affected greatly in composition by the clay.

All the Miami types were once heavily forested, but the topographical condition did not usually permit the accumulation of very great quantities of organic matter. The little humus that existed in the soil from the decay of vegetation has, on the more rolling surface, been leached out and washed away, leaving the soil whiter, less friable, more compact and more difficult to till. The mineral foods are dissolved and carried away, making the problem of restoration troublesome and expensive.

Miami Silt Loam.

The Miami silt loam is the dominant type throughout the county, covering about forty-five per cent. of the total area. It has a rolling topography and within the vicinity of the streams it often is quite hilly. The stream erosion in Howard County is young, geologically speaking, which is shown by the steep bluffs of the upland that form the banks of Wild Cat and its tributaries, and the approximate levelness of the surface that extends back from these bluffs. The hilly district is narrow, seldom more than a mile wide on either side of the larger creek. Even though many small level areas lie in this division, the majority is given over to meadow and pasture land, except on small farms.

The cultivated soil is light gray to brownish gray. Any clods upon the surface are easily crumbled to a fine powder. The fine structure and texture makes under drainage inadequate. Artificial drainage of numerous tiled ditches paralleling each other only a few rods apart would remove the stagnant water that causes the sour, "soggy" condition, and would assist in a more thorough ventilation and oxidation of the soil, which would make the mineral food available and bring about a more favorable temperature in the soil for plant growth.

The removal of the excess of ground water would make earlier cultivation possible and give a better control over the moisture conditions in the time of drouth, as well as in times of excessive rainfall. Liming the land is an immediate remedy for "sour soils"; however, it does not measurably increase the amount of mineral plant food.

The hay produced upon this type of soil is mostly a mixture of timothy and clover. Timothy alone is very hard upon the soil. A field that has been in timothy meadow for several years and then prepared for a crop of corn, will grow stunted, yellowish-green plants, showing that some of the important foods are not present; but a field where a good sod of clover and timothy is plowed under usually produces a reasonably good tillage crop. The clover tends to balance the condition that the timothy alone brings out, and leaves the soil is almost the same condition as it was when the meadow was seeded.

At present this soil cannot be called a first-class "corn soil", but in its virgin state it produced excellent crops of either corn, wheat or oats. Its fertility can be restored and its life prolonged indefinitely by a carefully selected system of crop rotation. A process of crop management that is used by a few farmers of the county is given here, and the results that they have obtained are surely sufficient argument in its favor.

The first year in the process of soil restoration of the Miami type, which will serve for practically any of the others, were as follows: A crop of sugar corn was put in after the soil had been thoroughly ditched, was marketed at the local factory. The ground was kept clean and well cultivated.

Early in August vetch or rye was sown between the rows of corn, vetch being preferred. Under no circumstances were the stalks pastured. They were left for plowing under with the vetch, which was done about the first of May with a double disc plow. The vetch was not pastured in the spring.

The field was planted in corn and the yield was amazingly increased. Vetch was sown in the corn as before and left to be plowed under for the next tillage crop. The second corn crop, produced in this method of rotation, was followed by a crop of wheat and clover, then back to corn, as before.

With this method, soils that formerly produced from ten to twenty-five bushels of corn are increased in fertility so that in two seasons they produce from fifty to one hundred bushels.

If alfalfa is wished to be sown, the vetch can be plowed under before it ripens, and thus keep cultivating the ground until about the middle of July or the first of August, at which time it can be seeded. The vetch will inoculate the soil and a good stand of alfalfa is insured. The first clippings of the alfalfa, when it is about five or six inches high, are left on the ground, and if the growth is considerable before winter it is clipped again.

The greater the amount of organic matter introduced, the greater will be its ability to retain moisture. There should be no fear that the introduction of such large amounts of green vegetation would make the soil sour; on the contrary, a remarkable degree of fertility has resulted from all the experiments, and a fertile soil is not a sour soil.

The value of this type varies greatly, as to the care it has received in cultivation and the condition of its improvements. In 1913 it was selling for $50 to $75 an acre in the worn condition, and $100 to $150 for the better improved. The price varies also as to its location, being valued at $200 to $250 per acre wherever it lay within a few miles of Kokomo. Truck farming and dairying are the principal occupations of the people in such a district, and the products are marketed in that city.

MECHANICAL ANALYSIS MIAMI SILT LOAM.

(S. ½ Sec. 34, Howard Tp.)

Subsoil.	*Soil.*	*Description.*
2.03	2.21	Fine gravel, per cent.
2.07	1.20	Coarse sand, per cent.
15.01	4.37	Medium sand, per cent.
13.37	8.32	Fnie sand, per cent.
12.27	11.14	Very fine sand, per cent.
55.25	72.76	Silt and clay, per cent.

THE SUBSOIL OF THE MIAMI SILT LOAM.

Below and in contact to the silty stratum, the subsoil contains a great deal of loess, but as the depth increases the clay content becomes higher. Its structure is more compact, its drainage is poor, and its mottled coloration usually noticeable. At a depth of thirty inches and quite often at a depth of four feet, the compactness of the subsoil becomes a distinguishing character. It is not absolutely impervious to water, however, the movement is so slow that most people who are acquainted with this condition call the layer "hard pan". At varying depths the "hard pan" underlies the major portion of the Miami silt loam, and in places it lies under the Clyde types, usually at a greater depth.

When this partially impervious stratum is deeper than five or six feet, good soil drainage is obtained in the more open subsoil above, naturally and artificially, but whenever it comes near the surface—that is, within eight to twenty inches—the possibility of obtaining good drainage even by tiling is difficult. Only very small areas were noticed, where surface drainage and shallow tile ditches were removing the excess of water. The surface soils in such localities are always "sour", the crops are generally unproductive and the plants seldom reach their customary size.

The process described in a preceding paper for soil reclamation will bring about a marked degree in the increase in fertility within a period of two years that will pay the expense of the necessary labor and time.

Miami Silt Loam, Flat Phase.

In the localities where the Clyde series is the predominant type, we find very gently raised portions that are of a lighter color. Upon these slight elevations are, in most cases, built the farm homes. They are high enough to cause good surface drainage and make excellent locations for buildings and orchards. The surrounding types are dark colored and make the lighter types conspicuous.

This type, the Miami Silt Leam, Flat Phase, is designated on the maps by vertical broken lines. The larger districts in which it lies are in Clay, Howard, Jackson and Taylor townships.

The soil is from eight to fourteen inches deep and of a dark gray to a light gray color, grading to a dark brown near the boundaries, where it grades into the brownish black or black soils of the Clyde type. The clay constituent is not so great as in the Miami Silt Loam, yet wherever a condition of poor farming exists, the flat phase assumes a compact nature similar to other Miami types. A high per cent. of humus gives the darker color to this Miami type and makes it loose, friable and easy to till. Underdrainage should be used to increase the aeration and control the temperature conditions. Water moves rather slowly through the heavy clay loam subsoil. At the depth of twenty to thirty inches the subsoil is locally heavy and mottled, friable and gravelly; thus the natural underdrainage is assisted.

The "hard pan", spoken of under subsoil of the Miami Silt Loam, was frequently found to lie within thirty inches of the surface.

The crops of corn, wheat, oats, clover and forage do excellently well, wherever the proper care of replacing the plant food in the soil has been done by either clover or some other legume. The corn produces from thirty-five to fifty bushels per acre, according to the care given to the soil before and during cultivation. This range of production may seem rather low to owners of the land; however, there are very few fields of thirty to forty acres that consist wholly of this type. The Clyde soils that lie adjacent have a greater yield and raise the average of the field.

When the fertility is increased by the application of refuse from the stables or by turning under repeatedly legume crops of clover, or vetch, the yield in all crops is greater accordingly. Under such conditions corn seldom produces less than fifty bushels per acre and often produces seventy-five bushels. Wheat produces from twenty to thirty-five bushels per acre under the same conditions.

The price of this land is influenced by the types among which it lies, being from $150 to $200 per acre. Its location in reference to the city of Kokomo causes some variation in the sale price also.

MECHANICAL ANALYSIS MIAMI SILT LOAM, FLAT PHASE.

(Center of East ½ Sec. 23; 1 mile north of Sycamore.)

Subsoil.	*Soil.*	*Description.*
2.47	1.73	Fine gravel, per cent.
2.86	1.94	Coarse sand, per cent.
14.20	8.92	Medium sand, per cent.
17.03	8.22	Fine sand, per cent.
10.11	14.61	Very fine sand, per cent.
53.33	64.48	Silt and clay, per cent.

Miami Gravel Loam.

The Miami gravel loam includes such a small area that its influence on crop production is very small. The two and one-half square miles of this type lies in narrow strips along the streams, especially along Wild Cat, west of Kokomo. The soil is of a light brown to a yellowish gravel-loam containing considerable silt. The silt is derived from the surface wash of the Miami silt loam that lies adjacent.

The gravel loam lies upon the slopes and terrace formations. It is derived from the weathering of the glacial till and is a heavier soil than the other Miami types, containing more clay and less humus.

Cultivation is often difficult where the gravel is too close to the surface and the topography is rough and broken.

Native forests once covered this type of soil, but since it has been cleared, blue grass pastures protect it from washing and leaching. In places where cultivation is followed and tillage crops are raised, extensive gullying becomes a characteristic feature.

The Miami gravel loam is splendidly adapted to fruit raising. Orchards grow well upon the slopes too steep for advantageous tilling. Clover makes the best orchard sod where it is possible to get it started. It will lessen the surface wash and be a benefit to the soil.

Where large areas are owned by one farmer, pasturing is perhaps the most profitable, especially on the hilly portions. In such districts dairying has become a profitable industry. This is, indeed, true when it lies within a few miles of Kokomo.

The price of the land ranges from $40 to $70 per acre, according to its condition and the amount of surface gullying. Plots that have received little or no care sell for a price less than stated above.

MECHANICAL ANALYSIS MIAMI GRAVEL LOAM.

(S. E. ¼ of N. E. ¼ Sec. 3, Center Tp.)

Subsoil.	*Soil.*	*Description.*
3.52	2.10	Fine gravel, per cent.
3.84	3.46	Coarse sand, per cent.
11.61	7.41	Medium sand, per cent.
18.63	8.94	Fine sand, per cent.
20.73	16.43	Very fine sand, per cent.
41.67	61.66	Silt and clay, per cent.

MIAMI LOAM.

The Miami loam is a variable type since it is influenced by the adjacent types. It lies upon the terraces of the stream, but it is not derived from alluvial deposits. The surface wash from the Miami silt loam and the Miami gravel loam is left upon the Miami loam phase and make a silty loam near those types. Uniformity in texture and structure is not to be expected. The deep subsoil is usually of a coarse texture and permits the free passage of ground water. The upper subsoil is generally a silty loam, moderately compact, but possesses good capillarity. Brownish or yellowish tints are the characteristic colors of this substratum. The lower part of the subsoil is brown or reddish brown, caused by the relatively high degree of oxidation of the iron contents that characterizes the upper part of the glacial till. The subsoil is usually high in moisture and the soil becomes seldom dry, due to the rise of the water by capillary attraction. It is this property, combined with good drainage, that enables this type to withstand seasonal extremes so well.

This phase is more silty than the Miami gravel loam and not so easily differentiated from the other silty phase of the Miami series. Quite often fine sand is found in appreciable amounts through the soil locally. Usually this type averages twelve inches deep and is a fine, sandy loam, but on inclinations the finer portion is removed by surface wash, leaving the coarser gravelly subsoil so near exposed that it eventually becomes mixed with the remaining surface soil. On account of the open structure of the soil and the shallow depth at which the glacial till lies, the entire soil type has good drainage and aeration. The small amount of Miami loam in Howard County lies in separated areas along the principal stream. The area being so small and of such unimportance in considering the whole county, it can hardly be said that it has a commercial value of its own. In regard to its position among other types it has a market value of \$60 to \$80 per acre. The adjacent types are either rolling or hilly and mostly used for pasture lands, and this is a determining factor in the use of the Miami loam. This soil itself has a high agricultural value and can be made into excellent farming land, because of its good conditions of underground water and the loose texture and structure of the surface, yet the isolated areas are so small that very little attention has ever been given to the improvement of them.

MECHANICAL ANALYSIS MIAMI LOAM.

(N. E. ¼ of S. E. ¼ Sec. 34, Howard Tp.)

Subsoil.	*Soil.*	*Description.*
8.47	1.31	Fine gravel, per cent.
4.03	1.02	Coarse sand, per cent.
18.96	7.46	Medium sand, per cent.
23.41	3.51	Fine sand, per cent.
13.04	11.01	Very fine sand, per cent.
32.08	75.69	Silt and clay, per cent.

CLYDE SERIES.

Clyde Silt Loam .... 55 square miles.
Clyde Loam .... 2½ square miles.

In the type list as given in the legend, the next series is the Clyde. This includes the black lands in Clay, Howard, Jackson and Taylor, where large tracts are found, as well as the small irregular patches scattered promiscously throughout the county.

The topography is generally flat to very gently rolling, and occupies the depressions that exist upon the upland.

Clyde Silt Loam.

The Clyde silt loam or Clyde silty clay loam, as it is sometimes known, is a black, silty clay loam. The per cent. of organic matter is high and imparts the dark brown to black color to this soil. It is friable and has a loose structure, especially in areas that are well tilled.

The subsoil is usually of a lighter color and containing a greater amount of clay. Quite often the clay constituent is so great that the subsoil is very compact, and apparently impervious, yet dry portions show a remarked tendency to break up in small cubical particles that even present within themselves a porous condition. At greater depth of twenty to thirty inches the subsoil becomes mottled with white streaks and reddish-yellow iron stains. This, when wet, has a plastic, sticky nature, but its tenacity is lost as soon as the material becomes dry, and crumbles freely.

The Clyde silty clay loam that lies in narrow connected or isolated areas has similar subsoil to the Miami phases which surrounds them. The glacial drift lies at about three or four feet below the surface. The drift often contains beds of gravel that lie beneath the silty clay subsoil. These small areas contain less organic matter and are not so dark colored. As a rule they are chocolate brown to brownish black. Some of the strips of this type that lie in the depressions in the upland are seldom more than a few hundred feet across. The surface wash has in many such limited areas silted in until the productive quality and physical appearance are scarcely different from the upland phases. The majority of the smaller areas of the Clyde silt loam are in the southern and western part of the county. They are in depressions that often present a meandering appearance as if they had been old beds of small streams. It is not likely that a stream ever flowed for a very long period in the depressions, but more that they have been irregularly formed lakes that wound about the uplands and were filled with swamp plants and marsh grasses that grew up, fell down and decayed under water. The partial decay of the plants in that condition left the black carbon unoxidized, which even yet gives the color that to most people means a rich soil.

The larger areas, as are found in Jackson and Clay townships, have been old lake bogs. The color of the soil is very dark brown to black, and is usually several feet deep, lying upon the lighter subsoil. The organic material is very abundant, though we do not believe that the black, partially oxidized organic matter enriches the soil; we, however, believe that the condition of texture and structure brought about by its presence tends to lighten the otherwise heavy clay soil and make it better adapted to plant growth, and gives it its present great agricultural value.

The Clyde silty clay loam is the leading corn soil of the county. It yields from fifty to seventy-five bushels per acre and often eighty to ninety. Seasonal extremes of wet and dry conditions do not measurably affect this type that is well drained. The smaller areas do show some effect of a dry season, especially during the growing months.

Wheat yields from twenty to thirty bushels per acre on the Clyde soil and it withstands the freezing of winter with remarkable persistence on the well drained areas. Wet, "open" winters are very injurious to the winter wheat on the Clyde silt loam, more so than on the Miami phases. The open, loose structure admits water freely, and during the periods of freezing, the wheat plants are lifted out of the soil. A relatively dry season during the winter months, with a few inches of snow protection is generally followed by a good yield. Clover, timothy, and alfalfa do well on well drained areas of this type. Oats usually grow so rank that before harvest they lodge badly.

In preparing this soil for alfalfa, good drainage that would lower the water table to at least five or six feet is necessary. Then before the sowing of the alfalfa, a crop of some good legume should be raised upon the soil—winter vetch preferred. If this is grown and turned under in the spring before the seeding of the ground to alfalfa in July or August, there will be no need of further inoculation. Commercial fertilizers are seldom if ever used upon this soil, and a good system of crop rotation with some good legume, and a little addition of phosphate and lime will, as a rule procure the desired results.

The Clyde silt loam commands the highest price of any farm land in the county, especially when the necessary drainage and improvements for cultivation have been made. There is very little that is not under cultivation, and that which is not, is able to be drained and improved. The present price varies from $150 to $200 per acre. The more desirably located farms are marketed at even a higher price.

The black soils that lie within a few miles of Kokomo are gardened and trucked. Tomatoes, sweet corn and peas are raised and delivered to the local canning factories. In this vicinity it is not unusual for land to sell for $250 or $275 per acre.

MECHANICAL ANALYSIS CLYDE SILTY CLAY LOAM.

(Center of W. ½ of Sec. 25.)

Subsoil.	*Soil.*	*Description.*
.12	.02	Fine gravel, per cent.
.31	.06	Coarse sand, per cent.
.47	.27	Medium sand, per cent.
.08	1.21	Fine sand, per cent.
2.02	1.76	Very fine sand, per cent.
97.1	96.68	Silt and clay, per cent.

Clyde Loam.

The soil of the Clyde loam is a deep sandy loam containing a very high per cent. of organic matter. It varies in depth from ten to sixteen inches. When dry the surface is very loose, crumbling to fine particles and having a very dark gray to brownish-black color. The organic humus keeps the soil from packing or crusting. When it is wet the color is intensely black. In the region of this soil that lies in the central portion of Clay Township there are limited areas that contain a medium fine sand, mixed with the fine carbonaceous granules, so that the whole presents the appearance of being composed of very dark to black sand. It is loose to a depth of a foot or more, and yields readily, even to the shuffling by one's foot.

The upper subsoil contains much clay, and is usually a bluish-black in color. It is plastic when wet, and when it lies close to the surface and is struck by the breaking plow it yields only after heavy pulling. It is called "gumbo" by the farmers, and is quite often considered a worthless soil. It contains considerable sand, crumbles to small, hard granules often cubical, and apparently infertile. The "gumbo" area, when well drained, reacts to the application of stable manure. However, the strength of the fertilization seems to last for only one year or two at the most. The corn on such soils sprouts and begins its growth in splendid condition, being of a very dark green color until reaches about six or eight inches high. Then the lower leaves begin to turn yellowish-green, the edges of them begin to roll and dry up completely. The stalk of corn grows very slowly, becomes a pale, yellowish-green, with the lower leaves dead and withered away. It may reach a height of four five feet, but the joints of the stalks are short and the tassel stunted, whitish and without much pollen. The stalks are easily blown awry and become crooked. A "shoot" appears, but it seldom if ever matures into a sound ear. The plant is easily pulled from the ground at any stage of its growth or after maturity. The "spike" roots are dead, being eaten off by some chemical. Only the surface roots are supporting the growth and weight of the plant. These prove insufficient, the plant is stunted and we have, what is well known as "chaffy" corn.

The improvement of this soil has been suggested by many different people to be brought about in many different ways, and it is the purpose here to give the experiences of people who have been endeavoring to make the soil yield more favorably to cultivation. This "gumbo" is what might be termed a "water-logged" soil. It is dead to plant life and contains a high percentage of various forms of alkali.

The process of reclamation is begun by a thorough tiling. In this case, it would mean that a large tile should be laid through the lower part of the area and tributaries leading from it to all parts. The smaller tile-drains should be only a few rods apart and at a depth not greater than twenty to twenty-four inches, in order to lie out of reach of the breaking plow, yet above the heavy blue clay stratum as much as possible. The drainage system would induce aeration and remove the stagnant ground water. The frequent rains would wash the soil free from the injurious chemicals that destroyed the roots, and it would be carried out by the drains.

Deep and frequent cultivation should be used when a tillage crop is raised. Organic substance should be introduced into the soil as soon as possible and in large amounts.

Winter vetch should be sown in the fall and plowed under in the spring as late as possible before the planting of corn. This should be repeated for several years. A coating of ground limestone flour, about three to four tons to the acre, and a quantity of commercial phosphoric acid or phosphate will in some cases be found a necessity, to supply those mineral plant foods and remove objectionable acid compounds in the soil. The benefit derived by this method has been found paying to the investor and profitable to the soil. The fertility is increased, and quite often permanently, at least the former "gumbo" nature is destroyed and the soil becomes similar to the remaining portions of the Clyde loam.

There is little soil of this kind in the county, only a few acres here and there in isolated plots throughout the Clyde series. The value of this land ranges, after in a good condition, from $125 to $150 per acre, being influenced greatly by the surrounding Clyde silty clay loam.

MECHANICAL ANALYSIS CLYDE LOAM.

(S. ½ of Sec. 22, Howard Tp.)

Subsoil.	*Soil.*	*Description.*
1.41	.05	Fine gravel, per cent.
3.36	4.10	Coarse sand, per cent.
15.41	18.62	Medium sand, per cent.
13.62	20.31	Fine sand, per cent.
11.98	19.49	Very fine sand, per cent.
64.22	37.43	Silt and clay, per cent.

GENESEE SERIES.

Genesee Sandy Loam .... 16 square miles.
Genesee Sand .... 1 square mile.
Genesee Loam .... 7 square miles.

The Genesee series of soils are all of alluvial or of partly alluvial derivation and lie next to the stream beds throughout their entire course. These soils along the smaller streams lie in very narrow strips and owe a great many of their characteristics to the surface wash from the upland types. West of Kokomo the bottom lands widen and maintain a reasonable width to the west county line. In this district the Genesee soils have a tillage value and the standard crops of corn, wheat and oats are raised, as well as a great many tracts being used in truck farming, producing, tomatoes, sugar corn, melons and peas.

GENESEE SANDY LOAM.

The Genesee sandy loam is a fine sandy loam of light brown to reddish brown color, and ranges from six to fourteen inches deep. The percent. of humus is usually low. The sand constituent makes tillage easy, and splendid seed beds can be prepared under almost any sort of weather conditions. The soil never packs or crusts after a heavy rain, though the soil particles are sufficiently small to retain ample ground water for tillage crops.

This soil is an ideal one for melon culture, and other truck crops that are adapted to loose, sandy soils do well.

The higher ridges often show effects of drouth, especially if the period of insufficient rainfall is prolonged.

The subsoil cannot be definitely separated from the soil stratum. The soil particles become coarser with depth and contain a considerable amount of very coarse sand and gravel. Natural drainage is generally sufficient only in the heavier silty areas.

The Genesee sandy loams occupy the first bottom along the streams and are composed of reworked glacial till and material of local origin. The occasional inundations assist in building up this type by spreading a layer of silt over the area.

The matter of cultivation is made more difficult by the reason of the overflows, as they act as carriers of weed seed, and the task of keeping the tillage crops clean becomes arduous.

The topography is generally level. The narrow areas east of Kokomo are gently rolling and they are used for pasture lands. Timothy does well either for pasture or for hay, since it is not so easily damaged by the overflows that bury it for a few hours.

MECHANICAL ANALYSIS GENESEE SANDY LOAM.

(Center of Sec. 4, in Harrison Tp.)

Subsoil.	*Soil.*	*Description.*
1.51	0.0	Fine gravel, per cent.
3.43	1.29	Coarse sand, per cent.
14.96	12.18	Medium sand, per cent.
19.17	19.18	Fine sand, per cent.
22.92	40.26	Very fine, per cent.
18.01	29.09	Silt and clay, per cent.

Genesee Sand.

In the larger areas of the Genesee soils, there was differentiated a type of coarse to fine sand as the Genesee sand. It lies in the inner side of the meander of Wild Cat west of Kokomo. The entire type scarcely covers more than a square mile.

The surface is a sand deposited by the currents of the stream during freshets and quite often is not covered with vegetation. The wind shifts the sand in the unprotected area. Recent fresh water shells and organic remains shows the recency of the deposit.

The depth for two or three feet seldom changes in texture or structure, save that the clay that has been carried in suspension by the receding inundations has sunken into the sand and causes portions of it to become packed and sticky to the touch, when wet.

Gravel is found underlying this sand at varying depths of four to five feet, or the sand becomes so coarse that the movement of ground water is quite free.

The agricultural value of the sand deposits is practically nothing. The moisture conditions fluctuate with the amount of precipitation and the humus contents is so low that there is no real firmness to the type sufficient for seed germination and growth.

Genesee Loam.

Along the small tributaries the bottom lands are very narrow, ranging from one-twelfth to one-tenth mile wide. The streams are young and shallow, and any heavy rain raises them above the shallow bed over the first bottom and quite often the water spreads back to the Miami types. The silt carried from these freshets is deposited upon the first bottom and makes up the greater per cent. of the Genesee loam, making it a silty alluvial deposit.

This soil is eight to ten inches deep and of a light brown to a chocolate brown color. Throughout the soil there is much coarse gravel and even pebbles. The organic matter forms a low per cent. of composition. The sand and gravel makes the soil friable and easily tilled. Generally the drainage is poor and parts of the area are semi-swampy during a part of the year.

The subsoil is a heavy silt loam containing a high per cent. of sand and gravel near the base. It is mottled with whitish, black and reddish spots, showing that aeration and oxidation has been impeded by the excess of ground water and the variable compactness of the structure.

In areas that have sufficient drainage the soil is productive and yields good crops of corn and wheat. Clover and grass do well and make excellent pasture lands. The contiguousness of the ground water induces growth during the entire spring and summer season, and when pastures are short elsewhere these bottom areas furnish abundant feed.

The type produces from thirty to fifty bushels of corn per acre, to sixty or seventy on the better improved. In areas that are sufficiently large to command a separate market value, the price ranges from $60 to $80 per acre. Usually the selling price is governed by the adjacent types, since no farm includes more than a few acres of the Genesee loam.

MECHANICAL ANALYSIS GENESEE LOAM.

(Center of Sec. 16, in Taylor Tp.)

Subsoil.	*Soil.*	*Description.*
6.01	3.01	Fine gravel, per cent.
5.62	3.05	Coarse sand, per cent.
13.41	2.74	Medium sand, per cent.
14.93	10.93	Fine sand, per cent.
10.11	20.64	Very fine, per cent.
49.91	69.63	Silt and clay, per cent.

Meadow.

The recent alluvial deposits along upper Wild Cat and along the small streams in the northwest part of the county have been mapped as meadow. This is a condition of a soil rather than a soil type, and may include more than one phase. These areas are narrow bottom lands that are frequently overflowed by the streams. The soil is a brown silty clay loam containing considerable "grit". As a rule it is wet, poorly drained and covered with coarse marsh grass. Some portions are drained sufficiently for cultivation. Corn makes a fairly good crop, yielding forty to fifty bushels per acre.

The small area of Clyde silt loam lies in the depressions that lead to the meadow land. Many of the short tributaries of the streams that drain the Clyde have cut narrow gullies and this washed material is the chief source of building up the low bottom lands where the water runs more sluggish.

There is not sufficient area of this land to give it an individual value; however, as a pasture land it has proven to be good, especially during the summer months of July and August when the rainfall is at a minimum.

Muck and Peat.

Old peaty bogs that have been drained are the best examples of mucky land. The soil is black, woody and deep. It is loose, easily pulverized at any time of the year, whether wet or dry, except when frozen. Remains of old decayed tree-trunks, leaves, roots and smaller vegetation makes up the bulk of the soil. In places, no limit to depth was found or no change in the composition, save only that the surface contained a little more silt that washed from the surrounding soils. Where a subsoil lies within three or four feet of the surface it is principally a bluish-drab silty clay and has every appearance of the clays that form the bottom of the present-day swamps.

In Section 22 of Howard Township is an area of peaty muck that resembles peat more than muck. It is of a reddish-yellow soil that is almost wholly composed of decayed organic material. In quantities taken from the field, the woody structure of tree trunks was easily made out. The area is not yet under cultivation, even though it is fairly well drained and quite level. On this land were growing many ferns in clusters of more than a foot in diameter, and they reached a height of three to four feet. Even though the year 1914 was an extremely dry one, these plants grew luxuriantly without shade or without water, other than that obtained from the ground.

Other areas of muck lie in Clay and Jackson townships, but they are smaller areas and have been under cultivation for several years.

Muck land has a value ranging from $150 to $250 per acre. It is a splendid corn land, yielding from seventy to ninety bushels per acre. Wheat and oats do not do well. The soil is so loose that the wheat freezes out, and the oats grow so rank that they usually lodge.

No fertilizer has yet been used on this type; however, a good legume would be well to place in the circle of crop rotations in order to secure an indefinite fertility.

EXPLANATIONS AND DIRECTIONS FOR THE USE OF THE SOIL MAP.

The map has been prepared with especial care, so that all information can be used by anyone. And the following gives the method of getting the description of any tract of land in the county:

First, the farm must be located on a civil map, according to the part of the section in which it lies. Then one could find the same area on the Soil Map and trace a lead pencil around its approximate boundaries.

Let us choose the N. E. ¼ of the S. E. ¼ of Section 21, Range 4 East and Township 24 North. This forty acres lies 2½ miles east and ½ mile north of the northeast corner of Kokomo. The house stands on the northeast corner of the forty, being represented by a small square dot.

Now in applying the classification below to the areas marked the same way, we find that the north edge of the forty is Miami Silt Loam, Flat Phase; south of this is a strip of Clyde Silt Loam, and next an area of Muck that resembles closely the Clyde Loam. South of this are small tracts of Clyde Silt Loam and Miami Silt Loam, Flat Phase, that would lie in the forty acres.

Now, having found the names of the types, the accompanying paper gives a detailed discussion of each, listed under soils.

Soil Survey of Jay County.

By Allen David Hole.

LOCATION.

Jay County is located on the eastern margin of Indiana, a little farther north than the central part of the State. It is bounded on the north by Wells and Adams counties, on the west by Blackford and Delaware counties, on the south by Randolph County and on the east by the State of Ohio. It includes about 375 square miles lying in Townships 22, 23 and 24 N., Ranges 12, 13, 14 and 15 E., of the United States land survey.

HISTORY.

So far as known, the earliest settlement by white men within the limits of the present boundaries of the county was made on the south bank of the Wabash River at New Corydon, in the extreme northeastern part of the county. Other settlers followed in the succeeding years, until in 1834 there were white settlers in sufficient numbers to organize the territory into a county. At first the area now included in Jay County was, with other adjacent territory, known as Randolph County. The following year the area now included in Jay and Blackford counties was laid out, and on January 30, 1836, the act organizing the present county was approved and the name of Jay was given in honor of John Jay, the first Chief Justice of the United States Supreme Court. The first election of county officers was held in August, 1836, and in 1837 the area now included in Blackford County was set off, leaving Jay County as it is today.

As is the case with much of the adjacent territory in Ohio and Indiana, the area now constituting Jay County was, before the coming of white settlers, claimed by various tribes of Indians. It is impossible to state exactly the boundaries separating the hunting grounds of one of these tribes from those of another, since accurate boundaries of this sort did not in many cases exist among the Indians; but the principal tribes occupying that part of Indiana and Ohio adjacent to Jay County were the Miamis, Wyandottes, Pottawatomies, Senecas and Shawnees. Before these various tribes were ready to give peaceable possession and allow the settlers to clear the land and make permanent homes, at least three separate treaties were made affecting the land in Jay County. One was made at Greenville, Ohio, August 3, 1795; another at St. Mary's, Ohio, October 6, 1818; and finally the last, by the terms of which the reserve known as the Miami Reserve, two miles west of Portland, was ceded to the United States, which was made with the Miami tribe on October 23, 1834, at a point on the Wabash River below Bluffton. At least one of these treaties was signed by Gen. Anthony Wayne and the chiefs of the tribes named above, together with the chiefs of a number of other smaller tribes.

There still remains geographical evidence of one of these treaties on the road extending in a northeast-southwest direction across the southeastern part of the county, a part of which has been abandoned, but which originally passed about one-half mile southeast of Salamonia. The village named Boundary City is also a record of the fact that this line was established as the fixed boundary line between the land ceded to the white men and that retained for the time being by the Indians.

As was the case with other large areas, especially in the northern part of the State, a large proportion of Jay County was originally a swampy wilderness. Forests covered almost the entire surface and over much of the area water was standing for a considerable portion of the year. This condition caused the prevalence of malarial diseases when white men first began to make their homes within the borders of the county, but at the present time nearly all of the former marshes and swamps have been well drained, and as shown by the census of 1910, about 85 per cent. of the land in the county is improved farming land. This means that the waters no longer stand on the surface for a sufficient length of time to prevent the successful growth of farm crops. Not only has the drainage of the swamps and marshes been accomplished, but throughout the county generally good roads have been made, crushed stone or gravel being in most cases used, so that now practically every portion of the county can be reached on good roads at any time of the year.

The chief line of travel across the county after the coming of the white settlers to the State, was in a north-south direction between the cities of Richmond and Fort Wayne. This road or trail was known in the early days as "The Quaker Trace," the name being given because it was the road travelled by settlers in Wayne

County, who were at that time mostly Quakers, on their way to Fort Wayne, which was the point most accessible to them for selling their produce and buying such supplies as were needed. With the increase of population, however, roads were constructed in various directions and in December, 1871, the first railroad was completed across the county called then the Cincinnati, Richmond and Fort Wayne Railroad, now known as the Grand Rapids and Indiana, which passes in a north-south direction a little to the east of the center of the county. Later, the Lake Erie and Western Railroad was completed, passing in an east-west direction from the southwest corner of the county to a point a little south of the center on the east side; and later still the Cincinnati, Bluffton and Chicago Railroad, which enters the county from the northwest and has been completed as far as Portland. In more recent years, a traction line connecting Portland with Muncie by way of Red Key and Dunkirk has added greatly to the facilities for travel across the southwestern part of the county.

As has already been indicated in the statement concerning the percentage of improved farming land, there is no considerable area within the county that is not under cultivation. The majority of the population, which numbers about 25,000, live on farms, most of which are well improved.

GEOGRAPHY AND GEOLOGY.

The topography of Jay County is in general determined by the uneven deposits of the drift left upon the withdrawal of the successive sheets of ice which once covered this area, together with the erosion which has taken place since that time. The drift constitutes the surface formation at all points in the county except two, where limestone of Silurian age outcrops. These two points of outcrop are located about two miles west of Portland, and in the northeast part of the county near Jay City, respectively. At other points in the county, limestone in place is encountered only after the drift has been penetrated to depths averaging perhaps seventy-five or a hundred feet, the maximum reported being about two hundred and twenty feet.

GEOGRAPHY.

For the most part, the surface in Jay County is level to gently rolling. The general slope of the surface is toward the west and northwest. All streams which drain any part of the county finally discharge their waters into the Wabash River or into some tributary of the Wabash River. The largest stream in the county is the Salamonia River, which takes its rise in the southeastern part of the county and makes its way in a meandering course with low gradient northwestward to the Wabash River, leaving the county, however, before joining that stream. The gradient of this stream is so low that in many places it has been dredged in order to give sufficient freedom of flow to permit its tributaries to be used as main lines of drainage for the adjacent farming lands. To the north of the Salamonia River the drift has been left with the surface somewhat higher than on the south, so that the tributaries from the Salamonia on the north are mostly short, while those from the south have on the average a length four to five times as great. This general arrangement of the drainage lines on the surface can best be understood when the surface of the counties to the north and to the south are also considered. By observing a map of the State, it will be seen that the course of the Salamonia is roughly parallel to that of the upper part of the Wabash River, which crosses the northeast corner of the county, and to that of the Mississinewa River, which crosses the northern part of Randolph County, at Ridgeville, being about one mile south of the Jay County line. In the case of each of these three rivers, the drift occurs as a well marked ridge on the north side of the stream; that is, the elevation of the surface of this drift is greater near to the north side of these streams, thus causing the tributaries in each case which come in from the north to be short, while those coming from the south to each of these streams are relatively long. As determined by geologists of the United States Geological Survey, these ridges or drifts which lie on the north side of the streams referred to, constitute respectively recessional moraines of the last glacial epoch. These moraines have slightly different configurations in different parts of the county, but the cause in each case of the peculiarity in drainage which gives short streams coming in from the north and long ones from the south is the deposition of these successive recessional moraines, as the lobe of ice which covered this part of the State gradually withdrew at the close of the last glacial epoch. Considered as a whole, the belt of drift in the south part of the county which constitutes a part of the moraine lying north of the Mississinewa River has a greater elevation and is more rugged and uneven in topography than the moraine lying to the north of the Salamonia River. This greater height and greater irregularity of surface was recognized by the early observers in the county and the fact is recorded in the term "Mountain" as applied to a part of this moraine by the geologists who first prepared a report on the county for the Department of Geology of the State of Indiana. However, the relief in any given square mile is rarely as much as eighty or one hundred feet and in most cases does not reach more than one-half or one-third that amount. Little can be said in the way of classifying the irregularities of the surface of these morainal tracts since they possess the usual characteristics of drift deposits everywhere, namely, the extreme irregularity of arrangement due to the uneven distribution of the materials carried by the ice, causing hillocks of different sizes and shapes, alternating in the most irregular manner with depressions equally irregular and uneven in form and size.

GENERAL GEOLOGY.

Considered in its more strictly geological aspects, the drift is observed to furnish excellent illustrations of some of the topographic and structural forms characteristic of deposits left after the retreat of a glacier. Chief among these may be mentioned the following:

(1) *Recessional Moraines.* This term has already been used and, as noted above, refers to the broad belts of hilly country, of which the most prominent and noticeable parts are the rounded hills of light colored soil carrying in some places a few boulders. The entire belt in each case extends in a direction somewhat north of west and south of east, parallel to the general course of the main streams which drain the area. Within Jay County there are two of these recessional moraines, namely, (1) the Mississinewa moraine, extending from the southeast corner of the county northward almost to the Salamonia River and then to the north of west to the western boundary of the county, and (2) the Salamonia moraine, extending from the central and south central part of the east side of the county likewise in a direction north of west to the northwest and northern boundaries of the county.

(2) *Ground Moraine.* The term ground moraine may properly be applied to a considerable part of the area already referred to as recessional moraine, but the distinction would in general be made by limiting the term recessional moraine to the more pronounced hills lying near the south line of the county and again lying on the north side of the Salamonia River, but within two or three miles from it, while the term ground moraine would refer (a) to the

more nearly level area lying south of the Salamonia River and extending for a distance of from five to eight miles from its banks, and (b) to areas likewise nearly level lying across the north and northeastern part of the county at a distance of more than three or four miles from the Salamonia River. This ground moraine portion in each of the two belts referred to, while it contains numerous low hills of light colored soil with some pebbles and boulders intermingled, has also a very considerable total area of soil that is very dark or black in color, occupying depressions between the numerous low round-topped hills. With respect to conditions existing at the time of formation, the part indicated as recessional moraine must have been deposited at a time when the edge of the ice remained more nearly in the same position for a considerable period of time, while the ground moraine must have been formed at times when the ice front was being melted away more rapidly, so that the edge of the ice was retreating to the northward at a rate more nearly uniform, thus not permitting the debris carried to accumulate in ridges so pronounced as when the recessional moraine proper was being formed.

(3) *Undrained Depressions.* The map accompanying this report showing the kinds of soil present in the county indicates clearly certain areas which for a long time following the withdrawal of the ice, must have been filled with water throughout a large part of each year, if, indeed, many of them were not the site of permanent ponds or small lakes up until about the time that white settlers came to the county. Early settlers in the county report that at numerous places in the areas here referred to as ground moraine, water stood in same cases the year round, in some cases in only the winter and spring, to a depth of five or six feet; places where now no water stands at any time.

Geologically, these depressions belong to the class called "kettle holes" where they are well developed. In most parts of this county these undrained depressions are, however, very shallow in proportion to their extent, and at the present day most of them would not be recognized as places where the water could possibly stand the year round. It is to be remembered, however, that with every rain, the water that runs off in smaller or larger streams, carries a certain amount of clay, sand and gravel, and it can readily be seen that many depressions which were originally basins in reality have had the rim cut through at one point, so that now the water runs off soon after the rain has fallen. Again, it is to be remembered that at the time when a thick growth of trees and underbrush covered most of the surface, fallen trunks and an accumulation of leaves could easily form dams which would cause the water to stand in places where the surface of the ground alone would not have permitted it. Besides these two systematic causes there is also to be taken into account the work of animals, particularly that of beavers, which were abundant in some parts of the county before white men came, and, by their work, dams were constructed which held back additional amounts of water, thus causing areas large in proportion to height of the dam to be covered, since the slope of the land is in general very slight.

(4) *Kames and Eskers.* Accumulations of glacial drift deposited in the form of typical eskers are not well represented. There are, however, at a few points, deposits which probably should be classed as eskers, although their extent is not sufficiently great and the exposure is not sufficiently good to put this matter beyond question. Specific illustrations of deposits of this kind are located as follows:

(A) Southwest quarter of Section 11, Township 22 N., Range 15 E., extending southward into the northwest quarter of Section 14. The area covered by this esker is a little more than one-half mile in length with a width varying from one or two to five or ten rods. This deposit lies near the middle line of the two sections referred to and consists of brownish sand and gravel sufficiently free from clay as a general rule to make it suitable for use as road metal. In places the deposit shows distinct signs of stratification; presumably the stratification exists throughout the greater part of its extent, but as excavation had not been made throughout this is not a matter of direct observation.

(B) East side of Section 31, Township 23 N., Range 15 E., another elongated area about three-fourths of a mile in length in a north-south direction, varying in width as before, from one to two rods to possibly two or three times that distance. This area shows characteristics almost precisely like the one already named in abundance of sand and gravel, in direction and extent of area and in color of the deposit.

At other points in the county deposits are found which at the surface consist of a sandy, gravelly loam precisely similar to the two areas just named, but which do not show at the surface a shape of outcrop which would suggest deposition in a channel. Some of these may be the tops of small eskers, or they may be merely deposits of gravel which should be classified as kames or small outwash plains.

By far the best illustrations coming within the general class of kames are found in Penn Township in the neighborhood of Pennville. The deposits in this area have been described by every careful observer who has visited the county, but the interpretation has varied somewhat, the latest being given by Leverett in Monograph 41 of the United States Geological Survey. He does not suggest the term kame for these deposits, though he does consider and reject

Figure 1. View in gravel pit south of road in n. w. ¼ of s. w. ¼ of sec. 25, T. 24 N., R. 12 E., one and one-half miles northeast of Pennville. Looking northwest. Note the unstratified drift at the surface resting unconformably on strata of sand dipping steeply (25°) to the southwest.

the name esker. It is no doubt true that some parts of the deposits to which he refers are too well stratified throughout to deserve the name kame. This is particularly true of the very prominent gravelly hills located in the southwest quarter of Section 24, Township 24 N., Range 12 E., known locally as "Twin Hills." Excavations for the removal of gravel from this deposit almost universally expose excellent stratification, the peculiarity being, as indicated by Leverett, that the planes of stratification are at high angles with each other. In the large area, however, lying to the south and west of Twin Mound and covering an area of four or five square miles, there is a very considerable portion of the deposit that is not well stratified, mingled with much that shows excellent stratification. In the work referred to, Leverett suggests that at least that part of the deposit which consists of a "sharp belt of hills" has been deposited by subglacial waters. This interpretation seems to be supported by the general field relations, yet it is also probably true that much of

Figure 2. Detail in same pit as shown in Figure 1. Looking northward. Note the frequent change in direction of dip in the cross-bedded layers.

the sandy, gravelly deposits in the larger area referred to should be classed as kames. Figures 1 to 3 show some of the more striking structures found in the gravel hills which lie within the kame area. It is to be noted particularly that in many places the angle of dip is high and in some places, as shown in Figures 2 and 3, layers having a considerable angle of dip are truncated by layers having a different angle. It is, of course, probable that these very striking changes in direction of dip may have been produced by currents of water alternating in direction, but they also strikingly resemble cross-bedding produced by the wind in the formation of sand dunes. It seems possible that in some cases the sand may have been rearranged by the wind after the first deposits had been made, but certainly, in a considerable number of the cases where high dips are found, the inclination must be due to currents of water carrying sediment from shallower to deeper portions, aided perhaps in some cases by readjustments in the entire mass after deposition had been completed; such adjustments, for instance, as might occur because of the settling of beds due to the melting out of huge bodies of ice, such settling being so uniformly in one direction as not to

Figure 3. Detail in same pit as shown in Figure 1. Looking south. Note the abrupt changes in amount and direction of dip.

cause much faulting or bending of the beds. In some cases, such readjustments have resulted in faults, as shown in Figure 4, giving the appearance of the stratification planes in the gravel pit at the south end of Twin Mound, where in a number of places faulting has taken place, the maximum amount shown being about one foot or fifteen inches.

(5) *Subglacial Channels.* In the work by Leverett already referred to, namely Monograph 41 of the United States Geological Survey, the valley in which the Twin Hills gravel deposits are found, is thought to have been formed by a subglacial stream, the

reason assigned being that the gravel hills as now found could not have been deposited except there had been present containing walls of ice to make possible the peculiar structural forms found in the material which has been deposited. This main subglacial channel extends from about the center of the north side of the county in a westerly and southwesterly direction to the valley of the Salamonia River near the point where that stream leaves the county. The northern part of this channel has been until recent years a swampy

Figure 4. View in gravel pit on south side of "Twin Hills", in the s. w. ¼ of sec. 24, T. 24 N., R. 12 E. Looking northeast. Note a slight dip of the faulted layer to the northeast, that is, toward the center of the hill.

area and only since the drainage has been perfected has it been possible to bring under cultivation the muck which forms the surface in the lowest part of this area. As shown by the map accompanying this report, the area covered by muck is irregular in shape, sometimes dividing and again reuniting, thus enclosing areas that are to be classed as ground moraine, and finally ending in a westerly direction at the point where the valley becomes notably narrower. The western limit of the area of muck just referred to is at about the middle of the north-south line marking the boundary between Sections 8 and 9 of Township 24 N., Range 13, E. From this point southwestward and westward there are no areas of muck large enough to be represented on the map until a point is reached about two miles west of north from Pennville, where there is another very considerable area much smaller, however, than the first; here, again, the valley is broader and the low lying areas, which are for the most part covered by muck, include certain "islands" of typical ground moraine. Just beyond the area of muck the valley divides, one part being occupied by the stream which enters the Salamonia River a little beyond the border of the county and th other forming a depression extending in a southwesterly direction to join the valley of the Salamonia River; this latter depression, however, is not occupied by a stream of flowing water of size greater than can be carried by small underground drains.

In this connection it is instructive to note that the large area referred to as a kame area lies to one side south of this subglacial channel, and there would thus seem to be some added probability that this considerable body of sandy and gravelly material north and east of Pennville is in reality a deposit which has been made at least in part by waters escaping from the edge of the ice instead of being deposited altogether by subglacial streams. This does not conflict with the interpretation given by Leverett for the particular hills to which he refers, known locally as Twin Hills.

The map accompanying this report does not make clear what is readily seen when the observations are made in the field, namely, that there are a number of valleys which connect with or branch off from this main subglacial depression, most of them being located to the west of the area of muck first described. The position of some of these valleys is, however, indicated on the soil map by an area of black soil extending in a west-southwest direction in Sections 7 and 8, Township 24 N., Range 13 E., continuing into Section 13 of Range 12 E.; and another lying nearly a mile north and almost parallel to it in Section 7 of Range 13, and Sections 11 and 12 of Range 12. These two areas of black soil lie in well marked valleys and there is but a small amount of ground moraine between them and another well marked valley in which there is black soil together with some small sandy hills which are probably to be classed as kames. This valley is a tributary to the valley in which the second area of muck referred to is found near the western portion of the county. The probabilities seem strong that a number of the valleys in this part of the county owe their origin primarily to the action of water flowing under the ice, though no doubt a part of their depth may be due to erosion since the ice withdrew.

The plain inference from the presence of these subglacial channels, together with the direction of flow of the various streams draining the area included in Jay County, is that at the time of the withdrawal of the ice the waters were moving in general in a westerly and northwesterly direction; and evidence from the counties adjacent to Jay on the west indicates, as suggested by Leverett, that the edge of the ice lobe probably dammed the lower course of the Salamonia for awhile, so that the drainage was for a time not directly to the northwest to the Wabash, but from the western part of Jay Couny southwestward through the continuation of the subglacial channel referred to above, till the withdrawal of the ice permitted the water to find its way along the south margin of the Salamonia moraine into the Wabash River.

(6) *Other Physiographic features.* In addition to the physiographic features already named, mention should be made of the fact that good illustrations are found in the county yof numerous minor physiographic features, such as are to be found associated with the drift or such as appear as the result of agencies acting on the drift since it was deposited. The more important of these are:

(a) *Alluvial Fans.* These are to be found in almost every square mile of the area studied wherever a considerable amount of soil has been loosened on a slope that is unusually steep, or wherever, by means of excavation or agricultural operations, the drift deposit is left with a slope steeper than twenty or thirty degrees. In such places, the small rivulets formed by showers carry down a larger amount of sediment from the steeper portion of the slope than they are able to carry when the more level portion is reached, and deposits are therefore made which, in many cases, offer perfect illustrations on a small scale of alluvial fans. In a few places fans of larger dimensions have been formed, but these are mostly in process of being eroded, so that their real nature is not so easily seen.

(b) *Flood Plains.* There are also found in almost all parts of the county adjacent to all brooks which are in valleys of size sufficient to allow the waters at time of flood to spread out in a broad sheet, and sufficiently permanent to cut a channel in the material deposited. These flood plains have in many places been destroyed by the work of dredging and straightening the natural channels to form ditches; but wherever undisturbed in this way, the larger streams are forming typical flood plains.

Many other forms might be mentioned, such as deltas, sandbars, and the like, which are educationally of value in illustrating the work of erosion, as these subjects are taken up in the various courses of geography and related sciences in the schools; but for the most part, these minor features are easily identified and require no further mention.

THE COMPOSITION OF THE DRIFT.

The details of the composition of the drift are discussed in this report in detail under the heading of the different soils found. These descriptions, however, refer only to the surface and the materials present to a depth of three feet. Well borings, and in a few places, excavations show that the drift often varies considerably in composition with depth, alternating without any definite regularity from typical glacial till to stratified deposits of glacial materials of various forms, including "clay," fine sand, gravel, etc. In some places, borings show that the ground moraine is continuous to bed rock. In other places layers of stratified sand and gravel are encountered at various depths, and sometimes a number of different layers of sand and gravel are found separated by layers of till. It therefore seems that a correct understanding of the drift in Jay County gives the conception of the drift material as being made up chiefly of till, that is to say, (1) of very fine mineral matter, made up partly of clay and partly of finely ground rock mixed in varying proportions with sand of different amounts of fineness, and (2) of coarser particles (gravel) most of them well rounded, but some subangular and bearing glacial striations, with here and there (3) some boulders in size up to five or six feet in diameter, all mixed together in most irregular fashion.

The kinds of rock found in the drift are indicated by the following table of analyses, which show the average of determinations made on the gravels at various points:

TABLE I.

Analysis of Gravel.

Dolomite (Magnesian Limestone)	65 per cent.
Limestone (Calcareous)	20 per cent.
Igneous rocks	7 per cent.
Metamorphic rocks	6 per cent.
Sandstone and shale	1 per cent.
Cherts and quartz	1 per cent.
Total	100 per cent.

This table shows that the main proportion of material in the drift, namely about 80 per cent. to 85 per cent., is of limestone, which has been broken up and the fragments rounded by the action of running water, and that the remaining 15 per cent. more or less is made up of fragments of the various igneous and metamorphic rocks found in Canada, together with a small percentage of sandstone, shales, cherts, flints, quartzes and such like.

Economic Geology.

(1) *Limestone.* As already stated, limestone in place is found at only two points in the county, and the total value of the product obtained from this source is therefore small. The outcrop in the northeastern part of the county is not being used at present, the quarries in that vicinity which are open being across the line in Adams County. Limestone is, however, at the surface in the northeastern part of the county and if the demand were sufficiently great, stone valuable for road materials could be taken out.

The quarry which has been most largely worked in the county is located about two miles west of Portland in the southeast quarter of Section 24, Township 23 N., Range 13 E. The surface of the limestone at this point is but a few feet above the level of the water in the Salamonia River nearby, so that it is necessary to keep the quarry free from water by means of pumps in order to obtain stone of value for the production of lime and for road materials. The plant at this place was not in operation in the summer of 1914 because of changes to be made in the process of producing lime; changes which have been made necessary on account of the failure of the supply of natural gas, which was formerly used as fuel. It is the plan of the company to resume operations when the necessary changes have been made, and when this is done lime of good quality can be produced from the quarry at this point.

(2) *Gravel.* Beds of sand and gravel suitable for use in the construction of roads, as ballast for railroads, in the making of cement blocks, and for building purposes in the making of mortar, etc., are found at various points at the surface and also at different depths beneath the surface. The gradient of the streams of the county is, however, so slight that gravel of value is to be found at but a few points in the beds of streams. In general, the southern and eastern parts of the county are not well supplied with good gravel except in the areas already referred to as eskers or kames, and these areas are relatively very small. In a few places, how-

ever, within these parts of the county, gravel is obtained by pumping or by some process of dipping. In other words, gravel deposits occur at a few points sufficiently near the surface to be taken out economically, but too far below the surface to avoid trouble on account of the presence of ground water. Points from which gravel is taken in this way are usually near the bottom of the valley, while in the case of gravel taken from the eskers and kames, the deposit is usually above ground water level, and the only difficulty encountered is the depth of soil to be removed, which, in some cases, is as much as eight to ten feet in thickness. When the thickness of soil reaches this amount the gravel cannot be taken out economically, and so in many parts of the county crushed stone has been shipped in for the making of macadam roads. The part of the county best supplied with gravel is the northwestern part near Pennville, where the deposits referred to as kames have already been described. Some of the gravel in this area is of number one quality for use as road metal, but much of it is not of the best grade on account of the presence of too large a proportion of fine material such as clay and silt. The sand found in this area is, for the most part, of the very vest quality for use in making cement blocks and for use in making martar and plaster. Sand and gravel from this region is shipped by rail in considerable quantities.

No sufficiently accurate record has been kept of the amount of sand and gravel taken from the various pits opened in the county to permit an estimate to be made which can be relied upon as even fairly satisfactory. The total amount, however, must be very large and the value in dollars to the county from deposits of this kind must be considerable.

(3) *Water Supply.* In practically all parts of the county water in abundance for the use of stock is found, either on the surface or at a depth beneath the surface so slight as to make the securing of it by means of pumps a very small task. Much of the water easily accessible in this way is, however, not astisfactory for drinking purposes because of the ease with which it becomes contaminated. Much of the sickness in the county in the early days was no doubt due to the unwholesome drinking water as well as to the malaria found in the regions where large areas of swamp and marsh exist. On account of the unsatisfactory character of the surface water for drinking purposes, a very large proportion of the

farmers throughout the county have wells which are deep enough to reach a supply which is free from impurities found at the surface. These wells are, for the most part, tubular wells put down either by driving or boring, and in many cases they go entirely through the drift to the surface of bed rock. Water derived from depths of fifty to two hundred feet its of the highest quality and diseases due to impure drinking water are becoming rare.

The methods used for obtaining water from deep wells varies from the use of pumps by hand to the use of power in the form of wind mills or gasoline engines. The number of pumps driven by power of some kind is continually increasing.

(4) *Clay Products.* In many parts of the county deposits of the finer parts of the drift are found to be suitable for the making of brick and drain tile. The great need of efficient drainage in the county has stimulated the development of the drain tile industry, and while exact data as to the amount of his product manufactured is not at hand, it can be said that thousands of rods of drain tile are annually made, and so far as materials are concerned, the industry could be developed to a much higher degree. The absolute necessity which faces all farmers in Jay County of greatly increasing the amount of tile drain put in if the lands of the county are to be brought to their highest degre of productiveness would suggest that a further development of the clay industry and the making of tile would be profitable for both the manufacturer and the farmer.

CLIMATE.

The general characteristics of the climate of the county are shown in the following tables, data for which have been supplied by J. H. Armington, Section Director, United States Weather Bureau, Indianapolis, Indiana. The data concerning temperature and precipitation are taken from observations made at Farmland, in Randolph County, as the nearest point at which records have been kept for a sufficient length of time to establish a normal.

TABLE II. *Mean temperature and average precipitation at Farmland.*

Month.	*Mean Temperature. Degrees F.*	*Average Precipitation. Inches.*
January	27.2	2.73
February	28.3	2.90
March	39.2	3.35
April	50.2	3.30
May	60.8	4.30
June	69.8	4.09
July	73.4	3.41
August	71.2	3.66
September	64.9	3.47
October	61.4	2.37
November	40.6	3.09
December	31.9	2.67
Annual	50.8	39.34

TABLE III. *Maximum and minimum temperatures at Farmland in 1914.*

Highest	100°F. on July 11
Lowest	7°F. on December 15.

TABLE IV. *Average dates of killing frosts at Salamonia, from a record of nine years.*

Last in spring	May 8
First in autumn	October 5

AGRICULTURE.

Of the 240,000 acres in the county, about 90 per cent., or 235,-191 acres, is in farms varying in size from less than three acres to 500 acres or more. Of the farms including more than 500 acres there is, however, but one within the county; and of the 2,836 listed by the census of 1910, 1,080 contain between fifty and a hundred acres.

In the ten years from 1900 to 1910, the farming lands in the county increased nearly 130 per cent. in value, being listed in the latter year at a total valuation of $16,247,188, or an average of nearly $70 per acre, while the total valuation of farming property, including buildings, implements, domestic animals, etc., adds over $6,500,000 to this amount, making an average of land and farm property together of about $100 per acre. It is to be understood, of course, that the better of the improved farms cannot be bought for this figure.

The following tables taken from the report of the census of 1910 show in condensed form of the principal crops raised, the acreage and the yield per acre and the number and valuation of the domestic animals and poultry. These figures are for the year 1909; no doubt the production in 1914 is considerably higher.

TABLE V. PRINCIPAL CROPS.

Crop.	*Acres.*	*Bushels.*	*Tons.*
Corn	60,209	2,659,277	......
Oats	41,724	1,121,280	......
Wheat	7,585	83,816	......
Timothy hay	19,577	......	24,701
Clover alone	1,897	......	2,189
Timothy and clover mixed	7,344	......	9,256

TABLE VI. DOMESTIC ANIMALS AND POULTRY ON FARMS.

Name.	*Total Number.*	*Total Value.*
Cattle	15,571	$472,852
Horses	11,696	1,338,572
Mules	211	26,889
Swine	56,051	365,507
Sheep	26,104	130,530
Poultry	229,188	121,678

It will be seen from the table giving the figures for the principal crops that the average yield for corn is about 44 bushels per acre; for oats, 27 bushels per acre; for wheat, 11 bushels per acre; and for hay, about 1¼ tons per acre. It is to be understood, however, that on many farms the yield is much higher than this. For instance, in 1914, ten acres of land near Pennville, Indiana, on Rodman silt loam soil, yielded an average of 49 bushels per acre. This particular field of wheat was sown on clover sod and fertilizer was used. Figure 5 is from a photograph of this wheat field as it was being harvested and shows how close together the shocks had to be set, indicating thus the great number of stalks per square foot which must have been grown in order to produce this unusual yield. The year before, 1913, on the same kind of soil, a field of twenty-five acres yielded an average of 38 bushels per acre. It is, of course, to be said that this soil is much better adapted to the growing of wheat than much of the soil in Jay County, yet it is also true that a large proportion of the soil in this county could, with proper treatment, be put in a condition almost as favorable for the growing of heavy crops of wheat as the Rodman soil.

In general, the same remarks would apply to the kinds of soil on which corn, oats and hay are grown, for the soil seems to have all the essential elements of fertility, and needs now more than anything else careful treatment in order to make it produce on the average perhaps fully 100 per cent. more than at present. Suggestions in regard to methods of treatment which are most important for the soils of Jay County are given at the close of this report.

Origin of the Soils.

The soils of this county are, for the most part, derived from the weathering and disintegration of mineral matter carried by the glaciers which formerly covered the entire northern part of the United States. As already noted, these minerals include calcite,

Figure 5. Wheatfield on Rodman silt loam soil, which in 1914 yielded 49 bushels per acre. Located in n. w. ¼ of sec. 25, T. 24 N., R. 12 E. Photo by A. B. Crowe.

dolomite, quartz, feldspar, hornblende, mica and various weathered products, of which the more noticeable are clay, sand, gravel and, in some cases, a sufficient amount of brown, yellow or red coloring matter to indicate the presence of oxides of iron. There are in addition, of course, very small quantities of a number of other minerals, and in the depressions in the surface occupied formerly by marshes and swamps there is a very considerable admixture of carbonaceous matter, which once existed in the form of tissue of plant growth and has been left by the partial decay of this vegetable matter. In some places the predominance of this vegetable matter together with an unusual amount of moisture produces soils that are described under the term muck or peat. The amount of soil formation which deserves the name of peat is very small, indeed so small as to be negligible in this county.

Soil Types.

The principal soil types found in this county are nine in number, as follows:

Miami Silt Loam.
Clyde Silty Clay Loam.
Genesee Loam.
Genesee Silty Clay Loam.
Muck.
Rodman Silt Loam.
Miami Sandy Loam.
Marsh Swamp.

The map accompanying this report indicates the location of each of these soil types with as much accuracy as was possible to be secured in the time which could be devoted to the work. In some places, boundaries between the different adjacent soil types have been drawn arbitrarily, as for instance, in the area lying next to the Salamonia River where the Genesee Loam alternates with the Genesee silty clay loam, as shown, for instance, about three miles east of Portland in Sections 22 and 23, of Township 23 N., Range 14 E., and also at various points between Pennville and Portland. The areas indicated on the map show the approximate location of areas in which the character of the soil is predominantly that of the name given for the respective locations. The change, however, from one of these soil divisions to the other is often very gradual and the boundary lines cannot be marked with distinctness at many places; nevertheless the line of division is placed on the map approximately at the place where a marked change in soil character occurs. The same thing can be said of the grading off of soils of the Genesee loam type into those of the Clyde silty clay loam type along the Salamonia River and along some of the other larger streams.

It is also to be understood that within areas mapped as of a certain type, there may be and often are included areas of other soils too small in area to be shown on the map of the scale necessarily used in this work. For example, the Miami silt loam is mapped as covering large continuous areas; yet in many places these Miami silt loam areas, which are in general light in color, include many small irregular patches of black or dark brown soils of other types. An especially noticeable instance of this is in the neighborhood of the city of Portland. As shown on the map, the city of Portland is built on Miami silt loam soil and this in general is true; yet at a number of places in the city of Portland there are irregular patches of dark colored soil which belong to the Clyde silty clay loam type, or even perhaps to some sandy and silt loams; but these areas are in general small and discontinuous and cannot therefore well be shown on the map.

Miami Silt Loam.

The general description of this type of soil as given in publications of the United States Bureau of Soils, is as follows:

> *Miami Silt Loam.* This is a light brown, yellowish brown or grayish silt loam, from eight to twelve inches deep, underlain by a compact, yellowish or brownish mottled silt loam or silty clay. The type occupies rolling to hilly areas and was originally timbered. It is the result of the weathering of glacial till, with the admixture, in places, of small amounts of loessial material.

This general description applies to the areas mapped in Jay County as Miami silt loam, but certain peculiarities should also be mentioned. In general it may be said that in Jay County the depth of the soil is rarely more than eight inches, and that the presence of loess is indicated only by the presence of a very high percentage of silt, as shown by physical analysis. Notice should also be taken of the presence of a small percentage (usually less than one per cent.) of pebbles, the amount increasing in the subsoil. Boulders also are present at the surface occasionally, though in cultivated fields they have for the most part been removed; in size these boulders are found up to five or six feet in diameter.

Soil of this type is now lighter in color and more extensive in area than at the time when the land was first put under cultivation, owing to the exhaustion of a large percentage of the carbonaceous matter that had accumulated while the land was covered with forests. As a result of this depletion of organic matter, the yield of the various crops has grown constantly less except in those cases in which special care has been taken to improve the conditions for plant growth by tile drainage, and to increase the fertility by the addition of humus or fertilizers.

The original forest growth on the Miami silt loam included as the principal kinds of trees, oak, beech and walnut; sugar maple where the proportion of sand is larger; and elm, hickory and ash in places where the drainage was not well established. The principal crops now raised on this soil are corn, timothy and clover hay, with a smaller acreage of oats and wheat. In a few places, apple orchards are found to do well, but in general the soil without underdraining seems to be too compact and cold to promise returns sufficiently large in proportion to the price which such land brings. Corn does not grow as vigorously or produce as large a yield on this type of soil as upon the black soils, but with proper treatment this difference in productivity can be overcome; indeed, experience seems to show that careful management will secure a proportionately larger increase in productivity from the Miami silt loam than from any other type of soil found in the county.

Clyde Silty Clay Loam.

The general description of this type of soil is given in publications of the United States Bureau of Soils, as follows:

> *Clyde Silty Clay Loam.* This is a dark brown to black silty clay loam, ranging from six to ten inches in depth and underlain by a drab or gray usually mottled clay subsoil. The topography is level and the drainage is naturally poor, so that ditching is necessary before crops can be profitably grown. When reclaimed through drainage, the type is strong and productive, and good yields of corn and general farm crops are secured. Such crops as cabbage and onions are also very well adapted to it. Timothy and redtop produce from one to two and a half tons per acre on reclaimed land.

As shown by the map accompanying this report, the Clyde silty clay loam occurs usually in irregular belts and patches surrounded by the Miami silt loam. These areas of "black land" are invariably on a lower level than the light colored soil around, and mark the sites of former ponds or marshes where water formerly stood for the greater part or all of the year. Because of their lower position topographically these areas have received by deposition from sheet wash and rivulets after every rain much of the finer materials originally left on the surface of the more elevated points of the moraine near by, thus producing a surface soil of silt and clay almost wholly free from pebbles. In the subsoil, however, at a depth corresponding perhaps to the level of the original surface, some pebbles are found. The color, too, changes with depth, due largely to the decrease in percentage of carbonaceous matter. In some cases, especially near the boundary separating the soil of this type from the Miami silt loam, the subsoil is found to be identical with that of the latter soil. This is evidently explained by the fact that at the edges of the ponds in which the Clyde silty clay loam was formed the accumulation of material to form the soil could not reach a great depth, leaving, therefore, the original morainal surface to be the subsoil.

Soil of this type ranks as the best corn-producing soil in the county. It is in most places, however, susceptible of much improvement by underdrainage, as it is inclined to be rather too compact and to hold the water too long after the rain has fallen. Exceptions to this are of course found in some places where a larger proportion of sand causes the type to approach a loam in composition.

In the subglacial channel, the position of which is indicated on the accompanying map by a strip of Clyde silty clay loam extending in a northeast-southwest direction along both sides of the stream, from Section 8, Township 24 N., Range 13 E., to Section 24, Township 24 N., Range 12 E., there are frequent deposits of sand and gravel. In some places these deposits are not noticeable at the surface, but in other places they are quite prominent. It is to be understood, therefore that in this particular area there is a much greater variation in the soil and subsoil than is usually found in the areas of Clyde silty clay loam in this county.

The original forest growth on this type included some varieties of oak, ash, maple and hickory with button bush in very moist locations, and often wild roses after the larger trees had been removed.

GENESEE LOAM.

The description of this type as given by the United States Bureau of Soils is as follows:

Genesee Loam. The soil consists mainly of a mellow friable, brown to dark brown medium loam to silty loam about eight to twenty inches deep. The subsoil is a fine loam to clay loam ranging in color from light brown to yellowish brown. In places a substratum of coarse material is encountered below three feet. The type mainly occupies level first bottoms subject to overflow. Artificial drainage is generally necessary to insure best results in the lower lying phase. When protected from overflow and thoroughly drained, this is a good soil for corn, wheat, grass, oats, onions, carrots and cabbage. Corn yields from forty to upwards of a hundred bushels per acre, oats about forty bushels, hay one to three tons, onions from 500 to 800 bushels, and carrots as high as 1,000 bushelss per acre. Potatoes and tomatoes do well. Celery, asparagus, beets and sugar corn produce fair to good yields.

The Genesee loam is represented in the county by but a small acreage, consisting of narrow belts along the larger streams. Although the areas mapped as Genesee loam have a general agreement with the description given above, yet the Jay County areas cannot be considered as typical for this type of soil. The reason for this is probably the low gradient of the streams of the county, which prevents the waters even at flood from having a sustained velocity sufficient to carry away a large enough proportion of the finer particles to produce a typical loam. Indication of this condition is found in the alternation along the Salamonia River between soils classed as loam and silty clay loam.

Where best developed, however, the type as found in this county has the characteristics named above, though the depth of the soil rarely exceeds ten or twelve inches. Owing to the small acreage of this type, it is not possible that any great addition to the resources of the county can come from better management of the soil or a choice of crops from which larger yields can be expected than from those now usually grown. Nevertheless, for individual farmers owning the larger part of this kind of soil, the suggestions made above as to the most profitable crops to choose, deserve careful consideration.

Genesee Silty Clay Loam.

The Genesee silty clay loam differs from the Genesee loam in containing a larger percentage of fine mineral particles, thus making the soil more compact, and more impervious to moisture. The depth of the soil is usually not more than nine or ten inches, and its color is a lighter brown that that of the Genesee loam. The subsoil is usually grayish or blue-gray with an occasional stain of brown due to the presence of iron oxide, and when exposed to the air as in the sides of excavations, it cracks, upon drying, into small cubical blocks, one-quarter to one-half inch on an edge.

As noted at another place in this report, this type grades into the Genesee loam on the one hand, and into the Clyde silty clay loam on the other. It is found almost universally adjacent to the Salamonia River; the only exception being a few areas in other parts of the county too small in size to be indicated on the map.

The type seems to be adapted to such crops as may be successfully grown on the Clyde silty clay loam; especial care needs to be taken, however, to see that it is well drained.

The description of this type given by the United States Bureau of Soils follows, which is on the whole a good summary of characteristics for the type as found in Jay County:

Genesee Silty Clay Loam.—This type is composed of a dark-brown or grayish-brown silty clay loam soil from nine to ten inches deep, overlying a plastic silty clay of a gray, bluish gray, or mottled gray and brown color. The natural underdrainage of the type is deficient, on account of the heavy character of the subsoil. The soil is found along streams and is subject to overflow. Following reclamation by drainage, it is well adapted to the heavier types of farm crops, and especially to grass.

Rodman Silt Loam.

The surface soil to a depth of about eight inches is a light brown silt loam, grading downward sometimes into a silty, sandy clay, but more often into sand and gravel at a depth of three feet. On the steeper slopes the finer materials have been washed away leaving the surface strewn with sand and pebbles, in which case the soil becomes a sandy loam or a gravelly loam. At depths greater than three feet, there are found in many places lenses and pockets of sand and gravel in which cross-bedding at high angles is commonly to be observed. Figures 1 to 4 show typical illustrations of this structure.

The topography is usually rolling to very hilly. Where most nearly level, the crops ordinarily grown on Miami silt loam are found to be successful, though in places, the underlying sand and gravel reduces the ground water level to such an extent that crops suffer in time of drought. The highest yield of wheat per acre in the county was realized in 1914 from ten acres of soil of this type. In places where the slopes are steepest, the soil is not valuable for cultivation, but is used only for pasturing.

As already stated, the soil of this type owes its origin to deposits of sand, gravel and boulders carried by waters flowing under the ice or issuing from its margin, the deposits belonging to the groups known as kames or eskers.

For the most part the soils of this type are well drained naturally, and increased yields can be secured chiefly through a judicious use of fertilizers and a wise choice of crops in proper rotation carefully put in.

Miami Sandy Loam.

A few small areas of sandy loam for the most part within a distance of one or two miles northwest from Pennville are classed here as Miami sandy loam. The chief difference between these areas and the Miami silt loam is the increased percentage of sand found at the surface. The areas are small, and the type, therefore, not of great importance, but the difference is too great to permit their classification as silt loam.

In general, a sandy loam is a more open, looser, warmer soil than silt loam, and is usually also better drained. The origin of the two is, however, the same, and the crops successfully grown are not in general greatly different.

Muck.

Muck is the name applied to very black, spongy soil in which the percentage of organic material is high. With increase of organic matter, muck grades into peat; with increase of mineral constituents it becomes a loam, a silt loam, a clay or some other type of soil.

As shown by the map accompanying this report, considerable areas of muck occur in this county, most of which are now under cultivation. The principal crop raised is corn, since experience has shown that no other grain crop is as likely to succeed. No doubt some other crops, such as celery, peppermint, and onions would yield much larger returns in proportion to acreage and time spent, but the experiment has apparently not yet been tried except in a very limited way.

The chief condition necessary to successful production on soils of this kind is the lowering of the water level. This is in general thoroughly understood, and the only reason that the muck areas were allowed to remain uncultivated so long was because of the difficulty encountered in securing a satisfactory outlet for the water. Since the areas of muck are the lowest of the region in which they occur, the greatest care must continually be exercised to keep the drainage lines open to their full depth. If this can be done, and if crops of vegetables adapted to the soil should be grown instead of the cereals, there can be no doubt that the total returns would be increased several hundred per cent.

Marsh.

At a few points in the county marsh land exists, but at one point only is the area sufficiently large to be mapped, namely in Section 4, Township 24 N., Range 13 E.

These marshes are undrained depressions, filled usually with shallow water in which grow plants adapted to such a location, the cat-tail flag being one of the most common. In course of time, these marshes will be filled up by wash from the surrounding land, and so may become valuable for agricultural purposes, even though they may at present be too low to be drained.

Swamp.

But one area of swamp was mapped in the county. This is found in Section 2, Township 24 N., Range 13 E., though some other small areas are found at various points, especially adjacent to or included in areas of muck. As in the case of muck and marsh, swamps depend upon the presence of ground water near the surface for their existence. When this condition ceases to exist either through drainage or filling, they become valuable for agricultural purposes.

Suggestions.

As a result of the observations made in this county, the following suggestions are offered as indicating the directions in which especial effort should be made in order that the soils of the county should produce the maximum amount of the various crops raised. The general lines of work which demand particular attention are (1) drainage and (2) certain farm methods.

Drainage.

The greatest need of the soil in this county is an increase in systems of drainage, and the especial kind of drainage most needed is tile drainage. Some farther work, to be sure, must be done to provide means for the removal of the excess of water remaining on the surface. There must be constant care exercised that the numerous open ditches already constructed shall be kept free from growth of weeds and shrubs, and that they be kept sufficiently free each season from the sand and silt deposited in their bottoms so that tile drainage depending on these open ditches for outlet may be successful. But in the main, the necessary open ditches are already constructed and are being well cared for so that now there is relatively but a small portion of the county from which the surplus surface waters do not readily drain away. It is also true that there have been put in thousands of rods of tile drainage, especially in the areas of lower ground, so that in many places channels which at one time were occupied for a part of the year by flowing water are now regularly cultivated because the water is carried away beneath the surface so rapidly that the erosion of even the lowest parts of the areas is prevented. All of this work which has been done to remove the excess of water standing upon the surface is indispensable, for the first step in the proper drainage of any nearly level area is to provide means by which the excess of water due to precipitation may readily be taken away. And the farmers of the county are to be congratulated that this first necessary work has been so well and so fully done in the fifty to seventy-five years which have elapsed since the work of reclaiming the soil of this county began in earnest.

But valuable and necessary as this preliminary work has been, the soil of the county can never reach its maximum productivity until the matter of drainage is carried still further on a large scale. Specifically, the thing which must next be done is to lay a network of tile drains across the higher points and ridges of land which have hitherto been for the most part neglected because the water did not stand there. Up to this time, the most valuable soil of the county has been supposed to be the black or dark brown soils, while the points and ridges of lighter colored ground have been considered less valuable. This judgment is, of course, correct with the conditions of the soil and methods of farming as they have existed; but it has been fully demonstrated in the case of the soils of the Miami silt loam type that if an adequate system of tile drains is put in the charcater of the soil is so changed that the total production may be increased 50 per cent. to 100 per cent. or more, and not only may the yield per acre of the ordinary farm crops be thus increased, but when the soil is thus thoroughly supplied with lines of tile drainage, it becomes possible to introduce other valuable farm crops, for which there is no opportunity whatever until this extension of drainage has been completed.

Some few farmers in Jay County already understand fully the value of an adequate system of tile drainage, and they are improving their lands as rapidly as possible in this way. In the course of the survey in the summer of 1914, four or five such cases came especially under the notice of those who were engaged in the work, and while it may be possible that still other farmers have undertaken improvements of this kind in a systematic way, it is undoubtedly true as learned by information gained when questions were asked concerning the matter, that by far the greater majority of the farms in the county are not yet adequately drained in this way.

What constitutes adequate drainage will vary somewhat with the topographical location and with the particular variety of the soil, but in general it can be said for soil of the Miami silt loam type, which includes practically all the soils which form the surface of knolls and ridges and which is of a light brown to grayish color, that the lines of tile drainage should be not farther apart than two to three rods, and should be placed at a depth of not less than thirty inches, and, except in rare instances, not more than forty-two inches in depth. It is to be understood, of course, that in putting in lines of drainage in this way, the utmost care must be used in order to be sure that there is a sufficient amount of fall in every part of the system, that the tile put in is of good quality, and that the outlet shall be so arranged that not only shall the water that accumulates have an opportunity to flow away, but that the air shall have access to the system, so that the oxygen contained in the air shall penetrate to the end of the remotest tributary line. This will require, of course, that the open ditch or stream which is the outlet of the system of tile drains shall be kept sufficiently deep so that the level of the water in the ditch shall be below the bottom of the tile; and furthermore, precaution must be taken that animals such rabbits, muskrats, etc., shall not have an opportunity to enter these tile drains from the outlet, since there is danger that they may never find their way out again and so obstruct and render almost valueless the entire part of the system above the point where their bodies may be lodged. This means that at the outlet of each tile drain, there shall be constructed, preferably of cement and iron bars, a protective structure that will accomplish the ends referred to. If, however, this and all other precautions are taken and the system of drainage is thus properly installed, the value of the land will steadily rise for a period of from ten to twenty years until the maximum productivity is reached. The initial expense of this kind of improvement is of course large, but the increased value of the crops secured from this improvement alone will in a few years repay all the expenses incurred and leave the land permanently of a higher value.

It is because of the certainty that systematic drainage of the kind referred to here will yield satisfactory results that the matter is referred to at this length, and the author of this report is so fully convinced of the paramount importance of this kind of improvement that he is ready to say that as a means of increasing the productivity of the land of Jay County that of a systematic extension of systems of tile drainage should receive first consideration. Information in regard to the various methods to be used in establishing such a system should be secured from the agriculture experiment stations and from the few men in the county who have already seen the need and have begun to improve their farms in this way.

Because there has been a lack of understanding of the valuable results which come from an extension of systems of tile drainage the following points are mentioned as being the most important benefits which accrue from carrying out this plan. It is understood, that the points here named are in addition to the necessary removal of the water which would otherwise stand on the surface.

(1) Tile drainage changes an impervious closely packed soil to a more porous and open granular one.

(2) Tile drainage is a safeguard against drought for the reason the soil will become more porous and much of the water which falls as rain will be held in the openings in the soil and while it sinks far enough below the surface to allow the soil to be tilled, it does not entirely leave the subsoil and so remains as a reservoir within reach of the roots to be taken up when the lack of moisture near the surface on account of dry weather threatens to dwarf or destroy the life of the plants.

(3) Tile drainage provides for the aeration of the soil, that is. the entrance into the soil of the atmosphere, which supplies the oxygen needed for growth of the organisms in the soil which in turn are needed for the growth of plants.

(4) Tile drainage makes soils warmer. This comes about because the excess of water is removed and air fills the pores making it possible for the soils to become warm earlier in the spring and so the growing season for plants is lengthened.

(5) Tile drainage, by reducing the amount of water in the soil, reduces the probability of damage to winter crops on account of freezing; reduces, or in some cases prevents, the washing of soils on slopes.

These and other beneficial results accomplished by tile drainage are fully discussed in bulletins issued by the various agricultural experiment stations, and every farmer who wishes to undertake the improvement of his land in the way to secure the greatest and most permanent results, should at once make plans for the extension of his system of tile drainage.

FARM METHODS.

Under the topic "Farm Methods", are, of course, included all those questions of farm management such as the matter of rotation of crops, the proportion of farming land which should be devoted to each of the crops raised, the value of live stock on the farm, etc. It is not the intention in this report to discuss these matters, but only such questions of farm methods as are more directly related to the soils and to the means by which the maximum crops may be secured.

During the progress of the work in the county, two of these general topics which may be included under farm methods came into prominence so frequently that it seems that mention should be made of them by way of suggestion.

(1) *Use of Fertilizers.* As shown by the 1910 census, 204 farmers in Jay County reported in regard to the use of fertilizers. The amount expended by these 204 farmers is given as $5,295, which is an average of something more than $25 per farm. It was impossible to collect data from every farmer in regard to the fertilizers used in 1914, but it is no doubt true that the amount of money expended in fertilizers in that year is far in excess of the amount reported by the United States census in 1910. As noted above, the largest yield of wheat in the county in 1914, namely 49 bushels per acre, was on land on which fertilizer was used. Many different farmers were interviewed in regard to the kind and the amount of fertilizer chosen, but it is impossible to make any general statement as to the amount or kind for a given soil or for a given crop which could be considered as a safe guide for farmers who have the same kind of soil and wish to raise the same kind of crop. In other words, the reports given were so various for the same kind of soil and for a given crop that it is impossible to make a summary which can be offered as certainly of value. There can be no doubt, however, that a judicious use of fertilizer of known composition is in some cases profitable. On the other hand, it is equally true that much money is spent for fertilizers for which no adequate return is received. All careful farmers, however, agree that the very best fertilizer which can be used on any kind of soil is stable manure; and those farmers seem to be able to secure the best results who sell but little hay or grain, keeping a sufficient amount of stock to eat the surplus which they may raise, and by this means, not only receiving full value for hay and grain, but also producing a considerable amount of fertilizer of the very best kind. This method, of course, cannot be pursued by all farmers, but wherever this plan can be followed, there is general agreement that it is the best course. Careful experiment should be made with the various commercial fertilizers offered, and without doubt in-

creased yields on most kinds of soils can be secured when such experimenting is carefully done.

(2) *Choice of Seed.* The necessity of choosing good seed applies, of course, to any crop whatever. Observations made in Jay County in the progress of the survey on which the report is here made touches, however, only one crop, corn. The observations referred to began soon after the work opened, for it was noticed that in most of the corn fields entered, the stand of corn was notably incomplete. Attention was therefore centered upon the matter and throughout the time in which the work was done, frequent observations were made in fields in all parts of the county in regard to the perfection of "stand". In making the observations in the somewhat general manner that was necessary, it was impossible to keep statistics with mathematical accuracy, but as a result of the series of observations through the weeks in which the survey was made, it was found that not more than one-fourth of the acreage in corn in Jay County could be said to have a complete or nearly complete "stand". For the most part, corn in the county is planted in drills, and the average distance apart when the stand was complete is perhaps fifteen to sixteen inches. In probably three-fourths of the fields in which observations were made, the number of stalks in the rows was often but two-thirds to three-fourths of the number which should have been present if the stand had been complete. This means that in perhaps three-fourths of the fields of the county the yield can be only two-thirds to three-fourths of what it might have been provided the full number of stalks possible had been present.

Some inquiry was made as to the method by which the seed corn was selected, and while the information gained included too few cases to arrive at a general conclusion which could be absolutely depended upon, it was nevertheless true that it was the exception to find a man who tested his seed corn by the sprouting method before choosing a given ear for use as satisfactory. Many rely on their ability to judge of the value of the corn for seed by its general appearance, by its firmness, etc., but those farmers who have been sufficiently careful to test a few grains from each ear which they propose to use for seed, have found that many ears are rejected when this method is used, which appear to be as perfect as others which are shown to be satisfactory by the sprouting test.

It is, of course, to be recognized that many causes may operate to reduce the stand in corn rows beside that of choosing poor seed;

yet from all the information which could be secured, it seems extremely probable that the total yield of corn in Jay County would be increased by not less than 25 per cent. or 30 per cent., that is, by about one-fourth if the sprouting method of choosing seed corn were universally used.

It is, of course, unnecessary in a report of this kind to give detailed instruction in regard to this method of determining whether a given ear of corn will make good seed corn, but information on this point can be supplied by any of the state agricultural schools, and unless some other method which is known to be equally accurate and satisfactory is being employed, this particular method should be investigated, and if put into practice, it would no doubt cause a marked increase in the total production of this one cereal.

Soil Survey of Clinton County, Indiana.

By W. E. THARP, of the U. S. Department of Agriculture, and R. H. PEACOCK and C. M. ROSE, of the Indiana Department of Geology.

EDWARD BARRETT, State Geologist.

DESCRIPTION OF THE AREA.

Clinton County is located in the north-central part of Indiana. It is bounded on the north by Carroll County, on the northeast by Howard County, on the east by Tipton and Hamilton counties, on the south by Boone County, and on the west by Tippecanoe and Montgomery counties. The county has an area of 398 square miles, or 254,720 acres.

The surface varies from gently undulating to moderately rolling, with a general elevation of about 900 feet above sea level. A rolling topography prevails for a distance of from one-fourth to one mile on each side of the larger streams. Along the lower and middle courses of these creeks bluff-like slopes from 20 to 50 feet high enclose the narrow valleys, which in most places are less than one-half mile wide. These low escarpments are a measure of the erosion that has taken place since the disappearance of the ice sheet. Elsewhere the surface configuration has been but little modified by running water.

The northern half of the county has stronger relief than the southern part. A considerable portion of the latter, extending from the neighborhood of Cyclone westward to Manson and Jefferson, is embraced in a wide and slightly depressed area known as Twelve-Mile Prairie. Frankfort is situated on the northern margin, while the southern limits are two or three miles north of the Boone-Clinton boundary line. The surface, especially in the west half, is characterized by many nearly flat areas from a few rods to one-half mile in diameter, while the relief of the remainder is not more than sufficient to give good drainage to the highest ground.

The southeastern townships have a slightly greater elevation than the Twelve-Mile Prairie, but the topography is so mild that a view conveys the impression of a slightly uneven plain. The Sugar Creek drainage north and west of Kirklin is entrenched in narrow valleys from 10 to 30 feet below the immediately adjacent uplands. The latter for a mile or so on each side of the main stream are strongly undulating, with occasional shallow ravines, but there is very little ground so rough as to prevent the convenient use of farm machinery.

Similar surface configuration generally prevails throughout the east-central and eastern sections of the county; also on the main interstream divides between Wild Cat, Kilmore, Campbell and Middlefork creeks. As previously stated, the land near these streams is moderately rolling, but some distance back the surface, for the most part, consists of low, broad swells and local divides of slight but unequal elevation and very indefinite direction of trend. The intervening depressions are similarly irregular in extent, but their margins, in recently plowed fields, are sharply indicated by the black color of the soil, which contrasts strongly with the gray silt loam of the higher ground.

From Jefferson northwest to the Clinton-Tippecanoe line, and thence to Mulberry, the surface is generally somewhat rolling, with limited areas of hilly land near Wild Cat Creek. Rather strong relief prevails between Mulberry and Rossville although there are occasional areas of a few square miles in extent that are nearly level.

Between Sedalia and Geetingsville there are a number of prominent morainic ridges, one-quarter to one-half mile long and rising from 25 to possibly 50 feet above the general level of the land in their vicinity. Smaller but less prominent mounds are not uncommon throughout the northern part of the county.

All the streams flow towards the west, except the southernmost, Potato and Sugar creeks, which flow southwest. The larger streams maintain their flow in all seasons, but the small tributaries and most of the dredged ditches were dry during the summer of 1914.

On the uplands excellent water may be obtained at depths varying from 25 to 50 feet, while on the low areas unfailing supply is usually found at 10 or 15 feet. The sources of the latter are the gravel beds that so generally underlie the larger bodies of the black soils. In recent years many farmers, on the uplands, have sunk driven wells from 100 to 150 feet deep that in nearly all instances, insure an unlimited supply for live stock.

Most of this county was originally very heavily forested. On the well-drained lands sugar maple, walnut, poplar, hickory, beech and several kinds of oak were the dominant varieties, while elm, ash, swamp white oak were more commonly found in the poorly drained locations. The "Prairies" were not wide areas of open land but had many island-like groves of white and post oak on the slightly elevated knolls, and there were numerous patches of small timber with much hazel brush on all the higher ground. The wide flats and all the depressed areas were either marshes or ponds during the greater part of each season.

The present remnants of the forest are mostly open woodland pastures but with little undergrowth, occasional "sugar camps", and many beautiful groves around farm buildings.

Nearly all the public roads are well graded and surfaced with crushed stone or gravel. Four railroads and two interurban lines radiate fom Frankfort. The rural population is 18,040, the urban 10,586, according to the 1914 census by postoffice. Most of the farmhouses are well built and have good outbuildings and barns, while in all sections silos are becoming a feature of farm improvements. Practically every farm home has telephone service and rural delivery of mails.

CLIMATE.

The following table compiled from the records of the weather bureau station at Lafayette, Tippecanoe County, 25 miles northwest of Frankfort, giving the normal monthly, seasonal, and annual temperature and precipitation and the occurrence of killing frosts in the spring and fall, represents fairly accurately the conditions in Clinton County.

NORMAL MONTHLY, SEASONAL, AND ANNUAL TEMPERATURE AND PRECIPITATION AT LAFAYETTE, TIPPECANOE COUNTY, INDIANA.

Month.	Temperature.			Precipitation.			
	Mean.	Absolute Maximum.	Absolute Minimum.	Mean.	Total Amount for the Driest Year.	Total Amount for the Wettest Year.	Snowfall, Average, Unmelted.
	°F.	°F.	°F.	Inches.	Inches.	Inches.	Inches.
December	29.7	69	—17	2.59	1.95	5.84	3.5
January	25.3	70	—33	2.47	1.18	0.40	7.0
February	26.9	69	—26	2.75	2.94	5.78	6.3
Winter	27.3	....	....	7.81	6.07	12.02	16.8
March	37.6	83	—5	3.20	1.41	3.30	4.4
April	50.5	89	10	3.27	2.94	2.25	0.4
May	61.5	97	25	4.40	2.11	3.82	Trace.
Spring	49.9	....	....	10.87	6.46	9.37	4.8
June	70.7	100	33	4.43	1.97	7.16	....
July	74.6	105	42	3.77	0.88	2.05	....
August	72.6	102	39	3.23	0.47	0.47	....
Summer	72.6	....	....	11.43	3.32	9.68	....
September	66.1	101	29	2.77	3.02	4.20	....
October	53.3	92	16	2.35	1.62	4.42	Trace.
November	39.5	95	—1	3.06	3.72	6.49	1.2
Fall	53.0	....	....	8.18	8.36	15.11	1.2
Year	50.7	105	—33	38.29	26.21	46.18	22.8[1]

[1] Included in mean precipitation.

The snowfall is quite variable from year to year. As a rule the snow drifts badly on account of the generally clean condition of the fields, and often occasions injury to fall-sown grains.

AGRICULTURE.

The first settlement in this county was made in 1826 on the margin of Twelve Mile Prairie. Since at that time and for several decades afterwards only ground having good natural drainage could be cultivated, all of the earlier homesteads were located on the more rolling land. As a rule the acreage of the oldest field was very limited and the extension of the cleared areas was necessarily slow. While some land has been in cultivation 75 or 80 years, the average period of tillage of the lighter colored soils is much less, probably averaging something like 50 years. The smaller and more easily drained areas of black soils were gradually being brought into tillage during all this time, but the largest tracts have, as a rule, been reclaimed within the past 25 or 30 years.

Corn, oats, and wheat have been the chief crops.

The steady increase in the acreage devoted to corn is due in part to the reclamation of the black land, and also in large measure to the fact that it is the most profitable of all cereal crops. Broadly speaking the acreage of this grain is limited only by the proportion of land in condition to meet the requirements of the crop. Three or more successive plantings of corn are almost out of the question on the light colored soils, and it is also necessary to frequently change to small grain and clover on most of the older black lands. A rotation including clover is now recognized as a necessity on practically all types of soil except some of the more recently drained Clyde soils and some bottom lands. There are a good many farmers who would eliminate wheat and oats from the rotation were it practicable to secure a stand of clover without seeding land to one or the other of these grains. Neither is very profitable in itself, and in unfavorable seasons, the value of the grain usually is less than the total cost of its production.

Owing to the practice of seed selection, thorough preparation of the ground, and the use of fertilizer on the light-colored soils, wheat is more generally profitable now than it was some years ago. In the season of 1914 land that had been fertilized, or to which much manure had been applied in previous years, produced from 5 to 15 bushels per acre more than similar land that had not been so treated. On the latter 15 to 20 bushels per acre was the range of yield.[1]

Oats are not given as much attention as either wheat or corn. The crop is never fertilized, and in many instances land out of condition for corn and not desirable for wheat is utilized for the oat crop. Very often the seeding is done when the soil is in poor condition for tillage, especially on the flat phases of the Miami silt loam. In the wet season of 1912, most of the oat crop on the Clyde soils was so heavy as to lodge badly, and much of the grain was lost, but on the Miami types, that season, the yield was generally good. In the dry season of 1914, however, the crop on the latter types was almost a failure, while average yields of from 40 to 50 bushels per acre were obtained on the Clyde and Carrington soils. Similar results in previous years show the greater sensitiveness of oats to seasonable conditions than is the case with wheat or corn.[2]

Rye gives good results, but is not extensively grown. This crop requires less moisture than oats, and is a good nurse crop for clover.

[1]Circulars No. 23 and 10, Agr. Exp. Sta. Purdue University.

[2]An oat crop requires about 500 pounds of water for each pound of dry matter—straw and grain—that is matured. Corn uses about 300 pounds of water per pound of dry matter.

If not harvested it affords sufficient pasturage to pay for the seed and labor of sowing. Timothy, which is quite commonly grown in combination with clover, is not a desirable crop from the standpoint of soil improvement. Of far greater importance are the hundreds of acres of bluegrass pasture in the county.

Sweet clover is common in some localities, but not generally abundant. Where this plant thrives well, conditions are generally favorable for alfalfa, especially with respect to bacteria in the soil. Many small patches of alfalfa have been successfully established and the number of fields is steadily increasing. This crop does well on the Clyde silty clay loam and in some parts of the creek bottom soils. On the Miami soils the water supply is not so good as on those just mentioned, while the deficiency in lime must be corrected. The brownish-gray soil, where the depth to brown, gravelly clay does not exceed 25 inches, is preferable to the lighter-colored land. Spring seeding with a nurse crop usually fails if dry weather follows the removal of the small grain. The best results are generally obtained by breaking ground in the spring, disking frequently to kill weeds and obtain a good condition of tilth, and sowing in July or August.

Tomatoes are the only truck crop of importance. There is a canning factory at Frankfort and shipping points at several of the smaller towns. The contract price is now $10 a ton, and the yields in recent years have ranged from two to three tons per acre. The Clyde soils are preferred on account of the earlier and stronger growth of the plants, but in favorable seasons the crop does as well on the Miami soils, and the quality is somewhat better.

The total acreage of small fruits in the county, according to the census of 1910, is 23 acres. The local demand is largely supplied from outside sources. Farm orchards are not generally given much attention. In the season of 1914 the yields of apples throughout the county were very small, except in one or two instances where special care had been given the trees.

A considerable number of cattle are fed in Clinton County, chiefly by farmers holding more than 200 or 300 acres of land. The smaller land owners do not, as a rule, have many cattle aside from milch cows. Although much milk and cream is sold in Frankfort or shipped to Indianapolis, dairying has not been so extensively developed as in some of the adjoining counties. On almost every farm the sale of fattened hogs affords the largest item of income. A few sheep are raised, and a very occasional practice is the purchase of Western lambs for feeding.

The cultural methods employed on most farms are quite as thorough and efficient as practiced anywhere in the Corn Belt. The latest and best types of farm implements are in general use. The disc harrow and roller, as well as other devices for effecting a "dust mulch" in corn fields at the close of regular cultivation, are now used on nearly every farm.

The rotation most commonly practiced on the Miami soils is wheat or oats, followed by clover, allowing the latter to stand two seasons, then corn. On the Clyde and Carrington soils, corn is often planted two years, or even more, in succession, and a regular change to clover is not so necessary as on the Miami types. In several instances, a three-year rotation, consisting of wheat, English clover, and corn, is most successfully practiced on the latter type. The clover is clipped for seed, but the bulk of the crop is plowed under, or used for pasture. From one hundred to two hundred pounds of commercial fertilizer is applied to the ground at time of seeding to wheat. On one or two farms where this system has been followed, a decided increase in the average yield of both wheat and corn has resulted.

During the last few years there has been a rapid increase in the use of commercial fertilizer. The brands most generally used contain from one-half to one per cent. of nitrogen, from two to five per cent. of potash, from eight to ten per cent. of phosphoric acid. The usual rate of application is from 100 to 200 pounds per acre and as previously stated is most frequently used on wheat ground. A few farmers are using commercial fertilizers for corn, using a grade of fertilizer somewhat higher in nitrogen than the above mentioned formulas. In some instances the proportion of potash is increased on lands inclined to be "chaffy". The increased yields and improvement in the quality of wheat where commercial fertilizers are used leaves no doubt as to the profitableness of this practice.

According to the census, there were 2,724 farms in the county in 1910, with an average size of 93.2 acres, while in 1890 there were 2,885 farms, with an average size of 87 acres. The number of small holdings near the larger towns and along the electric railways has undoubtedly increased in recent years, but a steady increase in the size of the moderately large farm, is observable in the county as a whole. While there are many farms of 40 acres and less, the majority range from 160 to about 240 acres. There are very few holdings exceeding 500 acres. Under present conditions the large farms can be operated more economically than small ones.

The average value of farms, according to the last census, is

$13,472, of which 78.3 per cent. is accredited to the land, 11.1 per cent. to buildings, 8.5 per cent. to domestic animals, and 2.1 per cent. to implements. This division of the total valuation leaves $113.20 per acre for the land itself, which is a conservative estimate, considering the prices that farm lands command at present. Very little unimproved land is held at less than $125 an acre, while well-improved and desirably located farms are held at prices ranging from $150 to more than $200 an acre.

Forty per cent. of the farms are now operated by tenants. Thirty years ago the proportion was less than 30 per cent. The present terms, in most instances, are two-fifths of the grain and cash rental for meadow and pasture land, with additional payment for the use of house and buildings. Most leases are for one year, but some tenants have arrangements for a longer period, and in a few instances a rotation of crops is planned and considerable attention given to live stock.

SOILS.

The surface formation of the area is a drift sheet usually referred to as belonging to the early Wisconsin period of glaciation. In the uplands the total depth of this bowlder clay—with included beds of gravel—is from 100 to 150 feet. The lower part of this heavy mantle of unconsolidated material doubtless represents older till, but neither this nor the underlying rock has influenced the soils to any appreciable extent.

The glacial material as exposed in road cuts and other shallow excavations, is a very light brown, or pale yellowish brown mixture of silt, clay, and sand, with somewhat variable proportion of gravel and small stones. The latter consists largely of rock so resistant to weathering as diorite, quartz, and quartzites, and fine-grained granites. There are usually no shale and very few sandstone fragments. At a depth of a few feet pieces of limestone are numerous, and the till from this depth downward is very calcareous.

The greater portion of the till consists of silt, clay and the finer grades of sand. It is quite compact but not impervious. The surface of artificial exposures usually assumes a loose crumbly condition, and a rather fine granular structure is more or less apparent throughout the mass so deep as weathering has affected it, which may be very roughly estimated at from 5 to 15 feet. Below this depth—except where gravel occurs—the till is more compact, of a dull bluish gray color, and very calcareous. In many places, particularly in the large structural depressions as well as in the valleys formed by post-glacial erosion, gravel beds are found at a depth of a few feet.

The friable structure admits of comparatively rapid absorption of water and the free movement of the soil moisture by capillarity. Effective aeration to a depth of two or three yards is indicated by oxidation of the iron content or by the prevalence of yellow and brown tints to that depth.

The till as described above, however, does not form the surface soils except in areas of very small extent. It is almost everywhere covered to a depth of three or four feet by a silty deposit in which there is comparatively little stony material. This resembles loess, having about the same mechanical composition, and general physical properties as shallow deposits of that material which overlie glacial formations in many other sections of the Mississippi Valley. From 50 to 70 per cent. of this silty surface layer consists of that grade of soil particles known as silt, or which are intermediate in size between very fine sand and clay. The first few inches of this material usually contains considerable fine sand, enough to be easily felt when the otherwise smooth, fine-textured soil is rubbed between the fingers. The lower part contains less sand, and a correspondingly higher proportion of clay, and consequently is more compact. At a depth of 20 or 30 inches on the moderately undulating uplands, and at a somewhat less depth on the more rolling lands, the silty material grades into bowlder clay. The contact in most instances is fairly well defined and seldom varies greatly from the above mentioned depths. The chief exceptions in this respect occur on steep slopes where the silty covering has been partially removed by erosion.

To the almost universal occurrence of this loess-like surface stratum is due the wide extent of silty, stone free soils of this and adjoining counties.

This deposit attains its maximum average thickness on the flat to very gently undulating portions of the uplands. Where such topography prevails the surface soil is very light colored and the subsoil is more or less mottled, light grayish and pale yellow tints predominating. Such coloration, with noticeable lack of granular structure in the upper part of the soil section, is generally evident wherever the depth to the bowlder clay exceeds 30 or 40 inches. Such a development of the upland soils has been mapped as a flat phase of the Miami silt loam. It is in this phase that the so-called "clay spots" most frequently occur.

On the undulating to moderately rolling uplands the silty stratum is thinner, and as a rule contains a slightly higher percentage of sand than where the relief is less pronounced. It is more permeable to air and water, and brown and yellow-brown shades prevail throughout most of the soil section, indicative of good physical structure. These well-drained and easily tilled lands constitute the typical Miami silt loam. This type corresponds in a general way with the "sugar tree" lands and "walnut lands" of the early settlers, names still retained to some extent in local usage.

Both the Miami silt loam and its flat phase are deficient in humus. This is owing to the fact that prior to the settlement of the country, all these uplands were heavily forested. With such a forest cover, well-drained upland soils in temperate climates accumulate little organic matter. Even that organic matter, which may have been gained when the land was prairie (as was undoubtedly the case here) may be largely lost after becoming forested. Evidence of this fact is furnished by the Carrington silt loam of this and adjoining counties. The mineralogical character of this latter type and its general surface configuration are almost identical with that of the Miami silt loam, but the soil is black on account of the high content of humus. This type was treeless, or nearly so, when the first settlers entered this country, and retains much of the organic matter that was accumulated during the long period when the surface was covered with grasses and herbaceous vegetation.

In the depressions without natural outlets, swampy or semi-marshy conditions prevailed until the present artificial drainage channels were made. Some of these basins were shallow lakes or prairie marshes, but by far the larger proportion of them were forested, the character of the timber being determined largely by average drainage conditions. Elm, hickory, ash, occupied the lands that were free from water a considerable portion of the time, while the scattering willow, cottonwood, sycamore, and other moisture enduring species marked the encroachment of the forest along the sluggish streams and margins of the lakes and muck beds. While a black humus-laden soil will develop in the poorly drained forest lands, it seems highly probable that the greater part of the black, carbonaceous material that gives the black lands their distinctive color, was accumulated during the prairie stage of their existence.

In general the development of the principal types has been determined (1) by topographic position, (2) by thickness of the superficial silty stratum, and (3) by character of the original vegetation. The first directly affects the drainage conditions as a whole, the second exerts much influence upon the average moisture content of the soil mass, while the last has determined the kind and amount of organic matter in the surface soil.

On account of the limited extent of erosional valleys in this county, alluvial types have not been developed except along the middle and lower courses of the streams. The material of these bottom lands consists of reworked silt and sand derived from the adjacent uplands. Owing to the presence of the gravelly substratum the aeration and drainage are generally good. Therefore, oxidation of the iron contents has quite uniformly extended to a depth of several feet and brown colors prevail in most of these soils. The rather low content of organic matter may be accounted for in the same manner as on the well-drained uplands. The debris from the heavy forest decayed upon the surface, forming a brown mold that soon disappeared after the ground was cleared; and only in semimarshy places did it accumulate in the form of persistent black carbonaceous material, thoroughly incorporated with the mineral constituents. Towards the upper courses of the streams dark colored soils of this character form a transition between the strictly alluvial types, or brown sandy soils, correlated with the Genesee series and the black silty soils or Clyde silty clay loam.

The soils of the county have been classified in five series and three miscellaneous types. The actual and relative extent of each type and their distribution are shown in the accompanying map.

MIAMI SERIES.

The soils of the Miami series are brown, light brown or grayish, and are underlain by yellowish and brown heavier textured subsoils. Mottlings of brown and light gray are present in the subsoils in many places, particularly in the case of the clay loam member, which is by far the most extensive type mapped. The surface drainage is usually good, but artificial drainage is necessary in some of the heavier types. The soils are in the main derived, through weathering, from glacial till of a generally calcareous nature. Some of the gravelly phases, however, are, in part, at least, water assorted, having been deposited as obscurely stratified material in the form of kames. Of this series, two types, the silt loam and loam, together with a flat phase of the former, are mapped in Clinton County.

MIAMI SILT LOAM.

The soil of the Miami silt olam, to a depth of six or eight inches, is a gray or very light brownish gray, friable silt loam. The upper part of the subsoil is a yellow or yellow and gray mottled silt loam that at a depth of 12 to 15 inches grades into a dull yellowish-brown, slightly mottled, stiff, compact silty clay loam. Usually at a depth of 20 to 30 inches below the surface this mottled material merges into a yellowish-brown clay or clay loam in which there is some coarse sand and a few pebbles. Below 36 inches the proportion of gravel and small stones is so large as to make the soil difficult to penetrate. A few large bowlders are scattered over the surface of the type, but most of these have been removed from cultivated fields. Both soil and subsoil are decidedly deficient in organic matter.

The lightest colored portions of the Miami silt loam have a decidedly ashy appearance and a tendency to form a firm but rather porous crust after rains. This condition is largely the result of long cropping with but few changes to clover and but scanty applications of manure. It is not noticeable, however, on the flat phase of the type.

On the steeper slopes, the soil has a decidedly brownish tint, is more or less sandy, and contains many small stones. At a slight depth the subsoil is a brown sandy or gravelly clay, quite compact, but seldom approaching a hard pan. The pronounced brown coloration of soil and subsoil in such locations is due to the more vigorous circulation of the soil moisture and air than takes place where the surface relief is milder and the subsoil contains less coarse material.

The Miami silt loam, with its flat phase, constitutes 63.7 per cent. of the total area of the county. The only considerable area in which it is not extensively developed is Twelve-Mile Prairie, and even that large tract of black land contains many small spots of the light-colored silt loam.

The surface of most of this type is strongly undulating and the natural drainage is good. Near the larger creeks the surface is more rolling than in the central parts of the interstream divides. As a rule, short, steep slopes face the narrow valleys and extend some distance back along the tributaries. There are also occasional low ridges a fraction of a mile long and mounds of a few acres extent that rise from 10 to 20 feet above the surrounding land.

The Miami silt loam yields easily to tillage and on all the undulating to rolling portions has a physical structure quite favorable to the maintenance of good moisture conditions and to effective aeration. Where gravel beds occur at a depth of a few feet the moisture reserve is correspondingly reduced, but such conditions are usually found only on the apexes of sharp knolls and near the escarpments overlooking the creek bottoms.

As a rule no free lime can be found within three or four feet of the surface, but at a slightly greater depth the material is very calcareous. The surface soil and the upper subsoil are acid, strongly so in all the lighter colored phases.

The average yield of corn may be placed below rather than above 40 bushels per acre. This estimate does not include the returns from low swales, where the soil approaches the Clyde silty clay loam, necessarily included in the mapping of the dominant type.

A marked increase invariably follows even moderate applications of manure or of clover, or the plowing under of clover, or blue grass sod. Clover is especially beneficial, since its roots penetrate the compact subsoil and by their subsequent decay render it more open and permeable.

All of this type responds to phosphatic fertilizers, but their most profitable use is limited to wheat. The yields of this grain are quite variable, ranging from 15 to 30 bushels on most farms.

As a rule this type will not carry a heavy crop of oats to maturity if there is a marked shortage in the rainfall during May and June. The best crops are secured when there is at least a normal precipitation well up to the period of ripening.

If a stand of clover is secured its subsequent growth is usually satisfactory although not so heavy as on the Clyde soils. Considering the acidity of the surface soil it is somewhat remarkable that clover does so well. No evidence of ''clover sickness'' is observable.

Blue grass thrives on this type notwithstanding the acidity of the surface soil and the fact that this is a lime loving plant.

Farmers generally state that the quality of all grains and grasses grown on the Miami soils is better than that of similar crops on the more fertile black lands.

Apples do well on this type, and it affords favorable location for orchards. The northerly slopes are preferred to southern exposures or to flat areas. This is also true with respect to pear and cherry trees.

All this type was formerly covered with a heavy growth of hardwoods. Sugar maple, walnut, poplar, and several kinds of oak were the prevailing species on the more rolling portions, which still are locally termed ''sugar tree land.'' Where the relief is less pronounced white and post oak, hickory, beech, ash, and elm were more abundant, the last two being partial to those local depressions that had very poor drainage.

In general statement the price of land of this type ranges from $125 to $150 an acre.

Miami Silt Loam—Flat Phase.—This phase of the Miami silt loam is distinguished from the remainder of the type by its smoother topography and lighter color. The relief is sufficient to insure good surface drainage except in many level or nearly level spots, and from which storm waters move slowly. The underdrainage of this phase is somewhat inferior to that of the more rolling land. This is caused in part by the very silty character of the soil, but chiefly by the greater depth to which the compact silty clay loam subsoils extend. As a rule the brown gravelly bowlder clay is not found at less than 35 or 40 inches from the surface. During wet weather the subsoil soon becomes saturated and after rains cease it parts slowly with its excess water, causing the surface soil to remain soggy and cold where superficial appearances would indicate comparative rapid drying.

In this phase there are many so-called "clay spots" where the soil is very light colored and often has ashy, lifeless, appearance when dry. Under tillage it becomes loose and pulverulent to a depth of several inches, but readily forms a rather firm crust after rains. The upper subsoil is a mottled gray and yellow silt loam with many dark iron stains, and usually many small, black concretions. The lower subsoil is a heavy silty clay, usually of a bluish gray tint, indicative of its imperfect aeration and frequent saturation. In some instances the subsoil throughout is a compact mixture of fine sand and silt but with nearly as undesirable properties as the clay.

Fortunately these phases are limited to a fraction of an acre, or of a few acres at most, on the crests of local divides and in places at lower levels. Approaches to such undesirable physical structure, however, are quite common in places, especially where the ground is not frequently sown to clover or liberally manured.

Obviously the first requirement of such areas is better internal drainage. Tile drains must be laid only a few rods apart, as the lateral movement of water through such a dense clay is very slow. Wherever stumps have been removed by dynamite, the physical condition of the soil is greatly improved, as indicated by its more rapid drying after rains and the better growth of corn on such spots. This suggests the possible employment of dynamite for loosening the subsoil of small patches where the tight bluish clay substratum is found to be the cause of imperfect drainage.

The best farmers have found that the most practicable means of improving this phase is by the growing and plowing under of clover, deep preparation of the land for corn and wheat, and liberal applications of burnt lime or ground limestone. The phase is more in need of organic matter than the typical soil.

As a rule no close line can be drawn between the areas of the *flat phase* of the Miami silt loam and the more rolling lands. The separations on the soil map are approximately correct with respect to the larger areas, but many small developments are necessarily included in the larger tracts of the dominant phase.

MIAMI LOAM.

The soil of this type is somewhat variable in composition but usually a heavy, slightly sticky, brown loam containing considerable coarse sand and gravel. At a depth of six or eight inches, it grades into a compact clay loam in which the proportion of sand and gravel may not be so high as in the surface soil. Below 20 or 30 inches the included pebbles and small stones are more abundant, and at some depth, usually less than six or eight feet below the surface, loose gravel is often found. Brown is the prevailing color throughout the entire soil section for the drainage and aeration is generally effective to a depth of several feet.

This type has been developed on slopes where erosion has removed much of the gray silt that occurs elsewhere on the uplands. In but few instances, however, is the silt entirely wanting. It forms an appreciable proportion of the surface soil on the steepest slopes while on the milder inclines it constitutes so high a percentage of the material that the soil is a gray silty loam similar to the Miami silt loam. Definite boundaries cannot be drawn between the two types, although the brown color, rougher topography, and more stony surface serve to distinguish in a general way the typical loam from the silt loam.

The bluff-like slopes facing the creek valleys are a rough phase of this type. For the most part they are untillable but afford good pasturage. Blue grass thrives well, and clover makes a better growth than on the lighter colored soils. This may be due to the slight depth at which limestone fragments are often found, indicating a calcareous subsoil. Only the widest portions of these areas admit of representation on the map. They are generally cultivated and produce good corn and wheat.

The areas between Sedalia and Geetingsville are prominent ridges. The slopes in part are quite steep but all of them are tillable. The surface is generally gravelly and there are many small stones on all the sharpest inclines. As a rule, gravei beds form the substratum, but in most instances at such depths as not to seriously interfere with the moisture conditions of the soil and subsoil. The drainage is very effective, however, and care is necessary to reduce the surface run-off to the lowest degree practicable. For cultivated crops this is best accomplished by deep plowing at right angle to the slope, so as to lessen tendency to gullying, and on ground set to clover or blue grass by avoiding close grazing and excessive trampling.

The average yields of corn and wheat on this type compare favorably with those on the Miami silt loam. Oats are more susceptible to the effects of dry seasons. This is also true with respect to clover and timothy on the mounds and ridges, but on some parts of the hillsides facing the valleys, slightly seepy conditions prevail and all grasses thrive. In such locations clover and alfalfa find the shallow depths to calcareous till especially favorable to their growth. Peach and cherry trees prefer well drained soils and this type is favorable to their best growth. In many instances old and thrifty apples trees are found on this type and on areas of the Miami silt loam resembling it.

CLYDE SERIES.

The soils of the Clyde series are characterized by dark-brown to black surface soils and gray, drab, or mottled gray and yellowish subsoils. They are derived through deposition or the reworking of materials carried under glacial lakes or ponds, the dark color of the surface soils being due to the high percentage of organic matter caused by the decay of plants under swampy conditions. The soils of the Clyde series grade into muck and peat on the one hand and into such glacial-like soils, as the Dunkirk series on the other, without very sharp boundary lines. They are distinguished from the Poygan soils by the gray instead of reddish subsoils, and from the Fargo in the general absence of calcium carbonate. The topography is level and the soils are naturally poorly drained, but when reclaimed they are highly productive and valuable for corn, grass, sugar beets, cabbage, and onions. One type of the Clyde series, the silty clay loam, was mapped in this county.

Clyde Silty Clay Loam.

The surface soil of the Clyde silty clay loam is black, crumbly, silt or silty clay loam, about eight inches deep. The subsoil, to a depth of 18 inches or more, is a stiff, compact, black clay or silty clay loam, which when dry breaks into rather coarse granules, but when wet is inclined to be heavy and sticky. The lower subsoil is generally similar in texture to the middle section but much lighter colored. Dark drab or bluish gray changing with increase of depth to light gray is the usual coloration, but in many instances there is more or less pale yellowish mottling. This lower subsoil usually lacks the jointed structure of the black material above, and therefore is more compact, and often a smooth, tenacious clay or silty clay loam that offers much resistance to penetration by any implement, and admits of rather slow water movement through it.

The black color of the soil is due to the high content of organic matter. In marked depressions, especially if recently drained, this humus may be so abundant that the soil is loose and spongy, or even approaches a true muck, but as a rule it is not present in greater amounts than to impart a very black color and crumbly structure to what would otherwise be a light colored but heavy clay or silty clay loam.

The organic matter consists of black carbonaceous material derived from vegetable remains decomposed in water, or under such conditions that air was partially excluded. Compared with the brown humus that forms in a well-drained soil from decay of manure, or of organic remains of any kind, this old black humus is inert and contains in itself but little of the elements of fertility, but it imparts a fine physical condition to the soil and renders it highly favorable to those organisms that develop nitrates.

Practically all of this type has poor natural drainage and only since artificial drains have been so generally installed has the water table been permanently lowered. In comparatively few instances does the ground water stand above three feet from the surface; usually it is several feet below. Its former high average level occasioned the light color of the lower subsoil. The latter frequently contains so much calcium carbonate that it will respond freely to hydrochloric acid.

The Clyde silty clay loam is found in all the swales and basins that are such a characteristic feature of the upland topography. It also prevails throughout all these broad, valley-like depressions in which the upper branches of the creeks formerly had tortuous and much obstructed channels. Phases of the type have also been developed in the flat portions of Twelve-Mile Prairie, and in other tracts that in their natural condition were semimarshy prairies. In the vicinity of Hillsburg and Scircleville the Clyde soils are found on comparatively high ground but the drainage was originally very poor.

The extensive distribution of the type and its close association with the local drainage is apparent at a glance at the map. Many small areas can not be shown, especially where the margins are a dark soil but only moderately richer in organic matter than the surrounding type or where the subsoil is a brown or yellow silty clay indicating fairly effective underdrainage. The central part of the smallest areas, however, is usually a typical Clyde soil.

In many instances small patches of "chaffy" ground are found in this type. They are simply places where the organic matter constitutes a very high percentage of the surface soil. In a few places shallow muck occurs and the agricultural value of the ground is somewhat uncertain. In all these extreme phases the upper subsoil is a very black clay or silty clay and as a rule quite compact, or often gummy.

Throughout most of the long, narrow areas drained by dredged ditches water-bearing gravel is found at six to eight feet below the surface. Gravel also underlies portions of the type elsewhere, but as a rule is erratic in occurrence, or too deep to appreciably affect the surface soil. All this gravel is more or less calcareous, and the whitish clay above it is usually limy. The substratum of the small areas is generally a yellowish bowlder clay.

The long, broken drainage lines shown on the map are mostly dredged ditches serving as outlets for thousands of rods of 6- to 10-inch tile drains. In wet seasons some of the type shows a lack of sufficient drains, but most of it is now farmed as conveniently as any of the uplands.

Corn is the most important crop grown on this soil, and yields of 80 to 90 bushels per acre are frequently obtained. The average yield is lower but probably is close to 60 bushels. In places where the soil has an excess of black vegetable matter and is somewhat mucky, the leaves of the corn frequently turn yellow, the roots partially decay, and the whole plant fails to attain a normal height. This condition also sometimes occurs on ground not exceptionally high in organic matter. Heavy applications of stable manure will remedy the trouble for at least one or two years. Deep fall plowing to mix the clayey subsoil with the muck surface soil is also beneficial. Muriate of potash at the rate of 100 to 200 pounds per acre will usually insure a good yield of corn on such ground, other conditions being favorable.

Wheat and oats do well on this type, except that in wet seasons the latter usually makes too much straw and is apt to lodge badly.

Wheat is not usually fertilized, and yields range from 20 to 30 bushels, on most farms.

Clover does well on this type and a stand is usually obtained with either wheat or oats except under very unseasonable conditions. Alfalfa also thrives and little difficulty is experienced in obtaining a good stand. Locations where the depth to water-bearing gravel is only a few feet are preferred to those underlain by the bowlder clay. While the soil often shows some acidity if tested with litmus paper, it is less acid than the Miami soils.

Tomatoes usually make an earlier and more vigorous growth than on the lighter colored soils, but it is doubtful if the quality is so good. Some canners prefer the tomatoes grown on the lighter soils but growers prefer the soils which produce the heaviest yields.

Late potatoes usually do well on this type, also cabbage, celery, beets and other crops requiring a rather long growing season. Most of this soil is earlier than the lighter colored Miami types and therefore preferable in most instances for early garden crops. Strawberries, where flavor of the fruit rather than shipping qualities, is desired, do best on a rich soil with abundant water supply. These conditions are fulfilled by this type, and it also seems possible that supplemental irrigation could be profitably pareticed on limited acreages along the big ditches.

The present price of most of this type ranges from $150 to $200 per acre.

CARRINGTON SERIES.

The types included in the Carrington series have dark-brown to black soils and light-brown to yellowish subsoils. They are derived almost exclusively from glacial till material. Their topography is gently undulating to rolling, with occasional nearly flat areas. The soils in this series are found in the glaciated region from the Ohio River westward. In this series, one type—the silt loam—was mapped in Clinton County.

Carrington Silt Loam.

The surface soil of Carrington silt loam is a very dark gray to black silt loam from eight to twelve inches deep. The subsoil is a brown to yellowish-brown silty clay loam, more or less mottled with grayish streaks. The lower subsoil is similar to that of the Miami silt loam, usually a brown clay or clay loam containing considerable coarse sand and small gravel. This lower subsoil and the material beneath is the till, or bowlder clay, that forms the substratum of all the upland soils. It presents the usual variations in shades of yellow and brown according to the degree of oxidation of iron content that has taken place, and also the relative proportions of clay, silt, and coarser materials.

The Carrington silt loam usually represents fairly well drained areas that were originally prairie or but sparsely covered with bushes and small timber.

The organic matter of the soil has been derived chiefly from herbaceous vegetation. It is similar to the black carbonaceous vegetal remains which give the Clyde silty clay loam its distinctive color and loose structure, but the Carrington soil contains less of this organic material. It seldom forms such an appreciable proportion of the soil as to obscure the textural character of the mineral constituents.

The soil is invariably acid according to litmus paper tests, but not to such a marked degree as the Miami silt loam. At a depth of a few feet the substratum is usually calcareous.

The largest areas of Carrington silt loam are found in the southern part of the county, forming a considerable portion of the Twelve-Mile Prairie. Nearly all the slightly elevated or undulating portions of this formerly treeless land consist of this type. The individual areas, however, occur in much intimate association with the somewhat lower lying Clyde silty clay loam that no very sharp boundaries between the types can be drawn. The areas in the western part of the county have more pronounced relief than those in the central portion. Much of the type south and southeast of Frankfort has but slight elevation above the adjoining areas of Clyde soils, while between the lower course of Potato Creek and the Clover Leaf Railroad the Carrington silt loam is mostly high, well drained upland.

For a mile or more to the north and south of Scircleville and Hillsburg and thence east to the county boundary there are many low, broad swells where the soil is a black silt loam practically identical with the Carrington type. In most instances the areas are less than 40 acres in extent, and very irregular and rather indefinite with respect to boundaries. The highest points are usually the Miami silt loam, the slightly sloping land is Carrington silt loam while all depressions and flats, however small, have a very black soil and other characteristics of the Clyde silty clay loam. Similar conditions prevail along the Monon Railroad from Cyclone toward Sugar Creek. Obviously no close distinction in soil types can be made in such localities, and the areas mapped as Clyde or Carrington represent the predominant character of black land in that immediate vicinity. Most of the areas of Miami soil embracing 10 acres or more, are indicated.

The average yield of corn on the Carrington silt loam may be placed between 50 and 60 bushels per acre. Farmers usually give a higher estimate, but they include returns from the small depressions where the soil is the Clyde silty clay loam. The effect of the higher organic-matter content of the latter type and its greater moisture-holding capacity were very apparent in the dry season of 1914.

Wheat yields show a rather wide range, but usually do not fall below 18 or 20 bushels per acre. Commercial fertilizer is not commonly used on this type, but where applied there is an increase of yield. The difference, however, is not so marked as on the Miami silt loam.

Oats, clover, timothy, and minor crops do well on this soil. It also affords desirable locations for small fruits and truck, being a warmer and earlier soil than the Miami silt loam and having some advantage over the Clyde soils with respect to elevation.

The present price of desirably located land of the Carrington silt loam is about $200 an acre. Farms not so near town or electric lines are held at prices ranging from $150 to $175 an acre.

FOX SERIES.

The types in the Fox series have gray and brown surface soils and brown subsoils. The series has typically a level topography, drained here and there by potholes or by valleys eroded since the deposition of the material as outwash plains or as terraces along streams within the glacial area or flowing out of it. The soils, therefore, consist largely or wholly of glacially derived material, but an essential characteristic is the presence of at least 25 per cent. of limestone. The Fox silt loam is the only member of this series mapped in Clinton County.

Fox Silt Loam.

The soil of the Fox silt loam to a depth of six to eight inches is a brownish-gray to light brown silt loam. The subsoil to a depth of 12 to 18 inches is a yellowish-brown silt loam, grading below into a yellowish-brown compact silt loam to a silty clay loam and this giving way to beds of gravel at a depth of 2½ feet or more. The soil material is very much like that of the undulatory uplands. The type, however, has somewhat better underdrainage than the Miami soils, owing to the occurrence of gravel at a depth of 2½ to 4 feet below the surface. This possibly is not true of the margins farthest from the streams of the larger areas, for the soil in such places does not dry so soon after rains as that nearer the outer margins. Portions of the type are somewhat droughty, but the depth of soil and subsoil in general is sufficient to retain moisture throughout even dry seasons.

This type represents the high terraces, or elevated bench lands found on the lower course of Wild Cat Creek, and similar areas of lesser elevation on the larger tributaries. The surface of each of these small table lands—only one or two of which embrace more than 100 acres—is level or nearly so except along the margins. The rim next the valley is a steep declivity, while toward the uplands the surface rises so gradually that no well-defined boundary can be drawn between hillside and terraces. The elevation of the areas near the Tippecanoe-Clinton line is from 30 to 50 feet above the bottom lands, that of the minor areas farther up the streams is from 10 to 25 feet.

Wheat and clover do well on this type, and the returns from corn are somewhat better than on the average of the Miami soils. The soil is benefited by frequent rotations with clover, as the organic matter supply is generally low.

GENESEE SERIES.

The Genesee series includes soils formed from dark-brown to grayish-brown alluvial sediments deposited along the major streams and their tributaries throughout the northeastern glaciated region, practically where the Dunkirk, Volusia, Miami, and Ontario series constitute the principal upland soils. The soils of this series also occur for a short distance south of the glaciated area, where main streams have their headwaters in areas covered by these soil series. The sandy members of the series are prevailingly light brown to gray and the loam and silt loam members darker brown. The soils of this series are subject to either annual or frequent overflow. Two types in this series, the fine sandy loam and loam, were mapped in Clinton County.

Genesee Fine Sandy Loam.

The surface soil of the Genesee fine sandy loam consists of a brown, friable fine sandy loam to silt loam from 10 to 20 inches deep. The subsoil has about the same texture as the soil, but is usually slightly lighter in color. In the narrow areas near the channels of streams the subsoil is usually brown fine sandy loam, grading with depth into a sand. On the wider areas, particularly those having some elevation as the hills are approached, the soil is darker brown in color and contains a much greater proportion of fine material, while the subsoil is a heavy fine sandy loam to silt loam in which the coloration ranges through various shades of brown, indicating good underdrainage but a slower movement of the soil water than takes place in the lower sandy areas of more recent deposition.

With the exception of the uneven sandy deposits along the channels, all of this type where the texture may vary to coarse sandy loam is in cultivation. Wheat makes good yields, although its culture is confined to the areas above usual winter overflow.

Notwithstanding the small content of organic matter, the average yields of corn on this type are generally higher than on the Miami silt loam. The good aeration to a depth of several feet and the presence of water at no great depth are undoubtedly favorable factors, while the occasional overflows of the lower ground and washings from the adjoining slopes onto the higher levels contribute much fertility.

Clover does well on these low lands and many small fields of alfalfa have been established. Many favorable locations for the latter crop may be found in all of these valleys. The best locations are those where flood water will not stand for any length of time, and where a comparatively fine-textured subsoil extends to or within a few feet of the water-bearing gravel. This practically assures an unlimited water supply, the first requirement for a heavy growth of vegetation. Liming is necessary for best results, as this soil is somewhat acid.

Genesee Loam.

The type mapped as Genesee loam occurs chiefly on the middle courses of Kilmore Creek and along the Wild Cat Creek branches.

The heavier portions resemble the Clyde silty clay loam but contain more sand and the subsoil is usually darker colored and has better natural drainage. Near the stream channel and also on the lower portions of these areas the texture is coarser, being often a loam or fine sandy loam of a dark brownish, gray to dark brown color and underlain at a depth of 12 to 15 inches by a brown and gray mottled loam. In such places the natural drainage is better than in the wider parts of these valleys. The latter have been tiled or have open ditches, so that all this land except that near the channels is cultivated. The agricultural value is very nearly the same as that of the Clyde soils.

Further down these streams there are occasional small areas at the foot of the bluffs where the drainage was formerly so poor that much black humus accumulated in the soil. In several places shallow muck beds had formed and there yet remains an excessive amount of organic matter in the soil. Such areas are limited to a few acres in most instances, and elsewhere the soil is a black silty loam changing near the stream to the usual brown sandy alluvium. All of these places have been drained and are excellent soils for corn and grass. Only the larger ones are indicated on the map as Genesee loam.

MEADOW.

Along the small branches the bottom lands are usually of such variable character that no consistent classification is practicable. The soil ranges in texture from a brown coarse sandy loam to black silty loam, while the uneven surface presents innumerable variations with respect to drainage. Nearly all of it is subject to frequent overflow, and therefore only the higher ground is suitable for cultivation. Most of these narrow valleys are used for pasturage. Blue grass thrives, making a heavier growth and remaining green longer than on the uplands.

The Meadow of the larger streams is usually a sandy deposit from recent floods, or low strips of ground immediately bordering the banks. Except for the timber and some pasturage afforded these limited areas are of little economic importance.

MUCK.

The largest body of Muck is found on Swamp Creek near the east boundary of the county. It is over a mile long and averages less than one-fourth mile wide. To a depth of 12 to 18 inches the material consists chiefly of very black, finely divided vegetal remains. More or less earthy material is present, especially along the margins of the tract and in the lower part of the deeper accumulations in the central portions. In most places a black, sticky clay forms the subsoil to depths of 20 to 30 inches, below which is a more compact light colored clay. At a depth of a few feet below the Muck water-bearing sand and gravel is found.

Smaller areas of Muck occur on Potato Creek north of Colfax, also on Spring Branch north of Jefferson. In most of these beds the Muck proper is less than 20 inches deep, underlain by clay, which in turn usually overlies gravel.

Occasional shallow accumulations of Muck are found on the uplands, while somewhat mucky soils, or "chaffy" land is quite frequently encountered in the larger areas of Clyde silty clay loam. In such instances the excessive quantity of black, carbonaceous material mixed with the mineral constituents of the soil imparts the loose, "chaffy" character to the land.

Practically all the above mentioned Muck accumulations are now cultivated. Corn makes a good yield, but the quality is not equal to that grown on normal soils. Liberal applications of stable manure or use of some form of potash salts is necessary to insure a stand and prevent the rotting of the roots and yellowing of the plants that often occurs on such land. From one to two hundred pounds of muriate or sulphate of potash will usually prove effective. Very deep fall plowing, in order to incorporate the clayey subsoil with the Muck, is also beneficial.

Timothy and blue grass thrive so well on such land that its use for hay and pasture is profitable. Onions, celery and cabbage do well.

PEAT.

In the northwest corner of the county there are several small peat beds. The largest, found in Section 31, Ross Township, embraces about 20 acres. The material to a depth of about three feet is a mass of coarse, brown, fibrous vegetable remains. The surface resembles rotten straw, while at a depth of a foot or so the material is not unlike decaying sawdust. A very light colored calcareous clay ferms the substratum.

In the dry season of 1914 this peat dried to a depth of two or three feet, and cracks several inches to a foot wide intersected the surface in numerous places. A very rank growth of smartweed and poke-berry covered most portions not occupied by alders. The other areas are in part Muck, but not sufficiently decomposed to be a safe soil for cultivated crops. Timothy would probably be most successful crop for such portions as are sufficiently firm to admit of seeding to grass.

SUMMARY.

Clinton County is located in the north-central part of Indiana, and has an area of 398 square miles, or 254,720 acres. Most of the surface is undulating to moderately rolling, with very little land unsuitable for tillage. All was formerly timbered except a tract in the southern part of the county known as Twelve-Mile Prairie.

Corn, wheat, oats, and clover are the principal crops. Many hogs are raised, but cattle feeding and dairying are not so extensively practiced as is desirable for the proper maintenance of soil fertility. Much grain is sold off the farms.

The soils are derived from a comparatively shallow surface layer of silty material usually less than three feet deep overlying bowlder clay of great depth.

The Miami silt loam is the most extensive type. The natural drainage is generally good. The soil is well adapted to general farm crops, although it has not a high degree of fertility.

The Clyde silty clay loam represents the black soils of the formerly ill drained depressions. All of this type is now reclaimed and produces good crops of corn, clover, and wheat.

The Carrington silt loam is found on somewhat higher areas than the Clyde soils, but associated with them. It was formerly prairie and has a much blacker humus in the surface soil than the Clyde soils. It is very desirable soil for grain, especially corn.

The Genesee fine sandy loam is the fourth type in extent, and is a good soil for general crops.

The creek bottoms are mostly brown sandy loams underlain by gravel, and are well drained. For the most part they are not subject to damaging overflows and regularly produce good crops of corn, wheat, and grasses.

The recent alluvial deposits on the immediate banks of the creeks are generally untillable, These, as well as the narrow valleys of the small branches, are indicated on the soil map as Meadow. A number of small areas of Muck occur in the stream valleys, and occasional small beds are also found in the black soils of the uplands.

The present price of land in Clinton County ranges from $125 to $200 an acre.

Soil Survey of Elkhart County, Indiana.

By GROVE B. JONES of the U. S. Department of Agriculture, and
R. S. HÖSLER, of the Indiana Department of Geology;
W. E. MCLENDON, Inspector.

DESCRIPTION OF THE AREA.

Elkhart County is situated in the northern tier of counties of the State of Indiana. It is bounded on the north by Michigan, on the east by Lagrange and Noble counties, on the south by Kosciusko County and on the west by Marshall and St. Joseph counties. It is rectangular in shape and contains 465 square miles, or 297,600 acres.

The topography of the area is characteristic of glaciated country and varies from flat to hilly. The level land lies within a large outwash plain, one branch of which enters the county from the southeast and another from the south at a general elevation of 828 feet. These branches unite just north of New Paris and extend in a northwesterly direction, following in a general way the present course of the Elkhart River. In the vicinity of Elkhart they merge into the main portion of the outwash plain, which embraces the whole northern part of the county. The general slope of this plain is from the south to the north and to the west, there being a difference in elevation of 79 feet between where it enters the county at the south and where it crosses the western boundary south of the St. Joseph River. In the western part of the county south of the outwash plain lies a large area of gently undulating country which extends to the southern boundary. On both sides of the outwash plain and to the southeast the topography is rolling to hilly. The most marked elevations are the moraines north of Middlebury and between that point and Bristol, extending usually in a northeast and southwest direction. The uplands are mainly between 800 to 900 feet above tide, though some exceed that height.[1]

The drainage of the entire county, with the exception of a portion in the southwest corner, is affected by the St. Joseph and Elkhart rivers and their tributaries. The St. Joseph crosses the northern part of the county, entering north of Bristol and leaving

[1]Vol. XXIV, Ind. Geol. Reports.

west of Elkhart. The Elkhart River, entering near the southeast corner, flows in a general northwesterly direction, uniting with the St. Joseph at Elkhart. Since the course of these streams lies within the outwash plain practically no bottom land is found. In the sections of the county where the streams are small, especially in the gently undulating portion to the southwest, drainage has been aided by large open ditches. Hydraulic power has been developed in many places along both the larger and some of the smaller streams.

The first permanent settlers of Elkhart County came from Ohio, Pennsylvania and some of the New England States about 1828. The county was organized in January, 1830, and unlike many other counties retains its original size. At the time of organization the total population was 935, while by the census of 1910 it numbers 49,008, about equally divided between town and country.

Goshen, the county seat, is situated in the central part of the county, and is a proseperous manufacturing town of about 10,000 population. Elkhart, near the northwestern corner of the area, is the largest town in the area with a population of 21,028. It also is a manufacturing center, its chief products being automobiles, buggies and band instruments. Other thriving towns and villages are Nappanee, Wakarusa, New Paris, Bristol, Middlebury and Millersburg. There are several springs of mineral water in various pats of the county and artesian wells are found at Wakarusa.

With the exception of the northern part of the county, where the roads are sandy, and so far unimproved, the area is well supplied with gravel surfaced roads. Radiating from the principal towns, roads of macadam and brick are being constructed and the passing of the Lincoln Highway through the county insures continued improvement along that thoroughfare.

Several railroads supply the county with adequate means of transportation. The main line of the Lake Shore and Michigan Southern traverses the area in a southeasterly-northwesterly direction, passing through Goshen and Elkhart. At these points branch lines from the north and east join the main line, affording shipping facilities for Middlebury, Bristol and Vistula. The Louisville-Benton Harbor branch of the Cleveland, Cincinnati, Chicago and St. Louis Railroad enters the county from the south and passes through New Paris, Goshen and Elkhart. The Wabash Railroad crosses the southern part of the area from east to west and the Baltimore and

Ohio Railroad traverses the extreme southwestern corner. In addition to the steam roads, three electric lines afford a convenient passenger and express service. The Chicago, South Bend and Northern Indiana Railroad connects Goshen with points in Michigan and the Winona Interurban affords transportation to Warsaw and Peru. The St. Joseph Valley electric line extends east from Elkhart through Bristol and Middlebury.

Climate.

The table following gives the record of the Weather Bureau Station at South Bend in St. Joseph County which borders Elkhart County on the West. The station at Goshen was not established until in the spring of 1914 and therefore has no satisfactory records. The data compiled from the South Bend Station is, however, applicable to local conditions.

The climate of Elkhart County is characterized by the wide variations in temperature common to inland countries. The mean annual precipitation is a little over 35 inches and is quite equally distributed throughout the year. The average depth of snow for the year is 60.5 inches which affords adequate protection for winter wheat, rye and clover seedings.

NORMAL MONTHLY, SEASONAL, AND ANNUAL TEMPERATURE AND PRECIPITATION AT SOUTH BEND, ST. JOSEPH COUNTY, INDIANA.

Month.	Temperature.			Precipitation.			
	Mean.	Absolute Maximum.	Absolute Minimum.	Mean.	Total Amount for the Driest Year.	Total Amount for the Wettest Year.	Snowfall, Average, Unmelted.
	°F.	°F.	°F.	Inches.	Inches.	Inches.	Inches.
December	27.9	61	—15	2.98	8.25	4.92	13.4
January	25.2	66	—22	2.60	3.77	3.42	14.4
February	21.8	63	—20	2.21	0.82	0.42	13.9
Winter	25.0			7.79	12.84	8.76	41.7
March	36.5	82	3	3.22	0.75	3.91	8.6
April	48.2	88	13	2.50	1.06	3.76	2.1
May	60.2	95	26	3.79	1.30	4.13	0.1
Spring	48.3			9.51	3.11	11.80	10.8
June	68.6	97	37	3.20	1.48	4.83	0.0
July	73.4	103	44	3.61	1.59	5.10	0.0
August	71.6	97	44	3.26	2.35	3.48	0.0
Summer	71.2			10.07	5.42	13.41	0.0
September	66.0	98	30	2.81	1.22	4.82	Trace.
October	53.3	95	12	2.29	1.49	2.43	0.9
November	39.5	74	7	2.80	3.84	2.36	7.1
Fall	52.9			7.90	6.55	9.61	8.0
Year	49.4	103	—22	35.27	27.92	43.58	60.5[1]

[1] Included in mean precipitation.
Average date of first killing frost in fall, October 12; last in spring, May 5. Earliest date of killing frost in fall, September 29; latest in spring, May 28.

AGRICULTURE.

Permanent settlement of the region now known as Elkhart County started about 1828 although a few settlers had entered the area the previous year. The Pottawattomie Indians who inhabited this section had turned up the sod and grown corn and vegetables prior to this time, but not extensively.

The fertile prairie lands along the Elkhart River in the present townships of Benton, Jackson and Elkhart were the first chosen, as they required less labor to bring under cultivation than the heavily timbered upland soils. Within a short time, however, small wooded patches were cleared and these were planted to corn and potatoes. Frequently the first planting was among girdled or deadened trees which were to be removed later. Mills were built and other conveniences came rapidly. In 1829 and 1833 the first grist mills were located at the mouth of Christiana Creek and Waterford, respectively.

The pioneer farmers brought with them from their homes in the older States the methods and ideas which prevailed then. The ground was plowed with a wooden moldboard plow drawn by several yoke of oxen. Plows with iron moldboards were introduced in a few years, but these were not considered a success at first. Cultivation was done with the hoe at first, but later on the single-shovel plow came and was used for a number of years.

Fall wheat was sown broadcast among the stumps and trees and the grain harrowed in with a wooden toothed harrow. Those who did not possess such an implement would drag it in with a brush. On the prairies, plowing and cultivation were easier and could be done more rapidly. The same methods were used. Frequently the first year's crop of corn was not cultivated from the time it was planted until it was husked.

In harvesting the corn, the prevailing practice was to pull the ear from the stalk and husk it later on. "Husking bees" soon became the fashion.

Wheat was harvested with the cradle and sickle and the thrashing was done either with a flail or the grain was tramped out with horses.

In the early '40s a machine consisting of only a cylinder and operated by horse power was in use. After thrashing it was necessary to separate the grain from the chaff by fanning with a sheet, the wind blowing the chaff away. Later fanning mills were introduced.

Other crops that were grown were oats, rye, potatoes, flax and buckwheat. Only enough oats were thrashed out to furnish seed for the next year's crop, the bulk being fed in the straw.

Flax was grown for many years and manufactured into homespun clothing.

No attention was paid to the rotation of crops. Corn was planted after corn and wheat after wheat, and this succession continued year after year. Sometimes these crops were alternated, for the sake of convenience and not in order to prevent the exhaustion of the soil.

The native grasses furnished an abundant supply of hay for the needs of those located on the prairie soils, but those who settled in the timber were compelled to depend upon marsh hay for their stock feed.

However, in 1835 timothy was successfully introduced and redtop followed in 1838. The latter crop thrived in the wet and shady places where timothy did not do well. Clover was first grown in 1845 on the soils of the Elkhart prairie, and in a few years it won universal favor. It was not grown as a renovating crop until a few years later.

Apple orchards were set in the latef '30s or early '40s and in 1860 fruit growing was started in the now famous fruit section southeast of Bristol.

Wheat was formerly the money crop and was grown more exclusively than any other grain in the early history of the county. Within the past 20 years the profits have greatly decreased and more recently this falling off in acreage has been due to the ravages of the Hessian fly.

At the present time corn is the most important crop grown, and, like hay and oats, the greater part is fed to the live stock.

The following table shows the comparative acreage of wheat and corn.[1]

Year 1880	Wheat	50,716 acres.
Year 1880	Corn	30,589 acres.
Year 1890	Wheat	45,832 acres.
Year 1890	Corn	37,053 acres.
Year 1900	Wheat	51,901 acres.
Year 1900	Corn	41,950 acres.
Year 1910	Wheat	34,877 acres.
Year 1910	Corn	46,845 acres.

Oats are grown quite extensively on the upland soils, while the acreage on the outwash plain is limited. In 1910 there were 21,349 acres of oats as against 10,585 acres in 1880.

Rye is being more extensively grown and is confined chiefly to the lighter textured soils of the county.

The hay crop is an important one in Elkhart County. The hay consists of timothy, clover, timothy and clover mixed, cow-peas, alfalfa and marsh grass. In 1910 there were 19,110 acres planted to timothy aolne, to clover alone 4,052 acres, and to timothy and clover mixed, 9,736 acres, making a grand total of 41,659 tons.

Clover is usually seeded in the spring with oats as a nurse crop. Best results are obtained by using the proportion $\frac{3}{4}$ to 1 bushel of oats to 1 bushel of clover. This is sufficient to seed six acres.

Alfalfa is being successfully grown on a number of soil types and the acreage is gradually increasing. Its importance as a feed

[1]United States Census.

and a soil renovator is generally appreciated. Inoculation is advisable although it is not always necessary. Soil from an old alfalfa field may be used for this purpose, or introculture may be applied to the seed. Alfalfa may be seeded in the spring with oats as a nurse crop, or it may be sown in August or September without a nurse crop. For its production the soil should be well drained, liberally manured, limed, and in the best physical condition. About 20 pounds of alfalfa seed per acre is sown. Three cuttings, sometimes four, can be obtained each year, the total yield ranging from three to five tons per acre.

Cow-peas are extensively grown particularly in the northern part of the county. They are well adapted to the light sandy soils and furnish an abundance of feed for a section where timothy and clover do not thrive. About three pecks to the acre are drilled in the first part of June and the crop is harvested about the middle of September. Cow-pea hay is nutritious and makes a good feed, and the green vines are sometimes used for ensilage. Cow-peas sell for $1.75 to $3.00 a bushel. The New Era and Whippoorwill varieties are in most general use.

Rape is grown in a limited way for hog and sheep pasture. Only small fields of barley and millet were seen during the survey.

The trucking industry has been quite extensively developed in some sections, especially in the vicinity of the larger markets. The sandy soils are well suited to this industry and some well drained muck patches are used.

The growing of tomatoes for canning has assumed large proportions in the vicinity of Middlebury where the only canning factory in the county is located. From five to eight tons per acre are generally obtained and the price, delivered at the factory, ranges from $8 to $10 per ton. Much of the crop is grown under contract with farmers. Some of the surplus tomatoes are shipped outside the county.

In the vicinity of Nappanee cabbage is grown more extensively than elsewhere in the area. Since a kraut mill has been established at this point $5 per ton is the usual price paid for cabbages.

Since 1860 the section south and southeast of Bristol has been favorably known for its adaptability to fruit growing. The industry has been established on a commercial scale for a number of years. The fruit produced is of excellent flavor and quality and as a rule the orchards are generally well cared for. Most of the products are consumed locally. Small fruits, especially raspberries and blackberries, are grown extensively in the northern half of the county and form the chief source of revenue for this section. The grape industry has attained considerable proportions and is increasing.

For over twenty years the growing of celery at Goshen has been an important industry. Besides supplying the local markets, shipments are made to other points within the State. Three hundred dollars is the maximum amount received from an acre.

Peppermint and hemp form the other special crops. These are principally raised in the southern part of the county on reclaimed marsh lands.

Stock Raising.

The stock which the pioneers brought with them were scrubs, but as a rule the cattle were a better type of animals than were the hogs. The breeding of blooded stock was not begun until after 1850. The first swine introduced were white and somewhat resembled the old Chester Whites, but these were considered superior to that breed.

Later Poland China hogs were brought from Illinois and this breed became popular and has continued so to the present time. Duroc Jersey and I. O. C. breeds are also much in favor. Some Berkshire hogs are seen.

Hog raising is an important industry in Elkhart County, especially when carried on in conjunction with dairying is it found profitable. The census of 1910 states that at that time there were sold or slaughtered 25,991 swine. Hog raising is on the increase.

Pure bred or grade Shorthorn cattle were the first improved stock to be introduced. About forty years ago the Herefords were introduced, but this breed did not become very popular. Dairying did not receive much attention until a number of years after the general live stock industry had become established. Ayrshires, Jerseys, Durham and Holsteins have been popular at one time or another. There are more Holsteins in the county than pure breds of any other class. They are noted for the large quantity of milk they produce and their calves being large bring in more money than calves of smaller breeds when sold for veal.

On many farms dairying is carried on with profit as an adjunct to mixed farming. The average farmer keeps from six to ten milch cows, while others keep a large number and make dairying a speciality. The silo is in general use and a large acreage is devoted to corn for ensilage. Several creameries are in operation throughout the county. A condensed milk factory at Goshen affords a ready market for this section. Enough milk is produced in the county to supply the local demands and some is shipped outside.

In 1900 the dairy products, excluding home use, were valued at $174,819, while ten years later they had increased to $407,772. Dairy farming is coming into greater favor, and since the conditions in the county are very favorable this important industry should continue to increase.

Sheep were brought into the county by some of the earliest settlers and they continue to be raised. The Merinos were the first blooded sheep to be raised, but this breed has been supplemented by the mutton breeds, including the Shropshires, the Oxfords and Southdowns. In 1910, 15,754 sheep were either sold or slaughtered.

The use of stable manure is general and a liberal supply is usually applied to the plowed land in the fall. Manure spreaders are quite generally used.

What commercial fertilizer is used is confined mainly to the upland soils and to those farms where there is not sufficient barnyard manure. The sandy soils are enriched by growing such legumes as cow-peas and soy-beans, since farmers on these types do not as a rule keep much stock.

The rotation of crops is practiced and its importance recognized by the majority of farmers. The rotation most extensively practiced consists of wheat, clover and timothy one or two years, followed by oats and again to wheat. Where dairying is practiced the system of rotation is corn two years, followed by oats, and one or two years of clover.

The agriculture of Elkhart County is in a prosperous condition, and the crops which are being grown are well adapted to the soils.

The barns and farm buildings are, as a rule, spacious, substantial and well kept. The general appearance of neatness and the modern farm dwellings with latest improvements and conveniences, give evidence of thrift and prosperity existing among the agricultural classes.

Labor is scarce. The average farm wages range from $20 to $30 per month, with board. Harvest hands and extra help receive $2 to $2.50 per day.

Farm machinery of the latest designs—corn planters, shredders, wheat drills and harvesters, disc plows, manure spreaders, rollers, ditching machines, needed to handle the soil and the crops are found upon the farms.

As compared with many sections of the country, there is little tenant farming in this county. The census of 1910 states that 71.6 per cent. of the farms are operated by the owners. Leasing is generally on a share rather than on a cash basis. When the owner furnishes the seed, he gets one-half of the products. The tenant must deliver the owner's share.

The average size of farms is 84.9 acres. Ninety-one per cent. of the area is in farms, and of this 91 per cent., 84.2 per cent. is improved. In 1910 the average value of farm land per acre was $66.58. The value of farm lands in the county varies from $35 to $50 an acre for Plainfield sand to $165 an acre for well improved prairie land—Waukesha sandy loam. On the Miami loam, gravelly sandy loam and silt loam types, which are highly improved, land values range from $75 to $150 an acre. Small desirable tracts situated along the electric line between Elkhart and Goshen and to the south have been sold at high prices.

While there is need of improvement in the agricultural practices of today, they are, as a rule, well adapted to present condi-ditions.

On the Miami loam plowing should be to a depth of at least eight inches. The matter of drainage is an important problem for the farmer of Elkhart County. The cost of establishing a more effective drainage system on some of the soil types would soon be returned through increased crop yields.

Many marshes and areas of wet land remain to be reclaimed and when this is done much valuable land will be added to the resources of the county.

To the present prosperity of Elkhart County much credit is due to the county fairs, the first of which was held in 1851, under the auspices of the Elkhart County Agricultural Society. It is believed that these fairs held from year to year did much to advance the agricultural interests of the county. Later the Farmers' Institute did much to improve the agriculture of the whole county. The first institute held in the county was in the circuit court room in Goshen, January 22 and 23, 1890.

A county agent is at present imparting information to those who are interested along agricultural lines.

SOILS.

The soils of Elkhart County are of foreign origin and show no relationship to the underlying rocks. They are all derived from glacial material in a more or less modified form and fall into two main groups, the uplands and the sand plains. The latter, which represent glacial outwash, cover the northern portion of the county with tributaries from the south.

This glacial drift varies in depth. At Elkhart it is known to be 125 feet deep; at Goshen 162 feet and at New Paris 90 feet.[1]

Well borings at Elkhart show the first 25 feet to be of sand and gravel underlain by indurated glacial clay with occasional thin strata of quicksand.

The uplands, locally known as "clay soils", which vary in topography from undulating to hilly are a disorderly mass of drift, sand, gravel, clay and boulders, with a more homogeneous surface covering.

The rough morainic areas are chiefly confined to the eastern part of the county where the highest elevations are attained.

Another feature of topography peculiar to glaciated country, is seen in the holes and areas of muck and peat which mark the beds of former lakes.

In this survey four series of soils have been recognized. All these were originally derived from glacial material, but varying conditions and forces have developed in each distinguishing characteristics.

In the Miami series, light colored upland soils, four types of varying texture were mapped.

Two members of the Clyde series were found occupying depressions and old glacial lake beds. The Plainfield series embracing the light colored soils of the outwash plain, is represented by four types.

The Waukesha series, represented by one member, was found as a prairie soil associated with those of the outwash plain.

Including the miscellaneous types, muck, peat and meadow, fourteen soil types have been mapped in this area.

MIAMI SERIES.

The Miami soils are brown, light brown or grayish, and are underlain by yellowish and brown heavier textured subsoils. Mottlings of brown and light gray are present in the subsoils in

[1]Vol. XXV, Indiana Geological Reports.

many places, particularly in the case of the clay loam member. The surface drainage is usually good, but artificial drainage is necessary in some of the heavier types.

The soils are derived through weathering, from glacial till of a generally calcareous nature. The series represents considerable range in texture and its members are adapted to a wide variety of both general field crops and special truck and fruit crops. Dairying is an important industry on the heavier types.

In Elkhart County four types are recognized, the Miami sandy loam, gravelly sandy loam, loam and silt loam.

Miami Sandy Loam.

The Miami sandy loam consists of a brown medium to fine textured sandy loam to an average depth of 10 inches. There is usually present on the surface and mixed with the soil varying amounts of gravel, large pebbles and small boulders. In some places, notably northeast of Goshen, occasional small spots of the Miami sand are found, usually occupying the tops of the hills and ridges. These areas, however, were too small to separate and the Miami sand type was not recognized in this survey.

The subsoil consists of a light-brown to yellowish sand or light textured sandy loam grading into a sticky sandy loam or loam at an average depth of 20 inches. Near the Miami loam areas, the surface soil of the Miami sandy loam becomes heavier and the texture is inclined to be fine. In such locations the subsoil generally becomes heavier with depth, grading into a heavy loam or clay loam in which the sand and gravel content is low. In the rougher areas beds of gravel are found underlying gravelly clay at depths ranging from 4 to 10 feet beneath the surface.

The Miami sand loam in extent and agricultural importance, ranks second among the soils of the uplands. The largest areas of the type occur in the eastern and central parts of the survey, east of the outwash plain. Another good-sized area occurs as a narrow unbroken strip bordering the western edge of the outwash plain. This area broadens southwest of Goshen and embraces the high and rolling country north of Foraker.

The surface varies from gently rolling to rolling and hilly and the soil with its porous and friable texture is thoroughly drained. The steeper areas are excessively drained and on these, as well as on the sandier areas, crops suffer considerably from drought during the long continued dry spells.

Approximately all of the Miami sandy loam is under cultivation and is devoted almost exclusively to general farming. Small uncleared areas supporting a growth of maple, oak, hickory and beech with some elm and walnut remain.

The type produces good yields of corn, oats, wheat, clover, alfalfa and buckwheat. Individuals cultivating this soil estimate their yields of corn at 30 to 50 bushels, with an average of 40 bushels per acre; wheat from 12 to 25 bushels, with an average of 17 bushels per acre; oats from 25 to 50 bushels, with an average of 35 bushels per acre. Hay yields from three-fourths to one and one-half tons per acre. Potatoes of very good quality for fall and winter use are grown for local markets and home consumption. The average yield is about 100 bushels per acre. During wet seasons the yields are better than on the heavier soil and the quality of potato is superior.

Apples, peaches, pears, grapes and small fruits are successfully grown, but not extensively. Trucking is also carried on to a limited extent.

The Miami sandy loam is easily cultivated and requires less labor to secure a pulverent seed bed than on the other upland soils. While the yields are slightly under those secured on the heavier types, the better grades command practically the same price.

The application of barnyard and green manure is particularly important. No commercial fertilizers are used, and the supply of farmyard manure in many cases is insufficient. Cow-peas and clover should be grown more extensively for green manuring.

Miami Gravelly Sandy Loam.

The Miami gravelly sandy loam consists of a light-brown medium sandy loam to loam, 8 to 10 inches deep, underlain by a yellowish or reddish-brown gravelly sandy loam often containing enough clay to make the soil particles cohere. Gravel, stones and boulders occur on the surface and mixed with the soil, the greatest amounts being found on the crests of hills and ridges. The gravel content as a rule increases in quantity with depth and frequently a layer of gravel is encountered at 30 to 36 inches.

Areas of the Miami gravelly sandy loam are confined to the northeast part of the county, principally in the vicinity of Middlebury. The type covers only a small proportion of the county. The isolated area southeast of Bristol is much sandier than the typical soil and in places is a gravelly sand. The same is true of that portion of the large area north of Middlebury which borders the outwash plain. Small areas of Miami stony loam are also included within the type as mapped.

The Miami gravelly sandy loam has a rolling, hilly, and in places hummock topography. It occupies the highest elevations and roughest positions in the county.

On account of the irregular surface and the underlying gravel the natural drainage is good. On the more elevated positions drainage is excessive and the soil often suffers from drought. The steeper slopes are subject to erosion, though it is severe in only a few places.

The type is derived from glacial drift, and consists almost wholly of morainic material.

The Miami gravelly sandy loam is devoted to general farming and to the growing of fruit. The portion of the type too uneven for cultivation is used for pasturage, but this does not exceed 5 per cent.

Corn, wheat, oats, clover and alfalfa are the principal farm crops. The average yield of corn is 35 bushels per acre. Wheat yields from 10 to 20 bushels; oats 20 to 35 bushels per acre. Some rye is grown, the yield averaging 15 to 25 bushels. Clover and alfalfa do especially well. Both are usually seeded with a nurse crop. Clover gives a yield of 1½ to 2 tons per acre and alfalfa 3 to 5 tons.[1]

The area of Miami gravelly sandy loam located southeast of Bristol is devoted almost entirely to trucking and the raising of fruits. On account of its higher sand content it is a typical early truck soil, its loose, loamy structure and thorough drainage adapting it to market garden produce. All the varieties of vegetables adapted to the climate are successfully produced. Cantaloupes and watermelons occupy a large acreage. (See illustration.) Strawberries, raspberries, and blackberries are extensively grown and produce abundantly.

In the line of fruits, plums, peaches, apples, pears cherries and grapes are extensively grown, and fruit of very fine quality and flavor is produced. For these fruits the Miami gravelly sandy loam is considered one of the most successful.

Most of the fruit and vegetables are sold to local markets but some are shipped outside.

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[1]These figures represent averages as obtained in the field

Barnyard manure is almost universally used where general farming is practiced. When combined with green manuring the productiveness of the soil is increased and more easily maintained. Cow-peas, soy-beans, clover and all leguminous crops would do much to improve its productiveness.

Fruit growers and truckers use commercial fertilizers in addition to stable manure. Some use cotton seed meal with success.

Land of the Miami gravelly sandy loam type varies in price from $65 to $100 an acre. Orchard land in good condition is valued higher.

Miami Loam.

The Miami loam consists of a brown, mellow loam to heavy fine sandy loam about 12 inches deep, containing a rather high percentage of silt. When moist the soil has a decidedly brownish color, but on drying out, it becomes light-brown to grayish and in some cases whitish.

A few glacial boulders and rock fragments, consisting of granite, quartz, green stone, and syenite are occasionally found scattered over the surface, but the greater part of the larger of these has been removed from the cultivated fields.

The subsoil is a yellowish-brown clay loam containing varying amounts of coarse sand and fine gravel. This material frequently holds throughout the 3-foot section where the type occupies rolling or hilly topography, but generally at about 24 inches it gives way to a brown heavy sandy clay or clay. This material known as boulder clay contains boulders and rock fragments and not infrequently beds of gravel at depths ranging from 10 to 25 feet below the surface.

The Miami loam is the most important and best developed soil in Elkhart County. It is the main upland type and covers a greater proportion of the county than any of the other types of soil. The largest and most typical areas occur in the southwestern and southeastern parts of the area. It does not occur north of an east and west line passing through the city of Elkhart.

The surface features are gently undulating to rolling and even hilly in the eastern part of the county. The roughest phase occurs between Bristol and Middlebury, where it is associated with the Miami gravelly sandy loam. In the vicinity of Wakarusa the surface is level to gently undulating.

Where the type occupies the higher positions there is nearly always present in the soil a greater percentage of medium and fine sand than is found in the typical soil, and the subsoil also contains more sand and gravel. Boulders and rock fragments are more numerous. On the more level developments there is present in the soil a higher silt content and the subsoil is more plastic and tenacious.

The Miami loam is derived from glacial till and the roughest areas of the type represent morainic material.

For the most part the natural drainage of this soil is very good and artificial drainage is not necessary except in the flatter areas and draws which have been greatly improved by tiling.

The original tree growth consisted of oak, hickory, maple, ash, beech, elm and walnut.

The type is devoted to general farming. All the farm products common to this region are grown successfully.

From those cultivating crops on this type the following figures concerning yields were obtained.

Corn produces an average yield of 50 bushels per acre; wheat yields from 20 to 30 bushels; oats yield from 20 to 60 bushels, and 1½ tons is considered an average yield of clover and timothy hay.

Cow-peas, rye, buckwheat and millet are grown to a limited extent. Alfalfa succeeds well on this soil, but the acreage devoted to it is small.

Difficulty is frequently experienced in securing a good catch of clover and some farmers advise sowing it with oats in the spring rather than with wheat. From clover grown for seed from one to two bushels are secured.

A common rotation practiced on the Miami loam consists of wheat, clover and timothy one or two years, corn, oats and again to wheat.

Truck crops and fruit are grown for home consumption. Apples, peaches, pears, cherries, grapes and small fruits do well.

The type is well adapted to the crops at present grown upon it.

The Miami loam is a mellow, friable soil of early tillage if plowed at the proper time. If plowed when too wet or too dry the soil forms clods which are difficult to pulverize. The soil is usually plowed to a depth of eight inches and considerable fall plowing is done. Practically all of the type is under cultivation, except small forest reserves or woodlots.

Commercial fertilizers are not used on this soil to any extent, but the available stable manure is applied to plow land. Green manuring is a very valuable means of adding organic matter to the soil, and this method should be resorted to when the supply of stable manure is limited, since the type is naturally deficient in organic matter.

Cow-peas grow readily, and besides furnishing a splendid hay build up the soil and help to maintain its productiveness. The acreage planted to cow-peas should be increased.

Alfalfa and clover also increase the nitrogen content of the soil through their ability to collect this important constituent from the air.

Recent land transfers show that the Miami loam commands a price of from $85 to $100 an acre without buildings, and from $100 to $125 an acre with improvements.

MIAMI SILT LOAM.

The Miami silt loam consists of a light-brown to grayish silt loam about eight inches deep, underlain by a mottled yellow and gray compact silty clay.

Very little stone or gravel occurs in the soil or on the surface and the subsoil is practically free from coarse material.

The soil mapped as Miami silt loam in this county is not a typical representative of the type. The surface soil is shallower and the subsoil heavier than in other areas. As mapped, the soil of the two largest areas of this type really represents a shallow phase of the Miami silt loam while the small areas adjacent to small drainage ways approximate the standards of a clay loam.

Most of this soil, which is of only limited extent, is included in two areas, the larger at Jonesville in Harrison Township and the other in Olive Township along the county line. Four small areas also occur along small drainage ways in this section of the area.

In surface features the Miami silt loam is nearly level. On this account and also on account of the dense subsoil, the natural drainage is not good.

Tile drains are common, but the type as a whole would be greatly improved by more complete systems of underdrainage.

The soil is devoted to general farming. Practically all of it is used for agricultural purposes, a few woodlots being the exception.

The crop yields vary with the seasons and methods of cultivation, but are usually slightly below those secured on the Miami loam. Timothy and clover, separate or mixed, do very well. Alfalfa is successfully grown, but the acreage at present is limited.

Of the grain crops wheat and oats do best. Under intelligent methods of cultivation good yields of corn may be secured.

Even greater care must be exercised in the cultivation of the Miami silt loam than the loam. Cultivating when wet causes clodding and baking and if plowed when too dry large clods form. By judicious handling, however, a mellow seed bed can be secured.

Deeper plowing and more thorough drainage, to give better aeration, would result in great improvement in this soil. Alfalfa and other deep rooted crops, such as the larger clovers will be found beneficial in aerating as well as keeping up the nitrogen content.

The Miami silt loam is deficient in organic matter. When barnyard manure is not available in sufficient quantities green manuring should be resorted to as a means to keep up the productiveness of the soil. No commercial fertilizers are used at present. Where there is an indication of acidity the application of about 20 pounds of lime per acre will prove beneficial.

Farm values on this type do not vary much on either side of $100 per acre.

Clyde Series.

The Clyde series comprises dark-brown to black surface soils, with gray, drab, or mottled gray and yellowish subsoils. These soils are derived through deposition or reworking of the soil material in glacial lakes or ponds, the dark color of the surface soils being due to the high percentage of organic matter caused by the decay of plants in the presence of water under swampy conditions. The soils of the Clyde series grade into muck and peat on the one hand and such glacial lake soils as the Dunkirk series on the other, with very sharp boundary lines.

The topography is level and the soils are naturally poorly drained, but when reclaimed they are highly productive and valuable for corn, grass, cabbage, onions and peppermint.

The series in this county comprise two types, the Clyde sandy loam and loam.

Clyde Sandy Loam.

The Clyde sandy loam consists of 10 to 15 inches of a grayish-black to black material, varying in texture from a sandy loam to sand or loamy sand, underlain to 36 inches or more by a drab, gray or yellowish sandy loam or slightly sticky sand.

The subsoil contains some calcareous material and small gravel is found both in the soil and subsoil. The relatively high percentage of organic matter present gives the soil a dark color and renders it loamy, mellow, and easy to cultivate.

The type occurs in the outwash plain and occupies a physiographic position intermediate between the Muck and the Plainfield sandy loam. The largest areas are found northeast of Elkhart.

The Clyde sandy loam has a level topography and the drainage is poor. When reclaimed this type is a fairly good corn soil, the average yield being about 50 bushels per acre. A large percentage of the type is used for pasture. It is for the most part treeless, although in places willows and hardwoods are found.

The Clyde sandy loam is admirably adapted to small fruits and vegetables. The type as a whole is greatly in need of more efficient systems of drainage.

The price of this land varies from $75 to $125 or more an acre, depending upon drainage conditions.

Clyde Loam.

The Clyde loam consists of a dark-gray to black heavy sandy loam to heavy loam, underlain at about eight inches by a heavy bluish-drab clay loam or silty clay. In places the subsoil is a dull brown or yellowish and frequently yellow and gray mottlings occur.

There is considerable variation from the typical soil. The surface for a few inches may consist of mucky material while thin layers of fine sand frequently occur in the heavy subsoil. Again it is not uncommon to find muck underlying the clayey subsoil usually at a depth of two feet. Strata of muck, sand and clay may be found within the 3-foot section, but there appears to be no regular order.

The Clyde loam is found most extensively developed in the southwestern part of the county. The areas are of small extent and for the most part occur as narrow strips along the smaller drainage ways, especially in the upper reaches. Other small tracts occur in glacial lake beds and depressions. Because of the nearness to natural outlets most all of the type has been drained and placed under cultivation.

When well-drained the Clyde loam is especially well adapted to corn, peppermint, potatoes and cabbage.

These crops produce well, the average yield for corn being 75 bushels per acre. It is the leading corn soil of the county.

For the improvement of this type better drainage is essential.

The natural growth consists of wild grasses, low-growing bushes, reeds, elm and willow.

PLAINFIELD SERIES.

The Plainfield soils differ from the Waukesha in having lighter color. The surface soils range from brown to grayish yellow, while the subsoils are usually yellow to pale yellow. This series is developed in the deep drift covered areas and comprises soils formed from sandy and gravelly glacial debris washed out from the fronts of the glaciers. It is also developed as deep filled-in valleys. The greater part of the material of the series has been assorted by glacial waters, and consists mainly of sand and gravel. The topography varies from flat to gently undulating. The deposits are deep and the soils are well to excessively drained. Four members of this series are recognized in Elkhart County, the Plainfield sand, loamy sand, sandy loam and gravelly sandy loam.

PLAINFIELD SAND.

The Plainfield sand consists of yellowish medium to fine sand, extending to a depth of six to eight inches, underlain by loose, incoherent yellow sand which becomes coarser with depth. In places the soil is drifted so badly that it is impossible to secure a stand of any of the seeded crops. On account of the loose structure of this soil it is easy to cultivate and can be worked under a wide range of moisture conditions.

The Plainfield sand is confined to the northeastern corner of the county where the larger of two areas occurs in a continuous strip north of the Little Elkhart River. This stream separates this main body from the smaller area near Bristol.

The type occurs as low ridges and knolls with intervening country having a nearly level topography. The elevations are heaps of loose sand to a depth of several feet and in appearance closely resemble sand dunes. These probably owe their origin to wind action and at the present time are materially influenced by this agency.

As may be inferred the type is well to excessively drained. The moisture holding properties of this type can be greatly increased through shallow cultivation and crops when properly handled suffer less from ordinary droughts than those on some of the heavier soils.

Cow-peas, corn and rye are the principal crops but the yields are only fair. For general farming this soil is too light. Cow-peas do best and a considerable acreage is devoted to this crop. Peas yield from eight to ten bushels per acre and usually sell for $1.75

to $2.50 a bushel. The vines are cured for hay and afford an excellent feed. Besides furnishing roughage and revenue cow-peas are a splendid soil renovator and especially are they valuable in a locality where but little live stock is kept.

Since the Plainfield sand is naturally deficient in organic matter as much vegetable matter as possible should be returned to the soil.

Small fruits, peaches and apples and vegetables do especially well in seasons of normal rainfall.

The price of land of the Plainfield sand ranges from $35 to $50 an acre.

Plainfield Loamy Sand.

The Plainfield loamy sand consists of a light-brown or yellowish brown, rather loose loamy sand from 10 to 15 inches deep, grading into a yellow, loose, incoherent sand of similar texture. In the few inches at the surface there is enough organic matter, together with fine material, to make the soil more loamy in texture than the Plainfield sand. On the other hand the Plainfield loamy sand is not as heavy as the sandy loam of this series. In structure and agricultural value it occupies an intermediate position.

The Plainfield loamy sand is closely associated with the sand and sandy loam, and like them occupies the broad outwash plain in the northern part of the county. The largest areas occur in the vicinity of Vistula. The surface of the larger areas is gently undulating while the smaller isolated areas occur as low ridges seldom over three feet above the surrounding sandy loam.

The drainage is good, but not as excessive as in the Plainfield sand; consequently there is less leaching, and the organic matter is retained longer.

Soils of the Plainfield loamy sand are better adapted to early truck crops than to general farming. Melons, cucumbers, tomatoes and small fruits are grown successfully and a large acreage is devoted to these and other crops requiring a light textured soil. A large proportion of the truck crops, as well as raspberries, blackberries and strawberries supplying the Elkhart markets is produced on this soil. For these it is probably the best type in the county. Peaches, apples, and plums do fairly well. Grapes are successfully grown. (See photo.)

One grower southwest of Elkhart has installed the Skinner sprinkling system with gratifying results. (See photo.) The growing of wormwood and tansy for extracts is being successfully conducted northeast of Elkhart. For general farming the Plainfield loamy sand is a little too light, although fair yields are secured with a normal amount of rainfall. Corn, hay, and cow-peas are the principal farm crops. The organic matter content of the soil should be increased for whatever crop intended.

Farms on this type of soil range in value from $50 to $125 an acre, depending upon location.

Plainfield Sandy Loam.

The Plainfield sandy loam consists of a brownish or yellowish medium to fine sandy loam 10 to 15 inches deep, underlain by reddish-brown sticky sandy loam to a depth of 24 inches. The last foot of the 3-foot soil section is a slightly coherent to loose coarse sand and fine gravel. There is a generous sprinkling of fine gravel, and small cobblestones are not of uncommon occurrence.

The texture of the Plainfield sandy loam varies greatly in different parts of the area, but the subsoil possesses greater uniformity. In the northeastern part of the county, and as far south as Dunlap, the soil contains a larger proportion of medium sand and fine gravel than in other parts of the county, while south of Goshen the soil is composed of a more decided brownish colored compact sandy loam or light-textured loam.

The topography is level to gently undulating and the soil with its porous friable texture is thoroughly drained.

The Plainfield sandy loam is devoted largely to general farming, though considerable trucking is also carried on, especially in the vicinity of Elkhart. As previously stated, that type is more sandy in this section and better suited to such crops. On this phase cow-peas are extensively grown. Corn, rye, wheat and potatoes form the main crops. The yields are from 10 to 20 per cent. below those secured from the heavier phase. Strawberries, raspberries and blackberries produce well and are extensively grown. Grapes are grown very successfully.

The heavier phase is devoted largely to the general farm crops. Corn, the leading crop, averages about 50 bushels per acre, wheat 18 bushels, and rye 20 bushels. Barley is grown only to a limited extent, but its acreage, as well as that planted to rye, is increasing. Barley yields about 30 bushels per acre. Oats do not prove satisfactory and very little is grown.

Clover and alfalfa yield well, but timothy is not very satisfactory. The production of such flowers as asters, gladiolas and carnations has been carried on at one or two places.

Commercial fertilizers are used only to a limited extent and then usually when the amount of stable manure is insufficient to meet the demands of the farm.

Present values range from $75 to $150 an acre. Along the electric lines small tracts sell at a much higher figure.

Plainfield Gravelly Sandy Loam.

The Plainfield gravelly sandy loam consists of a yellow or brownish gravelly sandy loam from 8 to 10 inches deep, underlain by a yellowish subsoil of the same texture. Both soil and subsoil contain a high percentage of fairly well-rounded gravel, while cobblestones of varying size are numerous. In places the type resembles a stony loam and often as high as 50 per cent. of stone and gravel is found on the surface. (See photo.)

The type is found bordering the St. Joseph and Little Elkhart rivers and occupies terraces or second bottoms slightly below the other Plainfield soils. The largest areas occur on the north side of the St. Joseph River near Elkhart and Bristol. The surface of the type is level to gently undulating and the areas are all well drained.

Fair yields of corn, oats and hay are obtained, but it is rather too droughty for the general crops. Its texture makes it an early soil, well suited to market garden crops and fruit. It is well adapted to potatoes, strawberries, blackberries and raspberries. Apples, pears, peaches and grapes are successfully grown.

WAUKESHA SERIES.

The soils of the Waukesha series are dark-brown to black, underlain by yellow subsoils in which fine gravel is usually present. The color differentiation has been developed under prairie conditions. These soils occur in association with the Plainfield soils in the areas of deep drift in the Central Lake States. The Waukesha soils, like those of the Plainfield series, are derived from water-assorted glacial debris deposited in broad filled-in valleys or as outwash plains and terraces and are sandy and gravelly in general character. They are more productive than the Plainfield soils, on account of their higher content of vegetable and greater moisture holding capacity. The topography is level to gently undulating and the soils are usually well drained. Only one member of the Waukesha series, the sandy loam, is mapped in this county.

WAUKESHA SANDY LOAM.

The Waukesha sandy loam consists of a dark-brown to black medium to fine sandy loam, 10 to 15 inches deep, underlain by a brown sandy loam in which a stratum of gravelly sandy loam is reached at about two feet. Beneath this a slightly sticky yellow sand to loose sand is found extending to a depth of three feet and more. The relatively high percentage of organic matter gives the soils the dark color so characteristic of this type. The surface soil is free from stone and gravel.

This type occupies level topography and represents the only true prairie soil in the county. The largest area occurs southeast of Goshen and is known locally as "Elkhart Prairie." It was upon this tract that the early development of the county was begun. Two areas near Elkhart and one at Bristol constitute the total development of the type.

The Waukesha sandy loam has good surface drainage and underdrainage. When plowed to the proper depth and cultivated frequently it conserves moisture well. It has been found advisable to break the ground to a depth of at least eight inches. Owing to its thorough drainage the soil warms up early and crops mature earlier than on the heavier upland soils.

The soil is more productive than any of the types located within the outwash plain.

The Waukesha sandy loam is devoted to general farming, corn, oats and wheat being the chief grain crops. Corn yields on the average 40 bushels per acre, though as much as 65 bushels are frequently obtained. Oats average 30 bushels and wheat 18 to 20 bushels per acre. Rye is not grown extensively.

A stand of clover can best be secured by sowing with oats as a nurse crop. The average yield is 1½ to 2 tons per acre. Timothy does well and little difficulty is experienced in getting a good stand. Alfalfa succeeds well and this crop is gaining in favor, but the acreage devoted to it is still small.

No definite system of rotation is practiced, but the following one is practiced to some extent: Corn, oats or wheat, clover or timothy. Commercial fertilizers are not used and the soil receives comparatively little barnyard manure. As a rule the land receives an application of manure before being planted to corn.

In the vicinity of Elkhart some trucking is carried on, but not to any great extent. Fruit, vegetables and truck crops are grown for home use and excellent results are obtained.

Farms on this type of soil are valued at $150 to $200 an acre. Recently a sale was made south of Goshen, the consideration being $165 an acre.

MUCK.

Muck, or what is known locally as "Marsh", consists of decayed and decaying vegetable matter to which has been added varying amounts of mineral matter by the wash from the adjoining higher lands. The muck varies in depth from a few inches in small areas and in narrow strips along streams to several feet in the large marshes.[1] There is usually considerably more mineral matter in the smaller areas, especially in the uplands, while in the large marshes much of the material is peaty.

The subsoil of the muck occurring in the uplands consists of a thin deposit of stiff blue to bluish-black clay, which in turn is underlain by grayish fine sand and in places gravel.

The clay stratum is usually absent in those areas found within the outwash plain. Some of these are underlain by marl deposits. Peat, or organic matter in a less advanced stage of decomposition, is frequently encountered below the surface stratum of muck, and this sometimes reaches the surface.

Several good-sized areas of muck occur in Elkhart County. The more important of these are east of Simonton Lake, east of Elkhart, northeast of Jonesville, east of Goshen, and east of Nappanee.

These larger areas occupy flat depressions and the natural drainage is poor. These were at one time lakes, and until recently the area east of Simonton Lake contained Mud and Cooley Lakes which have been drained by means of large open ditches leading south. Practically none of this area is under cultivation, but large amounts of marsh grass are cut for hay.

Marl deposits are found throughout this marsh and this material has been used to a limited extent as a fertilizer.

The Goshen area has been planted almost exclusively to celery for the past twenty years and the industry has proved very profitable. However, the lack of rotation of crops and possibly too generous applications of barnyard manure have apparently caused a decrease in yield as well as an inferior quality of celery. This condition has been especially marked within the last two years.

Very few of the celery growers at present use commercial fer-

[1]Well borings in the area east of Goshen show the depth of the Muck and Peat to be as great as 49 feet.

tilizers and then only in small quantities. The practice is said to be profitable and is increasing. Commercial fertilizers containing a large percentage of potash are especially beneficial upon the muck soil.

The large development of muck east of Nappanee is devoted to mint, onions and hemp.

Onions yield from 400 to 500 bushels per acre, according to growers, and sell for 28 cents to 50 cents a bushel.

The growing of hemp has recently been introduced, and while of limited extent has proved successful. In the adjoining county of Kosciusko, a large acreage is given over to this crop, and no doubt in the near future this profitable industry will become well established in Elkhart County.

The yield of hemp is from three to four tons per acre and the price paid is $12.50 per ton delivered to the factory located at Nappanee.

The growing of peppermint is confined almost exclusively to the southern half of the county and a considerable amount is produced on muck soil. The industry is considered profitable.

Mint is planted in the early spring from roots, in rows three feet apart. The cost per acre for roots is $10. Weeds are usually troublesome and it is necessary to weed by hand after the plants attain some size. Mint is grown upon the same field for a succession of years but finally runs out. Worn out mint beds are frequently planted to corn or potatoes for a year or two before replanting. Mint is cut in the same manner as grass, with the mowing machine. It is allowed to cure for several hours and is then hauled to the distillery. (See photo.) Numerous distilleries are scattered throughout the mint growing section. Two cuttings are sometimes made, but the second yield is light. Harvesting begins the latter part of July or the first of August and continues until October. Peppermint oil sells at $1.50 to $3.25 a pound; there are seven pounds to the gallon and the yield per acre is 25 to 50 pounds.

Mint hay taken from the still and dried is relished by stock.

Truck crops are grown on some of the muck areas near the larger markets. (See photo.)

Huckleberries grow wild on some of the marshes in the northeastern part of the county and when placed on the market sell for $1.25 to $1.50 a bushel.

Many of the areas are treeless, supporting only a growth of reeds and wild grass in the wetter portions. Others are heavily timbered with elm, maple, willow and some tamarack and low-growing bushes.

A great many of the Muck areas remain unclaimed and uncultivated and there is yet room for an extension of the special crops to which the soil is adapted.

Drainage is the first essential in bringing about cultivation.

PEAT.

The Peat soil of Elkhart County consists of three feet or more of coarse, brown vegetable material, in which the percentage of combustible material is high. The decaying vegetable material is fibrous and but partially decomposed. There is practically no mineral matter in the soil.

Only a few typical areas of Peat were mapped in Elkhart County, but where possible these were separated from Muck. Many small patches were mapped along with Muck and in places a mucky-peat, a gradation from the one to the other, was classified as Muck.

The topography of the Peat areas is flat and the natural drainage poor. Some areas have been reclaimed and planted to the same crops as are grown upon Muck, with approximately the same yields. The natural growth consists of wild grasses, weeds, bushes, including huckleberry, and also elm, willow and maple trees.

MEADOW.

In this survey the type Meadow includes poorly drained narrow strips of low-lying land along streams. The soil is quite variable in texture and is subject to overflow.

The limited areas found along the St. Joseph River are the result of backwater caused by the building of dams. These areas together with that at the juncture of Turkey Creek and Elkhart River, near Waterford, are the most poorly drained and at present have no agricultural value.

Owing to the fact that Turkey Creek and several of the other smaller streams have been straightened and the channels deepened, the Meadow along these is at present fairly well drained. A large total acreage has thus been reclaimed to such an extent that it is used for pasturage.

The Meadow soil for the most part consists of a dark-brown to black sandy loam to loam underlain by a heterogeneous mixture of sand, clay and gravel. A coating of Muck a few inches or more in thickness is not uncommon and in places the mucky material is frequently three feet or more in depth.

Some areas along the Elkhart River in the vicinity of Benton and others bordering Turkey Creek near New Paris, mapped as meadow, are a brown, medium to fine sand or loamy sand.

With the exception of a few better drained spots which are usually planted to corn, the type is devoted to pasturage. The timber growth consists of elm, oak, maple, sycamore and willow.

SUMMARY.

Elkhart County is located in the northern part of Indiana and has the State of Michigan as its northern boundary. It comprises an area of 465 square miles or 297,600 acres. The surface consists of level plains and rolling to hilly uplands.

With the exception of the southwest corner which drains into the tributaries of the Mississippi, the entire county is drained into Lake Michigan by the St. Joseph River.

The first settlement was made in 1828, and the county was established in 1830. The pioneers came from Ohio, Pennsylvania and some of the New England States.

Elkhart, the largest city in the county, is about 100 miles from Chicago. Goshen is the county seat and has a population of about 10,000. The entire population of the county is about equally divided between towns and country. Settlement is quite dense except in the northeast part of the area.

Transportation facilities are good and the county is well provided with steam, electric, and wagon roads.

The mean annual rainfall is about 35 inches. The average depth of snow for the year is 60.5 inches. The mean annual temperature is 49.4° F. The maximum range recorded is from 103° F. to -22° F. The average date for the last killing frost in the spring is May 5 and for the first in the fall October 12.

The type of agriculture followed in Elkhart County consists chiefly of general farming in conjunction with dairying. The milk output is utilized by the urban population and by creameries and factories located within the county. Some milk is shipped outside. Dairying is steadily increasing and the quality of the cattle is being steadily improved.

The principal farm products are corn, hay, wheat, oats, rye, live stock and dairy products. A large per cent. of the corn, oats and hay is fed to live stock. Much of the corn is grown for ensilage, since the silo is in general use. Alfalfa grows successfully and the acreage is increasing.

The light sandy soils in the northern tier of townships are devoted to truck crops, small fruits and cow-peas.

The region between Bristol and Middlebury has a reputation for fruit production. Celery, peppermint, onions and hemp are special crops grown on the more poorly drained soils. As a rule, fruit and truck are grown on the lighter soils while the heavy soils are used for hay and grains.

The importance of crop rotation is recognized and is practiced, but no definite rotation is adhered to. Stable manure is widely used. Commercial fertilizers are not widely used. Clover and cow-peas are frequently used as green manure.

The average size of the farms is 84.9 acres. About 71.6 per cent. of the farms are operated by the owners. Labor, when engaged by the month, is paid from $20 to $30 per month with board.

The value of farm land ranges from about $35 an acre for the most sandy land to from $100 to $125 an acre for heavier upland soils. The prairie land of which there is but a comparatively small amount, has recently been sold for $165 per acre.

The soils of Elkhart County have all been formed from glacial drift material which covers the entire area.

Two main soil series occupy nearly all of the county. These are the Miami and Plainfield. The former occupies the uplands while the latter is found in the level to gently undulating outwash plain.

Fourteen types, including Muck, Peat and Meadow, were mapped.

The Miami series is represented by four types. The loam is the most extensive soil type in the area and is well adapted to general farming and stock raising. The sandy loam is considered a fair general farming soil, but the crop value is generally below that of the loam. The silt loam is the heaviest soil of the county. It is well suited to grass and grain. The gravelly sandy loam is of limited extent, occupying rolling to hilly country in the northeastern part of the county. Portions of this type are devoted to the successful growing of fruit. The Miami soils are light colored.

The Plainfield series is represented in this survey by three types. The sandy loam is a fair to good general farming soil. The loamy sand and sand are too light for general farming, but when properly handled are ideal soils for all truck crops and small fruits. The soils of the Plainfield series are light colored.

Two Clyde soils, the loam and sandy loam, are found. They are dark colored and contain a high percentage of organic matter. The loam occurs as depressions and poorly drained areas in the uplands. The sandy loam is found in the outwash plain and the natural drainage is poor.

The Waukesha series in this area is represented by the sandy loam. It is a well drained, dark colored type of the outwash plain. It is the prairie soil, with a level surface and well suited to general farming. This was the first of the soils to be placed under cultivation and today commands the highest price.

Muck areas when reclaimed proved remunerative for growing corn, truck and special crops. Celery, onions, peppermint and hemp prove especially profitable.

Peat, when drained, is adapted to similar crops.

Meadow land is usually too wet and uncertain for cultivated crops and is best suited to pasturage.

Soil Survey of Warren County.

By E. J. Grimes of the Indiana Department of Geology and
E. H. Stevens of the U. S. Bureau of Soils.

DESCRIPTION OF AREA.

Warren County is situated in the western part of Indiana a little north of the center on the western boundary of the State. It is the fourth county south of Lake Michigan. It is bounded on the north by Benton County, on the east by Tippecanoe County, on the southeast by the Wabash River, which separates it from Fountain County, and on the west by Vermillion County, Illinois, and a small part of Vermillion County, Indiana. The county is somewhat triangular in shape, with the northeastern and southwestern part of the triangle truncated. The area is approximately 364 square miles, or 232,960 acres.

The county is divided into three distinct physiographic regions: (1) The river flood plain and terraces; (2) an undulating to rolling belt of timbered land; (3) the level to undulating prairie. The maximum width of the first division is about two and a half miles. It is continuous along the Wabash, but narrows down rapidly eastward from Independence. The river flood plain proper is relatively narrow for a stream of its volume, the average width being about one-fourth mile. The bottoms are usually bordered by broad, level benches or massive gravel terraces that rise from 25 to 75 feet above low water in the river. The best defined terraces of this division are the "Barrens" southwest of Williamsport, the terrace east of Kickapoo, and "Mound Prairie" on the southern boundary of the county. The second division, comprising the area fronting the Wabash River, has a somewhat broken surface. The larger streams and their tributaries on approaching the Wabash have deeply dissected the plain, and often acquire steep or precipitous valleys, sometimes walled in by perpendicular bluffs of sandstone. Some of these bluffs, as well as the Wabash valley escarpment are from 80 to 150 feet in height. This area of broken land extends along Pine Creek nearly to the northern boundary and is broadest in Liberty Township.

An area of pronounced relief comprising about 15 square miles occurs along the lower course of Possum Run. It is characterized by numerous abrupt slopes and deep ravines. A similar topography prevails along the lower course of Redwood, Little Pine, Mud Pine and Kickapoo creeks. This division extends back from the river to an average distance of five miles.

The third division embraces the Grand Prairie. It occupies the western and northern three-fourths of the county. In general it may be said to be a gently undulating prairie, but varies from nearly level to gently rolling. There are numerous broad areas with but little or no relief except near the streams. Such topography prevails in the extreme southwest portion of the area around Pence and east of Pine Village. The dominant, gently undulating surface of the prairie is broken only occasionally by morainic ridges or long sloping-like elevations. The most prominent of these moraines is known as "Blue Ridge" in Prairie Township. It extends in an easterly and westerly direction for four or five miles. The south side stands in clear relief while the north declines almost imperceptibly to the average surface level. The prairie as viewed from one of these elevations presents an undulating or billowy surface stretching away in all directions. Timber growth—islandlike—dot here and there its surface, and substantial farmhouses and barns are seen on every side, amid the fields of waving corn and oats. There are belts of rolling prairie. This topography is to be found more often where the prairie merges into the timber. An area north and west of West Lebanon, and northwest of Pine Village, has a decided relief. The long easy slopes that characterize this division are never too steep to interfere with cultivation. The average level of prairie above the river bed is about 175 feet.

Warren County is drained directly into the Wabash River, that flows in a southwesterly direction along the southeastern boundary. The course changes to a south direction at Covington. The river from Attica south occupies its preglacial channel, while above Independence for a few miles it seems to have a recent channel with bed and rarely banks of rock. The canal survey shows a fall of 19 feet from Lafayette to Attica, a distance of 25 miles; from Attica to Covington, 17 feet, a distance of 20 miles.

The principal drainage outlets on the north and east are Little Pine and Kickapoo. The lower courses of these creeks are flanked with bold bluffs of sandstone and gravel. Big Pine Creek enters the county near Pine Village and flows southwest to a point below Rainsville where it is joined at the south bend southward by Mud

Pine. It enters the Wabash at Attica. The valley is deep and tortuous, being 75 to 150 feet below the average surface level. From Rainsville to the junction, Pine Creek has carved a channel in sand rock. The generally broad bottoms and terraces together with the high bluff lines suggest that at one time this stream was an important drainage way.

Redwood, Rock and Fall creeks drain the central and southeast portions. Possum Run rises in the prairie north of Marshfield and flows south to join the Wabash at the great bend. At the headwaters it is a superficial stream, but farther south it is skirted by bold till bluffs. The north fork of Spring Creek flows south through a corner of Vermillion County. The hilly or rolling uplands adjoining the above streams include but very little untillable ground. The steep slopes break with remarkable quickness into the level plain. Frequently the slopes are cultivated to the very brink of the slope.

Prairie and Jordan townships are drained by Jordan Creek, a tributary of the Vermillion River in Illinois. The upper branches of this stream are surface streams with artificial channels that usually represent the former ill-defined and obstructed channels artificially enlarged and straightened by dredging.

In the first settlement of the county, much of the prairie was too wet for cultivation, and a number of marshes which had not reached the state of "wet prairie" were scattered at intervals within its bounds. To properly drain these water-logged areas was for years the chief problem of the farmers. This has been effected by the construction of a great system of surface and tile ditches that ramify through every portion of the prairie.

The elevations above sea level in feet of the different points, taken from railroad surveys, are as follows: Williamsport, 668; West Lebanon, 700; Marshfield, 706; State Line, 730; Pence, 700; Judyville, 771; Hedrick, 709; Pine Village, 702; Winthrop, 677; Kickapoo, 546, and Mound City, 628.

In 1824 a great many settlers had located in this region, largely in Warren Township. They were attracted by the fertile valleys and excellent pasture land on the adjoining slope. Here they were free from the pestilential ague. The county lines were located and the county organized January 19, 1827. Williamsport was selected as the county seat the same year. The early immigrants came largely up the Wabash from Southern Indiana, Kentucky and Ohio. The proximity of Indians somewhat retarded the advance of settlement.

The picturesque hills and chasms of Pine Creek had been for a century the favorite home of the Weas and Kickapoos. Independence, the oldest town in the county, was a trading point with the Indians as early as 1811. The first conveyance of land was recorded in January, 1828. The development of the area was burdened by the lack of transportation facilities. The only market was to the south; this was reached by the lengthy and perilous journey to New Orleans. The nearest grist mill was at Terre Haute. Lafayette, Chicago and Cincinnati were the markets for the early farmers. The advent of the Wabash Railroad in 1856 gave an outlet for the county's produce, and stimulated development.

The railroad facilities of the county are ample. Two north and south lines, the C. & E. I. and C. & Ind. Southern give direct connections with Chicago, about 100 miles north. The Wabash and the Peoria Division of the Big Four crosses the county east and west. A branch of the Illinois Central Railway enters the county from the west and meets the Wabash at West Lebanon. A branch of the main line of the C. & E. I. in Illinois terminates at Judyville.

The county has a total of 366 miles of improved roads. They are surfaced mainly with gravel. There is yet an inexhaustible supply of this road metal. Although the county is making a substantial progress toward a permanent system of good roads, there is yet an urgent need for a few roads in certain sections of the prairie not now open to travel.

The area is in a very prosperous condition. The improvements are of the best type. Well built farmhouses, large barns, good outbuildings and labor saving machinery are the rule. The fences, particularly on the prairie, are not much good. The land waste from osage orange fences is immense. Telephones and rural mail routes reach all parts of the county. Most of the farmers own high power motor cars.

The small country school is still maintained. There is an apparent need for a number of substantial brick schoolhouses conveniently located and equipped with modern conveniences.

Warren County is essentially an area of large holdings. The best farms in the county today, the farms that represent the substantially prosperous end of the business, are those that average at least 100 acres or more. There are several estates that exceed 1,000 acres. Consequently it is sparsely settled as compared with other sections of central Indiana.

According to the census reports the population has steadily decreased. The statistics are as follows: 1870, 10,204; 1880, 11,497; 1890, 10,955; 1900, 11,371; 1910, 10,899 inhabitants. The occupations are wholly agricultural. Some coal is mined, but only for local use. The future of the county will lie in the improvement and intensive development of its fertile soils.

Williamsport, the county seat, is a modern resident town of about 1,200 people, located on the west bluff of the Wabash River. It is not conveniently connected with most parts of the county.

West Lebanon and Pine Village are the only two remaining incorporated towns, with a population of 642 and 352 respectively. State Line and Independence are the next largest points. Kramer is the site of Mudlavia, a popular health resort. Pence, Tab, Hedrick, Marshfield, Foster and Judyville are small villages and shipping points for the prairie farmers.

There are eighteen railroad stops and as many elevators within the county. Danville, Lafayette, Attica and Covington are business centers for most of the farmers.

Climate.

The climate of Warren County is characterized by wide variations in temperature and rainfall. Sudden changes of temperature are frequent. It is difficult to forecast the weather one day in advance. Periods of drought or years of too little rainfall for the requirements of corn and grass are frequent, and have been especially numerous in past five years. In all of these respects it resembles the climate of the general region.

The natural physiographic regions of the county are fairly well defined by climatic features. The prairie belt is marked by wider variations in temperature and smaller total amount of rainfall than the timbered portions. The proximity of the Wabash Valley tends to equalize the extremes of the eastern portions. It is popularly known that the storms follow the course of the river, and are more numerous than farther inland. The prevailing westerlies pass over the prairie without much deflection.

The following tables show the normal monthly, seasonal, annual temperature and precipitation at Lafayette, Indiana, and Danville, Illinois. The former records are representative of the Wabash Valley portion of the county, while the latter data is applicable to the prairie belt.

NORMAL MONTHLY, SEASONAL AND ANNUAL TEMPERATURE AND PRECIPITATION AT LAFAYETTE, TIPPECANOE COUNTY, INDIANA.

Month.	Temperature.			Precipitation.			
	Mean.	Absolute Maximum.	Absolute Minimum.	Mean.	Total Amount for Driest Year.	Total Amount for Wettest Year.	Snow Average Depth.
	°F.	°F.	°F.	Inches.	Inches.	Inches.	Inches.
December	29.7	69	—17	2.59	1.95	5.84	3.5
January	25.3	70	—33	2.47	1.18	0.40	7.0
February	26.9	69	—26	2.75	2.94	5.78	6.3
Winter	27.3			7.81	6.07	12.02	16.8
March	37.6	83	—5	3.20	1.41	3.30	4.4
April	50.5	89	10	3.27	2.94	2.25	0.4
May	61.5	97	25	4.40	2.11	3.82	Trace.
Spring	49.9			10.87	6.46	9.37	4.8
June	70.7	100	33	4.43	1.97	7.16	0.0
July	74.6	105	42	3.77	0.88	2.05	0.0
August	72.6	102	39	3.23	0.47	3.08	0.0
Summer	72.6			11.43	3.32	12.29	0.0
September	66.1	101	29	2.77	3.02	4.20	0.0
October	53.3	92	16	2.35	1.62	4.42	Trace.
November	39.5	95	—1	3.06	3.72	6.49	1.2
Fall	53.0			8.18	8.36	15.11	1.2
Year	50.7	105	—33	38.29	26.21	48.79	22.8

Average date of first killing frost in fall, October 5; last in spring, April 26. Earliest date of killing frost in fall, September 14; latest in spring, May 27.

NORMAL MONTHLY, SEASONAL, AND ANNUAL TEMPERATURE AND PRECIPITATION AT DANVILLE, VERMILLION COUNTY, ILLINOIS.

Month.	Temperature. Mean. °F.	Precipitation. Mean. Inches.
December	30.5	1.99
January	26.5	2.92
February	27.1	1.75
Winter	28.0	6.66
March	39.6	3.54
April	52.0	2.78
May	64.8	3.55
Spring	52.1	9.67
June	72.5	2.82
July	76.6	2.96
August	74.0	2.91
Summer	74.4	8.69

Month.	TEMPERATURE. Mean. °F.	PRECIPITATION. Mean. Inches.
September	67.8	3.55
October	55.1	2.55
November	40.6	3.25
Fall	54.5	9.15
Year	52.3	34.17

It appears from the foregoing table that the mean annual precipitation is about 38 inches. The greatest amount occurs in months of May, June and July, nearly four inches each, and the lowest amount in the winter months. The total amount of rainfall even in the driest years is sufficient for all crops grown if proper cultural methods are employed on the different types to conserve it.

The snowfall is quite variable from year to year, but the average is 22.8 inches. It is generally sufficient to protect the winter wheat, rye and clover seedings.

From the Weather Bureau records it is ascertained that the average date of the last killing frost in spring is April 26th and the first in fall is October 5th, giving an average growing season of about 160 days. The records give the date of the latest killing frost in spring as May 27th, and the earliest in fall as September 14th.

The springs are ofttimes premature. The vegetation gets well started and is afterward injured by a severe frost or freeze. This is particularly damaging to the peach and apple crops. May and October are the balmiest months of the year, July and August the warmest, and January and February the coldest.

AGRICULTURE.

Warren County comprises large areas of productive, well drained soils, which are susceptible to easy cultivation, and have endured continuous cropping remarkably well. The soils are still comparatively fertile and the crops produced in favorable years are yet large, but sufficient evidence is at hand to show that profitable yields of certain crops are not being obtained because of the deficiency of certain necessary elements, or because of the lack of proper physical conditions in the soil. Maximum crops may be obtained indefinitely if proper methods of farming are instituted at once. The decreasing yields of late years clearly show that it is now time for the farmers and landowners to make their greatest effort to maintain the fertility and increase the productivity of their soils.

Farming operations were begun in this county about 1824 in Warren Township along the Wabash Valley. The rich soils of the bottoms and the good pasture land on the adjoining slopes and the freedom from malarial fever, together with the transportation facilities afforded by the river, caused the early settlers to select such sites. The water-logged areas of the prairie were ignored by the early farmers and their descendants in their search for well drained lands with timber for fuel and constructive purposes. It was then supposed that they would never be cultivated. As the settlers gradually pushed westward these areas were gradually taken up. The first part of the prairie section to be reclaimed was the better drained portions around West Lebanon and Marshfield. In the beginning the prairie lands were utilized by the men in the timber section for grazing purposes. Cattle feeding became an extensive industry of the early prairie farmer. The native prairie grasses were cut and used for hay, while corn was brought from a distance. Thirty years ago the prairie sod was unbroken. About 1882 tile drainage was undertaken and extensive systems of open and underground drains have since been completed, until today nearly all the black land has been freed of surface water and the areas thus reclaimed are the source of the enormous wealth of the county. The value of these lands may be seen from the assessed valuation of the county, which in 1914 was $13,300,000; that of Prairie Township alone is $1,951,510.

The crops grown are those characteristic of the corn belt—corn, oats, clover and wheat ranking in acreage in the order named. The cultural methods apply almost entirely to grain farming. Corn and oats are grown almost exclusively on the prairie farms. Little or no wheat is grown on the Carrington or Clyde soil. The small clover acreage has rapidly declined. The general trend of agriculture may be seen from the statistics of the U. S. Census tabulated below.

U. S. CENSUS.

	Corn.		*Oats.*		*Wheat.*		*Hay.*	
	Acreage.	Yield.	Acreage.	Yield.	Acreage.	Yield.	Acreage.	Yield.
1880......	62,952	2,134,441	10,587	355,666	15,862	363,651	13,043	14,527
1890......	54,613	1,740,244	25,285	886,023	12,695	177,851	19,323	23,689
1900......	78,667	3,792,210	36,195	1,495,400	8,189	70,430	14,529	16,509
1910......	75,789	3,250,565	48,071	1,664,179	7,973	153,023	12,196	14,218

Corn is the chief crop. All problems of soil management are planned in relation to the production of this crop, and will continue to be thus on account of the high prices offered for this grain and its adaptability to most of the types of soil in the region. The highest yields are obtained on the Clyde and Genesee soils, which produce nearly twice the amount of the Miami soils. Corn frequently goes less than 40 bushels per acre, but average yields of 70 bushels are not uncommon. The present practices in the cultivation of corn conform closely with the methods generally used throughout the prairie section of the corn belt. The land is fall plowed and the following spring the bed is stirred, leveled and pulverized with harrows. Most of the crop is planted with the check drill and cultivated both ways. The land is usually harrowed when the corn is coming through the ground or while yet young. The roller then finishes pulverization. Three to five shallow cultivations are given as a rule and crop laid by about the first or middle of July. Most of the corn is husked by hand, shelled and hauled to the elevators, but in late years a larger percentage of corn is being cut for ensilage, especially on the Miami farms. The number of silos is increasing rapidly, and is frequently the determining factor between profit and loss in cattle feeding. The planting of cow-peas or soy-beans in the corn at the last cultivation, to be cut with the corn for ensilage, is to be recommended. The limited quantity of barnyard manure on hand is applied to the land intended for corn. Some commercial fertilizers are applied to the corn on the gray soils. The applications are usually too small and not properly balanced. The corn produced on the Miami soils grades better than that grown on the dark types. The prairie corn ofttimes fails to mature properly, and the cob averages large. Strains of Reed's Yellow Dent and Leaming constitute the main varieties grown. Seed selection is not generally practiced. The seed is brought from Illinois. More attention should be given to the improvement of corn by breeding up varieties on the different soil types. Good seed corn is available from growers in the same latitude in Indiana and would be preferable to that from other States. As to cultivation, the prevailing practices are good. Deep or shallow cultivation depends upon seasonal conditions, but in general the first cultivation should be as deep as possible. It should go down almost as deep as the furrow that has been turned. This will restore the connection of the soil and subsoil. The remaining 3-4 cultivation should be as shallow as possible. A dry dust mulch should be maintained at all times.

Oats are generally sown broadcast over the corn, or oat stubble land and harrowed under in the early spring. The acreage of this crop has steadily increased until on some of the prairie farms the acreage is almost equally divided between corn and oats. An average yield over a period of years will be about 30 bushels. Oats are cut and left shocked in the fields until the thresher outfit arrives, and thus are frequently damaged by exposure. Most of the grain is shipped out of the county. The straw is baled and sold. The seed oats are grown locally. At present it does not seem profitable to breed up a local strain, but the seed should be secured about every three or five years from more northern latitudes. Smut reduces the yield of oats at least 3-10 per cent. All seed oats should be treated with formalin before planting. Fertilizer tests by the Indiana Station show that the use of commercial fertilizers on oats is uncertain, and positively unprofitable where nitrogen is used in the formula. Two hundred to three hundred pounds of 6-8-4 mixture might prove successful on the Miami soils.

Winter wheat production has gradually declined and, much like oats, is grown mostly for its value as a cover and nurse crop for clover and timothy. But little wheat is grown on the prairie on account of the winter killing by heaving. Some of the farmers prepare the land for wheat by ploughing, while others drill the wheat in standing corn; when the latter is done the surface should be kept clean and mellow. By cutting the corn and removing from the fields, and harrowing before drilling would insure a better stand. Wheat responds better to commercial fertilizers than either corn or oats, and there are but few farms on which fertilizers of proper composition will not give a profitable yield when applied in connection with good farm practice. The Indiana Station recommends for general use about two hundred to three hundred pounds per acre of a fertilizer containing about 2 per cent. nitrogen, 10-12 per cent. phosphoric acid, and 4-6 per cent. of potash, drilled at the time of seeding. The nitrogen may be omitted on soils well supplied with organic matter. Where commercial nitrogen is used in the rotation it should always be applied to the wheat crop. On most of the farms wheat follows corn to better advantage in the corn, wheat and clover rotation. It does unusually well after soy-beans or cow-peas; hence a rotation of corn, soy-beans, wheat or oats and clover. Better drainage should be established on most soils. Winter killing is a sign of poor drainage. The hardy Russian types, particularly the Turkey Red strains, are best for the prairie regions. The last week in September is the best time, as an average, for seeding. The seed should be properly selected and graded. If attention were given to these details, and the information of the Experiment Station utilized, there seems to be no reason why the average yields could not be doubled and the profits enlarged from this useful crop.

The problem of securing a stand of clover within the last five years has been the most troublesome one confronting the farmers of Warren County. As an average it fails about three years out of five. The last two or three summers have been very dry and hot in this county so that when the nurse crop is removed the young clover burns out. This is usually induced by attempting to get a full crop of grain that draws too heavily on the available moisture supply. Other failures are due to acid soils, low germinating vitality, and failure to get seed properly covered. It appears that when land begins to decline in production of clover it is a sign that it is going to decline in the production of other crops as well. Under the above conditions it must cease to be included in the rotations and a substitute found for the short rotations. At present when the clover fails the farmers plow it up and follow with a cereal; as a consequence much of the land is suffering an enormous loss.

Doubtless a high percentage of the poor stands is due to the acidity of the surface soil; this is especially true on the Miami and lighter phases of the Carrington soils. One to four tons of ground limestone per acre will correct this condition and after it has been neutralized one-half to two tons once in the rotation should prove ample to prevent it from again becoming acid. Where clover is seeded in wheat or oats the stubble should be left as high as possible and the shocked grain removed as soon as possible after cutting. About one-third the usual amount of grain seed should be used and in some cases cut for hay before the heat of the season.

Numerous small plats of alfalfa were seen throughout the county. The acreage is increasing and giving profitable returns. But it deserves far more attention. Applications of lime are found necessary on most soils, but barnyard manure is frequently the determining factor of success. The average upland and sometimes the terrace soils lack proper physical as well as chemical condition. They need an addition of some substance that will increase the moisture holding capacity and will improve drainage by opening up the upper subsoil layers. Ten to fifteen tons of barnyard manure will serve for this purpose, and should be applied sometime before seeding. Top dressing in late fall or early spring where good stands have been obtained are very beneficial. Alfalfa can be profitably produced on all the upland soils that are well drained, if they be thoroughly limed and inoculated.

Only a few tracts of cow-peas and soy-beans were observed in the survey. Both of these crops are well adapted to soil and climatic conditions of the area. They are more resistant to heat and drought than clover or alfalfa. This feature alone recommends them for the Fox and Sioux types. They gather nitrogen from the air and store it in their roots, thereby improving the soil in which they grow. They may be grown on a soil too acid for clover or alfalfa. They rank with linseed and cottonseed meal as a concentrated feed for cattle and hogs. They may be substituted as a catch crop for clover when the latter kills out. Cow-peas can be cut for hay or used for pasture, while the soy-beans could be threshed and the vines returned to the land either directly or as manure.

Sweet clover can doubtless be used to advantage on a number of soils, the Fox, Shelby and prairie types, when clover fails. It should be drilled in the oats at the time of seeding at rate of 12 pounds of hulled seed per acre. The nurse crop does not shade it out and the sun does not kill it when the oats are removed. The extensive root system is beneficial in many ways. Only a single field was seen, but it grows spontaneously everywhere.

There are a few principles of soil improvement applicable to all types of soil, in the use of the crops common to the region. In the first place the physical conditions of the soil with respect to the moisture content should be carefully maintained near the best as possible. This is dependent upon drainage and cultivation,—the most important factors in all farming operations. The second step is the proper rotation of crops. A legume should be included at least once in the 3-4 year rotation.

The next factor is the maintenance and increase of the organic matter and nitrogen content of the soil. The materials for this purpose are barnyard manure, crop residues and green manures. In conjunction with humus would be the use of ground limestone to neutralize the acidity present. The last operation will be the use of phosphatic fertilizers. According to the best evidence of the Purdue records, the phosphorus can be most profitably applied in the soluble forms, at least so by the renter. Five hundred pounds of acid phosphate once in the rotation should be sufficient. As the mechanical condition of the soil is improved the almost inexhaustible supply of potash present will become available.

The soil of Warren County is deep, averaging about 18 inches, and for this reason subsoiling will never be practicable, but the use of deep tilling machines is to be strongly recommended on several types of land.

Stock raising and feeding has been considered unprofitable in the last few years. Cattle is imported from Chicago and fattened for the markets. This industry has received most attention in the vicinity of Judyville and Green Hill. But on account of the high priced lands there has been a tendency to plow up the pastures and grow more corn. Most farms should include sufficient livestock so that the rougher portions of their farms may be utilized, to help maintain fertility, to utilize the waste products of the farms, and to consume a part of the enormous quantities of grain produced Dairying has received no attention. Hogs are best paying animals, and most of the corn consumed in the area is fed to them.

According to the census, the number of renters has rapidly increased in Warren County. In 1910, 41.6 per cent. of the farmers were renters. In the prairie sections, no less than 75 per cent. are tenants, renting on the share basis, the landlord demanding one-half the grain delivered at the elevators, the tenant furnishing everything. In most cases, pasture privileges are extra; some even exact a cash payment for the use of houses and other outbuildings. Cash rentals range from $5 to $9 per acre. This pernicious system of tenantry is largely responsible for the decreasing fertility.

The average size of farms has increased from 135 acres in 1880 to 161.4 in 1910. The prairie farms are all large. There are more than twenty holdings in the county exceeding 1,000 acres. Farming anything less than 160 acres is considered comparatively unprofitable.

But little land has changed hands in the past five years. The better prairie land is held for $200 to $225 per acre. The other sections sell for $125 to $200. Measured by its productive capacity, the price of realty is inflated on many types of land.

Truck or special farming has not received much consideration in the county. Suitableness and favorable locations warrant more interest in fruit growing, at least to meet home demands.

The prices paid for farm labor as well as the supply is about the same as that of the general region.

SOILS.

The soils of Warren County are derived mainly from the unconsolidated deposits left at the retreat of the great ice sheet at the close of the Glacial Period. When the glacier covered this portion of Indiana, it contained a heterogeneous load of clay, silt, sand, gravel and boulders, in different proportions. The material varied with the character of the rock over which it passed. Foreign and local rocks were ground up and mixed. Upon the melting and retreat of the glacier this load, known as glacial drift, was dropped, leaving an uneven and undrained surface, consisting of numerous knolls, ridges, ponds, marshes and small lakes. Many of the latter became filled so as to be converted into swamps or even dry land, while others continued down to our day. Artificial drainage rapidly converted the swampy areas into dry, tillable land.

The drift is quite variable in thickness, ranging from only a few feet to more than 250. The average is perhaps less than 100 feet. The deeper portions lie on the western and northern side of the area, gradually thinning down as the Wabash River is approached, where the younger sedimentary rocks are exposed.

Two ages or divisions of the boulder till are discernible in the county. The upper exposures of the prairie region are a light or grayish colored, friable, sandy or gravelly clay. The till of the timbered section is prevailingly a yellowish brown clay, containing less coarse material, as a rule. The difference in color may be due to the unequal changes of the iron compounds in the upper strata on account of the relative amount of humic acids and other substances that have been contained in the percolating waters.

The geological epochs represented in the rock platform of the county are the Knobstone of the Lower Carboniferous and the Mansfield sandstone and the Coal Measures of the Carboniferous periods. The Knobstone occurs beneath the drift in the northeastern corner and is exposed in a narrow strip along the north side of the Wabash from where the river enters the county to Williamsport. The Mansfield sandstone covers a large portion of the eastern half of the county and outcrops along the Wabash and its tributaries from the eastern line to the mouth of Redwood Creek. The Coal Measures rocks lie just beneath the deep drift of the western half of the county.

Generally, these rocks exert no influence upon the soils; but where the drift is thin, as are portions over the Knobstone, they have weathered to a sufficient degree to modify the composition of the soil, and especially the subsoil and substratum. But the extent of purely residual material is very local.

The boulder till is covered with a layer of fine grained loess like material to a depth of two feet or more. The uniformity of depth and distribution of this stone free layer strongly suggests that it was transported by the action of wind, probably from deposits of exposed till before it was protected by vegetation or to a lesser extent from the melting and evaporation of glaciers. Flats, hills and valleys alike are invested with this silty veneer covering. The depth may vary somewhat with the surface irregularities, the steeper sloping areas being thinnest and the level and low-lying areas deepest. This silty material, modified by differences in topography and drainage conditions with the consequent variations in the different agencies such as weathering, erosion and vegetation, have given rise to the different soil types of the uplands.

The upland soils have been divided into timber soils and prairie soils, according to the kind of original vegetation. The large amount of humus and consequent dark color is one of the most striking characteristics of the prairie soils. The existence of dark colored soils over areas naturally well surface drained is explained by the absence of timber, which in turn is supposed to be due to the annual prairie fires. But chemical and physical agencies have no doubt influenced or even restricted the growth of trees. Investigations have proved that there is a relation between the high content of lime (that is found in these soils) and other soluble materials and moisture.

The prairie types were separated largely according to topography. The Carrington silt loam covers the nearly level to gently rolling prairie that was naturally fairly well surface drained. The soil color is brown. The Clyde silty clay loam was formed in the lower lying flat areas that were originally poorly drained and in swampy condition. The color is termed black on account of the higher content of organic matter.

The timbered soils are readily distinguished from those of the above region by (1) the general light or gray color, (2) lower percentage of humus, (3) native vegetation, generally timber, (4) more irregular topography, (5) lower average productiveness. These soils are included in two series—Miami and Shelby. The Miami silt loam embraces the gently undulating to rolling areas. A small percentage of this soil has a nearly level surface and was separated out as the flat phase of that type. A zone of eroded and badly hilly land along the stream courses of low agricultural value has been classed as the Shelby silt loam.

The Wabash River is bordered by massive terraces of gravel and sands covered with a veneer of 1½ to 3 feet of sandy loam, coarse sandy loam, and silt loam. Similar but smaller areas occur in the valley of Pine Creek. These terraces or benches were built high on the side of the valley by the ancient stream at the melting of the ice sheet. Then they flowed at a much higher level than at present. These soils are divided into three series. The Fox series constitutes the brown or grayish brown originally timbered soils. The substratum of gravel is largely calcareous. The type of the Sioux series is a brown to black, coarse, sandy loam, formed under prairie conditions. In a few areas along the Wabash and Pine Creek, the soil forming material of the terraces is derived from the underlying sand rocks. These areas are correlated as the Allis stony loam.

The alluvium of the flood plains or overflow land is of local origin, being derived mainly from the uplands and has many of its characteristics. The first bottom of the Wabash River is relatively narrow, and the soils are of a grayish brown color, so they were classed as the Genesee. Other typically developed areas of this series are found along the lower courses of the large tributaries. The silt loam and the fine sandy loam are the only members separated. Most of the course of Pine Creek is bordered by some well defined areas of black sandy loam and loam soils recognized as members of the Wabash series. Meadow is a brown mixed loam type found along the minor drainage ways.

Muck is an organic soil formed by the accumulation of remains of various plants, chiefly spagnum moss. It is of limited occurrence.

The following chapters describe in detail the several soil types.

Carrington Silt Loam.

The surface soil of the Carrington silt loam consists of a grayish brown to almost black, friable silt loam 12 to 22 inches deep, with an average depth of 17 inches. The subsoil is a dull yellow, compact silty clay loam, or clayey silt, passing at about 30 inches into a more friable yellow, sandy clay that contains an appreciable amount of gravel, especially in the lower depths. The type description prevails uniformly over most of the county, but many variations are found where the type grades into the Clyde and Miami soils. In a few small areas in the western part of the county the top soil is quite sandy or loamy, but in areas too small to map as a general rule. In Section 23 and 26, T. 23, R. 10, and S. W. ¼ Sec. 3, T. 22, R. 9, and other smaller spots, the soil is a brown, fine sandy loam or loam, resting on a compact but friable yellowish sandy clay. The sand content increases with depth until at about 40 inches it is a loamy sand. This phase is found on crest of sharp ridges or on elevated spots in level areas.

The Carrington silt loam constitutes the common rolling prairie land of Illinois and Indiana, and is the predominating type in Warren County. The surface features vary from almost level to undulating or gently rolling. The irregular topography is found on approaching the timber line. Large areas are characterized by a flat or depressed surface, ofttimes so flat that adequate drainage was quite a problem. The crest of the knolls or swells may be only a few inches above the level of the associated Clyde soils where it is developed as islandlike bodies in that type. However, the larger portion of the type has fair to good natural drainage.

On approaching the drainage lines the color of the soil becomes lighter as the humus content decreases, until the color coincides with the Miami soils. This zone varies from one to two miles wide, and originally supported a light growth of timber. It was doubtless at one time a part of the prairie, and the present light color of the soil was produced by the gradual invasion and occupancy by forest growth. This gradation or transitional condition sometimes extends over a considerable strip, and might possibly be considered as another type. But in the present survey it was included in the Carrington soil, for the reason that the content of organic matter is higher than the average Miami soils and is underlain with the characteristic yellowish or buff subsoil of the Carrington member.

The Carrington silt loam was derived from the weathering of the glacial or loessial material intermingled with organic matter, supposedly from the roots and tops of prairie grasses that formerly grew luxuriantly on the native prairies. The depth of the root system is marked by the zone of darkening, which usually extends to a depth of about 18 inches. This high percentage of organic matter has produced a marked contrast in color betwen the soil and subsoil.

The boulder till underlying the prairie to a depth of 5 to 40 feet consists of a heterogeneous mass of clay, sand and gravel of light grayish color. The contents of coarse material increases from the subsoil downward and the deeper substrata are usually quite stony.

The type is extensively developed in the western and northern portions of the county. The inner boundary of this type representing crudely the former timber line, will average about five miles back from the river front. It attains its best development in Ranges 9 and 10. In Mound Township it approaches within two miles of the river. It invariably extends up to the creek valley on the west and south side, while the corresponding area on the north and east are timbered soils.

This county lies in the path of the prevailing southwesterlies of summer and autumn. This condition is perhaps the result of the check given to the advancing prairie fires by the creek and valley slopes.

Besides the artificial planting of silver maple and osage orange there are a few islandlike groves of native forests of oak and hickory through the prairie. The largest tract occurs in Sections 35 and 36, T. 23, R. 9, known as Walnut Grove.

Generally, the subsoil is well oxidized and is a buff to bright yellowish color on the ridges and knolls, and a pale yellow or gray and highly mottled with yellow and iron stains in the level portions. The mottled condition is always associated with poor drainage. An extensive area with the mottled subsoil occurs east of Pine Village, extending well toward the eastern boundary line. The surface soil of parts of this development is a grayish brown or brown heavy silt loam, resembling the flat phase of the Miami silt loam.

Most of the area lying north of Pine Creek and east of Mud Pine Creek is broken by morainic ridges and a lighter colored surface soil is developed. A few such areas were separated as Miami. The soil in such Carrington areas consists mainly of 12 to 30 inches of a grayish brown silty loam, grading into a friable brownish yellow sandy loam. Below two feet there is considerable sand and gravel. The surface also carries varying amounts of cherty gravel.

Granite boulders were numerous on this type in Prairie Township in Sections 35 and 27. A boulder trail was said to have existed in a belt about one mile wide passing from the northwest to the southeast, but could not be traced. Most of the boulders have been removed so they do not now interfere with cultivation.

The soil and subsoil have a remarkable capacity to absorb and retain moisture. The compact silty clay layer between the depths of 18 and 36 inches serves as a reservoir to hold the percolating waters. The same structure also insures good capillarity. This, combined with the good internal drainage induced by the friable sandy clay substratum, enables the soil to withstand drought to a marked degree and also does not suffer from excessive rains. However, many fields of this land would be benefited by an extension of the tile drainage system.

Formerly the Carrington silt loam was one of the most desirable and productive soils of the corn belt, but much of this type as well as the Clyde silty clay loam has been subjected to continuous grain farming for about thirty years, until now its fertility and productiveness has begun to wane. In addition, its former good physical condition has been reduced by improper cultural operations. The corn stalks are often pastured in later winter and spring when the tramping puddles the soil. Ofttimes it is plowed too early, before dry enough to handle safely. The organic matter is depleted by the burning and sale of the crop residues, such as stalk straw and weeds. Every effort should be made to increase the supply of humus. Clover or soy-beans should be grown in every rotation and the bulk of the crop turned under, either outright after threshing, or in manure. The oat straw should be returned to the soil if not utilized as feed or bedding.

The Illinois station has found this type to be deficient in phosphorus, and good results are reported in the adjoining counties of that State by applications of one-half to two tons of raw rock phosphate.

The lighter phases of this type, and particularly the undulating areas, are becoming low in lime, as shown by the litmus tests; and all evidence seems to indicate that lime is needed, and profitable results will doubtless attend its use.

Corn, oats, grass and wheat are the main crops grown on this type. A five year average for corn would be about 40 bushels; oats, 30 bushels; wheat, about 20 bushels, and clover, 1 to 2 tons. No attempt has been made to grow special crops except a small acreage of potatoes, which give about 200 to 300 bushels per acre. Sugar corn is grown extensively on this soil around Hoopeston, Illinois. It is an excellent grass soil, and a considerable acreage is in blue grass, especially in the rolling areas and near the timber line. Some fruit is grown for home consumption, but deserves far more attention.

Wheat is not generally grown. It winter kills badly, either by the accumulation of water in low places or smothered out by the ice in winter. Wheat plants are also heaved out of the ground by the alternate freezing and thawing in the fall and spring. This is due to the formation of ice in soil spaces filled with water. Winter killing is a sign of inadequate drainage. With the improvement of the drainage system and the use of hardy strains of Turkey Red, wheat culture could be profitably extended to this type. Alfalfa, soy-beans, cow-peas and sweet clover are admirably adapted to this land.

The Carrington silt loam is the prized farming land of the Grand Prairie and commands from $150 to $225 per acre.

This series constituted what was formerly called Marshall.

Clyde Silty Clay Loam.

The Clyde silty clay loam embraces the lower lying, flat areas, originally swampy or inadequately drained. This type is intricately associated with the Carrington silt loam, and also occurs as depressions through the Miami silt loam.

The surface soil to an average depth of 12 inches is a dark brownish gray or black heavy silt loam to silty clay loam. The content of organic matter is relatively high; it consists mostly of black humus, which imparts the granular character and keeps the soil mellow. As the content of humus is reduced by cultivation, the power of granulation is lessened and the soil becomes heavier and more difficult to handle. The intensity of color is proportionate to the amount of organic matter and moisture present in the soil. Why dry the surface is a deep chocolate brown, but changes to an intense black color when moistened.

The subsoil is a dark gray to drab or bluish black clay loam which grades at 18 to 24 inches into a gray plastic silty clay mottled with yellow, brown, and iron stains. The mottlings become more pronounced with depth and the silty clay becomes more plastic and tenacious in lower sections. Occasionally below 30 inches a gravelly or coarse sandy clay is encountered. The subsoil has no constant characteristics and is subject to wide variations, especially in color, over short distances. The plastic and mottled condition is the result of poor drainage and consequently bad aeration and oxidation. This internal characteristic of the subsoil readily separates it from the Carrington silt loam.

The type as a unit perhaps will average a heavy silt loam in Warren County. Most of this soil presents very wide variations from the brown prairie and the differences are so pronounced as to be recognized by most farmers. It is locally styled black prairie, and the heavier development is known as "gumbo". The value of realty is determined largely by the acreage of this type on the individual farms. In most instances the boundary is fairly distinct between this type and the associated Carrington silt loam. But there is frequently a zone or strip between the two soils that gives rise to a lighter phase containing less clay and organic matter than the Clyde type. The Carrington subsoil is frequently present and may continue inward some distance under the Clyde soils.

Local areas of this soil are a heavy black clay loam to a depth of 12 inches, passing into a granular bluish black clay loam to about 18 inches. This gives way to a heavy drab silty clay highly mottled with yellow blotches. This phase is found only in the lowest depressions. It is generally so wet and intractable that it is not cultivated. A few such acres are found in Sec. 35, T. 22, R. 9; another in Sec. 4, T. 22, R. 9, and a large body in Sec. 29, T. 20, R. 10.

Quite a high percentage of the type occurs bordering the minor drainage ways of the prairie, and larger creeks and along the lower courses of the streams where they begin to form a channel. The material resembles an alluvium, and is underlain with a highly stained sand and gravel at about three feet. Such an area is found in Secs. 16, 17, 8, 9, T. 22, R. 9; also in Sec. 12, T. 22, R. 10.

The soil along Jordan Creek is a black silty loam from 6 to 10 inches deep, underlaid with a bluish black, friable or sometimes gummy silty clay loam or clay to a depth of 8 to 22 inches. This grades into a very sticky, plastic drab or dark mottled silty clay. The soil and subsoil contain more gravel. These bottoms are subject to overflow in times of heavy rainfall; but on account of the similarity of the texture and structure (as most of the soil has come from this prairie) as well as agricultural adaptations, they were included in the series which is typically developed in the structural depressions of the uplands proper. The origin of this type is traced to the former wet prairie conditions under which it was developed. The low lying portions received the fine materials and organic matter washed in from the slightly higher uplands. The rank growing sedges and grasses added much vegetable matter to this soil. More or less of the clay and finer silt has been translocated to below the surface and accumulated in the lower soil and subsoil sections. This has been the work of centuries, beginning after the recession of the great ice sheet. Exposure of the surface after the periodical prairie fires accelerated the surface wash. The same agency (washing) is very active at the present time, and its influence can readily be observed on this type where it is contiguous to rolling areas.

The early settlers found this soil in a waterlogged condition. It then constituted the sloughs or wet prairie. Most of the type has been under cultivation less than thirty years. Tile drainage began about 1882 and gradually extended until all the type was reclaimed, so that now most of the type is well surface drained except a few ponds. Most of the large ditches now remaining open could be supplanted by underground drains.

The type is best developed in the western one-third of the county. Representative areas are found north of Tab, south of Pence for a distance of six miles, and in the southwest corner of the county. The timbered phase is not extensive; the largest bodies occur in a strip about two miles in width at the south edge of the Carrington soils in Warren Township. The soil in the larger bodies of the timbered phase is not essentially different from the prairie soil.

The greatest problem in managing the Clyde silty clay loam has always been to secure a good drainage; but as previously stated this difficulty has been overcome by artificial drainage. But there is urgent need for more lines of tile, especially so in the parts of the type having a gummy subsoil.

As a rule this soil does not seem to be very generally acid; but traces of acidity have been found with litmus paper. The subsoil is well supplied with lime. The phosphorus and potassium contents are known to be ample in most cases. The needs of the type for some time to come will be better physical treatment, and a constant supply of decaying organic matter should be maintained to improve the mechanical condition of the soil. Applications of limestone and phosphorus may eventually prove profitable.

The Clyde silty clay loam has endured the continuous grain farming unusually well. It is the premier corn soil of the corn belt. The average yield from this type is about 55 to 60 bushels, while 70 to 80 bushels are common. Oats will average about 40 bushels, with an occasional maximum yield of 80 bushels. These two crops have occupied the land either continuously or alternately for over twenty years until some fields show marked signs of decreasing production.

Farms containing a large portion of this type are held for $150 to $225.

The Clyde silty clay loam varies markedly from the same type in central Indiana. The most salient character of the former development are the greater depth of the surface soil. The color as an average is more intense and extends to a greater depth. The texture is notably lighter.

Miami Silt Loam.

The surface soil of the Miami silt loam to an average depth of 8 to 12 inches is a gray to a brownish gray silt loam; incoherent and mealy, but not granular, and quite deficient in humus. The soil rests upon a gray or yellow silt loam that extends to a depth of 18 to 24 inches. This is likewise mealy, but becomes more granular with depth as the clay content increases. This layer resembles the soil very closely in texture, but is readily distinguished by its lighter color. The average depth of the silt is 17 inches; the soil is composed chiefly of silt and very fine sand, with but a small percentage of the grades above fine sand. Limited quantities of cherty gravel and stone fragments occur on the surface and through the soil section, but such material is not frequent except on the steeper slopes, and on the crest of sharp ridges or mounds. The organic matter content is everywhere markedly low, perhaps averaging less than two per cent. This deficiency of humus is evidenced by its characteristic color. It gives a grayish or whitish color when dry, but changes to a dull gray or light brown when slightly moistened. Iron concretions are found on the surface and disseminated throughout the soil and subsoil in local areas of small extent. The soil is very compact but friable and porous when in good tilth.

The subsoil is a yellowish brown, compacted silty clay loam, grading at a depth of about three feet into a more friable clay loam. The content of gravel and sand usually increases to a depth of four to five feet, so that the substratum is often a sandy clay. The average thickness of the compact, dense layer is about 18 inches. Sometimes at a depth of twenty inches a gravelly clay is encountered. In such situations the coarse stony material increases rapidly, until the subsoil becomes quite open and permeable. This condition obtains along the largest stream courses, where the glacial materials have been assorted and rearranged in stratified deposits.

The prevailing subsoil of this type is well oxidized, as is evidenced by the characteristic brownish tint, but gray streaks or mottlings are common. These mottlings are closely associated with the denser and poorly aerated plastic subsoil, and when dry it may become so hard as to offer considerable resistance to the penetration of soil auger or implements of tillage. Naturally it is seldom so compact as to prevent a downward movement of excess water; at the same time the layer is so retentive that it acts as a reservoir for the storing of soil moisture.

The material composing the Miami silt loam has been derived from the weathering of the silty mantle that everywhere invests the boulder till to an average depth of 30 inches. The gray color of the soil is a result of leaching and slow accumulation of humus that follows a long continued occupation of a heavy growth of timber, all the type being originally forested with white, red, scarlet and shingle oaks, hickory, sugar maple, and poplar; the dominant species are white oak and hickory. With the exception of a small acreage of woods pasture, the type is now all cultivated.

The topography for the most part is wavy or flowing and sufficiently rolling in places that considerable washing may occur if not properly managed. Near West Lebanon the relief is quite pronounced, consisting of high morainic hills and ridges. North of Independence the type occupies some broad gentle elevations, distinct from the other topographic features of the county. The surface of other portions is interrupted only by pot or kettle-hole-like depressions.

In some places, as east of Independence to the county line and up Kickapoo Creek, the Miami appears to occupy a high terrace, but the soil structure disproves this origin. In Secs. 8, 9 and 4, T. 22, R. 6, the soil is a pale ashy gray silt loam to a depth of 10 to 12 inches, passing abruptly into a gray, heavy silty clay loam, mottled with yellow and iron stains. At about 30 inches the subsoil grades into a grayish or drab, silty clay, containing shale fragments. At about two feet bed rock is encountered. The subsoil seems to be largely residual. This phase is not very productive; it is much in need of lime, drainage and organic matter. The surface features of the type give it good natural drainage. However, more extensive tile systems seem advisable even on the gently rolling areas, to improve its physical condition.

The Miami silt loam occurs in one continuous body, fronting the Wabash River. It extends back from the river to an average distance of five miles; continues up Pine Creek in a broad belt, but does not reach far north of that creek. It extends in narrow strips along the drainage lines, being widest on the west and north side of the valley. A few other isolated bodies occur in the prairie types. The boundary or zone of land that represents the transition of this type and the prairie is not clearly drawn in most places. The topography usually becomes level on approaching the prairie and in some places the change is abrupt, being marked by a low sharp descent to the darker soils. The gray, gravelly till of the prairie may pass under this type for some distance, gradually giving way to the brownish yellow till of the timber section.

In normal seasons, corn will yield from 30 to 40 bushels per acre. Oats usually give less than 40 bushels. Wheat is generally recognized as the crop for this soil, and where good cultural methods are practiced averages of 20 to 35 bushels are obtained. Hay gives from one to two tons per acre. The yields as a whole are lower than the prairie types, but the products are of a superior quality.

The largest per cent. of owners farm their own land on this soil than any other type. The farms are smaller; systematic rotations are practiced, and more live stock is kept than in other sections. Some portions are not so prosperous; this is true only in the region about Possum Run and near Independence.

Organic matter is the first need of this type. It will prevent the soil from running together and improve its moisture holding capacity. Much of the soil is subject to seasonal extremes. The drought of 1914 reduced the average yield of corn in numerous fields to 5 to 10 bushels. Since humus is the limiting factor on the main soils every effort should be made to have a constant supply.

Applications of one to two tons of finely ground limestone are to be recommended, as most of this type shows a pronounced tendency to become acid. The phosphorus supply is known to be low, and should be strengthened by the addition of acid or rock phosphate.

Land values of this type range from $125 to $200 per acre.

The Miami silt loam in Warren County is much deeper than the soil as mapped by the survey in central and eastern Indiana. The average depth of the compact silty clay layer is about 18 inches as compared with 8 to 12 inches in the latter location. The subsoil is also better oxidized and lacks the mottled condition that is so prevalent farther east.

Miami Silt Loam—Flat Phase.

The flat phase of Miami silt loam is not extensively or typically developed in Warren County. It occurs only in few areas large enough. The largest of these is found in Mound Township, and near Green Hill. The topography of this type varies from nearly level to gently undulating, and is less perfectly drained. It is of same origin (weathering of till) as the type.

The surface soil to depth of 8 to 10 inches is gray to brown silt loam underlain to depth of 20 inches by a light gray and mottled heavy silt loam to silty clay loam. This grades into a grayish-yellowish mottled silt clay containing more gravel and sand than above section. The subsoil may be somewhat plastic and sticky but is more friable in the lower depths. Iron concretions are common in both soil and subsoil. The surface soil of the flat phase is nearly identical with that of the type, the separation being based mainly upon the poor drainage conditions and mottled nature of the cold tight subsoil. However, the surface soil usually shows a whitish or leached appearance, especially on the more elevated portions. Frequently where the soil grades into the Clyde silty clay loam the subsoil becomes heavy, it being a drab silty clay highly mottled with iron blotches. The soil in such places is a heavier silt loam containing a larger amount of organic matter than the type.

The topography is so level locally that adequate drainage is quite a problem. However, greater portion of phase has sufficient slope to afford good chance for tile drainage. The soil and subsoil of this phase is very generally acid; this deficiency in lime, coupled with lack of organic matter, has impaired the physical condition of soil to the extent that it has a tendency to run and clod badly. Deep rooting crops, such as red, big English, or sweet clover would assist in loosening up and aerating the dense subsoil. All crop residues and if possible a crop of rye should be turned under occasionally to restore and maintain a good tilth. An application of one-half to one ton of ground limestone per acre is recommended in connection with organic matter for this type.

The flat phase is used for the same crops as the Miami silt loam, but the yields are somewhat better. The improvements on this soil are splendid and the land commands about the same price as Carrington silt loam.

Shelby Silt Loam.

The Shelby silt loam is a rather general type, embracing the soils found in the portions of the uplands that are very hilly and badly eroded, and cannot be used for ordinary cropping purposes very satisfactorily. The separation from the Miami silt loam is based almost entirely on topography. This varies from rolling to broken. On approaching the Wabash River the region is deeply dissected by the larger streams and their tributaries. They often acquire steep or precipitous slopes, sometimes walled in by perpendicular bluffs of sandstone. These bluffs, as well as the Wabash valley escarpment, are often 80 to 150 feet high. The most extensive areas are found along Possum Run, Redwood, Pine, Stony Creek and their tributaries. This soil is shown on the map in narrow bands, paralleling the valleys, or as finger-like projections in the Miami soils.

The surface soil ranges from a brown sandy loam to a yellowish gray silt loam to a depth of 12 inches. The subsoil is a yellowish brown to reddish brown compact silty clay loam to clay. The soil and subsoil have variable amounts of gravel, depending upon the extent of erosion. Running water has been very active in modifying the soil materials since their deposition, and more so since the land has been cleared and put under cultivation. The original silty mantle has been bodily removed from the steeper areas, exposing the underlying yellow silty clay or boulder till.

Included with this type are narrow patches of arable land, but the individual area of tillable fields is generally too small to be shown separately. The steep slopes break abruptly into the level plain which may extend even to the very brink of the slope. In a few instances the slopes cannot be represented on a map of the scale used in the survey. In most cases the width of the boundaries is exaggerated in preference to being omitted, mainly for the purpose of emphasizing their influence on farm values.

In the northeastern part of the county along the river, the Knobstone shales have influenced the topography and to a lesser extent the soils. The surface has eroded into the characteristic knob-like topography. The boulder till is often a grayish or bluish color, much like the color of the shale. In the same region the Mansfield sandstone has profoundly affected the surface configuration. Besides the exposures in the valleys, it is found capping the hills and narrow divides in a few places. A bold outcrop occurs at Black Rock that rises to about 140 feet above the river.

Under ordinary methods of cultivation this type is subject to serious loss from surface washing, and even where untilled there is more or less rapid erosion taking place. Some of the areas should never have been divested of their forest cover. Only a small percentage now possesses a protective covering of trees. In the management of this land, the following methods are at the disposal of the farmer to protect his fields against erosion: (1) Contour or circle plowing, and deep plowing; (2) better rotation, lessening the number of tilled crops and making larger use of fine rooted grasses; (3) actual tile drainage of the slopes, especially laying tile drains in gullies; (4) laying out of the hillside in narrow plow lands at right angles to the slope, cleaning out the dead furrow and leading them into sodded swales; (5) terracing and making side hill ditches where necessary and profitable.

The underlying boulder till is rich in the mineral elements of fertility, so the only problem of fertility is to increase and maintain the organic matter in the soil by the use of both animal and green manure.

This soil is suitable for fruit growing. The general experience with fruit in the county, together with the presence of old, healthy and productive trees on this and similar types, seems to be a safe guide for an extension of fruit production on this soil.

The price asked for this land is from $20 to $125 per acre.

Fox Silt Loam.

The Fox silt loam consists of a brown or grayish brown friable silty loam to a depth of 8 to 18 inches, underlain with a brown gravelly loam, coarse sandy loam, or gravel. The depth of the gravel is quite variable; the average depth is perhaps 18 inches; sometimes it is reached at 12 to 15 inches. On the low mounds or swells the gravel comes to the surface. There are numerous small areas covered with rounded cobble-stones about four to eight inches in diameter. Most of these have been removed and the soil put under cultivation. The surface ordinarily carries quite a bit of whitish and cherty gravel, easily seen strewn over the ploughed ground, but not so noticeable on boring. The surface soil while predominantly a silty loam varies locally to a gravelly loam or gravelly sandy loam. The extent of these types is so limited and so badly mixed that it was impractical to separate them. The color is likewise variable; the best defined areas are much darker than the small bodies which resemble more the uplands. However, in all places there is enough organic matter to darken the surface and make the soil granular.

The Fox silt loam embraces the greater portion of the Warren County terraces. It occurs as a broad level plain along the Wabash some 30 to 75 feet above low water mark. It begins just above Independence and widens out westward until a maximum width of one and one-half miles is attained. It ends almost abruptly at the valley of Kickapoo Creek. It appears again below Williamsport and continues southwest to about a mile below the mouth of Redwood Creek. The average width of the lower terrace known as the Barrens is about one and one-fourth miles. It is clearly defined from the upland by a high bluff line to a point near the Wabash Railroad, where it ascends gradually to the uplands. The terraces above Pine Creek are not very sharply differentiated from the adjoining Miami silt loam. The long gentle slopes of the uplands merge almost imperceptibly into the terraces. Near this boundary the soil is of same character as the uplands, and substratum resembles the boulder till.

The massive beds of gravel and sand composing these terraces are of remarkable thickness. They range in thickness from 75 to 100 or more feet. The supply of gravel is almost inexhaustible.

Two gravel companies operate near Kickapoo. The gravel is largely different kinds of granite rocks, although a high percentage is limestone. It varies in size from fine sand up to stone six inches in diameter, with occasional large boulders.

The high gravel terraces were formed when the river flowed at a much higher level than at present. At the melting of the Wisconsin ice-sheet great floods were formed which were heavily loaded with glacial debris, and it was deposition of this increased supply which built the former broad flood plains. When the ice withdrew and the excessive supply became exhausted, the velocity of the stream began to diminish and finer material was deposited over the gravel forming the veneer of soil.

The surface configuration varies from level to gently undulating. The level areas are found mostly bordering the uplands, while the central and outer portions are more irregular. The most conspicuous inequalities are found by the streams flowing from the uplands.

The lower four to six inches of the soil section is just a shade lighter and perceptibly heavier than the upper 12 to 14 inches in the typical development. There is a limited area just south of Williamsport in Sec. 22, T. 21, R. 8, that has a dark brown soil to a depth of 12 inches underlain with 12 inches of light brown silt loam. The subsoil is a compact brown and gray mottled silty clay loam from 24 to 42 inches. The moisture conditions of this phase are good and yields are larger than the type.

While the prevailing substratum of the type is the unconsolidated deposits of gravel, a few areas rest on rock at a shallow depth. The terrace in Secs. 8, 9 and 4, T. 23, R. 6, is underlain with the Knobstone shale at depths varying from one to three feet and the decayed shale fragments are found in the soil section. The terraces above Independence to the Tippecanoe line are underlain with the above formation, and have profoundly influenced the texture and productiveness. The soil is a pale grayish heavy silt loam to 8 to 12 inches, underlain with a compact gray mottled silty clay loam subsoil that gives way in turn at shallow depths to a shaly substratum. Large boulders are frequent over the surface. The soil in these locations is a poor one and used largely for pasture.

The Fox silt loam is friable and easily reduced to a fine seed bed, but compacts readily after rains or when allowed to remain unstirred any length of time. The greatest problem in the management of this type is the conservation of moisture. It is a greater one than fertility. The soil naturally is fertile, but on account of the subsoil the drainage is excessive and not very productive. This structure in conjunction with the frequent droughts in critical periods of crop production makes it imperative to make best use of the water that falls. This is accomplished by applying the principles of storing water in the soil; (1) the surface should be kept in a condition to catch the rains; (2) it should be cultivated to keep it loose and rough, thus reducing evaporation; (3) the weeds should be kept down so far as possible, both before and after seeding to prevent their use of water. When the gravel is so near the surface it is impossible to store sufficient moisture in such a shallow soil to carry the crop through a long dry spell. As soon as the moisture stored in the soil is exhausted the crop will suffer or die according to the length of the drought, but the above measures would not come amiss.

It is suggested that the small grain stubble be plowed or disked after the removal of the crop to kill weeds and get the surface in condition to hold moisture. Crops which will withstand considerable drought or escape drought by maturing early are recommended.

Live stock as a medium for marketing the crop and to insure an income during unfavorable years is essential to the success of farmers on this type.

The soil is devoted to the crops common to the region. The yields depend entirely upon the rainfall, more especially corn, oats and hay. In a normal year oats yield from 30 to 50 bushels and corn 40 to 60. The latter crop is most uncertain. In the season of 1914, large areas yielded only 5 to 20 bushels. In the past five years the loss on this crop has been enormous. Wheat is the most certain and profitable cereal grown; 10 to 40 bushels are secured. This type is well adapted to blue grass, and a larger acreage should be given over to permanent pasture.

Ground limestone is being used and phosphatic fertilizers are being tried on wheat with varying degrees of success. The greatest need is humus and this should be increased in every conceivable way. The value of the Fox silt loam ranges from $75 to $150 per acre.

Gravelly Phase.

This phase includes the portion of the "Barrens" or terrace from Rock Creek west to Redwood Creek. The separation was deemed necessary on account of the more gravelly and shallow soil of this area as compared with the remainder of the type. The surface configuration is uneven, consisting of two or more well defined terraces or benches.

The surface soil ranges from a grayish brown sandy or gravelly silt loam to loam, to an average depth of 8 to 10 inches, grading into a brownish gravelly loam or gravel that continues to an unknown depth. The content of gravel in the surface is quite noticeable, and far in excess of the amount found on the type. The shallower soil makes it very susceptible to drought, and the yields are somewhat less than secured from the better portions of the type.

This terrace is known as the "Barrens" but was heavily forested at one time.

The improvements are good, and same prices are asked as for the Fox silt loam.

Fox Sandy Loam.

The surface soil of the Fox sandy loam is a gray to light brown medium sandy loam to a depth of 18 to 24 inches, more often the latter depth prevails. The subsoil is a yellowish brown coarse sandy loam to gravelly sandy loam or loam. The substratum consists of stratified beds of gravel and sand. It occupies terraces that are fairly well defined. The largest unbroken area is found three miles southwest of Williamsport. Here it is found adjoining the upland slope. It is somewhat higher than associated Fox silt loam. Its surface is not so regular as the silt loam member, and is frequently interrupted by minor inequalities. It rises from the Fox silt loam in a billowylike ridge, that resembles an accumulation of wind blown material.

The areas along Pine Creek mapped as Fox sandy loam do not occupy as clearly defined terrace positions as the ones mentioned above. The plain is notably above overflow, but the texture and structure is somewhat characteristic of a flood plain. Most of the surface is from 8 to 20 feet above the level of the creek. The largest body along Pine Creek is found at Kramer. Here the soil is quite mixed in texture and structure. It consists for the most part of a brown friable sandy loam or fine sandy loam to a depth of 12 to 15 inches, grading into a brown heavy loam or gravelly loam. The content of gravel varies widely in the 3-foot section. Near the uplands the material may be a silt loam or loam to 8 to 12 inches that passes into a compact gravelly loam or gravel. Nearer the stream channel the soil becomes a gray to brown, medium incoherent sandy loam or sand with but little change in the 3-foot section except the color of the subsoil, which is a shade lighter. This phase is open and loose and may become droughty.

The area in Sec. 33, T. 23, R. 8, is underlain with the Mansfield sandstone. The soil to a depth of 12 inches is a gray sandy loam underlain with a bright yellow or cotton seed meal colored sand or loamy sand that appears to be residual from the underlying formation. It is subject to drought on account of the substratum.

The type as a whole is fairly well supplied with organic matter, as is shown by the characteristic brown color of the soil. The color becomes more pronounced away from the creek. The drainage is good, often excessive, so that in dry seasons the crops suffer from lack of moisture. The areas along the Wabash are subject to this danger, but the Pine Creek bodies have a greater moisture holding capacity.

Most of the type is regularly farmed to the staple farm crops. The soil contains sufficient coarse material to render it open, loose and easily tilled with light equipment. Corn will average about 5 to 40 bushels; oats, 10 to 30 bushels; and wheat less than 15 bushels. Melons of an excellent flavor are produced on the fine sandy loam phase. Alfalfa thrives well. Portions of this type having a loamy subsoil are well adapted to truck crops, and with judicious fertilization and management could be profitably handled in these crops. The type stands in need primarily of more organic matter, which can best be supplied by growing such crops as rye, soy-beans, clover or other legumes. Potassium fertilizers could be applied with profit on some fields.

Fox Gravelly Sandy Loam.

The soil of the Fox gravelly sandy loam consists of a brown medium sandy loam, containing a large quantity of calcareous gravel and coarse sand. The subsoil is a yellowish brown, very gravelly sandy loam. This in turn gives way at a depth of two feet or more to stratified beds of gravel and sand that extend to an undetermined depth. The gravel is often so abundant as to literally cover the surface, and is especially prominent and noticeable after heavy rains, and in cultivated fields where the water has washed away the finer materials. Most of the gravel particles do not exceed one-fourth to one inch in diameter. The interstitial material is fine sand and silt.

The drainage is good to excessive. The soil may be worked under a wide range of moisture conditions and a fine seed bed can be secured. The gravel to a certain extent prevents packing and baking of the soil, and insures better tilth through the growing season with a minimum of cultivation. These same conditions cause the soil to be droughty in years of low rainfall, and so the yields are uncertain; but during seasons of normal rainfall good yields are obtained. Only early maturing crops should ever be grown on this type. Of these, wheat seems to be the most profitable.

In the management of this soil, care should be taken to increase the humus content of the soil. This, together with shallow cultivation, would assist the growing crops to resist droughty conditions.

The Fox gravelly sandy loam occupies terrace levels along Pine Creek and the Wabash River. It is of very limited extent. The most typical body is found in Sec. 4, T. 22, R. 8, along Pine Creek. Other areas are distributed through the Fox silt loam along the Wabash.

Sioux Coarse Sandy Loam.

The surface soil of the Sioux coarse sandy loam is a dark brown or black, rather heavy coarse sandy loam to an average depth of 13 inches. The content of organic matter is relatively high. The subsoil from 12 to 20 inches is a yellowish brown compact coarse sandy loam or light loam in which there is a high percentage of coarse sand and fine gravel. The content of gravel is first noticeable at 20 inches and increases with depth. Below two and one-half feet the substratum is a bed of sand and gravel extending to a great depth. The substratum as exposed in the gravel pits was a mass of gravel and sand some 40 to 60 feet thick, resting upon a shelf of shale. The gravel is of a good quality for road surfacing and railroad ballast. Extensive pits have been worked in this type; the largest pit belongs to the Big Four Railroad. The gravel is largely of igneous origin but perhaps as much as 30 per cent. is limestone.

The terrace rises about 50 feet above the Wabash River. The surface is level to very gently undulating. Its average width is about one-half mile, and is about one and three-fourths miles long, and extends southward into Vermillion County about two miles. It is known locally as Mound Prairie. Its origin is similar to the remainder of the high terraces along the Wabash. It is a remnant of a former flood plain that was formed at the melting of the glacier, below which the river has cut its channel.

The western boundary of this terrace is marked by a distinct bluff line of the rolling uplands. However, it is separated from the upland types by a strip of the Fox silt loam. This border strip has resulted largely from the material washed from the adjoining slopes either by sheet erosion or the intermittent streams that come from the uplands.

The surface soil is remarkably uniform; apparently it is a coarse loam, but carries a high percentage of coarse and medium sand and gravel. These particles seem to be in an advanced stage of disintegration, as they can be readily pulverized between the fingers. On examining the soil in a moist condition, numerous small white particles are seen, which are probably limestone in a state of partial decay. While the amount of coarse material is large, there are sufficient fine interstitial materials, as clay and silt, to produce a structure favorable to the retention of moisture, but the droughtiness results from the subsoil. The soil materials are wonderfully coherent. Areas allowed to remain uncultivated become so compact as to be almost impenetrable with a soil auger and offer considerable resistance to the plow, although when cultivated under proper moisture conditions it is quite friable and easily brought to a good tilth.

Corn, oats, wheat and clover are grown with more or less success on this soil.

Corn probably occupies the greater acreage. The average yield in years of sufficient rainfall is about 40 to 70 bushels. These may go as low as 10 to 20 bushels in years of drought; oats from 30 to 50 bushels, and wheat 12 to 25 bushels. Clover is subject to winter killing, and is not often used.

The moisture conditions in early summer are generally good. Corn makes an early start and does well until tasseling time, when it begins to suffer if the rainfall is short. Of the principal farm crops, wheat seems to be the most satisfactory crop for this soil and should receive more attention. Sweet clover and possibly alfalfa could be made a profitable crop on this type.

The Sioux sandy loam just across the river is devoted to strawberries, raspberries, peaches and market garden crops. These find a ready market at Danville. Truck farming might be profitably undertaken on this area.

None of the Sioux coarse sandy loam can be secured for less than $150 an acre on account of the proximity to Covington.

The prevailing dark color is no doubt due to the prairie condition which existed. It contrasts with the light brown color of the typical Fox soils which were found on the timbered terraces. The State experiment station farm is located on a phase of this type.

GENESEE SILT LOAM.

The Genesee silt loam consists of dark gray or grayish brown to rather dark brown mellow silt loam to a depth of 12 to 42 inches. The soil grades gradually into the slightly heavier and lighter colored subsoil at an average depth of 18 inches. There is but very little change in color with depth, but the texture becomes perceptibly heavier as the clay content increases. The lower section is oftimes a heavy silt loam, grading in places into a brown and gray mottled heavy silty clay loam. The immediate substratum is variable, ranging from pure sand to gravel. Beds of gravel were encountered at a depth of 20 inches in places.

The color of the Genesee silt loam is very uniform. It does not contain a very high percentage of organic matter. At the mouth of some of the larger creeks the soil may be darker in color and more loamy.

The soil varies from a loam, where contiguous to the stream, to a silty clay loam next to the uplands or in local depressions. The Genesee silt loam is the principal bottom land of the Wabash River. It occurs in this area in a strip averaging much less than one-half mile in width with a maximum width of only three-quarters of a mile, with slope toward the river. The surface is mainly level, but may be uneven, due to the presence of overflow channels and sloughs. There may be ridges of sandy material intermingled with this type. The widest variation in texture is near the stream, where the water is more active. This type is subject to periodic inundation. The high waters are most troublesome in early spring; the water ofttimes remains on the surface until as late as the last of April. Also it not infrequently happens that the land overflows after the crop is planted. This was observed in May, 1914. The grown crop is sometimes lost by floods in August or September, but this is rare. The bottoms are so late in drying out in spring that by the time the ground is plowed the danger of floods is past. Otherwise the natural drainage is fair. There are a few depressions that are permanently wet. These are mapped as meadow. The long sloughs cut up the land and retard cultivation. Plowing is begun next the stream and worked toward the upland.

Corn is the only crop grown, and produces large yields of a good quality. Seventy bushels is considered a good average, although averages of 80 bushels are not uncommon. The season of 1914 was unfavorable and the average was less than 50 bushels.

This type is easily tilled and can be easily worked into a fine seed bed. The soil is mellow and friable, but sticky when wet, and has a tendency to clod when plowed too wet.

The matter of clean cultivation is made difficult by the frequent flooding that introduces large quantities of noxious weed seed, such as the wild sweet potatoes, morning glory, and cockle burr.

Farming is upon an uncertain basis, on account of the annual overflow. The small area of the bottoms would hardly seem to justify the outlay for a system of levees or dikes. In the management of this type, no soil treatment is needed except good farming and where the land is subject to annual overflow the rotation of crops is not essential.

Winter crops cannot be grown.

The surface is mostly level but many minor irregularities occur such as always characterize a flood plain.

The Genesee silt loam is developed sometimes in swales bordering the uplands along some of the larger tributaries of the river.

Areas at the foot of the upland are frequently gravelly. Other portions at the mouth of the small ravines are covered with shale fragments from the uplands.

These areas of colluvial wash or alluvial fans, whenever of sufficient extent, are planted in oats or alfalfa.

Genesee Fine Sandy Loam.

The Genesee fine sandy loam consists of a grayish to light brown fine sandy loam to a depth of 12 to 20 inches, containing but little clay and silt and large amounts of medium and coarse sand, underlain with a brownish yellow or brownish gray fine sand loam or loamy fine sand. The loamy material gradually decreases with depth, and at about 24 to 30 inches a clean gray or brown sand is often encountered. No definite line can be seen between soil and subsoil. The latter consists of essentially the same kind of materials but the color usually becomes lighter with depth.

The principal occurrence of the type is along Possum Run, Redwood and Little Pine Creeks. In these places it occurs as strips of overflow on first bottom land. It is also developed in small isolated areas along the Wabash River. In the latter location it exists in low alluvial ridges or natural levees on the bank of the channel. They are formed in times of flood when the river overspreads its plain, and the banks are the site of active deposition, due to the first check of the velocity of the flood waters. The patches are usually narrow and rise a few feet above the associated Genesee silt loam. When developed as a natural levee the sand may be ofttimes of medium texture with but little change in color in the three-foot section.

The surface of the type is quite uneven, especially so along Possum Run and Redwood creeks, consisting of low knolls and ridges and shallow depressions. A few level fields occur, but these are not extensive. A large part of the tract is subject to frequent overflow on account of the high gradient of the streams and narrow valleys. A few such areas are so dissected by the creek and the surface covered with gravel and stones that they are rendered unfit for cultivation.

Most of the soil is well drained and deficient in humus. However, it is naturally fertile and easily cultivated on account of its light, open structure. The lower depths are always moist on account of the permanent water table being near the surface. Some few of the sandier portions suffer in times of drought. It is largely farmed in corn, producing an average yield of about 40 bushels. Melons and sweet potatoes do well. The type also furnishes good blue grass pasture.

WABASH LOAM.

The surface soil of this type ranges from a light fine sandy loam to a silt loam. The soil is prevailingly black to a depth of 8 to 18 inches. The percentage of very fine sand is high. The soil rarely contains much coarse material. Owing to the predominance of organic matter, the surface is inclined to be loose and sometimes fluffy in the lowest spots.

The depth and character of the subsoil is quite variable. It usually consists of a loam or silt. The subsoil is of a dark color or drab, and mottled with yellow and reddish stains to a depth of 24 to 40 inches. This is mixed with grayish brown, or dark plastic clay or a grayish or bluish and yellow mottled sandy loam or sand. The subsoil is often quite plastic below 20 inches, but the content of sand increases rapidly and the heavier material gives way to a mixture of sand, clay and gravel. The gray sand resembles quicksand. The water table is encountered at about three feet.

The Wabash loam is developed in a few scattering areas along the larger drainage lines. The largest bodies occur along Pine Creek, Secs. 6 and 7, T. 22, R. 8, and along Kickapoo Creek, near its debouchure. It occasionally occupies depressions at the base of the valley slope, or the sites of overflow channels or old bayous, now silted up. The area mentioned no doubt represents an abandoned flood plain of Pine Creek formed when it carried a larger volume of water than at present. Subsequent agencies, such as erosion, have added much fine material from the surrounding higher lands.

Drainage is the first requirement of this type. A few areas are undrained on account of the small elevation above the stream, and cannot be freed of their excess of water at the present time. The total extent of these undrained areas is very small. With the dredging and widening of the stream channels, now progressing, they will soon be brought under cultivation. Numerous laterals are needed to lower the water table.

The area at Hygania Springs occupies a crater-like basin joining Pine Creek about one-half mile wide. A few peculiar serpentinelike islands—remnants of uplands—rise much above the level of the basin. The area was originally a swamp that was inundated most of the year, but has been reclaimed by drainage and is now under cultivation, and produces large yields of corn. A few areas furnish good pasture. Timothy and alsike clover might be produced profitably on this soil.

Wabash Sandy Loam.

The Wabash sandy loam to a depth a 12 to 20 inches is a very dark brown or black friable sandy loam, or a loamy sand. The content of organic matter is relatively high, and it imparts a mellow or loamy surface.

The subsoil is quite variable, but consists mainly of a brown or grayish brown sandy loam or loam. Frequently the subsoil may be a brown heavy loam to a silty clay loam, even becoming plastic and gummy in the lower portion of the subsoil; but the latter condition is confined to a few small depressed areas. The three-foot section usually contains coarse sand and gravel, and the immediate substratum may be a bed of gravel.

The Wabash sandy loam occurs as a long strip, bordering Pine Creek from near Rainsville to Kramer. The topographic position is essentially developed as a flood plain. But the larger parts of it are no longer flooded and occur as terraces while the remainder is notably above overflow except in extreme high water. Both positions, together with the lower plain, are included with the type.

This soil is very productive and desirable for a number of crops. Its position assures reasonable protection from flood waters. Its good drainage and its large organic matter content provide a high degree of available fertility. Its loose structure renders it easy of cultivation and retentive of moisture.

The Wabash sandy loam in Warren County is well suited to the production of muskmelons and watermelons. It produces a large muskmelon of a rare and delicious flavor. Quite a large acreage of this type is devoted to the production of melons that meet with a ready market. If marketing facilities would permit, more attention could be profitably given to the production of such superior products.

Alfalfa is easily set and does unusually well on the better drained portions. The short overflows are not liable to do much damage except introduction of weed seed. Corn, oats and wheat yield well.

Allis Stony Loam.

The Allis stony loam embraces a mixture of soils of local origin, developed on the terrace levels of the Wabash River and Pine Creek. Mansfield sandstone forms the substratum, and has contributed largely to the soil material. It is typically developed in an area extending from Williamsport southwest for about two miles. Three other small bodies are mapped along Pine Creek. It has a low agricultural value.

The surface soil ranges from a gray to black fine sandy loam to loam. The color is usually a brownish gray or light brown in the drained areas. In the swales it is light or dark brown, which may extend to a depth of 20 inches or more. The content of organic matter is typically low, and below six to eight inches the soil becomes a light yellow or bright gray sand. In the poorly drained spots the subsoil is a drab or dark colored silty clay, highly mottled with red and yellow blotches. In these places the bed rock is encountered at greater depth, or not at all in the three-foot section.

The surface portion carries a high percentage of angular fragments of a yellowish brown medium grained sandstone, known geologically as Mansfield. It belongs to the Pennsylvanian system of rocks that forms the base of the Coal Measures. A massive outcrop of this formation may be seen at Williamsport where Fall Creek has cut out a ravine over 60 feet in depth in this rock.

The bits of sandstone strewn over the surface are highly ferruginous and have resisted decay. The bodies along Pine Creek are not very stony at the surface, but are underlain at no great depth with bed rock, and so were included in this type.

The area below Williamsport appears to be the remnant of a former terrace. It lies about 8 to 10 feet above the flood plain and from 15 to 20 feet below the adjoining terrace. Material is mostly residual. The former covering of alluvium has doubtless been removed by stream action or erosion.

The surface is uneven, being intermittently wet and dry. The depressions are filled with buttonwood and willows. The drained parts are forested with white oak. The type has no other value than for the pasture it affords.

Meadow.

The first bottom or overflow land along the minor streams and a few areas through the wider bottoms in the county are termed meadow on account of the mixed nature of the soil and the poor drainage conditions. The area of different soil types was so small that it would be next to impossible to separate them. Moreover the alluvium is subject to regular changes by floods so that a given classification might change at any time. The predominating type is a mixed loam of a dark brown or black color. The material varies from a silt loam or silty clay loam, to sandy loam. The heavier and darker areas are to be found in the flat portions, while the wavy or gently undulating areas are lighter in color, and loamier.

The subsoil is mostly mottled drab or brown and grayish loam to silty clay loam, somewhat heavier than the soil. Usually there is no line of separation between the soil and subsoil, the only difference being a perceptibly lighter color in the subsoil.

Frequently the lower subsoil and the underlying substratum is a gray sand or reddish gravel. The gravel is found mostly along the prairie streams.

Most of the alluvial material is of recent origin. Many of the valleys are shallow, narrow, flat, and poorly defined. The blufflike bank that is usually present on either side of the stream is gradualy lost up stream, and the distinction between meadow and the Clyde silty clay loam is arbitrary. In the central part of the county and in the area fronting the Wabash, the streams have cut deep and tortuous courses in an effort to reach the creeks, and formed narrow flood plains. Sometimes at the base of the declivities there is a large accumulation of material that resembles the uplands in color and texture. This represents an accumulation of sediment washed down from above. Some of the valleys are walled in by perpendicular bluffs of sandstone and shale and these have influenced the soils a little either by disintegration or by contributing fragments to the surface.

Most of land classed as meadow is not suitable for cultivation on account of poor drainage and frequent overflow, but does furnish good blue grass pasture. Some areas are under cultivation but these are largely sandy spots. Corn is the chief crop on such areas and excellent yields are ofttimes secured.

A few irregular areas on the Wabash bottoms that are covered with water for several weeks in the spring, or permanently wet, were mapped as meadow. The soil is a heavy silt loam with a grayish silt loam or silty clay loam subsoil. Such bodies are covered with a dense growth of silver maple and elm.

The actual width of the strips of alluvium or meadow is in most places exaggerated on the map. The position of the stream in such areas is only approximate. The tracts of meadow bordered by the Shelby silt loam are usually of low agricultural value.

Muck.

The classification Muck includes the soil composed largely or almost entirely of organic matter. It has been formed by the accumulation of the remains of various plants, spagnum moss being the principal species. These deposits occurred either under water or in a condition of constant saturation. The first stage of formation is usually peat, in which the vegetable remains are still noticeable, but further advancement gives a very black, powdery organic material with a characteristic greasy feel when moist with the mass of organic materials mixed with varying amounts of mineral matter washed in from the surrounding higher lands. It varies in depth from only a few inches on the margin to more than three feet in the center. There is but little change in color with depth, but in the lower sections the vegetable fibres become more noticeable. The muck rests upon bluish black, stiff plastic clay which grades into a lighter colored or grayish mottled clay. The subsoil is highly streaked with iron stains. Some areas are underlain with coarse sand and less frequently an impure marl. The water table is encountered at less than three feet.

The smaller areas of muck indicated on the map are usually but a few inches deep, and generally have enough soil material mixed with it to give rise to a loam type. In other spots where the muck is in an advanced stage of decomposition it consists of a loose, chaffy surface and might also be classed as a loam. A small area of peat in Sec. 2, T. 20 and 21, R. 7, was included with the muck type.

The muck areas occur in the shallow basins or depressions which at a former time were lakes and ponds, gradually being filled with remains of aquatic vegetation. The largest area is located in the northeastern part of the county and covers about one section of land. Not much of the body is under cultivation at present, owing to its inadequate drainage. A drainage way was formerly established, but the settling of the muck after cultivation destroyed the power of the ditch. The area was resurveyed this year and the ditches will be lowered and drainage re-established. A few small patches occur as isolated patches in the prairie; most of these are under cultivation.

Large yields of corn, oats, timothy and alsike clover are secured in dry years. The greatest problem in handling muck is establishing good drainage, either by removing the surface water or lowering the water table. Another troublesome factor is the early and late frost. The use of a heavy roller to firm the seed bed is very effective in preventing damage by late frosts.

Muck soils have shown marked response to the use of potassium fertilizers. Coarse barnyard manure and lime are also to be recommended.

Boulder Areas.

Boulder areas embrace a few areas of limited extent on the terraces near Independence. The most typical area occurs in Sec. 23, T. 22, R. 7. The surface is so thickly covered with granite boulders that will average less than three feet in diameter as to be unfit for cultivation, and perhaps so numerous that the expense of removing them would be prohibitive. The soil occupied by these boulders is the Fox silt loam.

They were doubtless transported by the glacier to the position where they now rest, as the terrace seems to be one of planation.

The boulder areas afford fair pasture land.

Boulders are more numerous on the opposite side of the river at a similar elevation.

SUMMARY.

Warren County is situated on the western boundary of Indiana, north of the center of the State. It has an approximate area of 364 square miles or 232,960 acres.

The topography varies from level to undulating, becoming broken along the area fronting the Wabash River, and in a belt extending along the course of Pine Creek. The timbered or gray lands reach back from the river to an average distance of five miles. The average elevation above sea level is about 700 feet.

The drainage is made simple by the Wabash River on the east. All the principal tributaries flow southeastward to join the Wabash.

Artificial drainage has reclaimed all the former waterlogged areas of the prairie.

The first active settlement in the county was made in 1824. The county was organized in 1827. Williamsport is the chief town and county seat, and has a population of about 1,200.

The transportation facilities are ample. Six railroads cross the county. The county has a total of 336 miles of improved public roads.

The population of the county, according to the last census, is 10,899. It is wholly rural, and the occupations are entirely agricultural. The improvements are of the best type, and the inhabitants are enjoying prosperity, which is due largely to the fertile soils.

The climate is similar to that of the general region, which is characterized by wide variations. The average rainfall is 38 inches. The length of the average growing season is about five and one-half months.

The cultural methods and practices apply solely to grain farming. Corn and oats are grown almost exclusively on the prairie soils. More wheat and clover are grown on the gray or "clay" soils. Corn will average about 40 bushels per acre; oats, 30 bushels; wheat, 15 bushels. Clover failures have been quite general in past five years.

The general plan suggested for improving most of the soil types is better drainage, and to grow more leguminous crops in suitable rotation, with the aid of ground limestone and acid or rock phosphate, and to maintain more live stock.

Warren County is an area of large holdings. The average size farm is 161.4 acres. A complex system of tenantry prevails, 41.6 per cent. of farmers being renters; perhaps three-fourths of the prairie farms are rented.

Hog raising is the principal live stock industry. No attention is given dairying, and comparatively few cattle are fed.

The soils are derived largely from the unconsolidated deposits of the early Wisconsin glaciation. The main soil forming material is a silty or loess-like layer averaging 30 inches in thickness. The alluvial soils are quite extensive. Fifteen (15) types and three phases have been mapped and described.

The Carrington silt loam is the most extensive and important soil. It embraces the undulating prairie soils that are naturally well surface drained, and are brown in color. The phosphorus and lime supply of the soil is known to be low.

The Clyde silty clay loam represents the lower lying, heavier soils of the flat prairie. The type was formed under swampy conditions. Under artificial drainage it is a strong corn and oat soil.

The Miami silt loam occupies the timbered or gray colored lands. The surface ranges from undulating to rolling. It is best adapted to wheat and grass. The nitrogen, phosphorus and lime content is low. A small area of this soil has a level or flat topography and was separated as the flat phase.

Bordering the streams there is a zone of badly eroded or hilly land that was mapped as Shelby silt loam. This soil has a low agricultural value and cannot be used for ordinary cropping purposes satisfactorily.

The Fox silt loam includes most of the soils on the high terraces along the Wabash River. It consists of about 18 inches of a brown silty loam, overlying a massive bed of gravel. Only early maturing crops should ever be grown and more live stock kept as a medium for marketing the crops and to insure an income in unfavorable years. The gravelly phase has a shallower soil.

The Fox sandy loam and gravelly sandy loam are similar soils of small extent. They are inclined to be droughty.

The Sioux coarse sandy loam is a black colored terrace soil which was developed under prairie conditions. Corn, oats and wheat are grown, with varying success.

The Allis stony loam is a derivative soil on the terraces, of little agricultural value.

The Genesee silt loam embraces most of the alluvium or first bottom lands. Corn is the only crop grown and yields high. The sandy loam member is an associated type of limited area.

The Wabash sandy loam and loam occur as first bottoms along Pine and Kickapoo Creeks. The soil is dark brown or black in color, and very productive when well drained. Corn does well on the loam type while the sandy loam produces a superior product of muskmelons and watermelons.

Meadow includes the narrow strips of alluvial land along the minor drainage ways, and in a few areas through the wider bottoms. The soil is a mixed brown loam, generally poorly drained.

Muck is an organic soil. The boulder areas embrace a few small fields of stony land.

Warren County soils are still comparatively fertile and crops produced in favorable years are yet large, but sufficient evidence is at hand to show that profitable yields of certain crops are not being produced either because of the deficiency of certain necessary elements or because of the lack of proper physical conditions. As a whole the soils are among the most fertile in the State, but the methods of farming are the most destructive. The farmers of the prairie have relied too much on their rich soils and have been backward in realizing the benefits and possibilities of scientific methods. The present practices seem to be leading headlong into ruin. Maximum crops may be obtained indefinitely if proper methods are instituted at once.

Geology of the Bloomington Quadrangle.

Field Work and Report by J. W. BEEDE.

EDWARD BARRETT, State Geologist.

During the past two summers the stratigraphy of the Bloomington Quadrangle was worked out, together with suggestions regarding the utilization of the waste limestone of the quarry belt.

A number of persons were associated with the writer in this work, whose names are given below.*

Many of the characters of the rocks have been described in previous reports and no effort will be made here to reprint them. The object has been to see them more in the large, and to map them in detail. Space forbids any historical treatment, which would necessarily be rather long.

It is impossible to finally correlate the formations with the type section of the Mississippi River, since that section is being critically revised and correlation at present would add confusion later.

THE ROCKS AND THEIR ECONOMIC VALUE.

The position of the outcrop of the rocks is shown on the accompanying map, which also shows their thickness and the manner in which the different formations rest one upon another. The lowest rocks are found in the valleys on the east side of the map and the highest ones on the hills on the west side of the map, or, rather, in the southwest part. The lower layers pass under the higher ones to the west, as indicated by the colors on the map, and underlie the entire quadrangle.

The rocks dip a little south of west with an average dip of some 34 feet per mile. The dip varies somewhat from place to place, sometimes being nearly horizontal and again having a dip of as much as 70 feet to the mile for a short distance. What warping has taken place has produced monoclines, or steps, rather than arches or anticlines and sags, or synclines, and these steps are low and indistinct.

One condition in the western part of the quadrangle has caused considerable trouble in mapping. The harder rocks are located in

*Harry Warren Wood, Hal P. Bybee, C. A. Malott, Thomas F. Jackson, and G. C. Mance the valleys and bluffs while the soft shales form the tops of the hills. The result is that the highlands are rounded and the shales of the Pennslyvanian, or Coal Measure rocks, which look much like that of the Chester, have been washed or slumped down over the latter to such an extent that it is hard to form an accurate idea of the extent of the beds or the age of some of those that are occasionally exposed. This same condition is also responsible for the almost total absence of exposures save where soil wash has reached bed-rock. The soft material lies at the angle of repose of slump and creep under a cover of vegetation. Where this is removed and the ground neglected, the soil is quickly washed away.

Riverside Sandstone.—The "Knobstone" in the vicinity of Bloomington is, according to Newsom,* 50 feet thick. The lower part of the formation is shale and the upper part is a sandstone. The lower part of the shales were described by Borden as the New Providence shales.† (The town of New Providence is now known as Borden.) The sandstone has been called the Riverside sandstone from the outcrop where it is quarried at Riverside, Warren County.** Only the Riverside sandstone outcrops in the Bloomington Quadrangle.

It is a fine-grained sandstone cemented with clay, an argillaceous silicilutyte. On account of its toughness and elasticity it is nearly free from joints and bedding planes, both of which are usually effectively closed on account of the clay content of the rock. The largest sand grains of specimen sectioned were from .02 to .05 mm. in the longer diameter. From this size they grade down to mere points under moderately high magnification. On account of the fineness of the sand grains and the clay cement the formation is remarkably free from water. It will absorb water but will not transmit it, and as a result, wells in the formation are usually dry, or, if deep, contain a very small amount of salty water, so that where this formation is the surface rock of a region, the inhabitants have to rely upon cisterns. There are, of course, no springs of consequence in this formation. The color of the rock is blue or bluish gray, weathering light to rusty-brown.

Locally there are rather large lenses of limestone, as at Stevens Creek, five miles east of Bloomington, where the maximum thickness is about 35 feet, and of clay shale, as found in the cuts at the Leary and Chitwood places on the Illinois Central Railroad

*Ind. Dept. Geol. Nat. Res., 26th Ann. Rept., p. 263, 1901.
†Geol. Surv. Ind., 5th Ann. Rep., p. 161, 1873.
**Hopkins, Ind. Dept. Geol. Nat. Res., 20th Ann. Rep., p. 317, 1895.

northeast of Bloomington, included in the sandstone. This clay shale bed is somewhat smaller in size than the limestone lens at Stevens Creek. Neither is on the Bloomington Quadrangle, and so far as known, only sandstone occurs upon it.

Whether this sandstone is referred to as a sandstone or a shale about Bloomington depends upon the nature of the exposure. In

A.

A. Grout pile (discarded stone) in the Clear Creek District.

outcrops well exposed to the sun's rays the stone weathers to a very massive sandstone, usually with some white efflorescence upon it. Where the sun does not reach the surface of the stone effectively and the stone is continually moist, it shatters on weathering and has the appearance of shale, unless the debris is washed away as fast as formed by some stream at the base of the exposure. As is pointed out by Newsom in the article cited above, the Riverside sandstone weathers chiefly by exfoliation. One not accustomed to observing such things would regard many exposures as demonstrating nearly vertical bedding on account of the extent of exfoliation somewhat normal to the bedding planes; but the bedding planes are apparent to the careful observer.

An example of the peculiarities of weathering was furnished in the cut at the west end of the Unionville tunnel on the Illinois

B.

EXPLANATION OF PLATE B.

B. Sharp synclinal fold in Chester shale and sandstone. The surface of the sandstone bed forms the side of the cut. The fold is caused by the development of a sink beneath the beds. This feature renders almost useless much of the otherwise valuable shale resting on the Mitchell limestone.

Central Railroad, northeast of Bloomington. On the north side of the cut the sandstone retained its normal appearance for a few years, while the same on the south side of the cut where the sun's rays could not reach it quickly took on the appearance of shale, which it still possesses. In any excavation which penetrates the rock for a few feet the "shale" quickly changes to a very tough sandstone that is very difficult to dig or blast.

The Outcrop.—The main outcrop of the formation is along the east side of the Quadrangle. The greatest thickness exposed is in the northeast corner, where there are 200 feet of it to be found between the creek bed and the tops of the bluffs of Muddy Fork, and its tributary ravines. The top of the outcrop here is about 800 feet above sea level. There are high bluffs of the Riverside sandstone along Bean Blossom, Stouts and Griffys creeks, and a thin outcrop along Jacksons Creek south of Bloomington, forming a part of a large inlier of the formation. The remaining outcrops are confined to the southeast corner of the quadrangle. The highest outcrop of the Knobstone in the extreme southeast corner is 620 feet. From this it will be seen that the southwest dip makes a difference of at least 180 feet in the elevation of the Harrodsburg-Knobstone contact along the eastern edge of the quadrangle, in a distance of sixteen miles.

In the southeastern part of the region the Riverside sandstone occurs in the bluffs of Salt Creek and extends up Clear Creek nearly to Cedar Bluffs and up Little Clear Creek to within three-quarters of a mile of Smithville. From the point south of Harrodsburg east of Clear Creek to the northernmost exposure in Section 4, west of Smithville, there is a rise in elevation of the Harrodsburg-Riverside contact of 100 feet.

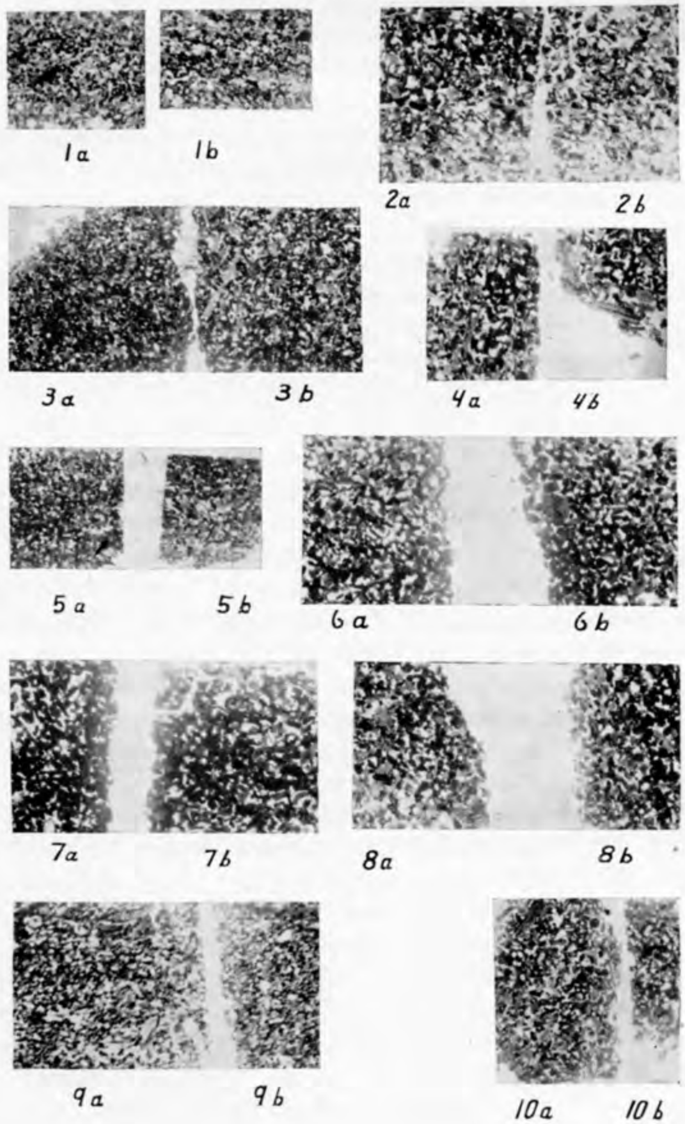
Economic Value.—The Riverside sandstone is at the present time of less economic value than any other formation on the quadrangle. It is of no value for structural purposes because the grain is so fine and the pore spaces so small that capillary attraction retains the water so tenaciously that disintegration from frost action and change of temperature is rapid. The fact that there is considerable clay between the grains, which tends to expand on becoming wet and to contract on drying, also facilitates disintegration, without acting as an effective binder. It makes a poor, acid soil, not suited to cereals, but valuable for strawberries and other small fruit and such vegetables as require an acid, sandy soil. It contains about enough clay to be used for brick and some other products, but its hardness and the difficulty of quarrying and grinding render it of little value for such purposes. Since it is not a water-bearing formation, there are no springs or wells in it, though on account of the deep valleys excavated in it and its imperviousness and the firmness of the unweathered rock, it offers ideal facilities for impounding water for any purpose, such as municipal supply, power, or irrigation.

Harrodsburg Limestone.—The next stratum above the Riverside sandstone and outcropping along its western border is the Harrodsburg limestone described and named by Siebenthal in 1896.* The Harrodsburg limestone is from 70 to 90 feet in thickness in the quadrangle. The lower part is interstratified with shales and some soft sandstones. The lowest limestone was taken as the base of the Harrodsburg. However, since there is a tendency for these lower layers to be lenticular it is not certain that the mapping is absolutely uniform in this respect. In fact it is pretty certain that this is not the case. However, the variation is but a few feet, probably not varying beyond the limits of accuracy of mapping on the present base map.

In a general way the Harrodsburg is a very coarse crinoidal limestone in its lower part, a calcirudyte, becoming finer near the central part where the crinoids and large brachiopods and pelecypods are replaced with Bryozoa. Near the top it assumes very much the character of the Salem limestone or "Bedford oolite" above, a calcarenyte. However, so far as the rocks of this quadrangle are concerned, careful inspection with the lens will differentiate them at once. At the overhead bridge across the Monon track, between Smithville and Saunders, the two are nicely separated by a strong stylolite seam. Much of the way they are separated by a brownish bituminous marl, which locally replaces the base of the oolitic limestone. At other places it is difficult to say within two to five or six feet just where the contact is. The upper part of the Harrodsburg is composed of comminuted bryozoan remains with certain elongate particles whose nature has not yet been made out. These elongate particles seem to be peculiar to the top six to ten or fifteen feet of the rock.

Reef structures occur in the lower third of the Harrodsburg limestone. One very pronounced reef was located on Stouts Creek, almost on the quarter section line east of the center of Section 19. Extensive quarrying has now passed beyond and removed the little that was left of it. Another is found a few rods northwest of the center of Section 1, northeast of Elletsville. The creek has undercut to a considerable extent at this place, the structureless character of the reef supporting the large undercut. All around the reef the rock is very thin bedded and highly jointed. There is another reef just a half mile north of the first one on Stouts Creek. It also supports a great undercut, this time in the side of the bluff above the reach of the creek. This undercut cave has been a human habitation.

*Ind. Dept. Geol. Nat. Res., 21st Ann. Rep., p. 296, 1896.


1a
1b
2a
2b
3a
3b
4a
4b
5a
5b
6a
6b
7a
7b
8a
8b
9a
9b
10a
10b

EXPLANATION OF PLATE D.

Figs. 1a, 1b. Horizontal and vertical sections of stone from the Bloomington Bedford Stone Co. Magnified 2½ diameters.

Figs. 2a and 2b. Horizontal and vertical sections of stone from the Crescent Stone Company's quarry. Magnified 2½ diameters. Cracks in 2b due to breaking section in grinding.

Figs. 3a, 3b. Horizontal and vertical section of stone from the Star Quarry. Magnified 2½ diameters.

Figs. 4a, 4b. Horizontal and vertical sections of stone from Hunter Bros.' Quarry. Magnified 2½ diameters. Crack in 4b due to grinding of section.

Figs. 5a, 5b. Horizontal and vertical sections of stone from Johnson's Quarry. Magnified 2½ diameters.

Figs. 6a, 6b. Horizontal and vertical sections of P. M. & B. blue stone. Magnified 2½ diameters.

Figs. 7a, 7b. Horizontal and vertical sections of P. M. & B. buff stone. Magnified 2½ diameters. Crack in 7b due to grinding.

Figs. 8a, 8b. Horizontal and vertical sections of National buff stone. Magnified 2½ diameters.

Figs. 9a, 9b. Horizontal and vertical sections of Indiana Quarries Co.'s stone. Buff. Magnified 2½ diameters.

Figs. 10a, 10b. Horizontal and vertical sections of Dark Hollow stone. Magnified 2½ diameters.

Along the base of the Harrodsburg limestone is a zone filled to a greater or less extent with geodes. This zone is frequently fifteen or more feet in thickness and extends down into the Riverside sandstone for a distance of five to ten or more feet. Those in the sandstone are usually much smaller than the ones in the limestone. Where the exposures are obscured the approximate line of contact can be made out within ten or fifteen feet by the geode deposits if sufficient judgment is used in determining the extent to which the geodes have worked down the hill.

The type section of the Harrodsburg limestone as published by Siebenthal is given below, together with a detailed section from north of Harrodsburg from which an extensive suite of fossils was collected.

THE TYPE SECTION OF THE HARRODSBURG LIMESTONE SOUTH OF HARRODSBURG, INDIANA.

C. E. Siebenthal.*

	Ft.	In.
Massive fossiliferous limestone	6	0
Gray heavy-bedded limestone	16	0
Blue argillaceous shale	2	0
Limestone	0	4
Chert	0	3
Heavy-bedded blue to gray crystalline limestone	6	0
Yellow calcareous shale with geodes	1	3
Fine, heavy-bedded blue crystalline limestone	11	0
Flaggy limestone	1	0
Gray argillaceous limestone	0	10
Calcareo-argillaceous shale with bands of limestone and some goedes	18	0
Heavy limestone, weathering shaly	3	0
Calcareous shale in bed of creek	?	?
	65	8

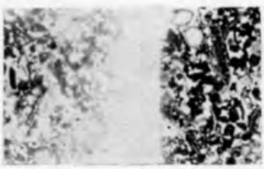
Commenting on this section, Siebenthal says: "The Harrodsburg limestone varies from 60 to 90 feet in thickness. * * *

"The 'beds of passage' from the Knobstone to the Harrodsburg limestone contain great numbers of geodes, or, as more familiarly termed, 'mutton heads', ranging from the size of a pea up to 18 or 24 inches in diameter. The geodes are confined to the lower members of the Harrodsburg, though a few are scattered through the Knobstone."

*Twenty-first Ann. Rep. Ind. Dept. Geol. Nat. Res., p. 297, 1896.

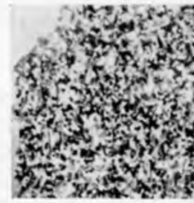
HARRODSBURG SECTION.

From first ravine on railroad on west side of point north of bridge north of Harrodsburg	1.40	0
27. Base of Salem limestone in the road.		
26. About fifteen feet of very irregular textured buff and blue limestone, quite fossiliferous in places	15±	0
25. Hard fine-grained limestone, weathering somewhat; somewhat shaly in places, cross-bedded, extending to the road, 15 or 20 feet	20	0
24. Thin-bedded, hard, fine-grained limestone, upper one rough on top	5±	0
23. Hard blue, fine-grained crinoidal limestone (fine grained roe crinoidal limestone) weathering very rough on top	5	0
22. Buff fine grained limestone	1	0
21. Hard fossiliferous limestone	0	6
20. Hard green limestone, shaly above, geodes	4	6
19. Hard, fine-grained blue limestone in 2 layers with rounded and angular chert concretions and large geodes	1	6
18. Hard blue fossiliferous limestone	0	6
17. Blue cherty limestone, somewhat geodiferous	1	0
16. Hard green shales	1	4
15. Hard, blue, crinoidal limestone with chert	0	7
14. Like number 15	1	3
13. Mostly unseen except at the top which is thin, blue limestone weathering buff	5	0
12. Thin limestone like No. 11, but with large *Productus* in the upper part. Occasional geodes	5	0
11. Several layers of hard blue to greenish crinoid-limestone	5	0
10. Hard, slabby, greenish to gray limestone containing abundant *Spirifer*, *Derbya*, *Aviculopecten*, etc. Third fossiliferous horizon	2±	0
9. Limestone like No. 8, but with thin layer of chert in lower part	7	0
8. Buff to blue, very fine-grained arenaceous limestone or calcareous sandstone with small goedes and occasional long crinoid stems	2±	0
7. Like No. 8	4	0
6. Greenish, coarse, hard, extremely fossiliferous limestone with abundant *Spirifer*, etc. Second fossil horizon	1	0
5. Mostly covered up, some buff shaly limestones, no fossils	4±	0
4. Two layers of hard, coarse, greenish-gray, very fossiliferous limestone, *Spirifer* and *Productus* in abundance	1	3
3. Hard crinoidal limestone, green to blue	2	4
2. Similar to No. 3	2	2
1. Massive blue sandstone, very fine-grained	2	6
Total thickness of section, about	100	0
Total thickness of the Harrodsburg limestone, about	95	3



11a 11b

12



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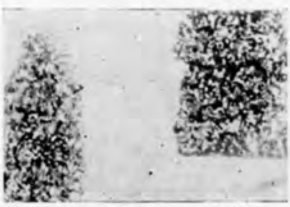
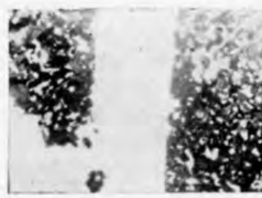
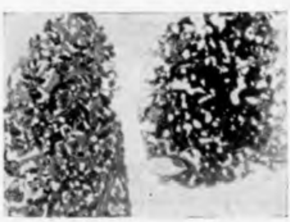


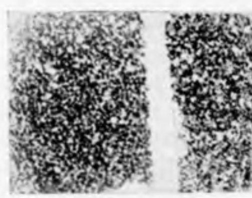
14a 14b



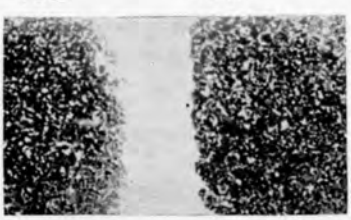
15a 15b



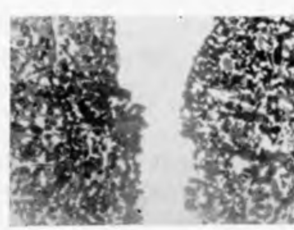
16a 16b



17a 17b



19a 19b



18a 18b

Explanation of Plate E.

Figs. 11a, 11b. Horizontal and vertical sections of stone from the United Indiana Quarries. Magnified 2½ diameters.

Fig. 12. National buff stone. Magnified 2½ diameters.

Fig. 13. Horizontal and vertical sections of Indiana Quarries Company's No. 1 blue stone. Magnified 2½ diameters.

Figs. 14a, 14b. Horizontal and vertical sections of Indiana Quarries Company's No. 1 blue stone. Magnified 2½ diameters.

Figs. 15a, 15b. Horizontal and vertical sections of Consolidated Company's stone. Magnified 2½ diameters.

Figs. 16a, 16b. Horizontal and vertical sections of Consolidated Company's stone. Magnified 2½ diameters.

Figs. 17a, 17b. Horizontal and vertical sections of Perry Stone Company's stone. Magnified 2½ diameters.

Figs. 18a, 18b. Horizontal and vertical sections of National Stone Company's quarry run. Magnified 2½ diameters.

Figs. 19a, 19b. Horizontal and vertical sections of Perry Stone Company's stone. Magnified 2½ diameters.

There is not a specimen of limestone figured in this series that is not to be sold as A1 stone. There is some variation of the grain, as can readily be seen. However, there are other factors to be considered than mere fineness of grain. Neither the strength of the stone nor its durability are necessarily proportional to the fineness of grain. Finer or coarser, all the stone shown here is first class.

The horizontal and vertical sections shown an absence of fine beddings or lamination even in the microscopic structure.

Numbers 1 and 2 of this section belong to the Riverside sandstone, the remainder are classed with the Harrodsburg limestone.

ROCKY BRANCH SECTION.

19.	Covered to Salem limestone, about	...	..
18.	Massive, buff, fine-grained limestone	2	6
17.	Covered	7	4
16.	Hard limestone, lower part filled with bryozoa, thin bedded	17	6
15.	Marl filled with bryozoa	...	6
14.	Limestone with bryozoa	...	6
13.	Unexposed	9	2
12.	Laminated limestone, hard, coarse, fossiliferous, in four layers	7	7
11.	Unexposed	3	10
10.	Laminated limestone	3	4
9.	Blue shale	2	0
8.	Sandstone, very fine grained, calcareous streaks	2	1
7.	Unexposed	2	11
6.	Coarse-grained fossiliferous limestone weathering laminated.	1	2
5.	Fine grained blue sandstone	1	10
4.	Unexposed	1	0
3.	Coarse grained limestone with large brachiopods	2	0
2.	Shale	1	9
1.	Fine grained blue sandstone weathering greenish to rust-brown. Limestone streaks in the top together with geodes.	26	3

Numbers 1 and 2 of this section belong with the Riverside sandstone and the remainder are classed with the Harrodsburg limestone. This and the previous section are twelve miles apart and show the extent of the general variations of the limestone in that distance.

If space permitted, local sections could be introduced showing the lenticular character of the three or four basal beds of the formation, and there would also be some local difference in the fauna, but nothing, at present known, would lead to a modification of the present classification or boundary of the formations.

The Outcrop.—The outcrop of this formation is much more extensive and irregular in form than that of the previous formation, the Riverside sandstone. This is because all the larger streams and their branches on the eastern third of the quadrangle have either cut into it or through it. All the tributaries of Salt Creek and all those of Bean Blossom Creek, except Jacks Defeat Creek, cut into the formation within the boundary of the quadrangle. The outcrop is also made more irregular by the fact that the divides between some of these streams retain irregular shaped masses of the higher formations over considerable areas.

Economic Value.—The Harrodsburg limestone makes a moderately good road metal if the lower half or two-thirds is used. The upper part is too soft to stand the rather heavy traffic to which many of the main roads of the region are subjected. The lower part is rather siliceous for the best grade of lime, and the stone is too coarse and thin-bedded to be of much value as a building material. However, it is available for good stone fences, and for rough work around the farm. If strong stone fences were built along the sags at the sides of fields and across small bottoms, leaving ample opportunity for flood water to get through in the latter case, they would be of great value in retaining the soil and preventing its washing away. An example of the value of this kind of treatment is to be seen on Rocky Banch, three-fourths of a mile north of the city limits of Bloomington. These walls really are terraces and are comparable, in a way, to those constructed in Europe and Asia for the purpose of retaining the soil. In this case they would also play the part of permanent fences, if properly constructed. When these fences are built across low places in the fields, the soil in a few years accumulates to a point nearly level with the top of the wall. It will not accumulate higher. This can then be put back on the steeper parts of the field from which it was washed and which are painfully evident in practically all the fields of the southern Indiana region.

The Harrodsburg limestone is of some importance as a water-bearing stratum. The rock is rather closely jointed and thin-bedded, which contributes to the ease with which water is allowed to flow through it, and furnishes holding capacity for ground water. As a result, wells of sufficient flow for domestic use are possible, and springs of small capacity, but enough for household purposes, are not rare. Seeps occur all along the contact of the Harrodsburg with the Riverside sandstone, and it is here that the springs occur. There is another line of springs near the base of the more massive part of the upper Harrodsburg limestone, where the streams have cut their valleys sufficiently deep in the rock. This water is derived from the joint and percolation flow of the overlying Salem or Bedford limestone which comes to the surface when the less porous part of the Harrodsburg is reached.

Salem Limestone.—(The trade names of this limestone are, Bedford Oolitic Limestone, and Indiana Oolite.) In dealing with the economic phases of this limestone, the term Bedford limestone will be used. It is the proper trade term, and Indiana Oolite is also applicable as a trade term, meaning precisely the same layer of rock as the Bedford Oolitic limestone.

Since much of the descriptive matter regarding the Bedford Oolitic limestone was published by Hopkins and Siebenthal in the Twenty-first Annual Report of this Department and copied with additional notes by R. S. Blatchley in the Thirty-second Annual Report, it will not be repeated here. Most of the changes in the quarry operations since the local maps of the Thirty-second Report were published are of minor importance, and they have not been redrawn. The method of deposition and the discussion of the grain of the stone, with photographic reproduction of thin sections, is given and the question of utilization of waste is covered by Mr. Mance.

The work on the Bedford Oolitic limestone in this vicinity has thrown considerable light on the manner in which the stone was laid down and, too, the probable quantity of the highest grade of stone available. There is frequently associated with the stone of this region a bituminous marl, usually with rank odor, often very finely sandy, and varying from a dirty brown or almost black to buff in color. The usual color is a dirty brown. It is bedded much like fine shale but behaved like an impure limestone in the creek beds, but more like a shale in dryer exposures. Sometimes this marl is found below the oolite and sometimes above it, while occasionally it is found both below and above it in the same exposure. This is the case in the northeast quarter of Section 30 and the southeast quarter of Section 19, just northwest of Harrodsburg. In the road at the crossing of the creek the oolite is pinched out and this marl, or "bastard", of the quarrymen, occupies the whole interval between the Harrodsburg limestone below and the Mitchell limestone above. There are several feet of oolite to be seen on the south side of the creek in the bluff by the side of the road, but none at all on the north side of the creek. Going up the creek, about two feet of oolite may be found on the south side in one place, but the continuous exposure in the creek bed does not reveal a bit of it. A half mile north of this there are nearly thirty-five feet of the oolite to be seen in the hill. A considerable amount of this "bastard" also continues south past Harrodsburg to the south edge of the quadrangle. A similar condition occurs at Lanesville, in Harrison County, but the fine material which replaces the oolite is more sandy than that found about here. Similar conditions are known to occur in other parts of southern Indiana. In other words, the Bedford Oolitic limestone is a series of great lenses imbedded in finer, more or less calcareous material, the interval of space between the over and undrlying rocks being maintained by the finer material. Occasionally, as northwest of Victor, parts of it are interbedded with the marl. The finer material occupying the place of the oolite where the latter is missing is very evenly and finely stratified. The oolite is highly cross-bedded and composed of fair-sized, even grains, more or less comminuted and the interspaces nearly filled with crystalline calcite. The rock flour and decaying organic matter seem to have been all removed from most of the rock by the waves and undertow and other currents and deposited in the quieter water nearby. Where this has not been complete and locally this fine rock flour has been deposited in thin layers, the thin layers are dense and firm and weather to a lighter color than the rest of the rock, and form what the quarrymen call "hard streaks" which are a detriment to the stone. The grain of the rock, its universal cross-bedding, the occurrence of the great lenses of granular rock imbedded in the finer rock flour, all seem to be in harmony with this conclusion, as well as the suggestion that the material was deposited fairly rapidly. It is to be regretted that there are no drill cores or accurately kept logs with samples from the deep wells west of the outcrop to show the condition of the rocks occupying the interval of the oolitic limestone toward the center of the basin.

From the fact that the oolitic limestone bed, as pointed out above is lenticular; from the fact that much of the stone cannot be quarried economically because of the abundance of joints or mud seams; from the fact that some of the stone locally contains hard streaks and stylolites, so frequent as to prevent its use as first-class stone; from the fact that some of the stone is too coarse or too poorly cemented, the conclusion of the observations of this region, and in fact, the whole Indiana region, is that the quantity of No. 1 stone available is limited. While there are great quantities of this grade of stone yet to be quarried, nevertheless the time has arrived when the grading of the stone should be given careful attention. The selection, through close competition, of the highest possible grades of stone as No. 1, has reached such a state of over-grading that a readjustment, and normal, uniform grading of the product is necessary. In many instances no one but an expert can tell the difference between the best No. 1 stone and the next grade, and when properly selected, the next grade is as strong, as durable, and as good as the highest No. 1 available. In this connection it should be pointed out that durability of the stone is not necessarily connected with the fineness of the grain. Indeed, frequently the reverse is the case. The durability of the stone, for many purposes, rests rather upon the size of the pores than the percentage of pore space. In very fine-grained dense rocks, the capillary attraction holds the water and prevents its escape so that the rock is much more easily damaged by frost than the stone with coarser pores, where the water has free avenues of escape, so that rarely if ever will the pores be more than nine-tenths full on freezing. Water expands about one-tenth of its volume upon freezing, and with a force sufficient to raise a column of a mile in height the distance of a tenth of the depth of water in a cylinder sufficiently strong to hold it, the column of ice being of the same diameter as the cylinder. This is why green stone, or any stone that is thoroughly saturated, is ruined by freezing through.

As is pointed out by Mance in the following discussion, the lowest course of stone in a building may be of the finest grade and the remainder of the building above the base be of a slightly lower grade, so far as size and uniformity of the individual grains is concerned, and even a stoneman could not tell the difference from the walk, and at the same time the upper courses will be quite as strong and durable as the base.

The Outcrop.—Except in the Clear Creek District, the outcrop of the Bedford Oolitic limestone is always found on the west side of the outcrop of the Harrodsburg limestone. In the Clear Creek District, east of the creek, the oolite is surrounded by the Harrodsburg limestone. The details of the outcrop are shown upon the map. It has not been feasible to show where the "bastard" occurs, or to indicate the grade of the stone, since this cannot be done from surface inspection.

The Mitchell Limestone.—Under this head authors have grouped a series of limestones of different texture, appearance, and geologic age. Difficulty has been found in separating the lithologic formation into its integral parts. One feature that adds very greatly to the difficulty is the fact that the most of the formation forms a flat plateau or plain rather deeply buried in the residual clay of its own decomposition, the surface water being carried away by subterranean drainage. Rather close study in the Bloomington Quadrangle reveals characteristics that promise to serve as guides in the accurate differentiation of these limestones. The texture of the stone varies from the exceedingly fine-grained lithographic limestone with occasional fossils and calcite crystals, Calcilutyte, through a typical oolite, to brecciated limestone with the fragments varying from a foot or more in diameter down to the finest grains, a calcirudyte, and ending up with edgewise conglomerate, sometimes 40 or 50 feet thick. There are also shale and sandstone beds in it. In spite of all these differences of faces there is a striking similarity to the hard brittle limestone usually possessing complete or partial conchoidal fracture.

The bedding planes very often are in the form of stylolites. Indeed stylolites are one of the great characteristics of the formation, as many as 25 having been observed in eight feet of rock. Most of them are very small. However some of them are of large size, single projections having been measured that were fourteen inches in length.

It seems at present that the St. Louis, St. Genevieve and Chester groups are represented in lime, the limestones that have been referred to the Mitchell. Work is under way which, it is hoped, will succeed in differentiating them.

The thickness of the formation is probably a little over 220 feet in the southern end of the quadrangle. No estimate approximating accuracy can be made within the limits of the north end of it.

Some of the details of the stratigraphy of the formation may be outlined briefly as follows: The lower 40 feet, or thereabouts, contains shale beds and marl beds usually a few inches in thickness, sometimes a foot or two. The beds are usually quite thin but some massive ones occur in this lower part. It is near this upper limit of shale beds and massive layers that some of the caves of this region and many of the large springs are found. Above this the limestone is thinner bedded again and is usually lithographic in texture. About 80 feet above the base, toward the south end of the quadrangle there is a bed of shale and marl, sometimes 5 or 10 feet thick. Associated with these are slabs of very fossiliferous limestone. Over this shale and marl bed is more lithographic limestone. Some distance above it is a chert horizon, frequently very fossiliferous, which ranges from three to four inches to a foot or more in thickness. Much of the Mitchell carries chert, but this horizon seems to be a silicious limestone becoming chert on weathering. The blocks are hard and dense on the outside but are very granular and porous within, due to the very partial silicification of the limestone. Near this horizon, perhaps just above it, is a zone varying from an inch to several feet of oolitic limestone with quartz and other sand grains. These sand grains are very perfectly rounded and some are a millimeter or more in diameter. From near this horizon upward most of the stone is oolitic, but hard and usually possessing semi-conchoidal fracture. The grains are true oolite. Near the top is a layer of marly material, sometimes shale and sandstone, from 0 to 10 or 15 feet in thickness. This bed is confined to the region south of the latitude of Whitehall. It is frequently quite fossiliferous, the marly material containing excellently preserved little brachiopods and the sandstone having a more varied fauna. At the lower contact of this layer to the Mitchell is always brecciated or even conglomeratic in a large way. This brecciation seems to be persistent throughout the quadrangle. At the east end of the abandoned tunnel, near Stanford, it is 8 or 10 feet thick and very coarse, mixed with marl or clay, though it does not possess the characteristics of an edgewise conglomerate, such as is to be seen in the gorge of McCormicks Creek, just off the north edge of the quadrangle. It appears to pinch out at the latitude of Whitehall, only the brecciated limestone remaining to mark its place. Above the layer just mentioned are from a few feet to 20 or 22 feet of whitish limestone, frequently oolitic (in the true sense), and fossiliferous, containing *Diaphragmus*, a Chester species of fossils. At Whitehall and northward this layer seems to lay upon the Mitchell limestone without any shale, marl or sandstone between them. Some detailed sections of the formation are given below:

SECTION AT THE WEST END OF THE ABANDONED TUNNEL SOUTHEAST OF OLD STANFORD.

	Feet.	*Inches.*
12. Shales, gray streaked with dark yellow	7	0
11. Limestone, oolitic in upper part, fossils, about	11	0
10. Sandstone, blue-gray, calcareous, fossiliferous, fine-grained. 1 foot to	1	2
9. Shale, blue varying from sandy to marly, fossiliferous. Fossils mostly on south side of cut, more sandy on north-side	1	6
8. Limestone breccia and conglomerate, fragments from microscopic size to a foot or so in diameter, 3 to 6-inch layer of pebble conglomerate on top of it, the pebbles of dark rounded fragments of lithographic limestone of the Mitchell. Sand in matrix of this conglomerate, 3 feet to	5	0
7. Limestone with conchoidal fracture, apparently oolitic	6	0
6. Marly streak about	..	3
5. Limestone, hard, oolitic	10	0

	Feet.	Inches.
4. Limestone, lithographic to roof of tunnel, shows a few sections of fossils, 25 stylolitic bedding planes	8	0
3. Limestone, sandy, thickens from about 4 inches at the west end of the cut to 3 feet near the end of the tunnel. Rocks above rest unconformably upon it	3	0
2. Shale, calcareous, sandy, two inches to	0	4
1. Limestone, somewhat oolitic, hard	3	0
Thickness of section	56	3
Thickness of "upper Mitchell"	49	3

The extent to which the top of the Mitchell has been dissolved away can not be stated, but the distance to the seep representing the location of the next limestone in the Chester seems to be five to ten feet too great, and it is probable that about this amount of the limestone has been removed or is covered by the overlying shales. The layer of brecciated limestone is recognizable over nearly the whole quadrangle, though the shale layer varies in thickness and seems to disappear in the north part of the area studied.

On the east side of the hill, in the excavation there, the sandy limestone, No. 3, seems to be two or three times the thickness on the west side, and the brecciated limestone has thickened to 7 feet 6 inches. It thickens rapidly to the eastward on the west side of the hill.

APPROXIMATE SECTION OF TOP OF MITCHELL LIMESTONE IN SECTIONS 23 AND 24, SOUTH OF HENDRICKSVILLE.

	Feet.
9. Sandstone and shale	10
8. Blue clay shale	18
7. Limestone about	1½
6. Blue clay shale	12
5. Massive sandstone	8
4. Blue clay shale	8
3. Limestone, 6 feet to	10
2. Sandstone and shales	15
1. Mitchell limestone, brecciated on top	65
Approximate total thickness	157½

WHITEHALL SECTION, AS EXPOSED IN 1913.

The section is in an abandoned road. In 1902 the road was still in use and part of the section covered. The section as it appeared in 1902 is as follows:

	Feet.	Inches.
21. Gray massive sandstone	3	0
20. Shale covered with sandstone	10	0
19. Shale	15	0
18. Sandstone, fine grained, fossil plants weathering mottled through red, purple and white	2	4
17. Sandstone, thin bedded, fossil plants	4	0
16. Blue to drab clay shales with rusty streaks, weathers reddish	14	0
15. Oolitic, very fossiliferous, coarse grained	7	0
14. Limestone, dense, fossiliferous, hard, diphygenic, fossils shell out easily	5	0
13. Limestone, hard, fossiliferous, lithographic, little oolitic in places	5	0
12. Oolite, hard, fossiliferous, brecciated in places near top	21	9
11. Limestone, yellowish, weathering in fine pieces	7	4
10. Limestone, conglomeratic, brecciated, pebbles composed of lithographic limestone. Matrix of dendritic limestone, hard, conchoidal fracture	2	3
9. Limestone, dendritic, lithographic, thin-bedded, pale-drab to yellowish brown, weathers craggy	5	0
8. Limestone, fine-grained, hard, oolitic in places	1	5
7. Very cherty limestone. Chert in large and small concretions and masses. Few fossils	2	6
6. Limestone, dense, oolotic, conchoidal fracture	2	0
5. Limestone, hard, lithographic, fossiliferous	1	0
4. Limestone, hard, fossiliferous, weathering rough and porous on the outside, oolitic, gastropods, brachiopoda, etc.	2	6
3. Limestone, thin bedded, fine grained, slightly shaly	2	0
2. Limestone, single layer, fine grained	2	4
1. Oolitic limestone	1	8

The brecciated limestone in No. 12 of this section represents, apparently, the horizon of the bed of shale near the top of the Mitchell farther south. It seems that the sandstone below the first limestone has thickened until it occupies most of the space between the top of the Mitchell, above the 14 feet of shale. The limestone is not seen on the east side of the Whitehall hill but is seen a little farther west on the other side of the hill.

SECTION UP THE ROAD FROM HENDRICKSVILLE TO LIBERTY CHURCH.

	Feet.	Inches.
10. Limestone, about two feet or		6
9. Olive clay shale	8	0
8. Massive sandstone, 3 to 4 feet, quarried by road	4	0
7. Covered	10	0
6. Blue clay, gray sandy shale and greenish shaly sandstone	10	0
5. Limestone, 15 or	20	0
4. Sandstone and sandy shales about	15	0
3. Mitchell limestone	23	0
2. Shale	0	6
1. Considerable thickness of cherty Mitchell limestone full of stylolites and fossils.		

No. 10 of this section is the first limestone. The thickness of No. 4 could not be accurately determined on account of poor exposure. It may not be as thick as indicated. At Whitehall this layer seems to be wanting so that No. 5 rests on No. 3.

The Outcrop.—The outcrop of the Mitchell limestone covers about half the area of the quadrangle. Where it rises considerably above the general drainage level it is always characterized by sinks, frequently of large dimensions. Some are a mile across and fifty feet deep. From this size they vary down to small holes. Its thickness together with the relatively low dip of the rocks makes this limestone an extensive surface formation. Another feature of the rock, which contributes quite as much to the unbroken nature of the outcrop, is its cavernous nature and the fact that the water falling on large areas of it sink into the ground and flow away as subterranean streams, instead of concentrating the energy of the water in cutting deep valleys in it and revealing the underlying formations. Aside from these reasons, the limestone is rather hard and resists stream action quite as much as any other rock in this part of the State.

Economic Value.—The Mitchell limestone is too hard and brittle to be of much value as a building stone in a large way. It is also thin-bedded, as a rule, and very fine grained except in the upper part, where it is oolitic. Even here, the oolite grains are bedded in a very fine rock flour cement which has the same effect, and frequently gives even the oolite a semiconchoidal fracture. The fineness of the pore space, even though the percentage of pore space is very low, unfits it for withstanding frost action, when used near the water line or in moist places. When used above foundations in superstructures it lasts well. Except for the foundations, the stone is adapted for rural dwellings and the thin beds in which it occurs and the relatively small blocks into which it is broken by the joint planes makes it rather easy to quarry. The value of stone for rural dwellings will be treated in the discussion of the following formation.

This limestone is of great value for four different purposes. They are: road metal, lime, Portland cement and as a waterbearing rock.

As road metal, the Mitchell limestone has no equal in Indiana, and probably not in the bordering States on the east and west. Its great thickness and availability make it cheap to quarry, as great faces can be carried back very economically. There is rarely any stripping to be done save of residual clay which can be removed by hydraulic stripping wherever water is available. Its value for crushed limestone, Portland cement and lime are covered in the preceding pages, the remarks about the value of the oolite for these purposes being equally applicable to the Mitchell. Many of the great "springs" (underground streams) issuing from the borders of the outcrop of this limestone have sufficient fall to permit the installation of hydraulic rams so that the owners may have modern water conveniences in their houses and frequently electric lights by proper utilization of the water and the use of storage batteries. They could also be made to furnish water for gardens.

The Chester Shales, Sandstones and Limestones.

Resting on the Mitchell limestone are 200 feet of shales, sandstones and limestones of the Chester group of rocks. These rocks were called Huron in some of the State Reports, but the Black Shales of Ohio have long been known by that name and inasmuch as it may be necessary to use that term in Indiana for some of the black shales of the Devonian, the term Huron must be ruled out.

The Chester rocks begin, in all probability, in the uppermost part of the Mitchell limestone. The treatment under this head includes only the clastic rocks above the Mitchell, and the map shows only these rocks, since it is a lithologic map. A geologic map represents the rocks of various ages and a lithologic map represents limestones, sandstones, shales, etc. The two usually concide, but do not on the Bloomington quadrangle.

The lowermost 30 feet of these beds is largely a clay or slightly sandy shale over the most of the area of the outcrop. There is a sandstone a few feet below the top of the shales usually only three or four feet, or even less, in thickness. It occasionally seems to occupy must of the space, at the expense of the shale. This is the case at Whitehall. Much of the way this shale would apparently make good brick and shale for Portland cement. In the vicinity of McVille there is a thin streak of carbonaceous shale and a few inches of coal in places, in the lower part of these shales.

On these shales is a limestone which in the southern part of the quadrangle is from two to three feet thick and in the northern part increases in thickness to five or even ten feet. It usually weathers to a yellowish-brown color and is rather coarse, though the lower part of it is sometimes nearly white in the northern area. The limestone itself is relatively unimportant except that it is the source of many springs which supply water for families and stock. It appears to be missing over considerable areas, at least the outcrop can not be found. When it is absent the springs which accompany it are not present and the usual houses, located on account of the springs, are missing.

Resting upon this limestone, which we usually call the first limestone, is a mass of 80 to 90 feet of shales with some sandstones. The shales are frequently interstratified with thin streaks of sandstone. They may be rather clayey but frequently are quite sandy. The sandstones seem to thicken locally. This seems to be the case in the region west of Cincinnati ridge between the Cincinnati region and Beech Creek south of the Hannum School.

Over these shales and sandstones is what we have called the second limestone. It varies in thickness from 8 to 20 feet. It is sometimes oolitic and sometimes crystalline. It is frequently dissolved from beneath the thick sandstone which rests upon it and the sandstone has moved down and occupied the place of the limestone. On account of the shales below the limestone, like the other limestones of the Chester, it has moved down hill considerably by creep. For this reason in opening quarries it is well to enter the hill well above the outcrop. The limestone in places is quite fossiliferous.

Over the second limestone is a layer of 30 feet or more of sandstone, where it has not been eroded away. This sandstone is usually rather fine-grained, buffish brown or light buff, where the iron cementing material has not been concentrated in it. It is well shown in most of the cuts between Elwren (Stanford Station) and Solsberry.

Over this sandstone are some 30 feet of shales with a little sandstone upon which rests the third limestone. This third limestone is the highest formation of the Mississippian found in the area of the quadrangle. It is thin, probably not much over 30 inches in the thickness and is found near the tops of the hills in the vicinity of Cincinnati. The higher shales and the third limestone are practically confined to the Cincinnati region, having been removed from practically all the rest of the quadrangle.

The Outcrop.—The outcrop of the Chester is confined to the southwestern two-thirds of the quadrangle and then mostly to the hills and ridges, while the underlying Mitchell occupies the valley. Throughout the eastern margin of the outcrop in the sink region west of Bloomington, it is very difficult or impossible to map the outcrop accurately on account of the sinks developed beneath the formation in the Mitchell limestone and into which the shale limestone and sandstone have settled, sometimes as much as 40 feet or more. Except in cases where there are exposures, which are very rare, it is impossible to locate the line of contact. Indeed the contact enters each of the depressions and comes up over the rim, and in many instances is worn off from the rim. In the absence of exposures it is impossible to locate these filled sinks, since they are filled and the ground appears fairly even. In other cases the sinks are cleaned out, the material having been all washed down through it when the bottom finally closed.

The limestones of the formation appear to be wanting locally in various parts of the region. At any rate they do not appear at the surface and the springs that usually accompany them are missing. This is true of the western part of the quadrangle north of Richland Creek, the region immediately southwest of Hendricksville, the region south of the Hannum School, and the second seems to be wanting over quite an area southwest of Kirksville. The second is found all along the Indianapolis Southern R. R. from the county line to Solsberry, in the vicinity of Solsberry, Cincinnati and in some places in the northeast corner of the quadrangle.

Economic Value.—The economic value of this member of the Chester is much less than that of the three underlying formations. The basal shales are of value for local brick and tile works, but are too much disturbed by the development of sinks below, into which they have sunk, and been jumbled, with limestone and sandstone in such a manner that it would be expensive to separate them for such extensive use, as the manufacture of Portland Cement. Where the outcrop is steeper and the sinks are less developed there is frequently but a rather narrow margin available without very extensive stripping. The upper shales that occur sufficiently close to the railroad to be available are of rather uneven texture, and probably of composition, though locations for clay products plants may be found.

The limestones are of value as water bearing strata, and as such have had a marked influence upon the settlement of the country and the present location of homes. The second limestone is by far the most important in this connection. The large springs in the region between Elwren and Solsberry, the region of the Sanborn School, Cincinnati, and other places are examples. There is always sufficient fall to develop springs to permit the use of hydraulic rams and frequently sufficient water for the home use and usually for garden irrigation.

The second limestone is a pretty hard, tough limestone, making good road metal where available. On account of the sandstone above it and the shales below it it is seldom that much of it can be quarried without excessive stripping. It has been rather extensively used with good results in the vicinity of Cincinnati.

In many places the sandstones of the Chester have been used for foundations, and in no instance that we observed had it crumbled or given way to any noticeable extent though some of the buildings had been standing for a great many years. The sandstone is rather soft when quarried and is easily worked. The fresh stone has, usually, a dark buff color which darkens some on prolonged exposure. It is much lighter than the well known Connecticut brown stone used so extensively in the northeastern part of the country. One of the main values of this stone lies in the fact that it may be quarried at times when farm work is less pressing than others and accumulated for a series of years, if necessary, until a sufficient amount of good, well shaped blocks of sufficient dimensions are at hand to build a good modern house which will be of good appearance and which will last for generations. Barns and other larger outbuildings can be similarly constructed with very little cash outlay, while to buy the stone for such houses and buildings, which would be no better, would be an expensive operation and require much hauling from the railway stations. The main thing is to be sure of firm foundations which will not settle. This is the most important part of the operation and should be thoroughly done. The limestones of the Chester, Mitchell, and the upper part of the Harrodsburg are available for such use.

SECTION ALONG WEST SIDE OF QUADRANGLE SOUTH OF SOLSBERRY, SOUTHWEST FROM THE CENTER OF SECTION 4.

	Feet.
7. Covered to house northeast of middle of section	55
6. Sandstone	25
5. Limestone, 12 to	16
4. Shales and thin sandstones, 80 or	90
3. Limestone, thin	2
2. Shales, mostly, 30 to	35
1. Limestone, etc., to creek bottom, about	80

The rocks above the sandstone northwest of the house in Section 4 represented in the 55 feet "covered" of the above section are probably largely of Pennsylvanian age.

The distance between Nos. 5 and 3 of the above section read 105 feet by barometer going down the ravine southwest from the center of the section. This is due to two causes. First it is the general direction of the dip and, second, the lower limestone has crept and slumped down some ten or fifteen feet or more. This is well shown in the road south of Solsberry where the limestone is found three times in the same grade in the hillside. The upper part of the next limestone below is also probably covered to some extent. The exposures do not show the full thickness of the sandstone and shale in the top of the Mitchell here.

Glacial Geology.

By C. A. Malott.

GENERAL TYPES OF TOPOGRAPHY.

The topography of the Bloomington Quadrangle is rather diversified, varying almost directly with the kind of rock structure in which the different types are formed. At the eastern edge are small, steep-sided, V-shaped ravines, heading with a steep fall of some ten or fifteen feet where the Harrodsburg-Knobstone contact occurs, and also the larger ravines or valleys with their steep, cliff-like sides and flat, widening valley floors. Succeeding to the west are gentle, undulating slopes characteristic of the Salem limestone topography. Next in turn comes the sink-hole plain of the Mitchell limestone, with its plateau-like appearance in relation to the main streams. The western half of the sheet represents the more rugged topography of the Chester sandstones and shales with the occasional thin limestones. Here occur deep, narrow valleys with sides of a steep angle, being vertical only where the limestones are a controlling feature. These various types of topography are frequently distinctly abrupt, but more often merge into each other, each gradually assuming its individual characteristics.

The Flatwoods District.

While the above outlined types of topography are dominant as a whole, there are some features, however, which are characteristic of none of them. The northwestern part of the region represented by the sheet is especially to be noticed in this respect. Just west of Ellettsville is a wide level tract of land, only a portion of which comes within the limits of the quadrangle, which has attracted the attention and study of geologists for some time. It is a low level basin, averaging about 740 feet above sea level, about two miles wide and reaching some six miles northwest from Ellettsville towards White River near Spencer. Its peculiarities consist of low marshy tracts of land with occasional monadnocks rising island-like above a surrounding periphery of hills or higher land, and of a striking ash-colored, silty soil, usually containing shot-like concretions of ferrous and ferric oxide, which are locally known as "turkey gravel". In the lower portions, especially near the middle of the basin the ash-colored silt is covered over with a black soil containing much vegetable matter. This black soil is very fertile. This peculiar basin, locally known as Flatwoods, is drained mainly by McCormicks Creek, only the very headwaters of which are within the area of the Bloomington Quadrangle.

About three and one-half miles west of Ellettsville in S. E. ¼ Sec. 1, T. 9 N., R. 3 W., is a narrow opening leading from the Flatwoods basin into Raccoon Creek valley. South from this opening on either side of Raccoon Creek occur remnants of the same flat as observed in the above described Flatwoods basin. In places the remnants are quite extensive, as in Sec. 24, 23, 14 and 13, T. 9 N., R. 3 W. Since the drainage of Raccoon Creek is much lower than the flat-surfaced remnants of the former continuous flat, many V-shaped ravines are cut into it, making the topography rather rough. Nevertheless, the flat tracts remaining form a striking feature.

Evidence of this Raccoon Creek portion of Flatwoods having been a continuous flat, as the present Flatwoods proper, are found in the structure revealed in the steep-sided ravines and in the wells of the region. Stratified sand is very often to be seen, not only revealing the fact that distinct water currents were present, but that the region was once as rugged as regions farther south and that the valleys have been filled up to a level of the present flat-surfaced remnants. In some places the region has been filled as much as a hundred feet. How this took place will now be briefly outlined.

As a matter of history it might be mentioned that Collett in his report on the Geology of Owen County (Seventh Annual Report, Indiana Geological Survey, 1875), in attempting to explain the narrowness of White River valley above Spencer and adjacent to the northwest end of the Flatwoods basin, asserted that previous to the Illinoian glacial period, White River passed up the narrow McCormicks Creek gorge, through the Flatwoods basin, through the opening leading into Raccoon Creek valley, and thence down that valley to the present White River valley below Freedom. Siebenthal, commenting on Collett's idea, says: "The Pleistocene terraces of Bean Blossom Creek clearly prove the pre-glacial valley of that creek to have been practically as it is at present. It is impossible to imagine how it could be cut down to its present depth, while White River, into which it emptied, was running at a level

150 feet higher than now, as it is alleged to have done. Morever, the gorge of McCormicks Creek is clearly post-glacial. And further, it empties into White River at least a mile below the upper end of the 'Narrows', whose existence it was brought forward to explain". (Twenty-first Annual Report, Ind. Geol. Surv., 1896, pp. 302.) Thus Siebenthal makes it clear that Collett's idea is not tenable. Siebenthal advances the idea that the Flatwoods basin was the site of a shallow lake during the Illinoian glacial period and for some time following.

There is no doubt that the phenomena of Flatwoods are due to the ponding of waters before the Illinoian glacial ice front. It seems that the ice advanced slightly into the area represented by the Bloomington Quadrangle. At its farthest advance it was quite likely occupying the extreme northwest sections, very probably entering the quadrangle near the middle of Sec. 33, T. 9 N., R. 3 W., and passing northward past Freeman P. O., and leaving the quadrangle near the Hardscrabble School. Near the residence of Thomas Coble in the N. W. ¼ Sec. 3, T. 9 N., R. 3 W., are remnants of an old moraine, the only direct evidence of any continued stand of the ice front upon the quadrangle. From the vicinity of the Hardscrabble School the ice front probably extended irregularly northward for over two miles and then swung eastward, crossing the headwaters of Big Creek, Jacks Defeat south of Stinesville, and then over the divide and across Bean Blossom valley. Thus, the stream draining the pre-glacial Flatwoods basin was ice-dammed, as well as the valleys of Jacks Defeat and Bean Blossom. The waters undoubtedly accumulated in Bean Blossom valley until they flowed over the divide at the old col on the farm of Jack Litten about two miles southeast of Stinesville. After coming into the valley of Jacks Defeat in this manner, they continued into the next basin west, which is the one now occupied by Flatwoods. The waters reached this basin through a low opening just west of Ellettsville. Quite an extensive lake was formed in this basin. From this basin the waters found an outlet to Raccoon Creek valley through the opening described above (hereafter this opening will be called the Raccoon Creek col), and passed down this valley, finding an outlet along the edge of the ice sheet or under it in the vicinity southwest of Freeman P. O. Ignoring the work of the post-glacial streams in the old lake-flat (which was the result of the long continued ponded waters), it can be easily seen by the contours of the quadrangle map that the general slope is about ten feet to the mile from the entrance into the Flatwoods basin just west of Ellettsville to the Freeman P. O. vicinity. This slope of the old lake-flat is in itself proof of the direction of the flow of the glacial waters.

On the withdrawal of the ice front, the portion south of the Raccoon Creek col was drained; but the region of Flatwoods proper remained a lake for a long time, with an outlet through the Raccoon col, or through the col just west of Ellettsville leading into Jacks Defeat Creek. Perhaps both of these openings or cols were outlets for a time; but the Raccoon Creek col is slightly lower, and undoubtedly persisted longer. The outlets to the Flatwoods lake were at these places because the old buried stream, or valley rather, was dammed so effectively at the lower end that it was much higher here than at the outlets above. Very probably a morainal dam was present, as evidence of such are to be seen near the head waters of Allistons Branch, which was the pre-glacial outlet of the old pre-glacial stream. The steep-sided, deep ravines and the wells of this region show that the filling here was considerably over a hundred feet. Moreover, the glacial material itself has all of the appearance of outwash from a moraine. The slope also is in the direction of the Raccoon Creek col, where the waters undoubtedly found an outlet.

The region immediately south of the Hardscrabble School (N. W. corner of the quadrangle) slopes rather rapidly to the southward, to a narrow opening in the line of hills in the middle of the southern half of section eleven. The glacial waters coming from the ice front in the upper portion of the pre-glacial McBrides Creek basin, no doubt flowed through this opening and escaped southward into the Raccoon Creek region. After the ice withdrawal, the waters continued in this direction, because McBrides Creek valley was filled by a moraine near the western edge of the quadrangle. Remnants of such a moraine have already been mentioned. Post-glacial stream action has been rapidly clearing the morainal and outwash material from the pre-glacial McBrides Creek; but there is much yet to be done. The present drainage in the region just south of the Hardscrabble School is mainly underground, which was, perhaps, already well developed in pre-Illinoian times. Much of the glacial material itself has been carried away through the underground drainage.

After the withdrawal of the glacial ice front from the Freeman P. O. vicinity, the streams went to work to clear out the material which had filled their valleys. Gradually Raccoon Creek has cut its way back into the glacial material, or old lake-flat, and at present a tributary is slowly making its way into the Raccoon Creek col, which connects with Flatwoods proper. Beautiful terraces were thus formed in the old lake flat. These are prominent features on either side of Raccoon Creek and its tributaries, and have a distinct influence upon the position of the contours. But long ago the waters of old lake Flatwood ceased to find release through the Raccoon Creek col. Underground drainage was well developed in pre-Illinoian times, and soon the old subterranean channels were cleared of glacial debris and the waters went through the subterranean pre-glacial routes. The main stream, however, was through Allistons Branch, and this stream was so thoroughly clogged that it has never been able to be much of a factor in the drainage of the Flatwoods region. The present drainage of Flatwoods is through the rocky gorge of McCormicks Creek, which is distinctly a post-glacial stream. It was initiated through underground drainage, and, having gained an early ascendancy through the peculiar suitability of its rock structure and great fall, it soon had practically the entire drainage to itself. Later, through mechanical action, and the forces of gravity, the drainage became surface, practically as it is today. The lake-flat, however, has always been imperfectly drained; even yet small depressions are either marshy or remain as small lakes; as, for instance, the Stogsdill Pond just east of the Hardscrabble School.

The Richland Creek Terraces.

Another instance of the effect of the ice in the near vicinity of the Bloomington quadrangle is seen in the beautiful terraces on Richland Creek. These terraces begin in the vicinity of the Vernal Church, where they merge into the present alluvium. Near Whitehall they are some twenty feet above the present stream channel; at Hendricksville they are forty feet above, and at the western edge of the quadrangle they are seventy feet above. The flat represented by the connected terrace surface has a slope of about five feet to the mile down stream. These terraces were caused by the damming of Richland Creek some two miles west of the quadrangle, where the pre-glacial channel was filled deeply with glacial material and Richland Creek itself deflected to the southward over a low divide into a small stream which leads into Beech Creek. (Leverett, Mono. XXXVIII, U. S. G. S.) Thus a lake extended up Richland Creek to near the Vernal Church, and the incoming waters brought in sediment and built up a lake flat, the surface of the terraces being the surviving remnant. As the divide just off the quadrangle was cut down the lake was drained, and in turn the stream has cut down into the old lake-flat, removing much of the material; and thus the beautiful terraces on either side of Richland Creek were formed.

Pennsylvanian or Coal Measures.

By T. F. Jackson.

The eastern outcrop of the Pennsylvanian rocks[1] in Indiana extends in a belt of varying width in an east-of-south direction from Warren County on the north to the Ohio River in Perry and Crawford counties on the south. Throughout the greater part of this area the Pennsylvanian rock consist of a series of strata which vary greatly in lithologic features both horizontally and vertically. In many places massive sandstone ranging in texture from coarse conglomerate to the fine-grained Hindostan whetrock of Orange County constitutes the bulk of the formation. Thin beds of coal, fire-clay and shale are frequently found interbedded with the sandstone. In other places a series of interbedded sandstones and shales make up the formation. Where the series is typically developed the massive sandstone is coarse-grained, more or less cross-bedded, and contains patches of quartz conglomerate and iron concretions. The color ranges from nearly white through various shades of gray, yellow and red to dark brown. It is overlain by a series of shales, sandstone and coal beds, in some places conformably, in other places unconformably. It rests uncomformably upon Mississippian limestones, shales or sandstones. In some localities shaly sandstone and shales immediately overlie the Mississippian rocks. Under such conditions, in the absence of fossils it is not always possible to determine whether these laminated strata are correlative of the Pennsylvanian or whether they belong to the Mississippian series.

The series of rocks above described correspond with the "Millstone Grit" of the early geologists. In the earlier State reports it is commonly referred to as the "conglomerate sandstone" or "conglomerate". In 1895 Hopkins[2] named the series the "Mansfield sandstone". Later Ashley[3] in his report on the Coal Deposits of Indiana placed the series in what he designated "Division I". He retained the term "Mansfield sandstone" to designate the massive bed or beds of sandstone in the formation.

[1]Hopkins, T. C. The Carboniferous Sandstones of Western Indiana. Twentieth Ann. Rep. of the Ind. Dept. of Geol. and Nat. Resources, 1895.

[2]Hopkins, T. C. Report previously cited.

[3]Ashley, G. H. Twenty-third Ann. Rept. of the Ind. Dept. of Geol. and Nat. Resources, 1898.

In stratigraphic position the formation corresponds with the Pottsville conglomerate of the Pennsylvanian system.

The general nature of the formation may be shown from the following sections from widely separated areas:

SECTION AT TROY,[1] PERRY COUNTY.

(Only the lower part of the section is given.)

	Feet.	*Inches.*
23. Coal II (Allegheny)	3	4
24. Fire-clay	2	0
25. White sandstone	3	0
26. Blue sandstone	13	0
27. Blue shale	11	0
28. Coal Ia	0	4
29. White sandstone	9	0
30. Blue shale	28	0
31. Coal I	0	2
32. Limestone (Mississippian)	1	6
Total thickness of "Division I"	66	6

GENERALIZED SECTION FOR THE ORANGE COUNTY AND MARTIN COUNTY AREA.[2]

	Feet.	*Inches.*
11. Coarse sandstone	14	0
10. Coal	1	0
9. Coarse sandstone	35	0
8. Hindostan whetstone	20	0
7. Coal	1	2
6. Coarse sandstone and shale	100	0
5. Upper Kaskaskia limestone (Miss.)	13	0
Total thickness of Pennsylvanian	161	2

The lower Pennsylvanian rock in Fountain and Warren counties are principally represented by the massive Mansfield sandstone. Locally coal or shale may occur.

SECTION NEAR THE MOUTH OF SUGAR MILL CREEK,[3] WARREN COUNTY.

	Feet.
5. Yellow sandstone	5
4. Black shale	3
3. Gray and yellow striped sandstone	12 to 15
2. Brown to black shale containing pockets of coal	12
1. Cross bedded sandstone, shale and coal	12 to 15
Total thickness of section	50 to 74

[1]See Ashley's Report previously cited, p. 1274.

[2]Kindle, E. M. The Whetstone and Grindstone Rocks of Indiana. Twentieth Ann. Rept. of the Ind. Dept. of Geol. and Nat. Resources, 1895.

[3]Hopkins, T. C. Article previously cited, p. 2[illegible]7.

The coal near the base is ten to twelve inches thick.

The Pennsylvanian rocks[1] that occur within the area included in the Bloomington Quadrangle represent in part the Lower Pennsylvania or Ashley's Division I. Geographically they occupy a position somewhat south of the center of the eastern outcrop of the Pennsylvanian in Indiana. The formation as here represented is confined to the higher parts of the hills in the western half of the quadrangle. A few isolated patches of Pennsylvanian strata occur on the higher ridges in the northern part of this area. The formation is best represented in the south and southwestern parts of the quadrangle. The formation in eastern Greene county and southeastern Owen county was indicated on Blatchley's Geologic May of Indiana.[2] The outcrops along the I. C. R. R. in Monroe county were described by Greene.[3] The Monroe county Pennsylvanian does not appear on Blatchley's map.

The formation as here represented is made up for the most part by a series of sandstones and shales, which vary greatly in lithologic features, both vertically and horizontally. Conglomerate was found at but one place. Iron ore is a very prominent constituent of the sandstones, particularly at or near the base. This iron ore layer is often of great importance in determining the Mississippian-Pennsylvanian unconformity. Thin carbonaceous layers are occasionally found and at two localities thin veins of coal outcrop. The massive Mansfield sandstone, so characteristic of a great part of the Lower Pennsylvanian elsewhere in Indiana, occurs in but few places. Where it occurs it seems to be merely a lenticular mass and rapidly changes to thin bedded sandstones and shales. Although it usually occurs near the base of the formation its outcrops are too widely separated to be of much value for stratigraphic purposes.

The formation as a whole has a maximum thickness of about sixty feet. This thickness is attained in the vicinity of the Yoho schoolhouse and about one-fourth mile southeast of Cincinnati. Owing to the heavy cover of soil it is not always possible to separate the Mississippian and Pennsylvanian rocks. The great similarity of the Mississippian sandstones and shales to the overlying Pennsylvanian sandstones and shales makes this problem a still more difficult one.

[1]For the distribution of the Pennsylvanian rocks within the Quadrangle see the Geologic map elsewhere in this Report.

[2]Blatchley, W. S., and others. Geological Map of Indiana, 1903.

[3]Greene, F. C. The Huron Group in Western Monroe and Eastern Greene Counties, Indiana. Proceedings of the Indiana Academy of Science, 1910.

The sandstones that occur interbedded with the shales are usually rather coarse and thin bedded. In many localities, however, they are rather fine grained and heavy bedded. In the latter case they may imperceptibly grade into the Mansfield sandstone. They vary in color from almost white to dark brown, depending on the iron content. They are often cross-bedded and show ripple marks and other evidences of shallow water origin. Those sandstones often undergo great lithologic changes within a short distance. Horizontally they may change from sandstones to sandy shale or clay-shale within a few feet. Vertically the same change may take place within a few inches. The cementing material is usually an oxide of iron. In a few instances the rocks seemed to be composed entirely of quartz. Iron concretions sometimes occur in those rocks, especially in those that contain a high per cent of iron.

Where those sandstones occur in beds of sufficient thickness, uniform structure, and free from iron concretions, they are suitable for building stone. They have been used for foundations, as bridge abutments, for walling cellars, and for various other structural purposes. Those sandstones are usually very readily quarried and dressed. Their durability is shown by their fine state of preservation where used as foundations for buildings erected three quarters of a century ago. The rapid advance in the cost of building material will likely cause those sandstones to come into more general use for such purposes.

The shales or clay-shales interbedded with the sandstone also vary considerably in lithologic characteristics. Usually they are grayish-white to light blue in color; frequently, however, they are of a brownish color. In a few places they are of a reddish color very similar to that of a part of the underlying Mississippian shales. They are usually of a sandy nature. Thin layers almost free from sand are occasionally found. Those thin layers are, as a rule, very plastic. About one-fourth mile south of Liberty Church is a layer of kaolin which was used for making a cheap grade of stoneware a number of years ago. As stated in the description of the sandstone, those shales frequently change into sandstone within short distances, both horizontally and vertically. Their economic value is slight. There are a few deposits that might be of local value for brick making.

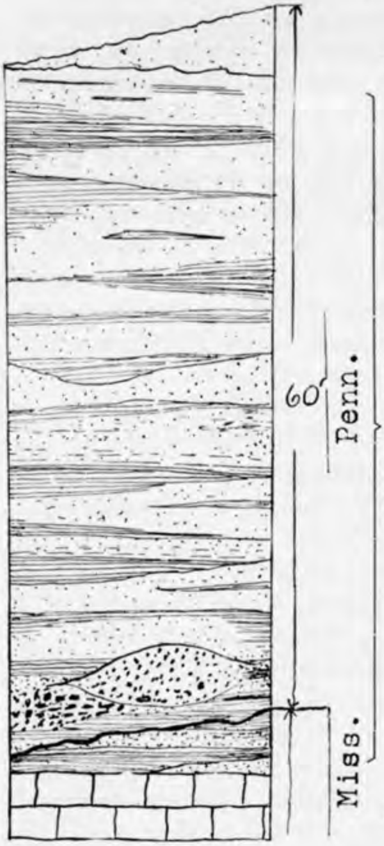
The typical Mansfield sandstone as before stated, occurs at but few localties. The conditions of deposition during Pennsylvanian time appear to have been of such a nature that a succession of interbedded sandstone and shales were laid down in most places in place of the massive sandstone member so characteristic of the Pottsville of many localities. It occurs as lenticular masses a few feet in thickness and rapidly disappears by pinching out or by changing to interbedded shales and sandstone. It is massive in structure, more or less cross-bedded and grayish dark brown to rusty dark reddish brown in color. It weathers to a rather rough surface. It is a more resistant rock than the surrounding interbedded sandstones and shales, the latter members often weathering away and leaving isolated masses of the Mansfield on the surface of the ground. It is usually somewhat harder than the surrounding sandstones above mentioned. Iron oxides are very prominent constituents and frequently iron concretions are abundantly distributed through this member, particularly near the base.

About one-half mile northeast of the Sandbourn school there is an exposure of the Mansfield in which iron ore makes up the principal part of the rock. A small amount of iron ore for smelting was formerly obtained here. An exposure of Mansfield that is conglomeratic occurs about one-half mile northeast of the iron ore outcrop. The conglomerate is made up of rather small rounded quartz pebbles with a few small angular quartz fragments in a matrix of coarse sand and iron ore. This is the only locality in the quadrangle in which the conglomeratic phase of the Mansfield was noted. Exposures of the sandstone that are probably the Mansfield occur in the first and third I. C. R. R. cuts east of Solsberry. Greene[1] assigned this sandstone to the Mississippian but the Mississippian-Pennsylvanian unconformity which he described as appearing near the top of the cut could not be discovered. It is probable that the unconformity occurs beneath the cut and is concealed. Exposures of Mansfield also occur along the west side of the road about one-half mile north of the Yoho School and along the creek bank about one-half mile east of it. At those two localities the sandstone occurs as huge blocks three to five feet in thickness, on top of the ground.

Carbonaceous layers varying in thickness from a thin streak to a few inches in thickness are found here and there in the sandstone-shale part of the formation. None of these layers appear to have a very wide horizontal distribution.

[1]Greene, F. C. Paper previously cited.

GENERALIZED SECTION OF THE PENNSYLVANIAN FORMATION FOR THE BLOOMINGTON QUADRANGLE.



Soil.

Interbedded layers of shale and sandstone which frequently grade into each other, both horizontally and vertically; thin carbonaceous layers of limited extent occur at irregular intervals; Mansfield sandstone lenses, iron ore layers and a few thin coal layers occur near the base.

Limestone.

From the nature of the members of the formation and their relation to each other it is inferred that they were laid down principally as a discontinuous, shallow water deposit. It is very probable that the formation was deposited principally in stream valleys in the eroded Mississippian land surface. This would account for the rapid lithologic changes in the sandstone-shale part of the formation and for the occasional occurrence of the Mansfield sandstone which could have been deposited at the mouths of the tributaries of the smaller streams. The absence of marine fossils except at Cincinnati in the extreme southwestern part of the quadrangle would seem to confirm this view. If such conditions prevailed during the deposition of the formation it is not likely that its original eastward extension was very far from that of the present outcrop.

Fossil plants of Pottsville age were found in a number of places in the southwestern part of the quadrangle. Collections were made from a shale bed about one-fourth mile south of the Yoho School and from a sandstone-iron ore layer one-fourth mile southeast of Cincinnati. An examination of those fossils has shown that the Pennsylvanian formation here represents an horizon as old or older, than the Sharon coal of northwestern Ohio, i. e., the lower part of the Upper Pottsville.

The Utilization of the Waste Stone.

By G. C. Mance.

The largest industries of the country have all been developed by improved methods of the utilization of waste. The success of the Standard Oil Company and the meat packing industries is directly traceable to their close utilization of the waste products of their business. The stone industry has been one of the most backward of all industries in its use of the waste stone that results from the operation of quarry and mill.

During the operations of quarrying, the loss of stone will reach from 30 per cent. to 50 per cent. of the solid cut, and one operator who was working a quarry where there was no adequate covering over the building stone layer estimated that as high as 60 per cent. of the solid cut of his quarry was wasted. The quarry in which 70 per cent. of the solid cut can be put on the market is an exceptionally good quarry. The probable average of waste for the whole quarry district is 38 per cent. to 45 per cent. of the solid measure.

The causes of this great amount of waste stone are many, but the most important may be grouped under the following heads:

(1) The texture of the stone.
(2) Mud seams and joints.
(3) The character and amount of the overburden.
(4) Irregularities in the stone.
(5) Crackings in the stone due to geological causes.
(6) Carelessness in the handling of the stone in the quarry.
(7) Variations in the color of the stone.

The general texture of the stone is granular and a wide variation in the coarseness of the grading may occur even in a single quarry. This variation may appear in the different beds or even in different parts of the same bed. The stone of too coarse texture has to be discarded, as there is no demand for the coarse-grained stone in the trade, and when the graining of the stone is very fine it may be harder and more difficult to work. The medium-grained stone is consequently the most desirable and gives a larger profit to the quarryman. In many places the stone contains small crystals of calcite, and when these crystals are numerous they produce what is known as "glass seams". When these occur the stone is usually rejected. The presence of any large fossils also causes the rejection of the stone.

When the stone in the quarry has been covered by nothing but the loose material resulting from the disintegration of the upper part of the formation, the stone will be traversed by a number of deep mud seams ranging up to ten feet wide and twenty-five feet deep. These seams are the result of the action of water which enters the ground and, becoming charged with the organic acids of the soil and the carbonic acid gases of the air and soil, dissolves the limestone along the natural joints of the rock formation and the connecting material from between the grains for some distance into the blocks. These seams may be developed in either direction, depending on the direction of the surface drainage at the point. In many of the quarries where the surface drainage has been at an angle with both sets of seams it will be found that both sets are developed. Most of the quarry openings have been made along the edge of the outcrop of the overlying Mitchell limestone; and the quarry is worked back under the Mitchell stone. In such cases the seams will be less developed and the thicker the overburden the fewer will be the number of mud seams and the less open will they be. All stone formations contain joints but the stone of this district is especially free from them and large blocks can be quarried in many of the quarries.

The overburden in the quarry is usually a few feet of loose material resulting from the disintegration of the rock strata at that point, and the overlying limestone of the Mitchell formation. When this limestone layer is lacking the amount of waste due to weathering of the building stone layer is greatly increased, and in fact the amount of waste resulting from the fact that the stone has no good cover makes it unprofitable to operate such a quarry. The result of thick stripping of the underlying stone is very noticeable in such quarries as the old P. M. and B. quarry operated by the Indiana Quarries Company and the George Doyle quarry in Dark Hollow, where upwards of thirty feet of Mitchell limestone is removed. In these quarries the seams are hardly noticeable and none of the joints have been opened and filled with mud, as is the case in many quarries where little stripping is necessary.

In many of the quarries there occur structural irregularities known as stylolites, usually called "crows feet" or "toe nails". These irregularities are the only representatives of bedding planes or horizontal joints. They usually are responsible for the loss of from three to six feet of stone on either side of the seam.

In at least three of the quarries the stone shows a tendency to split up in irregular blocks as soon as quarried and this splitting results in the loss of many valuable blocks of stone. The cracks seem to be present in the stone before it is quarried, but do not open until the stone is removed from its bed. This condition probably results from geological movements within the earth and the resulting stresses set up cause the stone to crack or at least develop lines of weakness. In one quarry all these cracks were in a horizontal plane and may have been caused by a settling of the formation as a result of the removal of the underlying beds, since the trouble existed only along the edge of a hill, and the cracks decreased in extent as the operations were carried farther into the hill.

The present methods of handling stone in the quarry result in much waste that could be avoided. Most of the operations in the quarry are performed by unskilled labor, as the quarry work is less desirable than the mill work. As a result the quarry laborer is underpaid and careless. The channeler, drill and scabbling machines each causes some waste and if the work is not well done the irregular breaking of the blocks will represent another great source of waste.

The Oolitic limestone is of two shades of color, known to the trade as "buff" and "blue" stone. The difference is caused by a chemical change in the small amount of iron compounds present in the stone. The original color of all the stone was blue, but the oxidation of the iron, which was present, originally, in the form of ferrous compounds, into ferric compounds, has caused the blue shade to turn to a light grey or greyish brown, known as buff stone. When the quarry block is entirely buff or entirely blue, it can be sold at full price; but the line of separation between the buff and blue stone is usually very irregular, and consequently there are blocks in which the colors are both present, with the result that this mixed stone has to be sold at a much lower price, some of it being rejected altogether. There is a growing tendency in the stone trade to disregard the difference in color of the stone, for the stone will take on a uniform color after a longer or shorter period of exposure to the atmosphere. In fact if a block of blue stone be exposed to the sunlight and atmosphere for a month it is difficult to tell whether it was originally buff or blue without chipping into it. A building made of the mixed stone although presenting a peculiar appearance at first will soon become uniform in color and the fact that it was mixed stone will be difficult for even a stone expert to decide. A building made entirely of blue stone will slowly change to the same color as a building of buff stone, so that the grading of the stone on this basis is unnecessary if the trade were educated up to this fact.

In the mills less waste occurs, but even here the amount sometimes reaches as much as 20 per cent. of the weight of the quarry block purchased. Estimates by the different mill operators place the amount all the way from 8 per cent. to 22 per cent., but Mr. Hunter, superintendent of the Oolitic Stone Mill of Bloomington, has figures of actual weights of rough stone shipped in and the sawed stone shipped out which show that fully 20 per cent. of the quarry block is wasted at the mill. This percentage of waste increases with each additional operation that the stone undergoes and in the case of decorative work is far more than the above figure. This waste is greatest where planer and lathe work is done and where the stone is turned out as columns.

Since a conservative estimate of the quarry waste would be 40 per cent. and the same estimate at the mill could be placed at 17 per cent. the part of the stone finally reaching the building trade is about 50 per cent. of the amount of the solid cut. The 1912 report of the United States Geological Survey on Mineral Resources places the output of the Southern Indiana Quarry District at 10,442,304 cubic feet and at the rate of waste given above the waste of the district must be close to ten million cubic feet of stone per year. Of this vast waste pile at present about 18,000 cubic feet is turned out as crushed limestone and about 8,500 cubic feet is made into lime, and allowing that as much more is sold for other purposes it will be readily seen that the present utilization of the waste stone amounts to nothing as compared to the amount produced. To this vast accumulation of any year must be added the amount of waste that has been in process for the last twenty-five years of active operation of the quarries of this locality.

The present method of disposal is to dump the waste stone into the old workings or give it to the railroads for hauling it away. In fact such a large amount of waste has accumulated at some of the quarries that the disposal of the present waste is a problem, and in many cases waste heaps of other years have to be removed so that new floors may be opened. The present method is to pile the waste in large piles at the sides of the opening by means of a derrick. When the floor is to be extended to the point where the waste pile is located, the pile must be moved to make room, and is usually thrown back into the worked-out floor. Since most of the quarries are located on the hillside a better method of disposal and one which would not interfere with the later recovery of the stone would be the use of cable ways and overhead cars for running the discarded blocks to a place well removed from the quarry and to a point where there was no available stone to be covered.

The usual price of the waste stone loaded on the cars at the quarry is fifteen cents per ton, this price being paid by the limestone and lime plants of the district. The charge of the railroad for moving cars in the stone belt when the product is to be rehandled is $2 per car, so that the product at a central point would cost about 20 cents per ton, but this is not a fair estimate, as almost any of the quarries or mills would contract to give away their waste if the contracting company would promise to take care of the entire output of waste stone.

The waste stone or at least a part of it might be taken care of by some one or more of the following methods:

(1) More careful grading of the stone and the use of a large amount of the rejected blocks in rougher buildings.

(2) The production of ground limestone for fertilizer and for use in the manufacture of glass.

(3) The production of lime.

(4) The production of Portland cement.

(5) The production of crushed stone for road metal and flux in the steel industry and for crushed rock concrete.

In the case of the last four uses mentioned the Mitchell limestone of the stripping would be just as useful as the waste oolite stone, and in the case of road metal and crushed rock concrete it would on account of its greater hardness be better than the softer oolite stone. The cost of stripping could be entirely offset by the use of the stone in any of the last four ways mentioned.

The amount of waste that could be utilized for these purposes would be increased by the amount of Mitchell limestone taken off as stripping and the ultilization of this stone would make profitable the operation of quarries which have been abandoned on account of the high cost of stripping this stone.

Stone Grading.—The present methods of grading stone are very unsatisfactory as there are no hard and fast rules to follow and the selection of the different grades of stone is left to each individual quarryman. This allows a wide variation in what is called "A1" stone, for what one quarryman having a good quarry will call second grade stone will be the same grade of stone that another operator will be putting on the market as "A1".

If a selection is to be made on the basis of graining or color alone there will be about as many grades of stone as there are quarries in the district. The result is that bids are made on the basis of a single sample, and since the quarrymen are in the habit of sending out as samples selected stone they are in most cases unable to furnish any large amount of stone that is truly up to the sample submitted. This causes a tendency on the part of the builders to be altogether too stringent in their specifications and much dissatisfaction results. The stone trade would be much benefited if every operator would exercise more care in the selection of his samples. It would be a benefit if the present method could be done away with and a single grade of stone be made.

In other words if all the stone could be sold for a single grade, it could be put out at a higher price than is now charged for the lower grades and the larger output would give a greater profit. The following table gives in general the grades recognized and the average prices paid for each grade.

QUARRY BLOCKS.

"A1" Buff	$0 25 per cubic foot.
"A1" Blue, fine grained	25 per cubic foot.
Trade Buff	20 per cubic foot.
Trade Blue	20 per cubic foot.
Mixed stone, part buff and part blue	13 per cubic foot.

To these prices must be added five cents per cubic foot if the blocks are scabbled. The higher grades of stone are the ones sent to long distances, the New York market especially demanding the best grade.

Every mill operation the stone undergoes increases its price. The cost of some of the simpler operations is as follows:

Sawing on two sides	$0 15 per cubic foot.
Sawing on four sides	30 per cubic foot.
Sawing on six sides	45 per cubic foot.

Planing: Charge made according to the surface area planed and the shape and weight of the stone.

The above figures were kindly submitted by Mr. Johnson of the Chicago and Bloomington Stone Co., and Mr. Freese of the National Stone Co.

During the earlier years of the stone industry in the Southern

Indiana Stone Belt only the finer grades of stone were made use of and large quantities of quarry blocks were discarded as waste. At the present time these are utilized more and more but there is still a large amount of stone piled on the waste heaps that could be used if the selection of the stone were carried on more carefully.

It has been suggested that a large amount of the waste quarry blocks and even a large amount of the waste of the mills could be utilized if a machine for cutting the stone in small sizes say brick size or cement block size could be perfected. It seems possible that an arrangement of small circular saws could be made that would turn out this stone in small rectangular blocks, and a demand be created for their use in cheaper buildings. In fact a very cheap product could be put on the market in this way and its development would assist materially in the solution of the waste stone problem.

Another way in which much of the rougher block stone could be utilized is by the use of the poorer grades of stone in the upper parts of buildings. The wearing and lasting qualities of this stone are equal to that of the better grades and the only reason for its rejection is the fact that its appearance is not as attractive as that of the better grades. If the lower parts of the building were finished in the fine grades of stone and the higher stories were made of the poorer grades the cost of the building would be materially lessened without a lowering of durability, or any impairment of appearance. No person at the street level can distinguish the grade of stone used in the second story of a building.

In the following paper I will attempt to show the economic value of the waste stone as a means of fertilizing acid soils and as a flux in the manufacture of glass. These two industries are growing rapidly and should offer a broad field for the disposal of much of the accumulating waste heaps.

Utilization of By-Products of Oolitic Limestone.

By G. C. Mance.

GROUND LIMESTONE.

This paper was written as a part of a larger paper which will appear later. The present paper is put out as an advance chapter of the same and the proper acknowledgments will be found accompanying the larger paper. The subject of the paper from which this is taken is: "The Utilization of the Waste Products in the Quarry Industry of Southern Indiana." The report of the United States Geological Survey on Mineral Resources for the year 1912 placed the output of building stone in the Southern Indiana Quarry District as 10,442,304 cubic feet, and since a conservative estimate of the percentage of waste in quarrying would be 40 per cent. at the quarry and at least 10 per cent. more at the mill it would leave almost ten million cubic feet of stone in the form of waste which should be utilized before the industry could be called economically handled.

At the present time about 18,000 cubic feet is turned out as crushed limestone and about 8,500 cubic feet is made into lime. If this quantity is doubled to cover the amount disposed of in other ways the amount of waste disposed of at the present time does not exceed 55,000 cubic feet. From the above figures it will be readily seen that the present utilization of the waste stone amounts to nothing as compared to the amount to be used. To this vast accumulation of any year must be added the amount of waste that has been in process of accumulation for the last twenty-five years of active operation of the quarries of this locality.

In addition to showing a method of waste stone utilization I have attempted to show the farmers of the State the value of the stone as a means of soil betterment and thus create a market for the product as soon as an effort is made to place the product on sale.

Ground Limestone.

Trace the history of agriculture back as far as possible and you will find that man has been familiar with the use of calcium compounds in the treatment of certain soils which had failed to produce their usual crops. The Roman farmer dug marl to treat his fields with before he planted them, and whether he originated the practice or whether the idea was handed down to him by some earlier agricultural people is still a matter of doubt. Nor were the Romans the only people of that early date that practiced the liming of their land when the soil failed to produce. The custom has been followed in China for long ages, only here it was muck dressing that was in practice, but since the beneficial part of the muck was its calcium carbonate content, the process was the same.

We have records to show that the farmers of England have made the practice of spreading chalk or marl on their soils for nearly two centuries and we are also in possession of the observations made on the results produced. Dr. C. G. Hopkins in his work "Soil Fertility and Permanent Agriculture", says: "An English record of 1795 mentions the prevailing practice of sinking pits for the purpose of chalking the surrounding land. At the famous Rothansted Experiment Station it has been found that the fields that had received a liberal application of this natural limestone a century ago are still moderately productive while certain fiields remote from the chalk pits which show no evidence of such application are extremely unproductive." There is no early record that the easily pulverized limestones and marls were burned to improve their fertilizing value. The burning of limestone to quick lime was probably first practiced with the idea of finding an easy method of pulverizing the resistant rocks so that they could be successfully applied to the soil. The treatment of soils with ashes may also have been in part responsible for the idea of burning the limestone before using it.

The early farmers of England as might be expected, appear to be the first to make use of the chalk on the soil to increase its productivity. This is easily explained by the great deposits of chalk outcropping in the southern counties. That the generous applications of calcium carbonate bearing compounds were of value to the lands and were concerned in their increased productivity is shown by the fact that the limed fields are still distinguishable.

Following a rather extended use of lime and calcium bearing compound on the soil there was a long period during which time the use of lime fell into disrepute. The cause of this disfavor was that the use of quicklime had become more general than the use of chalk or limestone and this dressing had been used in too large quantities. In fact we are only now coming back to the use of this helpful form of soil dressing. Some works on argiculture written as late as the early eighties are inclined to treat the use of lime on the land as an unnecessary waste of time and money. This attitude resulted from the fact that the chemical actions connected with the transfer of nitrogen from the atmosphere to the soil was not thoroughly understood. F. H. Storer, Professor of Chemistry in Harvard University, writing on agriculture in the late eighties says, "Many of the landlords of the present day absolutely forbid the use of lime on their lands." An old German proverb is quoted as follows by Professor Hopkins: "Kalk macht die Vater reich, aber die Sohne arm." (Lime makes the father rich, but the son poor.)

Probably no field of endeavor in scientific research did more to show the value of lime on land than the study leading up to the discovery of the bacteria which have the power of changing the nitrogen of the air to nitrates or as commonly spoken of as the fixation of nitrogen.

The average composition of the air by volume is often given as follows:

Oxygen	20.61
Nitrogen	77.94
Carbon dioxide	.05
Aqueous vapor and other gases	1.40

Of these constituents, plants need all for their proper growth and development. But one of the strange phenomena of nature is the fact that while plants can appropriate the oxygen and carbon dioxide direct from the air, the nitrogen is not directly available although it constitutes over three-fourths of the whole atmosphere. It has long been known that in some peculiar way the nitrogen of the air was, on some kinds of soils and with some crops, finally transformed to an available form, but the process was a closed book. Later science has shown that certain soils and the roots of certain plants formed the home of small bacteria or organisms which had the power to take up the nitrogen of the air and give it up in the form of nitrates to the soil. In this form it is known to be one of the most needed plant foods. Along with these discoveries it became known that these organisms thrived better in normal or slightly alkaline soils, and when a soil became markedly "sour" or when acid was present their development was arrested, and in fact a point was quickly reached where they failed to live. The scientists developed the fact that these microscopic organisms commonly lived in tubercles upon the roots of members of the family of plants commonly known as legumes (clover, peas, soy-beans, cow-peas, etc.). These tubercles can be easily seen on the roots of these plants, varying in size with the different kinds of plants, but the organisms are far too small to be visible to the naked eye. As the nitrates are formed they are drawn upon by the plant for its own food, but when the crops are harvested and the roots remain behind, or when the crop is ploughed over, the nitrates remain in the soil and increase its fertility. The reason for the use of lime or limestone upon the land is for the purpose of neutralizing the acids that may be present in the soil. These acids are always present to a greater or less degree as they result from the decay of any form of organic matter. The most common form of acid present in soils includes carbonic acid, nitric acid, as well as the various organic aeds as lactic acid, acetic acid, etc. The reaction between these acids and a base or basic salt gives a salt and leaves the soil free of acid. To supply this base, quicklime is often used, but it is now known that ground limestone will do as well in reducing the acidity of the soil and is far less destructive to the organic matter contained in the soil.

The burning of limestone into lime is a process of driving off the carbon dioxide contained in the calcium carbonate of which the limestone is formed and takes place according to the following reaction:

$$CaCO_3 = CaO + CO_2$$

In other words the calcium carbonate is broken up into calcium oxide which is the quicklime and carbon dioxide which is driven off as a gas. The calcium oxide thus formed reacts with the waters of the soil when it is applied and slacked lime of calcium hydroxide is formed according to the following reaction:

$$CaO + H_2O = Ca(OH)_2$$

when this water slacked lime comes in contact with the air it tends to take up carbon dioxide from the air and changes back to calcium carbonate of which the limestone was originally composed. The reaction takes place as follows:

$$Ca(OH)_2 + CO_2 = CaCO_3 + H_2O.$$

In addition to the fact that the crushed limestone is as effective as lime on soil, since both do the same work through the same chemical reactions, the lime is far more destructive to the organic matter that might be present in the soil. The use of crushed limestone is accompanied by less inconvenience than the use of lime, as the latter is injurious to the skin and must be handled with care. The burned lime in addition to being a powerful chemical agent in the destruction of organic matter tends to increase the solubility of the phosphorus and potassium in the soil. Although this may give larger crops at the time of dressing the soil it tends to cause a rapid improverishment of the field. Since the main object in the use of lime or limestone on land is to correct the acidity of the soil and thereby increase the amount of nitrates present, the use of ground limestone is just as effective as lime dressing and less expensive. Where the soil is especially rich in organic matter, as in the case of peaty and other swamp soils, the lime is probably the better dressing as the soil can spare a large amount of organic matter without becoming impoverished. There are types of soil also that contain large amounts of phosphorus and potassium which become available very slowly and in such cases the lime will hasten the liberation of these necessary plant foods. Professor Hopkins says, "Of course the landowner must be governed somewhat by the cost of material. As a rule fine-ground limestone will be both the best and most economical form of lime to use, wherever it can be easily obtained. If caustic lime is used we should make special provision to maintain the humus in the soil by making even larger use of farm manure, legume crops and green manures. It might be expected that burned lime would produce a greater increase in the crops for the first year or two than would be produced by ground limestone, more especially where the mineral elements, phosphorus and potassium, are not applied; for ground limestone produces only the milder action, chiefly of correcting the acidity of the soil and thus encouraging the multiplication and activity of the nitrogen-gathering and nitrifying bacteria; whereas the burned lime not only produces this same effect, but it also acts as powerful soil stimulant, or soil destroyer, attacking and destroying the organic matter and thus liberating plant food from the soil, usually resulting in more or less waste of valuable nitrogen and humus."

There are at least ten chemical elements to the life and growth of plants that are essential: (1) Oxygen, (2) carbon, (3) hydrogen, (4) potassium, (5) magnesium, (6) calcium, (7) iron, (8) sulphur, (9) phosphorus, (10) nitrogen. The subject of soil fertility in fact can be narrowed down to only two, as all the others can be obtained from the air and almost any soil that can be called in any way normal. These two are the phosphorus and nitrogen. In some cases potassium must be added, but this is the exception. Since the air contains an inexhaustible supply of nitrogen, and by properly controlling the acidity of the soil this vast supply of nitrogen becomes available through the action of the nitrifying bacteria, the problem can be termed one of securing lime or limestone and phosphorus bearing compounds. In the few cases where the element potassium is necessary it can usually be obtained by treating the soil with gypsum, as most all soils contain more or less clay or waste from feldspathic rocks and this contains the necessary potassium, and the calcium of the gypsum will slowly replace the potassium in the clay, giving potassium sulphate which is an available form of this element.

The farmer of Indiana should no longer waste his earnings on prepared fertilizers, as it is time that he learned what was necessary in a fertilizer and prepared it himself for the soil on which it is to be used. Prepared fertilizers must contain the necessary elements for a number of different soils and thus the farmer who purchases them must purchase a large amount of material which can not possibly be of use on his soils. An attempt should be made to educate the farmer to a point where he will be able to determine what fertilizers his soils need and from this knowledge buy the raw materials and mix his own fertilizer. The State of New York maintains a bureau of soils for the testing of soils of the State, and any farmer who cares to submit a sample of his soil can have it tested free of charge and with the analysis he receives advice as to the kind and amount of fertilizer to use in the treatment of his land. This State could find no more efficient means of helping her agricultural population than to maintain a bureau where free analysis and advice could be obtained. This idea has lately been taken up by a number of States, and in the future every large commonwealth will furnish free of charge all the scientific aid possible. The physical effects of the use of ground limestone on different soils are very peculiar. When the ground limestone is added to a clay soil it makes the soil more mellow. In fact the richer a soil is in limestone the more readily the soil crumbles and the more readily the rain can percolate through it. The cause of the compactness of a clay soil is that such soils are composed of very small particles which fit very closely together and water passes between these particles with difficulty, but when the limestone is added the lime cements a number of these small particles together to form a much larger granule, and as these granules increase in size the spaces between the granules increase also in size. When once thoroughly dressed with crushed limestone a clay soil will remain in a friable condition for a number of years and the effects pass away very slowly. On the other hand when a sandy soil is dressed with ground limestone the soil becomes more compact and has a greater ability to retain moisture. The particles of the sand on being cemented together by the limestone as it dissolves, causes the soil to become more compact and the soil is thus given an increased ability to hold water. This effect of ground limestone is readily shown by the appearance of the soil after a long drought. On fields that have been treated with the limestone the soil is markedly more moist than the fields not treated. This is well shown by a series of experiments which have been carried on by Mr. Perry Blackburn on his farm near Oolitic, Indiana, during the last two years. The writer visited the farm early in June after that section of country had undergone a severe drought and examined a field which had received a partial dressing of rather coarse limestone early in the spring. The line of division between the dressed part of the field and the portion which had received no limestone was marked, as the accompanying picture will show. The clover on the part of the field that received the limestone dressing was on an average six inches taller, the roots were on an average four inches longer and the soil markedly more moist than on the portion which had been left without the dressing. In the picture it will be seen that the part of the field on the right which received no limestone is hardly covered by the crop and the clover present is short and undeveloped, while on the left where the limestone dressing was applied the clover is much thicker, taller and more advanced in its growth.

The statements of those interested in commercial fertilizers that lime and limestone are not fertilizers have tended to keep many farmers from the use of these soil correctives. In the direct use of the word, limestone is not a fertilizer as it does not contain any one of the three essential plant foods, phosphorus, nitrogen or potassium. Such materials which act in a secondary sense have been called by Professor Vivian, in his work "The fundamentals of soil fertility", soil amendments. The chief value of these amendments lies in their ability to correct conditions in the soil that keep plant foods from becoming available. The condition most easily observed and the most widespread is soil acidity which causes the death of the nitrifying bacteria. Probably no one man has done more toward the development of the theory of raw fertilizers than Professor C. G. Hopkins, and the result of his experiments in the use of ground limestone and ground rock phosphate leave no doubt that the grinding of limestone and rock phosphate will soon be a great economic industry. The results of these experiments are published in pamphlet form and can be obtained from the Illinois Experiment Station. The results of these experiments will be outlined in this connection for the benefit of those who would be unable to obtain these circulars:

"In November, 1903, a farm of about 300 acres was purchased at less than $20 per acre. It was abandoned prairie land which was thought to be almost worthless, but by the scientific employment of a small quantity of farm manure and ground rock fertilizers, it was brought to a point where the yield of wheat on a 40 acre field was 35½ bushels. During the ten years that the experiment was in progress a six-year rotation system was used, one year each of corn, oats, and wheat, and three years of meadow and pasture with clover and timothy. During the ten years two applications of two tons per acre of ground limestone and two applications of one ton each of ground rock phosphate were made. These applications of fertilizer occupied twelve years and cost $18 per acre or a cost of $1.50 per acre per year and this outlay resulted in an increase of 24 bushels per acre more than the amount that was raised on an adjoining strip of land with liberal applications of farm manure. The differences in the clover were even more marked than the differences in the wheat crops. The following is given as the best directions for the southern counties of Illinois, and most of the southern part of Indiana closely resembles Illinois in the condition of the soils. The directions are as follows: First apply two to five tons per acre of ground limestone. Second, grow clover or cow-peas. Third, apply from 1,000 to 2,000 pounds per acre of very finely ground natural rock phosphate, to be plowed under with the clover or cow-peas. During late 318 tests to determine the effect of lime or ground limestone on crop yields in southern Illinois were made. These included 79 tests on legumes (clover, cow-peas, and soy-beans), 122 tests on corn, 55 tests on oats and 62 tests on wheat, these crops being grown in the rotations practiced. As an average of all tests the yield per acre was increased by one-half ton of hay, 5 bushels of corn, by 6.6 bushels of oats, by four bushels of wheat. The data at hand and here reported are amply sufficient to justify the conclusion that, in practice economy systems of farming on the common prairie and timber soils of southern Illinois, limestone at less than $1.00 per acre per year, will produce twelve tons more of clover or cow-pea hay, five bushels more corn, six bushels more of oats and four bushels more wheat than would otherwise be obtained. The only reason that the same statistics are not available for the soils of Indiana is the fact that the farmer has been too much inclined to let well enough alone and practice the system of farming followed by his father before him. He must realize that economic conditions have changed and what would bring success on the virgin forest soils of a century ago will lead to disaster at the present time."

Probably no better and more convincing data can be furnished at the present time than the following taken from the work of Prof. Hopkins in Circular No. 157 on Soil Fertility. He says:

"As an average of the first two years' work on two different experiment fields (Ewing and Raleigh) where the initial application was five tons per acre, the average increases were one-fourth ton of hay, nine and one-fourth bushels of corn, eight and nine-tenths bushels of oats and three and one-half bushels of wheat; and, as the increased farm manure or increased crop resources from these larger crops are returned to the land, the effect becomes more marked in subsequent years. On the Vienna experiment field in Johnson County about nine tons per acre of ground limestone were applied ten years ago. At a cost of $1.25 a ton, this amounted to $11.25 and the returns for this investment have thus far amounted to 90.3 bushels of corn, or to 42.2 bushels of wheat, or to three and one-third tons of clover hay. Any one of these will pay for the limestone three times over; and, in addition, two-thirds of the legume crops have been plowed under as green manure, and at the end of nine years, with no farther application, the land treated with limestone is producing five bushels more wheat, nine and three-tenths bushels more of corn and one and four-tenths tons more hay per acre than the land not so treated. Indeed, as an average of the last two years, this old worn hill land has produced larger crops where limestone had been applied than the average yield for the State for each of the crops, corn, wheat and hay."

As this paper is not supposed to go deeply into the agricultural phases of the limestone as a fertilizer, except to show what a broad market could be opened up by a proper process of education for the farmer, an outline of the kinds of soil that need this dressing with their distribution will be all that will be attempted in this connection but the work is ready and the field for experiment is broad and must be covered before we can say we know the possibilities of raw fertilizers and the principles that govern the use of them.

What Soils Need Limestone Dressing.

The idea that, since the soils of much of Monroe and Lawrence counties are on the limestones and in fact are residual soils from decomposition of limestones, they do not need limestone dressing, is responsible for the fact that the farmers of these counties have allowed these vast deposits to go untouched. In fact the operator of the only crushing plant in the district says he has sold less than a car load of crushed stone in these two counties since opening his plant over a year ago. No idea could be farther from the truth. Limestone while only slightly soluble in pure water is dissolved very rapidly in water containing only a small part of some acids, and even carbon dioxide in solution (carbonic acid gas) will dissolve it to a great extent. Through the long ages that these soils have been exposed to the leaching action of the rain waters, together with the acids formed by the organic remains present, there has been a steady loss of the calcium carbonate present and an increase of the amount of acids in the soils. The fact remains that there are no soils in the entire State that are any more acid than many of the hillsides of the southern Indiana driftless area. Probably the best indication of the effect of crushed limestone upon these soils can be seen in the condition of the fields which lie along the roads which have received a surface of limestone. The dust from the roads has been blown over the nearer parts of the fields while but little of it reached the more remote portions. The stand of grass or crops is always better on this portion that has received even this small amount of limestone. Another sample of the effect of limestone on this land can be seen along the stream beds which receive drainage from the hillsides that are underlain by the limestone above the level of the stream as compared to the stream beds farther east where no limestone is close to the surface in the adjacent hillsides.

The amount of acid soils in the entire State represents more than three-fourths of its area. Practically all soils west and south of a line passing along the boundaries of the following counties are strongly acid: the southern boundary of Newton and Jasper counties, the western and southern boundaries of White and Carrol counties, the southern boundary of Howard and Grant counties, the western and southern boundaries of Delaware and Randolph counties. In addition to this area there is a smaller area in the northwestern part of the State including most of Porter, Laporte, Starke, Pulaski, Marshall, St. Joseph and Elkhart counties that are in the same condition as far as soil acidity is concerned.

In addition to these larger areas, there are many smaller areas in the northern and eastern sections of the State that are acid soils. The larger area includes what is known as the driftless area of the southern portion of the State and the Wisconsin glacial lobe. The entire southeastern section of Illinois south of Danville also is acid and might provide a market for crushed limestone from this section if it were not for the fact that this industry has been developed to so high a level in that State and the cost of the product is kept very low by regulation of freight rates and convict labor.

Test for Soil Acidity.

Every farmer can easily make his own tests and satisfy himself as to the acidity of his soil, without skilled advice. One of the best and easiest methods of testing the acidity of a soil is by what is known as the litmus paper test. The test is carried on in the following manner: Take a fair sample of the soil to be tested (to make an average sample, take a small portion from several points of the field to be tested, mix carefully and reject one-half the pile cut through the middle, mix the remaining half carefully again and repeat the process until only a small portion remains), moisten with pure water and press together upon a small piece of neutral litmus paper. The presence of the acid will cause litmus paper to turn a reddish pink color. Allow a little time for the action to take place. Be careful not to touch the paper with the fingers after it has been moistened as perspiration is acid in reaction and will affect the paper. Another method of applying the test is to scrape away a little surface soil and press the paper to the moist earth revealed. Cover the paper and leave a few minutes. To obtain good results only the best grade of neutral litmus paper must be used. People are often misled in making this test by the direction to use "blue litmus paper which can be bought at a low price at almost any drug store." In fact the ordinary blue litmus paper is not sensitive enough to detect a quantity of acid which would entirely prevent the growth of clovers. Any druggist can procure the best grade of neutral litmus paper at only a slight additional cost. This small extra cost represents the difference between success and failure of the tests. A good crop of clover which stands well and continues its growth throughout the season is a pretty good indication that enough lime is present in the soil for present purposes, but where the clover fails to grow or where it only makes growth part of the season, limestone can be applied with good results.

Lime or Crushed Limestone.

When a soil is "sour", the acidity may be corrected by either caustic lime or crushed limestone, as both react with the acid of the soil to form salts. The reactions are as follows:

$$CaO\ 2HNO_3 = H_2O\ Ca(NO_3)_2.$$

In other words calcium oxide (quicklime) plus nitric acid equals water and calcium nitrate.

$$CaCO_3\ 2HNO_3 = H_2O + CO_2 + Ca(NO_3)_2.$$

Which means that calcium carbonate (crushed limestone) plus nitric acid equals water, carbondioxide and calcium nitrate the same compound that came from the caustic lime. The function of soil conditioning already mentioned is performed equally well by both, but where they differ is in their effect upon the organic matter present in the soil. Caustic lime is better than ground limestone only when the soil contains an abundance of organic matter or some form of phosphorus which is not readily available. It should always be borne in mind that caustic lime, although giving good results for a year or two, tends in the end to impoverish the soil.

Probably no more convincing experiments have been carried on along the line of the relative values of burned lime and crushed limestone than those of the Pennsylvania and Maryland Experiment Stations. The results of these experiments are summarized in Circular 110 of the University of Illinois as follows: "Four plots were treated with burned lime at the rate of two tons per acre every four years. Four other plots were treated with ground limestone at the rate of two tons per acre every two years. A four year rotation was practiced consisting of corn, oats, wheat, and hay, being mixed timothy and clover, seeded on the wheat land in the spring. Seven products were obtained and weighed each year; namely, corn, corn stover, oats, oats straw, and hay.

After twenty years results had been obtained showing that with every product a greater total yield had been obtained from the plots treated with limestone than from those treated with burned lime. Furthermore, with every product whose total yield for the last eight years was greater than the first eight years limestone produced greater increase than the burned lime, and with every product whose total yield for the last eight years was less than the total yield for the first eight years the decrease was less with the limestone. This demonstrates the tendency of burned lime to exhaust the soil."

The actual figures of the above experiments are, to say the least, startling, and the effect upon the soil shown by careful chemical analysis bears out the statements already made. The nitrogen present in the soil treated with crushed limestone was greater than the amount present in the soil treated with burned lime by an amount equivalent to the amount of nitrogen present in 37½ tons of farm manure. Or represents an equivalent of more than two tons per acre per year of the farm manure. The analysis also showed that the amount present in the second case was in about the same ratio as the amount of nitrogen. This alone should demonstrate that the ground limestone is the proper form of neutralizer as well as being the form provided in nature.

The Amount of Limestone to Use.

The amount of crushed limestone to use on the soil to correct its acidity depends on a number of things, among them the location of the field (whether hillside or flat land), the amount of acidity, and the fineness of the limestone used. Hillsides lose their lime faster than flat land, but the accumulation of acid is slower than on the flat land. If a rather coarse limestone is used the hillsides will need most limestone. The amount of acidity determines the amount of the limestone that is used up soon after its application and thus determines the amount that will be left in the soil to correct acidity that will occur later. The finer the limestone is ground the quicker will be its action and the quicker it will be used up and dissolved. Thus a ground limestone that contained both coarse and fine ground stone is the best. The larger lumps present may remain several years before entirely dissolved and used on the soil. The best average quantity to use is about two tons per acre every four years unless the soil shows acid tests in the meantime, then increase the number of applications in preference to increasing the amount used. This amount should keep almost any soil "sweet". A large amount of the acidity of the soil comes from the capillarity of the soil, which causes the waters of the soil to rise bringing with them the acids of the subsoil. If the subsoil is very acid the amount of limestone should be increased to destroy it. The time of year for spreading limestone makes little difference but the suggestion of the spring before the spring rains is probably the best.

Cost of Crushing Limestone.

Cost data on the cost of crushing stone is very difficult to obtain with any degree of accuracy on account of the numbers of factors to be reckoned with, but where a plant is already in operation in the kind of stone to be crushed, the data is more available. Such a plant operating in the Oolitic stone belt is located at Oolitic, Indiana, and the operating company is the Stone Products Company of Bedford, Ind. The superintendent, Mr. E. W. King, kindly furnished the following data on his work.

The plant has been in operation a little over one year and in that time the business has made a steady increase. The demand for the crushed product is growing till the operators are thinking seriously of the feasibility of enlarging the plant to increase its output. The present plant represents an investment of approximately $7,000 and the following figures represent fairly the cost of turning out this product in a mill of this size.

Labor at the mill	$0 08 per ton.
Total labor charge, including sales	31 per ton.
Power	06 per ton.
Upkeep	05 per ton.
Stone	15 per ton.
General expense	05 per ton.
Total cost per ton for present output	$0 63 per ton.

With an additional 10 cents per ton added to cover depreciation of machinery the total cost will be 73 cents per ton. And the price charged for the product free on board the cars at Oolitic, Indiana, at present is $1.18 per ton. The present equipment could be made to put out 75 tons per day if the demand was large enough, but at present the output is quite considerably below this figure, as the market has not been worked up to its greatest development as yet. The plant is only equipped with storage bins for ten tons and this hampers the output, but the company has already made plans to enlarge this part of their plant and by so doing a larger amount of the crushed product can be handled. Any increase in the output will not be accompanied by a corresponding increase in the cost of production as the fixed charges on the equipment which represents a large part of the cost of production will not be increased, so the cost of production will decrease with increase of the output. The product is at present sold for agricultural purposes during the summer months and for use in fluxing in the glass industry during the winter.

The machinery in use at the plant consists of a Forster type crusher put out by the McLanahan Machine Company of Hollidaysbury, Pennsylvania. This reduces the stone to inch and on-half size when it is carried by belt conveyor to a pulverizer where it is reduced to 20 mesh. The crusher according to the statement of the superintendent is not giving satisfaction on account of the high cost of the upkeep and the owners are thinking seriously of installing a gyratory crusher of the Gates type. Power for the machinery is purchased from the Southern Indiana Power Company and the investment mentioned included the cost of wiring and motors.

The stone for the plant is purchased from the mill and is of the smaller sizes so that the crusher can handle them without further breaking. The quarry company furnishes this material free on board the cars at the fifteen cents per ton quoted. The company has a large belt conveyor to carry the waste from a nearby scabbler into the crusher. The preparation of the limestone for fertilizing purposes simply consists of pulverizing the stone until it will pass a certain mesh screen. The size of the largest lumps that will be of value upon land is still an open question, but the general idea is that the larger the lumps the slower the sweetening process takes place and the longer its results can be seen. The stone is usually fed to a large crusher called a breaker and this reduces it to a certain size. The largest piece that will pass a certain ring is the size by which the product is called. It is then fine crushed in some form of pulverizer and screened, the fine product stored while the material too coarse to pass the screen is returned to the pulverizer to be worked over again.

Rock breakers are of three general types depending on the form of their motion.

(1) Jaw breakers, in which the motion of the crushing parts is reciprocating.

(2) Gyratory crushers, in which the motion of the crushing parts is rotary and spiral.

(3) Roll crushers, in which the motion of the crushing parts is rolling.

The jaw breakers are of two types according to whether the greatest movement comes on the smaller lumps fed or on the larger. The first kind are known as the Blake type of crusher and those of the latter kind are known as the Dodge type. Very complete descriptions with sectional drawings of all types can be found in the work of Prof. R. H. Richards of the Massachusetts Institute of Technology, entitled "Ore Dressing."

Gyratory crushers are classified on the same principles as the jaw breakers. The type most widely used and the type that will give the best results in the crushing of limestone for fertilizing material are those known as the Gates or the McCully type of breaker.

The type of rolling crushers is known as the Forster crushers. The jaw crushers are usually selected where the output of the plant is small on account of their small first cost and the fact that the cost of the up-keep depends to a large extent upon the output. The cost of crushing a small quantity per unit of output is in favor of the jaw crusher. In the selection of a jaw crusher great care is necessary on account of the great strain that is necessary to withstand. Some of the following things should be kept in mind when a selection is to be made. Frame should be heavy and cast in as few pieces as possible, foundations should be low and very massive as jar is great. Machine should be low and size of jaws ample for the amount of rock fed. Larger jaws will accommodate larger lumps and the power expended per ton crushed is the same regardless of the size of the crusher. Larger crushers also cost less for up-keep than smaller ones. The average rate of crushing with a crusher of this type working in hard limestone is about eight tons per horse-power per hour of power used, with the output reduced to one inch size. This amout increases rapidly as the output is turned out in larger sizes. Prof. Richards gives the following amounts per horse-power per hour:

Thirteen tons to one and one-half inch size.

Sixteen tons to two inch size.

Nineteen tons to two and one-half inch size.

Twenty-one and one-half tons to three inch size.

Twenty-eight and one-half tons to three and one-half inch size

The cost of preliminary breaking with jaw crushers can be best obtained from the following table taken from Richard's "Ore Dressing."

ESTIMATED COST OF BREAKING WITH A BLAKE TYPE BREAKER.

Size of mouth	10x4	10x7	15x9	20x10	30x13
Tons per 24 hours, 2-inch size	92	120	192	360	600
Horse-power	5	8	12	20	40
Cost of breaker	$275	$500	$750	$1,050	$2,250
Cost in cents per ton for oil	0.020	0.020	0.020	0.020	0.020
Interest and depreciation	0.097	0.135	0.127	0.095	0.122
Power	0.705	0.865	0.811	0.721	0.865
Labor	4.348	3.333	2.083	1.111	0.667
Wear	0.815	0.815	0.815	0.815	0.815
Repairs	0.462	0.462	0.463	0.462	0.462
Total cost per ton crushed	6.447	5.630	4.318	3.224	2.951

Machines of this type are more widely used for crushing stone for road metal than in regular crushing plants as they produce less fines than is given by the gyratory crushers of the larger sizes. A jaw breaker uses more power per unit of output than the gyratory crusher on account of the large weight of the reciprocating parts and the fact that they are in the act of crushing only half the time while the action is continuous in the gyratory crusher. The cost list given in the above table was calculated as follows by Prof. Richards:

"Sizes, capacities, power and original costs were taken from the catalog figures of the different companies putting out these machines.

"Oil, costing 35 cents per gallon is estimated to be used at the rate of one quart per 24 hours, on a 30 by 13 inch breaker, breaking 600 tons in 24 hours to a maximum size of 2 inches. The cost per ton is $35 \times \frac{1}{4} \div 600 = 0.015$ cents. The cost per ton for a 10 by 4 inch breaker estimated to use one half pint per 24 hours, breaking 92 tons to 2 inch size is $35 \times 1/16 \div 92 = 0.024$ cents. The average of these two figures is about 0.020 cents.

"Interest and depreciation at 10 per cent. per annum: For a 10 by 4 inch crusher would be $27.50 per year. On a basis of 308 operating days per year and 92 tons being crushed per day, the cost would be $\$27.50 \div (308 \times 92) = 0.097$ cents. Other sizes can be calculated in the same way.

Power is estimated to cost $40.00 per horse-power per year of 308 days or $0.1298 per day. For a 10 by 4 inch breaker using five horse power and breaking 92 tons per day, the cost per ton would be $0.1298 x 5 ÷ 92 = 0.705 cents.

"Labor.—It is assumed that the breaker is fed by a sloping chute and can therefore be fed by one man at a cost of two dollars per 12 hour shift or four dollars per 24 hours. The cost per ton for the 10 by 4 inch machine would be $4.00 ÷ 92 = 4.348 cents. Other sizes to be calculated in like manner.

"Wear is estimated at 0.815 cents per ton, which is the average of the gross cost per ton at 18 mills.

"Repairs other than wearing parts. The maximum figure recalled was $155 per year. These repairs were required by a machine breaking 109 tons per day of 33,572 tons per year of 308 days, making the cost per ton $155.00 ÷ 33,572 or 0.463 cents per ton."

Although this table is taken from average conditions and average hardness of rock, it can be taken as a conservative set of figures for the conditions that exist in the limestone belt of Southern Indiana, and any estimates based on these will be sure to be high enough.

Jaw crushers are on the market in all sizes up to the giant Farrel which is for very coarse breaking to eliminate the necessity of sledging. This machine will handle 350 tons per hour crushed to 16 inch size. Another late improvement in jaw crushers to reduce the rock more in a single machine is the machine known as the "Sturtevant Roll Jaw Crushers". This machine has a grinding as well as crushing effect on the rock and its output is much finer than that of the ordinary crusher.

Gyratory breakers are the standard type for work such as grinding of rock fertilizer where a considerable output is to be handled and the mill is to be kept in continuous action. This type of crusher will be found in all the larger crushing plants such as those operated at cement mills and ore plants. The following table taken from Richard's "Ore Dressing" and recommended as correct by the leading manufacturers of today will give a fair idea of the cost of crushing with crushers of this type. The figures are calculated by the same method as that used in the case of the jaw crushers as shown on an earlier page.

ESTIMATED COST OF BREAKING WITH GYRATORY BREAKERS.

Breaker No.	0	2	4	6
Size of mouth in inches	4x30	6x50	8x68	12x88
Tons broken in 24 hours	72	228	720	1,500

Horse-power	3	8	16	32.5
Cost of breaker	$375	$760	$1,800	$3,300
Cost in cents per ton for oil	0.020	0.020	0.020	0.020
Interest and depreciation	0.169	0.108	0.081	0.071
Power	0.541	0.456	0.288	0.281
Labor	5.556	1.754	0.556	0.267
Wear	0.971	0.971	0.971	0.971
Repairs	0.308	0.308	0.308	0.308
Total cost per ton	7.565	3.617	2.224	1.918

It will be seen by a comparison of the two tables that as soon as the output passes the 200 ton per day mark it is cheaper to use a gyratory crusher and with the 10 by 4 inch crusher, it is only slightly cheaper than the crusher of the gyratory type of the same output. It must also be remembered that the higher cost has been included in the calculations or at least interest on the larger outlay has been accounted for.

Sturtevant Mill Company of Boston and Farrel and Bacon of New York deal in the jaw breakers, while the Power and Mining Machine Company of Milwaukee, Wisconsin, handle the McCully type of the gyratory crushers. All these companies have furnished figures on the cost of crushing with their especial type of machinery.

Following the coarse crushing the product is fed to some sort of pulverizer. The most common forms in use are what is known as rolls. These are heavy metal cylinders held together by powerful springs or gravity arrangements and are rotated at such high speed that their centrifugal force tends to hold them together and at the time impart a heavy blow to the stone as it passes between them. The closeness of approach of the roll is regulated by shims or compression bolts. The larger the roll the great its capacity since with the same speed of rotation its peripheral velocity is far greater. The cost of rolling 100 tons per 24 hours would be as follows, ten horse-power required: Power, $1.30 cents per ton; attendance, $1.50 cents per ton; wear on rolls, 0.02 to 4.00 cents per ton; repairs, oil, etc., 0.37 to 0.60 cents per ton. Total cost $3.19 to $7.40 per ton would be a good estimate. The above calculation can be found in Richards.

Several special types of machinery are in use for the final reduction of the product after it has passed through the crusher, and probably better results can be obtained from a hammer bar pulverizer or a set of ring rolls than can be secured from the com mon type of rolls. The hammer bar pulverizer depends upon a blow struck in space to the effect of crushing, the harder the impact the finer will be the product. The mill works on the principle that a weight placed to swing freely on a revolving shaft will stand at right angles to the shaft when the shaft rotates rapidly, and that the faster the rotations of the shaft the harder the blow that can be struck by the weight before it will be forced back. The stone is fed into this machine and struck by the first set of weights and thrown against the retaining case of the machine from which it rebounds in the way of the next set of weights to receive a greater impact due to its own motion as well as the motion of the swinging weight. These mills are rotated at speeds from seven hundred to fifteen hundred revolutions per minute. The lower walls of the mills may be made of cast iron screens so that the pulverized material may escape while the uncrushed stone is carried around again till it is reduced to the size that will pass the screen. The advantage of these mills is that the screening and pulverizing can be done in one machine. One drawback to their use is the large amount of power used to drive them. The cost of pulverizing the output is about 10 cents per ton for 200 tons per day. This figure will be increased for smaller output and decreased for increased output. The high speed of rotation of the machine tends to drive out the crushed product by air pressure, the swinging parts acting as a fan. Many of these machines are coming into use for this work and seem to be giving satisfaction.

The ring roll mill is a mill in which the rollers are placed inside of a ring or cylindrical case and the crushing force comes between these rolls and the inside surface of the mill. The rotation of the ring imparts a motion in the same direction to the rollers, and since they are held firmly to the inside of the ring the material in passing between the ring wall and the roller is brought under great pressure. Much force is applied, due to the centrifugal force of the rotating parts. And this force also keeps the material fed to the outside of the ring and tends to draw it under the rolls. Its great advantage lies in the fact that there are few wearing parts. The mill is very accessible and the speed is slow enough so that there is little vibration and the parts can be so well balanced that elaborate foundations are not necessary. Another advantage is the fact that the consumption of power per unit of output is comparatively small. These machines will handle about one ton per horse-power per hour in limestone crushing. These machines for the larger units are built duplex, that is, two like machines on a single shaft. This has the advantage of less cumbersome parts and less vibration with less cost of repair, as the smaller parts of the two mills cost less than large parts for a large single mill would.

The cost of handling limestone through such a machine from 2 inch size or finer down to pass a 20-mesh screen can be calculated with all investment charges, including interest, depreciation, wear and tear and repairs, to be about 8.455 cents per ton in a plant handling 200 tons per day, and this figure will be decreased with an increase of output and increased with a decrease of the output. The Sturtevant Mill Company are putting these mills on the market and the above figures were taken from their catalogues.

The cost of screening and elevating the crushed stone is a more difficult proposition to calculate, as conditions differ so much in every separate plant that it is almost impossible to give anything but the most approximate calculations. Screens are named from the motion they have as shaking screens or riddles, gyrating, rotating screens or trommels and inclined separators. These do not need defining as the name is self-explanatory. Of these the trommel is the type most used in fertilizing plants, although the Newaygo Separator of the Sturtevant Mill Company which is an inclined separator, is coming rapidly into use. Their chief advantage lies in the small amount of power consumed in vibrating them, the largest sizes taking less than one horse-power. The vibration in this type of screen is imparted to the wire cloth by a number of small hammers while it is held taut. The inclination of the screen allows a coarse wire to be used even when a fine product is desired. In the trommel the material is fed in at one end and the coarse particles pass out of the other end while the fine material passes through the sides. These screens are rotated and slightly inclined, the greater the inclination the finer screening can be done. They use but little power and are rotated from 16 to 20 times per minute. Screening is improved by faster rotation and greater slope, but the decrease in the output of screened material under these conditions is very rapid and the limit is soon reached. Plates with slits are often recommended in place of wire cloth and are more lasting, but the percentage of openings is necessarily less and the screening is slower. The cost of screening will, when all charges are taken into account, be about one cent per ton when the output handled is as before quoted 200 tons per day of limestone to 20 mesh. Another thing to be taken into account when deciding which type of screen to purchase is the size of the machine necessary to do the work. The trommel must necessarily have a larger screening surface than a vibrating screen for only a small portion of its screening area is in use at once while the entire surface of the vibrating can be in operation at one time. The other types of screen can, for this connection, be considered simply as modifications of those already mentioned and need no detailed description.

Elevating the product is necessary in practically every plant unless the location selected was so placed in respect to the slope of a hill that every movement of the product from the machine to the next could be controlled by gravity. Plants where this condition prevails are very few, as such a favorable location would in most cases make the switching of the stone to the plant and its removal from the bins to cars a problem. The most common types of apparatus used in carrying crushed stone material from one point to another is the belt conveyor. In this piece of apparatus a belt is run over wheels arranged to cause the upper surface of the belt to be concave and thus the product will remain on the belt. Rough belts or cleats are sometimes used. The capacity of a belt conveyor is determined by its velocity and width. They are in operation up to 40 inches wide with a speed of 650 feet per minute. Such a belt will handle about 1,220 tons per hour. As the elevation increases an elevator becomes necessary and the bucket elevator is the only one giving satisfaction in this kind of work. They consist of an endless belt running over two pulleys, one above and one below. The buckets are riveted to the belt and act as scoops as they pass through the material and carry a quantity along the belt in each bucket. These are run at speeds up to 400 feet per minute but the slower they are run the longer life they will have and less repairs they will need.

Bins are the one problem that needs to be figured on closely by any company about to start a plant as the capacity of the storage bins limits the running time in case of dull market. Bins are at the best expensive, and if extra large ones are put up, the first cost of the plant is so high as to seriously interfere with the profit of the young venture.

Bins are usually of wood construction and elevated so that the material may be delivered by chutes. They must be roofed and must not be leaky.

To show that even the large manufacturing companies which put out crushing machinery will not give any but approximate figures, we publish the following letter received from one of the leading firms which handles crushing machinery in reply to a letter asking the cost of crushing in certain size plants.

"Dear Sir—The necessary equipment of your plant would include a crusher, set of rolls, screens, elevator, transmission machinery and power, but we can give no figures as to cost till a stated project is laid before us and our engineering department has gone into the matter. If you care to fill out the inclosed blank we will gladly make an estimate."

The blanks returned, the following data was submitted including a plan of a ten ton per hour plant.

"Dear Sir—The machinery required will be as follows together with weights and prices:

One crusher, No. 4	23,000 lbs.	$1,134 00
One fine crusher	4,000 lbs.	1,000 00
One 10x6-inch bucket elevator, 38 feet, 6 inches	1,700 lbs.	201 00
One No. 3 screen	1,600 lbs.	350 00
Pulleys, five in all		90 00
Shaft, boxes and set collars		23 00
Belts, four in all		55 00
Total cost of plant without buildings and bins		$2,853 00

This figure lacks the freight, cost of installation, and the work of building plant and bins. If the above figures were taken and to them were added the following:

Freight	$205 00
Building	850 00
Installation	300 00
Bins	250 00
Total	$4,458 00

This would be a fair estimate of a small plant that would handle about 100 tons per day. The power necessary to drive such a plant would be about 40 to 45 horse-power. The cost of crushing in such a plant should not exceed the following figures:

Interest and depreciation, 6 and 9 per cent	$668 70
Taxes and insurance, 2 per cent	89 16
Labor	2,230 00
Power, at 2 cents per kilowatt hour	1,848 00
Wear and repairs	420 00
Oil and waste	35 00
Total year's operating expense	$5,290 86

With a total year's output of 30,800 tons, the cost per ton of the product turned out of the mill will be about 17.5 cents. To this must be added the cost of advertising, and the office and sales force. With these put at thirty cents per ton it still brings the cost of the product well under fifty cents per ton. The accompanying plan of a plant of this size was submitted by the Power Mining and Machine Company of Milwaukee, Wisconsin.

Another firm suggested the use of a jaw crusher and a swing hammer pulverizer, but the cost of the pulverizer made the entire investment a little higher than this estimate.

The following figures on a large plant turning out from 20 to 25 tons per hour would be about as follows: These prices are subject to the discounts given by the firm and are for the material free on board the cars at the manufacturing plant.

One steel breaker for heavy duty, set to crush to two-inch size and handling 25 tons per hour:		
Size 10x20 in. Horse-power 18, speed 150 r. p. m., wt.	12,500 lbs.	$1,407
One No. 2 ring roll mill, horse-power 75, speed 325 r. p. m., wt.	45,000 lbs.	8,857
Four separators, each 0479, horse-power 5, wt.	7,200 lbs.	1,916
One elevator, horse-power 10, wt.	2,200 lbs.	395
Pulleys, belts and supports		325
Building and bins, including labor		2,000
Freight, foundations and cartage		950
Total outlay		$15,850

Fixed charges on this investment would be as follows:

Interest at 6 per cent	$951 00
Depreciation at 9 per cent	1,426 50
Taxes and insurance at 2 per cent	317 00
Total fixed charges	$2,694 00

Operating charges about such a plant would be approximately as follows:

Labor, at $2.00 per day	$5,544 00
Power at $40.00 per horse-power per year	4,320 00
Wear and repairs	810 00
Oil and waste	98 00
Total operation expense for one year, 308 days of 10 hours.	$10,772 00
Total yearly output, 77,000 tons.	

Cost per ton slightly under fourteen cents per ton. To this must be added the fixed charge of about three cents per ton, which brings the cost up to approximately seventeen cents per ton. This figure is plenty high, as the liberal discounts and the fact that the estimates on the other costs are very conservative would tend to reduce the cost in case of a plant being actually built.

The breakers of the type included above are made in capacities from six to forty tons per hour and the prices range from $715 to $2,572. In cases of large output, roll-jaw fine crushers are often used following the breakers before the product is fed to the ring-roll mill. This increases the output of the equipment materially. They range in sizes from one to twelve tons in capacity per hour and cost from $429 up to $2,858. These machines can be used on large size rock without previous crushing. They are slower in action than a breaker.

Ring-roll mills are made to handle output of 40 tons per hour and cost up to $8,857.

Vibrating screens cost from $400 up to $600 according to the fineness of the product desired. Their capacity ranges around six tons per hour for limestone grinding to 20 mesh.

The estimate of one of the leading firms on the cost of wear and up-keep on the machinery of a limestone crushing plant is one-fourth of a cent per ton for the material turned out. This cost is divided up as follows:

Total, including belts, etc.	1/5	cents per ton.
Ring roll mill	8/100	cents per ton.
Elevator	7/1000	cents per ton.
Screens	5/100	cents per ton.
Total, including belts, etc.	1/5	cents per ton.

Since the average farmer would rather purchase a ready mixed fertilizer than to trouble to mix it himself it should be an economic project to construct a mixing plant in connection with a crushed limestone plant in this district, and to that end the proposition of getting the raw rock phosphate was taken up with several of the phosphate dealers in the phosphate belt of Tennessee, which is the nearest available deposit of this raw material. The owners of these deposits quoted prices averaging $6.00 to $6.50 per ton laid down in Bloomington in small lots and these prices would probably be reduced to at least $5.00 per ton on a large contract with a plant which was handling a large part of their output. These figures are on a phosphate rock that carries from 11 per cent. to 14 per cent. of phosphorus, or in other words, represents about 25 per cent. phosphoric acid.

The amounts usually recommended for treatment of ordinary soils is two parts of limestone to one of ground phosphate. At this rate the mixture could be turned out ready for use at about $2.25 per ton and allowing a fair profit to the operator it could be sold F. O. B. Bloomington at about $3.50 per ton. This would bring it to almost any part of the State at less than $5.00 per ton. The Indiana Railroad Commission has fixed the rates on natural fertilizers such as crushed limestone at a very low rate, in most cases ranging not over seventy to eighty cents per ton.

If lands were known to be lacking in potassium, gypsum could be mixed with the fertilizer. The average cost of gypsum in this country last year was according to the report of the Bureau of Mineral Resources about $2.00 per ton and the amount used on land as fertilizer was about 55,000 tons. The three could be mixed as follows for land deficient in potassium salts: Four parts of crushed limestone, two parts of phosphate rock, one part gypsum. This mixture could be put on the market at the same price as the former one mentioned. Deposits of gypsum occur in northern Ohio and the cost at this point in large quantities would undoubtedly be markedly lower than the $2.00 per ton mentioned.

The total output of phosphate rock from the fields of Tennessee was approximately 450,000 tons last year which represents about 14.5 per cent. of the total output of the country. The deposits are very large and this valuable mineral fertilizer should have a much broader use in the treatment of worn out soils than it has at the present time. The use of crushed limestone in the treatment of acid soils has increased so rapidly that the figures given for any one year are far below what they are the next year. The last available figures are 200,000 tons for the year of 1912.

Waste Limestone in the Manufacture of Lime.

The generally accepted theory with regard to the origin of limestones is that most of them are of organic origin, although some geologists still hold that the massive beds of limestone deposited in the earliest geological periods were chemical precipitates. Limestone, or at least the chemical compound, calcium carbonate, which constitutes the main part of limestone may occur in a great number of forms in nature. Common limestone, marble, aragonite, calcite, and travertine are composed almost entirely of calcium carbonate, while dolomite is composed of calcium and magnesium carbonate.

Pure calcium carbonate is composed of 44 per cent. carbon dioxide and 56 per cent. of calcium oxide. These two chemical compounds can be separated by means of heat and this is the chemical reaction carried out in the manufacture of lime. The carbon dioxide, being a gas, is driven off by heat and the calcium oxide, a white solid, known as quicklime, remains in the kiln.

Calcium the metallic constituent of limestone is very abundant in nature; in fact only oxygen, silicon, aluminum and iron are more abundant. An estimate of the amount of limestone in the earth's crust by T. Mellard Reade placed it as equivalent to a layer around the earth with a thickness of 528 feet. Van Hise estimates the amount of calcium carbonate in solution in the waters of the ocean as one hundred and sixty trillion metric tons. Calcium can not exist in nature as the metal or the oxide on account of its great affinity for water. Water changes it immediately to the form known as slacked lime or calcium hydroxide. The hydroxide in turn is acted upon by carbon dioxide to form carbonate. The formation of quick lime takes place according to the following reaction:

$$CaCO_3 + \text{heat} = CaO + CO_2.$$

which means that when calcium carbonate of limestone is heated it gives up carbon dioxide and becomes calcium oxide or quick lime. Quicklime when acted upon by water in the process commonly known as slacking gives the following reaction:

$$CaO + H_2O = Ca(OH)_2.$$

$Ca(OH)_2$ is the substance commonly known as slacked lime or the milk of lime. This slacked lime on exposure to the air when wet takes up carbon dioxide from the air and again forms calcium carbonate as shown by the following reaction:

$$Ca(OH)_2 + CO_2 = CaCO_3 + H_2O.$$

Although the chemical explanation of the above changes has been known but a few decades, nevertheless the fact that the changes themselves took place was known even in the early ages where the Egyptians were engaged in building their great works. In fact some of their mortars are still to be seen and they are known to be very similar to our present common lime mortars. All the great structures built before the time of the Roman Empire were constructed with lime mortars, but the Romans used a cement made from volcanic ash in many of the great structures built under the Empire. The use of this cement was soon abandoned, and the mighty castles of the middle ages are constructed with lime mortars.

Limestones are widely distributed and they differ materially from one locality to another. They are found interbedded with other sedimentary rocks and often grade into them insensibly. Their purity may vary from rocks containing but 45 per cent. calcium carbonate to limestones with as high as 99 per cent. calcium carbonate. The limes of commerce are produced by calcining almost any of these limestones, the resulting lime varying in its uses with its varying purity. The impurity most often found is magnesium carbonate and when the percentage of this runs above 20 per cent. the rock is called dolomite. Following magnesium carbonate the most common impurities found are silica or sand, alumina or clay, and iron.

A limestone composed of nearly pure calcium carbonate will furnish a high grade of quicklime. This product is known as white lime, hot lime, or fat lime while the product from a limestone containing magnesium is called cool lime, brown lime or lean lime. In scientific language the former is called a high calcium lime while the latter is known as dolomitic or magnesium lime.

The limestones of both the Mitchell and the Salem formations are very free from magnesium carbonate and in fact are among the purest limestones of this country, so that any lime burned in this district would be classed as a high calcium lime. In other words it would be composed of almost pure calcium oxide.

The West Virginia Geological Survey, Volume III, in discussing lime describes lime oxide as follows: "Lime oxide when pure is a white solid, without crystal form, infusible and non volatile at temperatures below 3,000 degrees Centigrade. The commercial oxide is more or less tinged with color due to the impurities present. The metallic lime (calcium) free from oxygen may be made by electrolysis of fused lime chloride, or more readily by heating seven parts of the iodide of calcium with one part of sodium in a crucible. The metal is yellow in color, soft, with a specific gravity of 1.578. It is both malleable and ductile and does not tarnish in dry air. If heated in a stream of air or oxygen the metal burns into lime oxide with a very brilliant light. Lime oxide can be obtained in a very pure form by heating the nitrate of lime $Ca(NO_3)_2$".

White lime slacks readily, and rapidly with the evolution of much heat and becomes a perfectly white paste. Any impurities present tend to retard this chemical action. The presence of magnesium makes the process much slower, and less heat is evolved. Limes containing less than ten per cent. of MgO show no effect but as soon as the amount goes above this figure the slowing up of the reaction is noticeable.

The presence of aluminum and silicon oxides in a limestone tends to color the lime produced to a gray color but when present in small quantities they only make the action of the lime less vigorous; that is, these impurities do not ordinarily exert any chemical influence or in any way change its physical properties. They have a dilutent action the same as sand when mixed with lime to produce mortar. If this alumina or silica be present in finely divided particles it will be susceptible of chemical combination with the lime if the temperature employed in burning the lime be high enough. As these constituents increase the limestone is called argillaceous or arenaceous, and from this grades into shales or sandstones according to whether the dilutent is clay or sand. The presence of these impurities in small proportion produces on higher heating a hydraulic lime; that is, it gives the lime the property of setting under water. When the quantity of clayey impurity in a limestone reaches 6 per cent. it begins to produce hydraulicity but below this percentage its only noticeable effect is a retardation of slacking. In fact many limestones containing between six and twelve per cent. of clayey impurities make good, cool, slow slacking limes, but the risk of over-burning them is very great. This is not true of white limes. When earthy limestones are over-burned they form a hydraulic cement and must be finely ground to be of use. From the above discussion it will be seen that the limit between common lime and hydraulic cement is only in the amount of clayey material or alumina present and the percentage of alumina present is the only difference between the hydraulic cement and a true Portland cement. In fact these products form a series with the hot or white limes at one end and true Portland cement at the other. The dividing lines are more or less arbitrary and depend upon chemical composition. The following divisions are commonly made:

(1) Common or fat lime.
(2) Hydraulic limes.
(3) Hydraulic or Roman cement.
(4) Portland cement.

The main difference between limes on the one hand and cements on the other is that cements are burned at a much higher temperature, contain a much higher percentage of alumina and silica, and must be thoroughly pulverized before water will have any great effect upon them.

The presence of iron or sulphur in a limestone in any amount spoils it for the manufacture of lime. The iron in addition to coloring the lime dark has a fluxing effect. The sulphur darkens the lime and forms sulphates of calcium or magnesium. Organic matter when present in a limestone does not interfere with its lime making properties since it is completely removed by the calcining process which the limestone undergoes.

Mortars made from hot limes harden more quickly than those made from magnesium limes, and tests made at the end of 30 or 60 days show the mortars made from hot limes to be harder and more resistant than those made from lean limes. This superiority does not appear to persist, for tests made on mortars after they have been set a year or more show their resistance to be about equal.

When water is added to lime, calcium oxide hydrates and changes to calcium hydroxide. On exposure to the air the excess of water is given up. It has been generally held that the set of the lime was complete when all the water disappeared from the lime but it has been determined by Chatelier that the slacking of lime takes place in four stages.

(1) Simple absorption of water.

(2) The mixture is warmed by contact and by the heat of the chemical action taking place, and a portion of the added water is evaporated.

(3) The mass cools and moisture is fixed by the silicates, although some of the free lime remains unslaked.

(4) The unslaked lime removes this water from the silicates and becomes completely hydrated.

The above is quoted from Volume III of the West Virginia Survey.

The time taken for a lime to set depends on a number of factors; among them the amount of impurities present, the amount of water used, the air temperature, and the thickness of the lime layer. Fat, or hot limes, set much more rapidly than lean ones, and when a mason has been taught to use one it is difficult for him to handle the other. After the set has started, any movement of the plaster tends to weaken the bend and injure the work. After the first set the lime hydrate takes up carbon dioxide from the air and forms carbonate of lime, as shown earlier in this paper. This process is a slow one and in the case of some limes it may be years before the lime has finally returned to the state of a carbonate. The rapidity with which this change takes place depends on the amount of exposed surface of the mortar, the thickness of the layer and the porosity of the mortar. As this action goes on a crust of the carbonate forms over the surface of any considerable mass of mortar and protects the soluble hydrate within from being dissolved or changed and therefore this final carbonate condition may never be reached throughout the mass.

In regard to the final reaction of the lime with the sand in a mortar, S. W. Beyer says in his paper on "The Physical Tests of Iowa Limes" in volume seventeen of the Iowa report:

"Long contact of lime hydrate with finely divided silica is known to cause a reaction by which the silica combines with the lime forming stable silicates of lime. The extent to which this reaction progresses depends on the physical and chemical qualities of the siliceous impurities in the lime or of the sand used with it. If these are very fine, chemical action is favored. Silicates, such as clay or feldspar, for example, are more susceptible to attack by the lime than is quartz sand. Hydraulic limes are apt, therefore, other things being equal, to give a more durable final product than the purer limes. In the same way, muddy or clayey sand used with lime, although less desirable at the start, will likely contribute to the durability of the mixture in time because of the development of these stable compounds by the caustic action of the lime. In the case of silicates, it is probable that other elements, especially alumina, also enter into combination."

Lime has many uses in the various industries but by far the most important use is in the production of lime mortars for structural work, interior walls and plastering. In these uses the lime can not be employed alone on account of the great shrinkage of the lime paste in setting and its own lack of inherent strength when set. It is also cheaper to add some foreign substance, which material will always be cheaper than the lime itself. The most common material used for filler in mortars is sand. Any type of sand grain is superior in hardness to the set lime and when the lime mortar cements these hard grains together the resulting mortar is hard and durable. In the production of mortars any inert substance which does not shrink nor deteriorate may be used. Ground or rough crushed limestone may be used and will give equally good results. In fact crushed stone being rough edged gives the lime more chance to adhere and thus the resulting mortar is very durable. Dolomitic limes are more durable and show less shrinkage than high calcium limes.

A long series of tests of the proper percentages of lime and foreign material for the strongest mortar, and the type of lime best adapted to the manufacture of mortars have been conducted by the Geological Survey of the State of Iowa and the results of these tests can be found in the annual report of that State for the year 1906, Volume 17, pp. 106 to 146.

The reaction by which limestone or carbonate of lime is broken up into lime oxide or quicklime and carbon dioxide takes place above the temperature of 850 Centigrade or 1,562 Fahrenheit. This reaction will go on to completion only in a current of heated air, which carries away the carbon dioxide as fast as formed. Dr. Thorp in his Industrial Chemistry says: "Calcium carbonate begins to decompose below a red heat into calcium oxide and carbon dioxide, but the decomposition is not complete until a bright red heat (800 to 900 C.) is reached. The temperature should not rise above 1,000 to 1,200 C., as there is danger of overheating the lime. For successful burning, it is essential that the gases escape freely from the kiln, the draught usually being sufficient to remove them as they form. This escape may be accelerated by blowing steam or air into the kiln during the burning, or even by wetting the carbonate as it is introduced."

The amount of heat required to produce this change of limestone to quicklime is 3,735 calories for one kilogram of calcium carbonate changed. This amount of heat is equivalent to 747 B. T. U. These are the figures given by Gruner, while Eckel gives the heat requirement as 784 B. T. U. The above figures are quoted from Volume III of the West Virginia Geological Survey.

Limekilns are of two general classes, periodic and continuous. After a charge has been calcined, the periodic kiln is allowed to cool before it is emptied and recharged. With the continuous kiln this delay is not necessary. The calcined material can be withdrawn and fresh material can be added without loss of time or the great waste of heat, which we have with the periodic kilns. Kilns are fired by two general methods. In the first case with what is known as "short flame burning", the material to be calcined is charged in alternate layers with the fuel. In this method the limestone is in close contact with the fuel, and is, of course, more or less contaminated with ashes after burning. In what is known as the long flame method of burning, the fuel is burned on a separate grate and only the flames and hot gases pass into the shaft of the kiln. With this method no ashes are left in the product and a purer lime is produced. With the long flame method there is a materially greater loss of heat, but the purity of the product more than counterbalances the loss. With any of the various forms of kilns other fuels than coal can be used as, for example, natural gas. producer gas, or oil. Any one of these fuels has the advantage over coal of cleanliness and regularity. The fact is becoming generally recognized that producer gas as a fuel for lime burning is the ideal fuel, because the heat can be applied more closely to the charge than in the case of any other fuel, and because the product will be more even and cleaner than with any other fuel.

Continuous kilns are preferred where fuel is expensive, and where a regular output is desired. In fact where close figures are necessary on the cost of fuel the periodic kiln is out of the question. The continuous kiln is a tall, narrow furnace or shaft, built of brick or iron plates, and may vary considerably in size. Such kilns are usually thirty-five to forty-five feet high by six to eight feet in diameter. The limestone is fed in at the top and is calcined as it passes down through the kiln, the lime being taken out at the bottom. The burning goes on without interruption even during the process of charging or removing the lime. In this country many long flame periodic kilns are now in use, the main reason for their installation being their cheapness and simplicity of construction, but they are very expensive in their use of fuel. With these kilns an arch of large blocks of limestone is built about three feet from the bottom of the kiln, openings being left for the flames to pass through. On top of this arch small lumps varying in size from a cocoanut to an orange are piled till the kiln is full. The fire is then built and the temperature of the whole mass is slowly raised during six or eight hours till a full red heat is obtained. This heating must be slow in order to prevent the arch from crumbling. The high temperature is maintained for about two days after which the fire is allowed to burn out and the kiln is allowed to cool. The material is removed and the kiln recharged, much time being lost by the process.

The first method of burning lime, and one occasionally used at the present time for fertilizing lime, was to pile together heaps of logs on which blocks of limestone were laid. The whole mass was fired and the over-burned or under-burned blocks were thrown aside, the remaining material being used. This method was followed by the heap or ditch method in which the limestone was piled in long heaps on a bed of wood and long openings for draught channels were left through the piles. These huge heaps were fired as the smaller heaps had been fired before, but the burning took a much longer time. These ditches were modified into trenches upon hillsides where the material to be burned slid down through the trench much as it does in the limekilns of today; the burned product came out at the lowest level. This type of kiln required four times as much wood fuel as the amount of lime burned, but the small cost of wood in the earlier days made the method practicable. Next came the stone pot kilns which were square chambers of stone about eighteen to twenty feet high and about twelve feet square. These would produce as much as eight hundred cubic feet in 24 hours. They were the forerunner of the modern type of intermittent kiln, and many of them are still in use. The modern lime plant has three floors. The top one is for charging the kilns, the middle one for charging the fires, and the bottom one for removing the burned product. The upper floor is connected by inclines to the quarry, up which the limestone is drawn in cars to be dumped in the top of the kiln. The second floor is on a level with the coal bins and is usually also level with the ash dump. The lowest floor is at the ground level so that the product can be loaded in cars.

Under present conditions one ton of coal will burn from three to five tons of lime. The problem is to keep the fires at their greatest efficiency and to force or draw the hot gases up into the kilns. These things can be best accomplished by means of forced or induced draught. There are four methods of securing better draught on lime kilns at present and they are as follows:

(1) Air jets.
(2) Steam jets.
(3) The Eldred process.
(4) The Suction process.

In the first process jets of air are forced under the grates and the fire boxes are kept tight, on the same principle as forced draught under a boiler.

In the second method steam jets are introduced through the grate bars to give the necessary force to the upward gaseous currents.

The fourth method is to apply suction fans at the top of the kiln to draw off the waste gases as fast as they are formed.

The Eldred process is a combination of the two methods in which steam and air jets are forced into the kiln and suction fans take away the waste gases.

There is no question as to the fuel economy with any of these methods for increasing the draught, but as to their relative value expert engineers are not at all agreed. Of course, the use of reinforced draught in the manuacture of lime is a source of danger if not properly handled because careless handling is sure to give an inferior product, and the danger of over-burning is much greater. A carelessly burned product in addition to being inferior for use is also inferior in its keeping properties. These difficulties would be lessened if the lime were hydrated before being put on the market.

One hundred pounds of good limestone will yield from fifty-six to fifty-eight pounds of lime, but the shrinkage in volume does not exceed fifteen per cent. and is usually much less. There is little difference in the hardness of lime and limestone, but the lime is much more porous and when acted upon by water it falls into powder.

Pure lime is infusible at the temperature of the oxyhydrogen flame and is therefore used in the production of the calcium light. For light pencils the lime must be very pure, as any impurities cause it to fuse and form a glass slag. Lime is a powerful base and reacts with acids to form salts of calcium.

With the development of the use of gas producers and producer gas in all lines of industry the increased use of gas in the manufacture of lime is only a matter of time. Several types of gas producers are in use at the present time. The Morgan system is one of the oldest of these. It consists of a cylindrical steel shell which extends into a water filled ashpan. The fuel is automatically fed in at the top of the producer and scattered over the entire fuel bed. A jet of air and steam is introduced through a central tuyere in the bottom of the producer. All the operations are continuous and automatic and the ashes are removed under water. This producer is capable of a very steady and uniform flow of gas and is admirably adapted to the manufacture of lime. At a lime plant in New Milford, Connecticut, a two weeks' run showed a saving over old methods of forty per cent. in fuel, and an increase of twenty per cent. in the capacity of the kilns. The cost was lowered from twenty-five cents to seventeen and one-half cents per barrel of 300 pounds, and the capacity of the two kilns equipped with this apparatus increased from 65 to 80 barrels per kiln per day. The above is quoted from Rock Products, Volume IV, and from Volume III, of the West Virginia Survey.

Professor G. P. Grimsley in his comprehensive work on lime and cement in the third volume of the West Virginia Geological Survey Reports, describes five general kilns at present in use in the industry in that State as follows: "The Shoop kiln, manufactured by S. W. Shoop and Company of Altoona, Pennsylvania, is what is known as a center draught kiln and rests on a foundation of common brick or stone. The stack is made of 3/16 inch steel, twelve feet in diameter and and about 25 to 30 feet high. The inner cylinder is made of fire brick supported by a back wall of red brick. The inner diameter of the cupola is 5½ feet near the fire boxes and eight feet near the top. This leaves a space about 18 inches below, between the brick cylinder and the steel cylinder, which is filled with ashes or earth packed solidly. The shape of the interior of the cupola is conical to about the middle and then becomes a cylinder. The barrel below the furnace to the cooling pot which is made of one-fourth inch steel and about four feet long, is bolted to a base five feet square so that it may be easily repaired. The opening of this pot is closed by shears readily operated into the car below. Fire brick pillars at the furnace opening into the cupola prevent the lime dropping into the fire boxes and choking the draught."

The following explanation and claims are made by the designer of this kiln (S. W. Shoop) for the natural draught:

"The kiln is constructed with two chambers or ashpits to each side under the firing doors. One is located centrally underneath the other, with foundation on the floor line connected with flumes around the cooling formation of the lime chamber, which gather the heat and hot air from the cooling lime and distribute it underneath the grate bars. The velocity that this heat gathers passing through these flumes is almost equal to forced draught, making it the strongest natural draught kiln constructed. Not only are there advantages derived through draught, but a large saving in fuel is effected by the utilization of this hot air.

"Taking into consideration that it requires about twelve pounds of air, or fifty cubic feet, to consume one pound of coal, and that this air flowing under the grate bars in the ordinary style of kiln at an average temperature of 70 degrees Fahrenheit has to be raised to a temperature of nearly 2,000 degrees Fahrenheit, there is economy in collecting the waste heat from the cooling lime. By the introduction of a small jet of steam underneath the grate bars in connection with the hot air, there is an excellent forced draught for coal."

The Broomell kiln, known as the Keystone limekiln, made by the Broomell, Schmidt and Steacy Company of York, Pennsylvania, is a steel clad kiln built on a somewhat different plan than the Shoop kiln. The supporting base of the kiln is heavy steel reinforced by vertical double angle iron posts. The steel cooling cone within the supporting basal cylinder is made of heavy boiler plate suspended from a heavy cast iron bed plate and can be readily removed for repairs. At the bottom of the cooling cone are patented draw gates opened and closed by hand wheels which project outside the supporting base so that the workman can turn the gates without coming in direct contact with the hot lime and dust. The heat of the kiln is generated in four independent furnaces, each twenty-four inches wide, thirty inches high and about four feet long. The furnaces can be used with forced draught under the grate bars by forcing a mixture of steam and air through an inserted steam pipe. Induced draught is obtained by using an iron cover with a door and attaching a suction fan to the top of the kiln. The shell of the kiln is composed of heavy steel plates bolted together, and the interior is lined with fire brick supported by common brick. Near the top of the kiln is placed a heavy steel cone to protect the brick and above this cone is a large storage space, the full diameter of the kiln. The rock is heated in this space by the heat passing through the kiln and its temperature is gradually raised as the rock passes down to the burning zone. These kilns are usually placed in batteries with three feet of space between them, and any kind of fuel may be used. The most popular sized kiln is the Number 3 which is described as follows by the company:

Diameter of shell outside	11½ feet.
Diameter of brick lining inside	6½ feet.
Diameter of cooling cone at the top	7 feet.
Diameter of cooling cone at the bottom	2 feet.
Height of cooling cone	7 feet.
Total height of kiln	48 feet.
Shipping weight of kiln	44,000 pounds.
Weight of special brick	14,800 pounds.
Fire brick required	8,463 pounds.
Common red brick	15,700 pounds.

Capacity, 90 to 140 barrels of 200 pounds each per 24 hours.

The O'Connell kiln patented in 1899 has boilers set in the arches of the furnace openings into the body of the kiln. These boilers supply the necessary heat for the kiln and also provide a means whereby steam generated in the boilers may be used to aid combustion. By this means the fuel used for burning the lime produces steam to run the blowers and conveyors to elevate the stone. and operate quarry pumps and other necessary machinery. It is claimed to save twenty per cent. of the fuel ordinarily required for burning the lime.

The Hoffman kiln, a horizontal circular kiln, invented in Europe for the manufacture of brick, is also extensively used for lime burning. It consists of an arched circular room divided by movable partitions into sections (usually twelve in number). The limestone is placed in these sections and fired through openings in the roof into the first section, and when the lime is burned the fire is added to the next section and so on around the circle. The air enters the section in which the lime is being removed and cools the burned lime, becomes heated in the section where the full fire is being maintained, and then reaches the sections charged but not burned, giving off its heat, and finally passes from the last section out through a chimney at the center of the kiln. Dampers serve to regulate the air current, and sections not in use can be shut off, since all are connected with the central chimney by openings which can be readily closed. In England, according to Frasch, the Hoffman kiln produces daily 1,200 to 1,500 cubic feet of lime with a consumption of only five pounds of slack coal per cubic foot. In Germany the saving of fuel in the Hoffman kiln is almost 75 per cent. over the old methods. The lime is said to slack more easily and cannot be stored so long a time as that made in other kilns. The saving in fuel in the Hoffman kiln over the best drawn kiln is said to be 40 per cent. This form of kiln is well adapted to use where the lime is to be hydrated before it is placed on the market.

Rotary kilns are in use in a few instances but not enough data is available to determine their economic value. The following figures indicate the cost of lime burning with oil fuel and a rotary kiln:

Average output, twenty-five tons per day.
Fuel consumption, forty barrels (52 gallons per barrel).
Stone, 98.5% $CaCO_3$.
Labor cost, $22.00 per day.
Oil consumption per 100 pounds of lime, 26.2 pounds.

This represents a total cost of about nine cents per bushel.

The cost of lime manufacture differs markedly in different sections of the country. Some of the most important factors in the cost of lime or the factors which cause variations in cost of production are different labor costs, variations in fuel cost, and the cost of quarrying the rock.

The following figures are given as the average cost of a two-kiln plant with a daily capacity of 500 bushels. The expenses run as follows:

Interest on plant and land	$1 60
Repairs, taxes, etc	1 30
Cost of quarrying 30 tons of rock	7 00
Fuel cost (Coal $1.25 per ton)	5 00
Additional labor cost	12 00
Total cost of 500 bushels	$26 90
Cost per bushel, 5.4 cents.	

These costs for the Southern Indiana district would be, with up-to-date plants:

Interest on plant and depreciation	$2 00
Repairs, taxes, etc	1 30
Quarry cost or cost of waste stone (15 cents per ton)	4 50
Fuel cost (coal $1.50 per ton)	6 00
Labor cost	10 00
Total	$23 80
Cost per bushel, 4.8 cents.	

There are approximately twenty-seven bushels to the ton of quicklime. A fair estimate of the cost of lime burning in the quarry district of Southern Indiana with the cheap waste limestone as a raw material would not exceed $1.50 per ton after all expenses are counted in.

In slacking a high calcium lime there is an increase of about forty pounds to the bushel. Quicklime weighs about seventy-five pounds per bushel.

Uses of Lime.

Lime probably has the greatest number of uses of any mineral product. Approximately one-half of the lime burned in this country is used for structural material and the remaining half is used for chemical purposes. Different grades of lime have different uses and in fact most grades of the product have some special use to which they are best adapted. Some purposes require a high calcium lime and some require a slow slacking lime such as results from the burning of dolomitic limestones. The principal uses of lime as a structural material are in lime mortars, and plasters in gaging Portland cement mortars, concrete, and gypsum plasters, and as a whitewash. Both quicklime and hydrated lime can be used for these structural purposes. The chemical uses of lime are given in the government reports on the industry as follows:

Agricultural industry—

As a soil amendment (either calcium or magnesium lime can be used).

As an insecticide (either).

As a fungicide (either).

Bleaching industry—

Manufacture of bleaching powder, "chloride of lime" (calcium).

Bleaching and renovating rags, jute, ramie, and various paper stock (either).

Caustic alkali industry—

Manufacture of soda, potash, and ammonia (calcium).

Chemical industries—

Manufacture of ammonia (calcium).

Manufacture of calcium carbide, calcium cyanamide, and calcium nitrate (calcium).

Manufacture of potassium and sodium dichromate (calcium).

Manufacture of fertilizers (either).

Manufacture of magnesia (magnesium).

Manufacture of acetate of lime (calcium).

Manuacture of wood alcohol (calcium).

Manufacture of bone ash (either).

Manufacture of calcium carbides (calcium).

Manufacture of calcium light pencils (calcium).

In refining mercury (calcium).

In dehydrating alcohol (calcium).

In the distillation of wood (calcium).

Gas manufacture—

Purification of coal and water gas (either).

Glass manufacture—

Most varieties of glass and glasses (calcium).

Milling industry—

Clarifying grains (either).

Manufacture of rubber, glue, pottery, and porcelain (either).

Dyeing fabrics and polishing material (either).

Oil, fat and soap manufacture—

Manufacture of soap, glycerine, candles (calcium).
Renovating fats, greases, tallow, butter, etc. (calcium).
Removing the acidity of oils and petroleum (either).
Lubricating greases (either).

Paint and varnish manufacture—

Refining linseed oil (either)
Cold-water paints (either).
Manufacture of varnish and linoleum (either).

Paper industry—

Soda method (calcium).
Sulphite method (magnesium).
For strawboard (either).
As a filler (either).

Preserving industry—

Preserving eggs (calcium).

Sanitation—

As a disinfectant and deodorizer (calcium).
Purification of water for cities (calcium).
Purification of sewage (calcium).
Water softening and purifying (calcium).

Smelting industry—

Reduction of iron ores (either).

Sugar manufacture—

Beet root (calcium).
Molasses (calcium).

Tanning industry—

Tanning cowhides (calcium).
Tanning goat and kid hides (either).

The uses of lime in the agricultural industry are many, but by far the largest part used is as a soil amendment, and this use is thoroughly treated in the portion of this paper dealing with crushed limestone as a fertilizer. It is there shown that crushed limestone will do the same work as lime and at a much smaller cost than with lime. The only case in which lime is better adapted to soil treatment is in the case of a soil very high in organic matter, as in the case of drained lands where the soil is of a peaty nature and a part of the organic matter in the soil can be sacrificed for quicker returns.

Lime is used in the preparation of nearly all of the insecticides and fungicides used for protecting plants. Lime and iron sulphate commonly known as copperas and water is much used as a spray under the name of Bordeaux mixture. This mixture is used to kill fungous growths on vines and trees. A mixture of about 20 pounds of sulphur, 15 pounds of common salt, 35 pounds of lime, and 50 gallons of water will make, when boiled, a spray that will destroy scale and other insects, without hurting the trees, at any time of year. Many other mixtures of this type are known.

Slacked lime when treated with an excess of chlorine gas forms calcium oxy-chloride $Ca(OCl)_2$, commonly known as "bleaching powder", much used in bleaching vegetable fibers for the textile and paper industries.

Quicklime is used in the manfacture of the alkaline hydroxides, such as sodium, potassium and ammonium hydroxides. The carbonate of the substance when treated with quicklime and water gives calcium carbonate and the hydroxide of the substance, as for example:

$$CaO+Na_2CO_3+H_2O=CaCO_3+2Na(OH).$$

That is, quicklime plus sodium carbonate plus water equals calcium carbonate plus sodium hydroxide.

Calcium carbide, much used in the production of acetylene gas, is made from a mixture of 100 parts of lime and 70 parts of coke. This mixture must be heated at the temperature of the electric arc for some time, so that plants for its manufacture must have cheap sources of power. The carbide breaks up slowly in the air but rapidly when treated with water according to the following reaction:

$$CaC_2+2H_2O=C_2H_2+Ca(OH)_2.$$

The manufacture of acetate of lime from which pure acetic acid is prepared, and the purification of wood alcohol and acetone, are carried on along the same line. Milk of lime is used to take up the acid from the impure wood spirits while the alcohol and acetone are carried over and condensed. Much lime is used in these reactions. The only method of obtaining wood alcohol of high purity is by distillation over lime.

In the manufacture of soaps the lime is used to obtain the alkaline hydroxides from the carbonates as described earlier in this paper. The action of the lime on tallow or grease is to form organic salts or calcium. The calcium is easily replaced by sodium or potassium from some of their compounds, to form the soluble soaps of commerce. Saponification with lime is a necessary step in the manufacture of candles, glycerine and the explosives derived from glycerine. The milk of lime is used also to remove any trace of acid that might be present in the pure products.

Lime plays a very important part in the manufacture of paper. The first use of lime in this industry is in the cleansing of the materials and the removal of foreign substances. This method is employed in the case of rags, straw, etc., that are to be used in paper manufacture. If wood pulp from soft woods is to be used, the pulp is boiled in a solution of sodium carbonate which has been rendered alkaline by the addition of pure lime oxide. In the sulphite process the wood of spruce, hemlock, etc., is boiled with sulphurous acid and milk of lime till the tars and oils are removed and the pulp softened. The paper pulp is usually bleached with chloride of lime before rolling. It will thus be seen that it plays one of the most important parts in this industry.

The uses of lime in sanitation are so numerous and so well known that space will not be given here to discuss them.

Lime is used in sugar manufacture in the process known as "Defecatio." The lime here removes the excess of organic acids and coagulates the albumen and mucus. Lime, although slightly soluble in water, is more soluble in sugar water and the lime unites with the sugar to form an insoluble compound, in which form it can be washed with alcohol and water. The calcium from this sugar of lime compound can be removed by passing carbon dioxide through the solution.

Lime is used in tanning hides where a strong solution of milk of lime is used to remove the hair from the hides. The lime also dissolves the fatty matter and dissolves the corium, loosening the fibres, which swell the hides. The length of time that the hides undergo this liming process determines the pliability of the leather formed. The addition of sodium sulphite to the lime gives a paste that will remove the hair in a few hours if spread on the hair side and rolled in.

I have only attempted to outline a few of the more important chemical uses for lime. A discussion of these industries can be obtained from any of the later texts on Industrial Chemistry.

It will be seen from the table above that high calcium limes are far more important and have a much larger use in the manufacturing industries of the country than the magnesium limes and those burned from dolomite.

The demand for these manufactured products is sure to increase very rapidly in this country during the next few years, and the demand for lime will increase accordingly. The price of high grade high calcium limes is sure to increase with the increased demand for them in the new manufacturing projects that are sure to spring up in the next decade.

The vast diversity of the uses of lime is sure to keep the demand constant even if the different industries make varying demands for it. The ability of lime to correct soil acidity has been thoroughly treated in the part of this paper treating the use of lime and limestone and their relative effects on acid soils.

THE HYDRATION OF LIME.

When a magnesium lime is packed for shipment its slow slacking action and little heat given off in slacking makes it possible to keep it a long time and to ship it in paper sacks without fear of its destruction, or danger to property near it. This is not true of the hot, high calcium limes. Their great affinity for water has always made them dangerous to property as well as causing them to spoil in storage or transit. In most industries the hydrate of lime is as useful as the pure quicklime and much easier to handle, being also less liable to spoil. This demand for an easily handled and shipped compound led to the placing of lime hydrate on the market. By whatever process quicklime and water are brought together the same chemical reaction results, namely:

$$CaO+H_2O=Ca(OH)_2.$$

When the oxide leaves the kiln it is in lumps about one-fourth larger than the lumps of limestone from which it was burned. These lumps on slacking fall into a fine white powder known as the hydrate of lime. The reaction is accompanied by the generation of a large amount of heat that under certain conditions may cause combustion. If this reaction is carried on directly after the quicklime is cool, and the resulting product is dried, it can be stored or shipped without any danger to property or to itself. The lime hydrate contains about 25 per cent. of water and has a specific gravity of about 2.08 while the specific gravity of limestone is about 2.8. The specific gravity of pure lime oxide may be as high as 3.1.

The burning of the lime has much to do with the rapidity with which it slakes. Lime burned at temperatures under 1,000 degrees Centigrade will slake quickly, while limes burned at higher temperatures are liable to take hours to slake thoroughly. When a hot lime and water are mixed temperatures as high as 310 degrees Fahrenheit may be reached; this temperature will under appropriate conditions cause combustion.

To slake the lime properly the water must be added slowly. About one-third the amount of water necessary to slake the lime should be added first, and after the heat is generated the rest of the water can be added. If the lime is mixed with a large amount of cold water the product will be very granular. The weight of high calcium limes is increased about one-third on slaking. One bushel of good lime will make about two and one-half bushels of slaked lime, with a weight about one-half as great per bushel.

The old method of lime hydration practiced by masons and plasterers consisted in pouring the necessary amount of water over the lime in a water-tight box lined with sand and lime paste. The lime was spread over the bottom of the box in a layer about eight inches thick and enough water added to make a thick paste. A layer of sand is spread over the lime to keep in the heat. This method when properly carried out by an experienced man, will give a good product, but careless work usually injures the lime and makes it inferior as a building material. The new method of lime hydration at hydrating plants and the marketing of the product already slaked, does away with the danger of careless slaking, and the resulting material gives much better satisfaction as a building material.

Many processes are now in use for slaking lime and several of them are operated under patents and the product is sold under various names, such as lime hydrate, limoid, cream of lime, etc. The process consists essentially of the following operations: First the lime lumps are crushed with some type of crusher to give a uniform size of lump so that the water will act rapidly. Second, the hydrating is accomplished as follows: A weighed portion of lime is placed in the hydrating pan, which is a pan holding 1,000 to 2,000 pounds. Scrapers in the pan level the lime down to a depth of about eight inches. The pan rotates under a number of stationary ploughs which are so arranged that the lime is thoroughly turned over and mixed every half revolution. An automatic sprayer which contains a predetermined amount of water is located over the pan and sprinkles the water evenly over the surface of the lime. As soon as the water and lime are thoroughly mixed the pan is emptied and a new charge is placed in it. The process of hydrating a high calcium lime does not require over half a minute per charge. Following the process of hydration the product is screened to remove particles of limestone, underburned lime and unslaked lumps. The product screened to about 40 mesh is stored in bins ready for bagging and shipment.

The equipment of a small hydrating plant should include two elevators, one to take the lime from crusher to bin and one to take the slaked lime from the hydrator to the storage bin; a hydrator, a crusher, and screens.

The above process is known as the batch process. Other methods use machinery which is continuous in operation, the most common being the rotating cylinder containing screens for discharging the product as fast as it is hydrated. Water is sprayed into the cylinder as well as jets of steam, which accelerates the process. The lime is fed in at the higher end of the cylinder and travels slowly toward the lower or discharge end. The usual capacity of these cylinders is about eight tons of hydrated lime per hour. They require about five horse-power to operate them.

The lime hydrating industry is one that is sure to grow in this country as the product has many advantages over quicklime for every use in which the caustic properties of the lime are not a necessity. The main advantages are as follows:

1. Hydrated lime will keep better than quicklime.
2. It can be shipped in paper bags instead of barrels.
3. The impurities have been removed in the hydrating plants.
4. It is ready for immediate use. No slaking or seasoning is necessary.
5. Less is needed to produce an equally strong mortar.
6. It can be mixed dry with sand or cement, thus requiring less labor.
7. Less danger in packing and in handling.

With these advantages favoring it the use of hydrate can not but develop very rapidly and plants for hydrating lime will be a paying venture. Mixtures of lime hydrates and Portland cement are already much used in making concrete walls. This is also recommended in the production of concrete building blocks, where it is claimed that it improves the water resisting qualities and gives a lighter shade to the blocks.

Lime hydrate is used with kerosene and copper sulphate or Paris green as a spray, and as such it is recommended as a very good insecticide.

The manufacture of building bricks from mixtures of sand and lime has been carried on for a number of years in regions where the soils were sands, and clays were lacking, but these mortar bricks proved very unsatisfactory and the industry never reached large proportions. The patent of Dr. W. Michaelis for hardening sand lime brick by high pressure steam has given the industry making sand lime bricks a great impetus. The patent, taken out in 1881, lapsed before any great use was made of it, but since 1900 a large number of plants for the manufacture of sand lime brick by this method have begun operations in Germany. The first plant to operate in this country was started at Michigan City, Indiana, in 1901, and at the present time about 100 plants are in operation in the United States.

Sand lime brick, or "Kalksandstein" as it is called by the Germans, is a mass of sand grains cemented together by hydrated calcium silicate. The union, instead of depending on the lime as a cement, depends upon the formation of the silicate by the high temperature to which the brick is subjected in the process of manufacture. This industry is sure to grow and with it the demand for lime.

The reasons why the lime industry has not been developed in the stone belt of Southern Indiana are many. In this connection I will quote from the paper on the Lime Industry of Indiana by W. S. Blatchley in the twenty-eighth annual Report of the Indiana Department of Geology and Natural Resources, as follows: "The average of eight analyses of specimens from eight of the leading quarries of Bedford stone showed the following percentage composition: Calcium carbonate, 97.62; magnesium carbonate, .61; iron oxide and alumina, .36; insoluble residue, .91. These analyses show the fitness of the Bedford oolitic stone for making a very pure quicklime; and the practical burning of the lime at Salem, Bedford and other points proves this fitness. For some reason, however, the lime industry in the oolitic stone district is not as flourishing as it should be. Abandoned kilns are found in a number of localities in the area, notably in Monroe County, near the old University building at Bloomington, and at Ellettsville, in Lawrence County; two southeast of Bedford, and three south of the same place along the Monon Railway, and in Owen County at Romona." Professor T. C. Hopkins in his report on the oolitic stone industry in the twenty-first Annual Report of the State Geologist, says in substance: "Seeing the great quantity of waste rock on the dump piles about the quarries one wonders why more of it is not burned into lime, and no satisfactory answer could be obtained to that query when put to the quarrymen. One said it did not make good lime. Another that the lime was too hot, and some had not thought of it, did not know that it had ever been tried, or would make lime at all. One need only to look at the average analysis quoted above to see that it would, as remarked earlier in this paper, make a rich fat lime." Quoting from the same source: "The reason that more of it has not been burned into lime may be due to a number of causes, as follows:

"(1) Freight rates, the cost of bringing in the coal and shipping the lime.

"(2) A prejudice in the local markets against rich lime.

"(3) Want of a large market, as they are situated in the midst of the Mississippi Valley, with large deposits of limestone on all sides.

"(4) The lack of some enterprising person to push the business into prominence, as all the stone dealers are interested in the sale of building stone and not lime."

With regard to these reasons for the lack of development of the industry in this district it will be seen that at the time of writing this report not all of them are effective. In the first place more railroads have penetrated the stone belt and are competing for the business, and this has had a tendency to lower freight rates. The quarry operators and the railroad managers have come to a realization that their interests were mutual and so they are better acquainted with conditions and will co-operate more fully to make rates that will allow the industry to develop. In the second place the development of the process of hydrating lime at the manufacturing plants has done away with the objections to hot limes by making them easy and safe to handle. With this objection removed the rich lime will be more popular in the market than the lean limes now used. In the third place the markets of the Central West are being supplied with limes from Ohio which must cross Indiana in transit, thus placing on them higher freight rates than would be placed on Indiana limes. In fact Ohio limes are being used at the present time in the stone belt of Indiana. This is the more to be lamented when it is known that most of the Ohio limes are dolomitic limes and that the Indiana limes are superior for most uses if put on the market in the form of lime hydrate.

The last reason urged is probably still the most effective in holding back the industry, but this can not long stand in the way, for the stone industry is filling up with a younger generation of progressive business men who find the profits of the industry not large enough to satisfy them, and realizing that a more careful utilization of the waste heap can add to their profits, they will develop any collateral industry as soon as convinced that the returns are proportionate to the capital invested.

The 1913 output of lime in Indiana was 96,359 short tons, valued at $323,905, while her neighboring State, Ohio, put out 497,693 tons valued at $1,976,316. To make up the difference of 401,000 short tons of output so Indiana would take rank with her neighbor it would be necessary to burn in the State eight million cubic feet of limestone more than is burned at the present time. It will be seen from these figures that if waste limestone that accumulates in the quarry district every year were used in the manufacture of lime, Indiana would take rank as one of the greatest lime producing States in the Union.

Approximately eighteen million cubic feet of limestone is burned per year in the State of Pennsylvania in order to produce their lime output of about 852,000 short tons. The price of lime in Indiana averages around $3.50 per ton and calculated on this basis the waste from the quarries in a single year would be worth nearly $1,250,000, if the product were in the form of lime. Of course, these figures are only approximations for the reason that any such an increase in the output of the State would probably cause a drop in the price paid per ton, but with the increase in the demand for a high calcium lime in the chemical industries of the country, due to the changed conditions of manufacture in Europe, the producer of this kind of lime can look for a strong demand and good prices for a long time to come. In Ohio the price of lime remains about $4.00 even with her large production.

At the present time there is only one lime plant in operation in the Southern Indiana quarry district. This plant was the property of the Ohio and Western Lime Company of Bedford, Indiana, until the latter part of 1914, when it was purchased by the Indiana Quarries Company. The plant is located on the site of the Old Perry Matthews and Buskirk quarry of the Indiana Quarries Company on Buff Ridge; and the limestone burned comes from this quarry. While the plant was operated by the first company the operators were furnishing derrick and switch connections for the lime company. Since the same company is now operating both quarry and lime plant the industry will be sure to develop. In reply to a request for information concerning the plant under its new owners, the following information was promptly furnished. The equipment of the plant consists of four kilns, two of stone and two of steel construction. The plant will furnish employment for 15 men at an average wage of 22½ cents per hour. The yearly output of the plant is about 225,000 bushels of lime and the coal consumption is about 5,200 tons. The cost of production of the lime is figured at about ten cents per bushel. The plant represents an investment of approximately $25,000.00.

Portland Cement.

The cement used by the ancient Egyptian builders was a type similar to our present lime mortars. There is no reason to believe that they were familiar with any form of hydraulic cement. The first use of this type of cement is attributed to the Roman builders who used it in the great engineering works of the early empire. This cement was made by burning a volcanic ash found abundantly in the vicinity of Naples and called puzzuolana. The product was called Puzzuolan cement. This type of cement differed very much from our modern Portland cement both in composition and method of production. A very similar cement is produced at the present time from blast-furnace slag. Following the fall of the Empire even this type of cement was forgotten and the great buildings of the middle ages were put up with plain lime mortars.

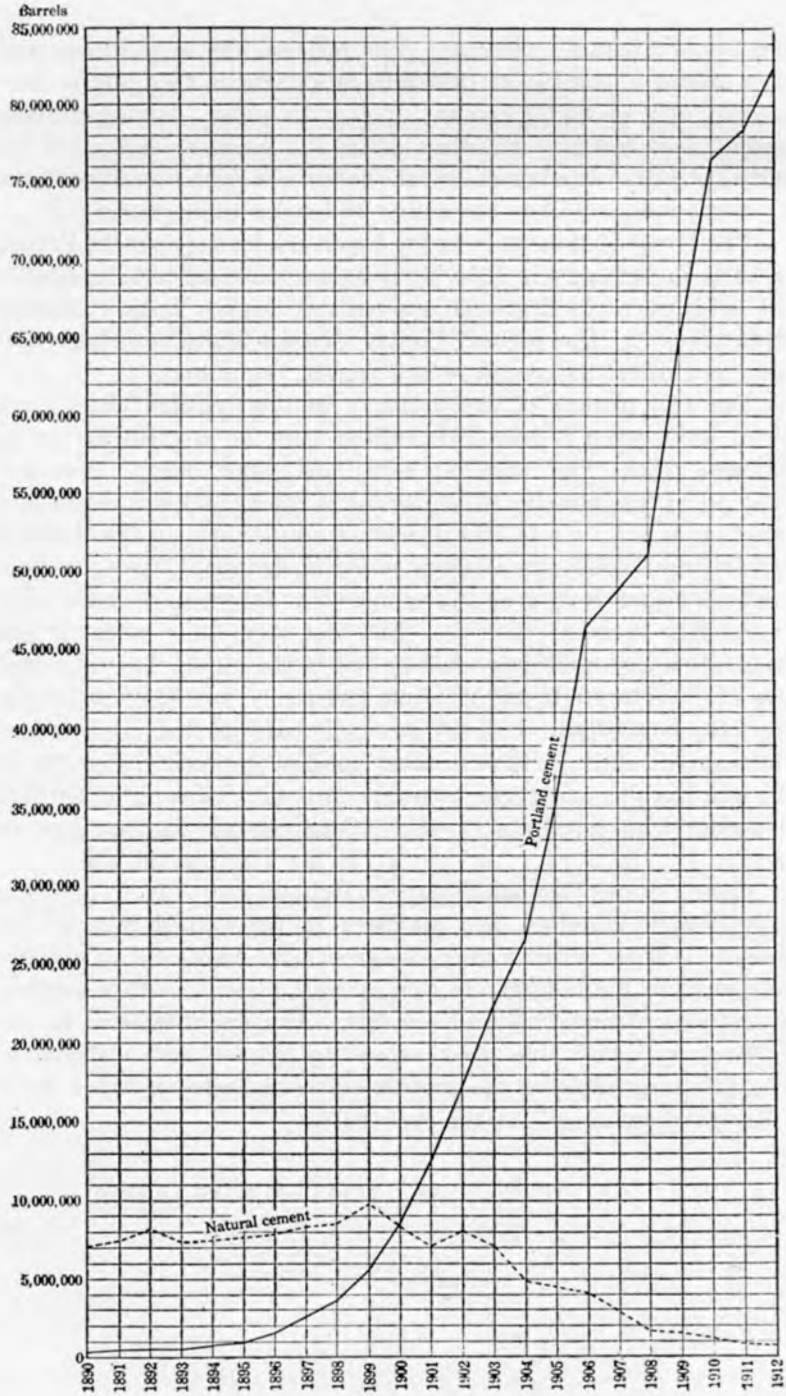
In 1756 John Smeaton, an English engineer, began a series of experiments with hydraulic cements for use in the construction of the Eddystone lighthouse. When the results of these experiments were made public in 1791 a number of other men began experiments and in 1796 a patent was given in England to a man by the name of Parker. The product was also patented in France about the same time, and both products were very similar to our present Rosendale cement.

The first compound approximating the composition of our present Portland cement was manufactured in England under a patent granted to Joseph Aspdin of Leeds, England, in 1824. No formula was given with the application for the patent, and consequently the exact composition of this cement is unknown, but to it was given the name of Portland cement on account of its close resemblance to the oolitic limestone of Portland, a well known building stone. Aspdin's cement was made from a mixture of chalk and clay and was burned at a higher temperature than is necessary in the manufacture of hydraulic cements. The method was to pulverize and then calcine a quantity of limestone in a furnace, then mix it thoroughly with an equal amount of clay in water, making a thick paste. This mixture was then dried and calcined and after the carbon dioxide was driven off the mass was again powdered, the resulting compound had the ability to harden under water.

The Portland cement industry began its development in France in 1850, in Germany in 1855, but was not taken up in this country till 1872, when the first mill was built at Coplay, Lehigh County, Pennsylvania. The present Coplay Cement Manufacturing Company is a direct outgrowth of this modest beginning.

The real history of the industry in this country dates from about 1880, when it was first realized that the methods in use in Europe, where fuel was expensive and labor cheap, were not adapted to the industry in this country where fuel was cheap and labor expensive. Up to this time the manufacturer in this country had followed closely the methods in use in Europe. From this time methods began to diverge and in time the American methods were to outstrip those of Europe. The first step came when it was known that dry materials could be fed to the kilns. The introduction of the rotary kiln and grinding machinery instead of millstones were the next steps. In 1895 powered coal was first used as fuel and soon all other fuels were abandoned in its favor. The size of the kiln has also undergone great changes until kilns up to 250 feet in length with capacities up to 1,000 barrels per day are now in use.

United States Geological Survey Bulletin No. 522, "The Portland Cement Materials and Industry in the United States," by Edwin C. Eckel, gives a very comprehensive treatment of the development of the industry in this country together with a number of analyses of materials and cements. Any one interested in the industry will find this work especially helpful and instructive. The following table of the growth of the industry is taken from "Mineral Resources" for the year 1912:


Barrels
85,000,000
80,000,000
75,000,000
70,000,000
65,000,000
60,000,000
55,000,000
50,000,000
45,000,000
40,000,000
35,000,000
30,000,000
25,000,000
20,000,000
15,000,000
10,000,000
5,000,000
0
Portland cement
Natural cement
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912

The total amount of cement of all kinds produced in this country during the year 1912 was 83,351,191 barrels valued at $67,461,-513. The output for 1911 was 79,547,958 barrels valued at $66,-705,136. This represents an increase of 4.78 per cent. in quantity and 1.13 per cent. in value over the previous year. Of this amount over 98.5 per cent. was Portland cement. This quantity of cement, which is given in barrels, represents a total weight of 13,985,034 long tons and a value of about $4.79 per ton.

Indiana with five producing plants put out (in 1812) 9,924,124 barrels with a value of $7,453,017. The average price per barrel for cement in Indiana for the year was 75 cents. Of this amount 9,634,582 barrels was shipped.

The five plants at present operating in Indiana are located at the following points:

Mitchell, Indiana. This plant uses limestone and shale.
Speed, Indiana. This plant uses limestone and shale.
Buffington, Indiana. This plant uses blast-furnace slag and crushed limestone.
Syracuse, Indiana. This plant uses marl and clay.
Stroh, Indiana. This plant uses marl and clay.

Indiana ranks second only to Pennsylvania as a producer of Portland cement, although only five plants are operated in the State.

The deposits of stone in Indiana, with which this paper is concerned, are included in the Mississippian rocks of the State and are described in an earlier chapter of this report.

The following analyses are taken from Eckel's work on "Cement Materials and Industry in the United States," and are quoted by him from reports on the limestones of Indiana:

ANALYSES OF MISSISSIPPIAN LIMESTONES FROM INDIANA.

	1.	2.	3.	4.	5	6.	7.	8.	9.
Silica (SiO_2)	0.50	0.70	1.74	1.60	0.65	0.90	1.13	0.31	0.48
Alumina (Al_2O_3) and iron oxide (Fe_2O_3)	.98	.91	.29	.18	1.00	3.00	1.06	.32	.15
Lime carbonate ($CaCO_3$)	96.60	96.79	95.62	95.55	95.54	95.00	96.04	98.09	98.91
Magnesium carbonate ($MgCO_3$)	.27	.23	.89	.93	.40	.22	.72	......	.63

	10.	11.	12.	13.	14.	15.	16.	17.	18.
Silica (SiO_2)	0.84	0.86	0.64	0.76	1.26	1.69	0.63	0.15	0.50
Alumina (Al_2O_3) and iron oxide (Fe_2O_3)	.13	.16	.15	.15	.18	.49	.39	.64	.71
Lime carbonate ($CaCO^3$)	97.39	98.11	98.27	98.16	97.90	97.26	98.20	93.80	93.07
Magnesium carbonate ($MgCO_3$)	.78	.92	.84	.97	.65	.77	.81	4.01	4.22

1. Chicago & Bedford Stone Co., Bedford, Lawrence County. Eighth, Ninth, and Tenth Ann. Repts. Indiana Geol. Survey, 1879, p. 95.
2. Simpson & Archer quarry, near Spencer. Idem, p. 94.
3, 4, 5. Dunn & Co., Bloomington. Twenty-first Rept. Indiana Dept. Geology, 1897, p. 320.
6. Monroe Marble Co., Stinesville. Report of a geologic reconnaissance of Indiana, 1862, p. 137.
7. Salem. Idem, 1886, p. 144.
8. Stockslager quarry, Harrison County. Idem, 1878, p. 96.
9. Milltown. W. A. Noyes, analyst. Twenty-seventh Rept. Indiana Dept. Geology, 1902, p. 98.
10. Acme Bedford Stone Co., Clear Creek, Monroe County. Twentieth Ann. Rept. U. S. Geol. Survey, pt. 6 (continued), 1899, p. 381.
11. Hunter Bros. quarry, Hunter Valley. W. A. Noyes, analyst. Twenty-first Rept. Indiana Dept. Geology, 1897, p. 320.
12. Indiana Stone Co., Bedford, Lawrence County. W. A. Noyes, analyst. Idem.
13. Twin Creek Stone Co., Salem, Washington County. W. A. Noyes, analyst. Idem.
14. Romona Oolitic Stone Co., Romona, Owen County. W. A. Noyes, analyst. Idem.
15-16. Hoosier Stone Co., Bedford, Lawrence County. F. W. Clarke, analyst. Bull. U. S. Geol. Survey No. 42, 1887, p. 140.
17-18. Indiana Steam Stone Works, Big Creek. L. H. Streaker, analyst. Twenty-first Rept. Indiana Dept. Geology, 1897, p. 320.

"Cement consists of certain anhydrous double silicates of calcium and aluminum, which are capable of combining chemically with water to form a hard mass." The above definition is given in most texts on industrial chemistry, but from an industrial standpoint it is an intimate mixture of limestone and shale or marl and clay that has been calcined and ground till it will harden under water. Cements differ from lime mortars in that they do not require carbon dioxide from the air in hardening and are very insoluble in water. The hardening of the cement takes place throughout the whole mass simultaneously and thus makes them very useful as a building material.

Cements are of three classes, as follows:

(1) Those cements formed from volcanic tufas or materials resembling them, such as Puzzuolan, blast furnace slags, etc. These cements require the addition of lime before showing their hydraulic properties.

(2) Those cements which contain large quantities of free lime such as Roman cement and "hydraulic" limes. These cements have been formed by burning a natural argillaceous limestone at a temperature that has driven off all the carbon dioxide present in the limestone without being sufficiently high to fuse the product.

(3) True Portland cements or those which have been prepared by burning, at a high temperature, an intimate mixture of clay or shale with a calcium carbonate rock.

The chemical composition of Portland cement has not been definitely determined, but the most exhaustive work on the subject has been done by a French chemist, Le Chatelier. After careful synthetic determination he gave the following formula for its composition:

$$x(3CaO, SiO_2)\ y(CaO, Al_2O_3)$$

in which x and y are variable quantities depending on the relative properties of silica and alumina in the clay used.

The essential ingredients of Portland cement may vary slightly in their chemical composition but the limits of variation are reasonably well marked. The average composition of the raw materials are shown in the following table. (Thorp):

	Clay.	*Marl.*	*Limestone.*	*Shale.*
SiO_2	42.20	0.50	3.00	15.00
Al_2O_3	12.30	0.20	1.50	7.00
Fe_2O_3	4.60	0.10	.....	7.00
$CaCO_3$	23.90	94.50	96.50	71.00
$MgCO_3$	16.05	2.25	3.00	4.00
Alkalies—Moisture, etc.	0.95	2:45	.....	.....

It will be accurate enough to state that the mixture from which Portland cement is made must contain approximately 75 per cent. of calcium carbonate, 20 per cent. of silica, alumina, and iron taken together while the remaining 5 per cent. includes the magnesia, sulphur and other substances that are present as impurities in the raw materials.

It is seldom possible in nature to find a rock deposit approaching the composition necessary for the making of Portland cement, so that the materials have to be derived from different deposits and mixed as used. The usual ingredients for the manufacture of Portland cement are obtained from deposits of limestone, which furnish the calcium carbonate, and deposits of shale, which furnish the silica, alumina, and iron.

The determining factors in the value of a deposit of limestone for the manufacture of Portland cement are as follows:

(1) Chemical composition of material.

(2) Physical character of the material.

(3) Amount if the material available.

(4) Location of the deposits with respect to accessibility of the different ingredients.

(5) Location of the deposits with reference to transportation routes.

(6) Location of the deposits with regard to location of fuel supply.

(7) Location of the markets to be supplied.

With regard to the possibilities of turning the waste rock of the Southern Indiana quarry districts into Portland cement, it would be well to look at the deposits in the light of the above requirements. In chemical composition the Mitchell and Oolitic stone are both very well fitted for the manufacture of cement. In fact the Lehigh Portland Cement Company is operating a plant at Mitchell, Indiana, in which the Mitchell limestone is used altogether. The United States Cement Company plant at Bedford, Indiana, operated for some time with Oolitic stone and pronounced it of first-class quality. Both deposits are very high in their percentage of calcium carbonate and contain very little other material which could be considered as an impurity in the manufacture of cement. It is generally conceded that, other things being equal, no better stone deposits for the manufacture of Portland cement can be found anywhere.

In its physical characters the stone is well adapted to cement manufacture, as it is easily crushed and carries a low percentage of moisture.

The question of the available supply of material for the manufacture of Portland cement from the waste limestone of the quarry district introduces a number of problems that are rather difficult of solution. The amount of material necessary for a paying plant is large, and the problem of getting the waste to a centrally located plant raises difficulties of transportation which will be taken up late in this paper. In so far as the amount of material necessary for the manufacture of cement is concerned, the supply is practically unlimited, but the problem of its delivery at a central plant is difficult of solution.

The relation of the deposits of the limestone to the deposits of shale is favorable for economic operation. The shale used by the Lehigh Cement Company is brought from the Knobstone formation (near Brownstown and Sparksville, Indiana). These shale deposits are available for any plant operating in the southern part of the district, as several roads enter the stone belt from the east. This formation outcrops east of Bloomington along the Illinois Central railroad and would be available for a plant located at Bloomington. There are deposits of shale in the Chester formation which outcrops west of the city, but it is not known how extensive the deposits are or whether they are adapted in composition to cement manufacture. This feature is discussed in another part of the present report.

A cement plant located at either Bedford or Bloomington would be in a favorable position with regard to fuel supply, markets, and transportation routes generally. The belt is penetrated by at least five east and west roads and by the Monon running from the north to the south.

"Run of mine" and slack coal can be laid down in either town very cheaply, as the coal fields are less than forty miles from either place.

There are two general methods of cement manufacture known as the wet and dry method respectively. The process adopted in any locality depends upon the deposits to be worked and the economic conditions under which the work is to be carried on.

In the wet process the clay and chalk or marl are ground fine in edge runners with heavy rolls. This material is then mixed with about half its weight of water. This slime, or as it is called "slurry", is pumped into buhrstone or tube mills where it is given a thorough grinding. After this wet paste is dried, it is sent to the kilns where it is calcined. The burned clinker is then ground fine to produce the finished product. The Hoffman's ring furnace which has been described in the part of this paper treating of lime, is often used in calcining the cement. Another type of furnace much used is the Dietsch two-storied kiln. This is a continuous kiln the material being fed in at the top and discharged at the bottom. Tests made on this type of furnace with regard to the fuel consumption give about seven tons of clinker per ton of coal burned. The Hoffman furnace uses about the same amount of coal per ton of clinker.

In the dry process the materials, shale and limestone, are ground separately to a good degree of fineness; then they are carefully mixed in predetermined amounts by large mixing machines and this mixed material is charged into the upper end of a long rotary kiln. The fuel (powdered coal) is driven into the lower end of the kiln by compressed air and burns as it enters. The hot gases and flame are driven up the kiln and meet the mixture as it rolls down, on account of the rotating of the kiln. The burned clinker drops from the lower end of the kiln where it is picked up by a bucket conveyor, carried to the top of a high tower, and allowed to fall through space to cool. The fuel charged into this kiln is powdered coal, which gives a very high temperature, on account of the powerful draught produced by the compressed air.

The cooled clinker is charged into a mill where it is finely ground and the product is then ready for the storage bins.

The shale and the limestone are first ground by large crushers for coarse crushing and following these the material is fed to fine crushers and rolls in succession before mixing. The crushers most commonly used are crushers of the Gate gyratory type which reduce the material to about two-inch size. Fine crushers follow these and are usually of the Gates and Gardiner types. The material usually needs drying before it is mixed, and this is accomplished by conducting it through a smaller kiln into which the waste gases from the calcining kilns are conducted. The tube mills used consist of horizontal iron tubes about 16 feet long by four to six feet in diameter, which rotate on a shaft, making about twenty-five revolutions per minute. The tube is about half full of flint pebbles, about the size of a hen's egg and these produce a grinding action as the tube rotates. These pebbles are retained in the tube by the screens at the outlet end through which the ground rock passes. The rock is fed to the mill by means of belt conveyors and a new supply of pebbles is charged into the tube as fast as the old ones wear out. The rapidity of rotation and the rate of the feed determine the fineness of the product.

This fine grinding of the clinker is often done by Griffin mills which consist of a heavy steel roll revolving on a vertical shaft with a gyratory motion, and pressing by centrifugal force against a steel inclosing ring. These mills have a great capacity and will grind very fine, but the cost of upkeep is much greater than with the tube mill. After leaving the Griffin mill the ground clinker is in some modern plants passed through tube mills, which grind it finer than is possible in the Griffin mills.

The power required in the manufacture of cement is given by Professor Bleininger of the Illinois Survey as 1.5 horsepower per barrel of output—that is a 1,000 barrel plant would require 1,500 horsepower. This is rather high for the larger plants where one horsepower per barrel of output has been realized. One 5,000 barrel plant is now operating on 4,500 horsepower.

The fact that the deposits of material for the manufacture of cement are located near coal mines does not always insure a cheap supply of fuel under present conditions where powdered coal is to be used as a fuel in the kilns. Many coals are not suited for the burning of cement, as the ash from the coal mixes with the cement in the kiln; and in the case of a coal of high sulphur content or high percentage of ash these impurities may spoil the cement. Coal must have a high heating value, as the temperature of the kiln should be kept up to about 2,500 degrees Fahrenheit. To insure even heating throughout the entire length of the kiln, the coal should contain a large amount of volatile matter. These considerations are so important that the location and supply of fuel becomes more important than the location of the deposits of cement material. As mentioned above, the cement deposits are located near the Indiana coal fields, but at the present time the Indiana plants are using Pittsburg coals. This difficulty could be remedied by the use of producer gas in the kilns. In fact the use of gas is increasing even in the coal districts of West Virginia and Pennsylvania. The advantages of the use of producer gas as a fuel for the manufacture of lime or cement are many and the use of gas as a fuel in both industries is sure to grow rapidly. Producer gas is better than coal for the following reasons:

(1) The absence of ash in the burned product. In the producer gas the ash remains behind in the producer and only the combustible gases are passed into the kilns to burn, thus insuring a purer product.

(2) The presence of a great amount of water as the gas burns. A large percentage of the gas consists of hydrocarbons and hydrogen, and the combustion of these gives water. This is of especial advantage in the manufacture of lime.

(3) The high heating value of the gas.

(4) The ready control of the point of burning and the temperature.

(5) The fact that any coal can be utilized in the manufacture of gas.

COST OF CEMENT MANUFACTURE.

The cost of the raw materials varies greatly in the different districts. Estimates on the loss of weight due to burning the raw material to cement clinker are: for dry, hard limestone and shale about thirty-three and one-third per cent., that is, 1,000 pounds of the mixture of limestone and shale will give about 665 pounds of cement clinker. A barrel of Portland cement weighs about 380 pounds, and Eckel states that if the losses of manufacture are included, it is safe to say that 600 pounds of raw material will produce a barrel of cement. The cost of excavation and delivery is given as from eight to fifteen cents per barrel. That represents a cost of from 27 to 50 cents per ton of raw material at the mill. Since it takes from four to five carloads of limestone per carload of shale and the price of limestone delivered in the quarry district is very low, the shale could be brought quite a distance without exceeding the above figure.

The fuel cost, as has been already stated, is a more important consideration than the cost of raw materials. In the use of powdered coal the coal must be dried, then crushed. The average moisture content of coals is about 8 per cent. and under favorable conditions it takes about a pound of fuel per hundred pounds of coal to dry it. The best type of dryer now in use is the rotary dryer. At the above figures the cost of drying fuel will be about three to four cents per ton of dried product. Coal, to give the best results, when powdered, for cement burning, must be very fine, and the usual practice is to reduce it to such a size that from 85 to 95 per cent. will pass a hundred-mesh sieve. The poorer the grade of coal used the finer it must be powdered. The coal is usually powdered by two operations. It is first reduced to about 30-mesh by means of ball mills and then fed through a tube mill. This process may be varied to fit the conditions in any mill, although the price will total about the same.

The total cost of crushing (provided fine slack is not obtainable), drying, and pulverizing the coal, together with the cost of elevating and conveying the coal to the kilns, will amount to as much as thirty cents per ton, which is equivalent to from one to two cents per barrel on the cost of the cement.

Power cost in a cement plant is also a large item. The power consumption is estimated as one horsepower per barrel of output per day, while a cost of one cent per horsepower is low except in the very large plants. Of course many plants are saving a part of the heat from the kiln and using it in the form of power, but even with this saving it will be seen that the cost of power is bound to be fairly heavy.

The cost of labor varies so in different localities that any figures will be only approximations. Professor Grimsley gives the relative cost of production as follows: fuel 35 per cent. of total cost, labor 45 per cent. and other expenses 20 per cent.

In Bulletin 3 of the Ohio Geological Survey the following figures are given for the cost of production per barrel of cement:

Labor.		
Quarrying	$0.050	
Crushing and drying	.005	
Grinding	.015	
Burning	.015	
Power generation	.011	
Coal grinding	.010	
Yard work	.015	
Machine shop	.0225	
Miscellaneous	.0025	
		$0.15
Raw Materials.		
Coal	$0.225	
Gypsum	.0125	
		$0.2375
Accessory Expenses.		
Repairs	$0.04	
Oil	.02	
Miscellaneous	.03	
		$0.09
Packing and loading	$0.04	
Works and management	.02	
		$0.06
Interest on investment ($700,000)	$0.07	
Sinking fund and deterioration	.10	
Management and selling expenses	.065	
		$0.235
Total per barrel of output		$0.7725

The total cost of production in Michigan is figured as follows in Volume 8 of the Geological Survey of that State::

Total cost of materials and labor of manufacture	$0.4785
Overhead and selling cost	.2015
Total	$0.68

The figures given above are on a plant with an output of 1,200 barrels per day. The cost of production would fall below this figure in a larger plant for the reason that several of the items quoted above will not increase in the same ratio as the increase of output.

No reliable figures are at hand on the cost of production in Indiana; but as the two States from which I have quoted prices are bordering states and operate under the same conditions, the figures for Indiana will be somewhere near those quoted above.

The cement industry has reached a point where cost of production and selling price are so close together that cement can only be manufactured economically in large plants. In fact with the selling price where it is the profits are very small in any plant with an output below 3,000 barrels per day.

Since it requires over 400 pounds of limestone to the barrel of cement, on account of the losses from ignition, a 3,000 barrel plant would require at least 600 tons of waste limestone per day. This would be equivalent to approximately 7,000 cubic feet of stone per day, or over two millions cubic feet per year for a steady run. Figuring on the same basis, a 5,000 barrel plant would require nearly three and a half million cubic feet of limestone per year. The superintendent of the plant at Mitchell gives 30 carloads per day, which very closely approximates the above figures.

Although the waste of the quarry district is probably considerably more than this amount during an active year, the collecting of this amount at a central plant with any degree of regularity would be impossible. It will thus be seen that a cement plant could not be constructed to use the waste of the quarry district economically, at least unless a special quarry were run to carry the plant over slack times. Another thing that would make it uneconomical, is the fact that most of the waste is in the form of large blocks which would need blasting and sledging before they would be in a condition in which they could be fed to the crushing machines. In fact this cost would be almost as much as the cost of blasting the material off the "solid" ledge with high explosives, with which also a large percentage of fine material would be produced.

Transportation charges to a central plant would be at least five cents per ton. (The price now paid for moving cars in the district if the product is to be hauled again.)

If the cost of material and the charges for loading it on the cars be added to this, the total figure will exceed twenty cents per ton at the mill. Practically every estimate of engineers as to the cost of mining the raw material and delivering it at the mill is as low or lower than this, where the deposits can be worked by quarrying with high explosives. It will thus be seen that this method of waste utilization does not commend itself as a means of solving the problem in hand.

There are a number of old quarries or openings that have been worked out or have proved poor building stone, that could be optioned at a very low figure, and many of these contain almost unlimited supplies of limestone that, while it will not make good building stone, would make a high grade of cement. In many cases the railroad tracks are still in position and where removed the grade still remains. Feeling that these might be utilized, I asked several companies interested in stone quarrying with explosives to give estimates of the cost of blasting the material of the solid ledge and delivering it to the crusher for a cement plant located near these quarries.

Among the answers received, the data furnished by the E. I. duPont de Nemours Company as to the cost of blasting with high explosives were very full and helpful.

Much work has been done by the United States Bureau of Mines on the production of explosives especially fitted for different grades of work and as a result much information is at hand as to the explosive best suited to the work in hand and the uses to which it can be put. These bulletins are for free distribution by the Director of the Bureau of Mines and can be had for the asking.

The following letter received from H. S. Gunsolus, Manager of the Technical Division of the duPont company will be of interest in this connection to any company interested in blasting out limestone for cement:

Quarry Blasting.

"Your letter of December 30th, in reference to the cost of explosives per cubic yard for blasting limestone to be used for fertilizing material is at hand.

"We have not replied earlier, due to our wishing to get some information together which might be of assistance to you. We are going to list below a number of shots which have either been supervised or witnessed by some of our own technical men and feel sure that the figures given are approximately correct. You understand, of course, that the variation in cost is due to local conditions, stratification, mud seams, etc., as well as the size crusher to be used, which of course will regulate the size of the broken stone.

"In limestone, used for railroad ballast, we had eight holes, spaced eighteen feet apart. Average face burden nineteen feet; average depth forty-eight feet, approximately 4,900 cubic yards.

There was used 3,300 pounds 40 per cent. dynamite, making a cost per cubic yard of about .084 per cent.

"A blast in cement rock, nine holes, spaced 22 feet apart: Average face burden 32 feet; average depth of hole 62 feet; approximately 13,000 cubic yards. For this there was used 2,500 pounds 60 per cent. dynamite and 1,800 pounds 40 per cent., making a cost of about .046 cents per cubic yard.

Another blast in cement rock of seven holes, spaced 15 feet apart: Average face burden 23 feet; depth 60 feet; about 5,400 cubic yards. For this there was used 500 pounds 60 per cent. and 2,900 pounds 40 per cent. dynamite, making cost of about 8 cents per cubic yard.

"Blast in hard, massive limestone, eight holes: Average space between about 28 feet; average face burden 33 feet; depth of holes about 95 feet; approximately 26,000 cubic yards. For this there was used 2,200 pounds blasting gelatin, 3,350 pounds 60 per cent. and 1,250 pounds 40 per cent. dynamite, making cost per cubic yard of about .046 cents.

"Blast in limestone for lime manufacturing, of three holes, spaced about 17 feet apart: Average face burden 24 feet; average depth of holes 100 feet; approximately 4,600 cubic yards. The dynamite used amounted to 1,200 pounds 60 per cent. and 1,600 pounds 40 per cent., making an average cost of .032 cents.

"Another blast in limestone for cement manufacture, nine holes, spaced about 20 feet apart: Average face burden 36 feet, and about 53 feet in depth; approximately 12,700 cubic yards. For this there was used 1,720 pounds 60 per cent. and 2,500 pounds 40 per cent., making cost of .045 cents per cubic yard.

"Another blast consisting of four holes 18 feet apart with about 25 feet face burden and 100 feet deep; approximately 6,700 cubic yards, for which there was used 2,200 pounds 60 per cent. and 1,600 pounds 40 per cent., making average cost of .056 cents per cubic yard.

"Eight holes blast spaced 15 feet apart, with a face burden of approximately 25 feet, holes 115 feet deep; about 12,800 cubic yards, for which was used 3,950 pounds 40 per cent. and 2,000 pounds 50 per cent. Cost per cubic yard being about .038 cents.

"Sixteen 70-foot holes, face burden of 25 feet, spaced about 15 feet apart; approximately 15,000 cubic yards, for which was used 3,750 pounds 60 per cent., 4,050 pounds 40 per cent., making cost per cubic yard of about .068 cents.

"Another, nine 50-foot hole blast, spaced 18 feet apart, with 25-foot face burden; approximately 7,500 cubic yards, for which there was used 3,350 pounds 40 per cent., making cost of .055 cents per cubic yard.

"Seven 60-foot holes spaced 15 feet apart, with about 20 feet face burden, approximately 4,600 cubic yards. For this was used 500 pounds 60 per cent., 2,900 pounds 40 per cent.; making cost of .095 cents per cubic yard.

"Eight holes which ran from 80 to 108 feet in depth spaced 27 feet apart, with 30-foot face. There was about 22,000 cubic yards in this shot, for which there was used 2,200 pounds blasting gelatin, 3,350 pounds 60 per cent. and 1,200 pounds 40 per cent., making cost of about .055 cents per cubic yard.

"Another eight 48-foot hole blast, spaced 18 feet apart, with 20-foot face burden, approximately 4,500 cubic yards, for which there was used 3,300 pounds of 50 per cent., making average cost of about 10 cents per cubic yard.

"A nine 62-foot hole blast, with a 32-foot face burden, spaced about 20 feet apart, approximately 13,300 cubic yards, used 2,500 pounds 60 per cent and 1,800 pounds 40 per cent., making average cost of about .045 cents per cubic yard.

"Had a 14-86-foot hole, spaced 18 feet apart, with a 30-foot face burden, making approximately 24,000 cubic yards. Used 850 pounds 50 per cent., 3,250 pounds 40 per cent. and 4,000 pounds 60 per cent., making cost of about .046 cents per cubic yard.

"Another shot was five 85-foot holes, spaced 18 feet apart, with about 25-foot face burden, about 5,000 cubic yards, for which there was used 1,300 pounds 60 per cent. and 1,000 pounds 35 per cent. This cost about .06 cents per cubic yard.

"These figures are taken from various sections of the country, not being confined to any particular locality, and we have figured the explosives on basis of 12½ cents for the 40 per cent., 13.7 cents for the 50 per cent., and 14.9 cents for the 60 per cent., and 25 cents for the blasting gelatin. These are about the average figures, and of course vary according to the location.

"Thinking perhaps you might be interested in the comparative cost between the steam or air drill and the well drill system:

"One of our technical men made a close study of this and found that the cost of drilling with an ordinary tripod drill varies from 10 cents to 25 cents per foot, this wide variation depending on the nature of the rock, cost of labor, fuel, oil, the number of drills in operation and the accessibility to source of power—water, etc. The fewer the drills in operation, if run from a central power plant, the higher the cost per foot.

"In rock of medium hardness, such as limestone, a man working industriously should average about 50 or 60 feet of hole per 10-hour day. The cost of drilling such rock seldom falls below 15 cents per foot in a quarry operating several drills.

"The cost of drilling a 5-5/8-inch hole with a well drill varies from 20 cents to 50 cents per foot, the general average being somewhere around 30 cents. A good operator and helper in ordinary limestone can make from 15 to 40 feet per day of 10 hours.

"A 25-foot headway is a very good average. Room for comparison—180 feet of drilling with each type of drill. Relative cost, 15 cents per foot for steam drilling, and 30 cents per foot for well drilling. Steam drilling 180 feet at 15 cents is $27.00. At a 7x7 spacing nine 20-foot holes will break about 325 cubic yards. About 140 pounds of 40 per cent. dynamite would be required, which would amount to $17.50, this, plus the cost of drilling, making $44.50. Breaking of 325 cubic yards would mean cost of about 13.6 cents. Working this by well drill system, take three 60-foot holes, drilling 180 feet at 30 cents equals $54.00. At 20x20 spacing thirty 60-foot holes will break approximately 2,600 cubic yards. About 1,300 pounds of 40 per cent. explosive would be needed, which would cost $168.75, making total of $222.75 to get out 2,600 cubic yards, or about .085 cents per cubic yard.

"We trust that this information will be of some interest and benefit to you, and that we have not delayed so long that you cannot use it in your paper, which we understand you are preparing for report of the State Geologist.

"Yours very truly,

(Signed) MANAGER TECHNICAL DIVISION.

Practically all the data furnished by other companies, although not given in detail, agreed with the above figures as to cost when the conditions under which the blasting was done were the same.

It will be seen that the cost of blasting out material in large amounts in localities such as this district would approximate eight cents per cubic yard. Figures on the cost of transporting this material to the crushers in a form in which they can use it (that is, including the cost of extra blasting and sledging where necessary) would be about the same figure, while labor and capital charges on the machinery would be about 26 cents per cubic yard, giving a total of about 44 cents per cubic yard for the limestone. This is about 19 cents per ton. Calculating along the same line, the cost of shale winning is about 11 cents per ton under favorable conditions. This makes the raw material cost on an average 17½ cents per ton or about 5¼ cents per barrel of output. (These figures are made on four parts of limestone to one part of shale and 600 pounds of raw material per barrel of cement burned.) It will be seen that this figure is rather low as compared with the figures given by engineers on the subject, but when it is taken into account that the deposits of limestone are in a very favorable location for quarrying in this district and no calculations have been made on the cost of bringing the materials together at a central plant the figure can be taken as a close approximation of the cost.

The demand for cement is growing rapidly in this country and as soon as cheaper methods of power production and cheaper fuels are utilized the industry is sure to be a good paying venture. The fact that the difference between cost of production and selling price is so small is an added incentive to the development of better methods and machinery of production.

CRUSHED LIMESTONE FOR ROAD MATERIAL, RAILROAD BALLAST AND CRUSHED ROCK CONCRETE.

The value of the output of crushed limestone for road making, railroad ballast and crushed rock concrete is greater than that of any other limestone product. In 1913 this output was 35,169,528 short tons, or approximately 470,000,000 cubic feet of limestone, with a value of $19,072,224. The output was divided up as follows:

Road making, 13,296,377 short tones, value $7,353,665.

Railroad ballast, 11,774,121 short tones value $5,551,415.

Concrete, 10,000,030 short tons, value $6,167,144.

The average price of this material was 54 cents per ton. In road making Indiana ranked third, with an output of $956,234, being outranked by Ohio and New York. In the production of railroad ballast Indiana was tenth with an output of $203,431. In the use of limestone for concrete Indiana ranked sixteenth with an output of $103,855.

The two properties of limestone which are of importance in its use as a road making material, are its wearing qualities and its cementing properties. The subject of good roads has attracted wide atention in a number of States, and while there are a great variety of rocks which can be used as a road metal none are better adapted to the work than a good hard grade of limestone.

The limestone of the Mitchell, which must be removed as stripping in many of the quarries, is admirably adapted to road construction, for it is a very hard limestone with good wearing qualities. The stone, although hard, is easily crushed because it is not tough but brittle, and it works up easily.

The stone of the oolitic formation is a softer stone and will not wear long on roads which are subject to heavy traffic. When a road receives a thick covering of this stone the surface of the stone coating tends to run together and becomes firmly cemented. If the travel is not too heavy during the time the material is setting the road will harden down in good shape. But if the traffic is heavy the stone is ground fine before it becomes cemented together. The roads of Monroe and Lawrence counties are to a great extent built of limestone, most of the material being taken from the Harrodsburg and Mitchell limestones which outcrop in those vounties. Most of these roads are in good condition, although some of them have been in use for a long time without any especial care.

The waste limestone resulting from the removal of the overlying Mitchell limetsone in many of the quarries is an ideal road metal, and if transportation charges were reasonable its use through the State would give Indiana far better roads than exist at the present time in many parts of the State.

The Office of Public Roads of the United States Department of Agriculture maintains a testing plant for the testing of road materials and many specimens have been tested, including eight samples of limestone from Lawrence County and five samples of limestone from Monroe County. All of these samples, although showing a low value for toughness, were high in their cementing value and good in hardness and percentage of wear. The data on these tests can be found in Bulletin No. 44 of the Office of Public Roads. Indiana has reached a period of active road improvement; and it would be a good thing for the quarrymen who are puzzling over methods of waste disposal to see that the limestone of Monroe and Lawrence are sufficiently advertised and brought to the notice of the officers in charge of road construction in the State.

The railroads that have tried to use the oolitic limestone for railroad ballast have been inclined to report unfavorably on it. The roads that have used the Mitchell ballast report that it is very satisfactory, but the softer oolitic stone will not give a firm enough bed. Where this latter stone has been used it has usually been over harder ballast which has previously been used. The softer stone held by the hard particles is under such conditions ground as in a ball mill by the jar of the passing trains. It is likely that if the entire bed of the road could be made of the soft stone, it would tend to cement into a solid mass and become in a way monolithic. If the material were ground reasonably fine before being placed in position, then wet down and allowed to settle, the jarring action of the passing trains would not tend to grind it fine as happened in the experiments mentioned above. Much of the waste from some of the quarries has been removed for ballast, but in most cases it was given to the railroad for removing it. In most cases the operator loaded the material free of charge.

In concrete work much crushed stone is used. The strength of the concrete is measured by the strength of the cement and so concrete made from crushed limestone is practically as strong as that produced from any other stone. In the manufacture of concrete the crushed rock should be angular, as the resulting aggregate is stronger than when made with worn particles.

In any of the above uses the material need only be crushed to, say, two-inch size, so that a single coarse crusher is all that is needed. The most common type used in this work is a Blake jaw crusher.

Extensive tables on the cost of coarse crushing are given in the part of this paper treating of crushed limestone as a fertilizer, and these cost figures will apply equally well to the work on road material, as the same machinery is used for rough crushing in both cases.

The cost of crushing with a Blake type crusher ranges from three to six and one-half cents per ton, depending on the output of the crusher. The power consumed per ton crushed to two-inch size is about one-sixteenth of a horsepower per hour.

Waste Limestone as a Slag for Blast Furnaces.

In the treatment of iron ore in the production of pig iron it is necessary to add some fusible material of low specific gravity as a means of removing the impurities present in the ore. The present method of ore treatment in use in this country is to feed the ore together with coke and limestone into the blast furnace by means of a pair of hoppers closed by means of bells. The object of the double valve is to avoid the escape of the furnace gases. Large quantities of air heated to 600 or 800 degrees Centigrade are forced into the lower part of the furnace at a pressure of from twelve to fifteen pounds per square inch. This air burns the coke and the heat thus generated melts the charge and as the materials settle to the bottom of the furnace the ore and the slag separate on account of their different specific gravities. The limestone is decomposed by the high temperature, giving up carbon dioxide and changing to calcium oxide or common lime.

The large amount of silica and clay or alumina which is contained in the ore unites with the lime from the limestone to form what is called the slag. This slag is the waste product in the manufacture of iron and usually has the following general composition: From 30 to 35 per cent. SiO_2, 10 to 15 per cent. Al_2O_3 and 50 to 55 per cent. CaO. The amount of limestone to be used with any given ore is determined by the amount necessary to produce an easily fusible slag.

If the slag is not to be made use of it is drawn off into large tilting ladle cars and dumped away. In most cases this slag has the proper composition for a good grade of cement, if properly handled. When the slag is to be used as material for the manufacture of cement it is drawn off into water, where it takes on a coarse granular form which makes it easy to handle. Great efforts are made to keep the slag of proper quality, and if a uniform grade of iron is to result the composition of the slag must be carefully watched.

Both limestone and dolomite are extensively used for fluxes throughout the country. Both these fluxes have their advantages, but as the manufacture of cement from blast furnace slags becomes more widespread, the demand for a high calcium limestone will increase, for the reason that the slags from dolomite flux are not suitable for cement manufacture.

The slag obtained from high calcium fluxes develops hydraulic properties when cooled quickly. This is accomplished by running the molten slag into water. The resulting granular product is dried and ground very fine, and mixed with a certain percentage of slaked lime. This mixture is again ground fine enough to pass a two hundred mesh sieve. The resulting powder will have the properties of a good hydraulic cement. This form of cement works best in places where it is constantly wet, since drying tends to disintegrate it.

Dolomite flux is favored in the Birmingham iron district, as shown by the following from the work of Burchard and Butts on Iron Ores, Fuels and Fluxes of the Birmingham District: "The fluxing power of dolomite is greater than that of limestone; an equivalent of carbonate of magnesia weighs eighty four while an equivalent of carbonate of calcium weighs one hundred; in fluxing power these equivalents are equal because the power of a base to combine with an acid does not depend upon its atomic weight but upon its chemical affinity. So the fluxing power of the two carbonates are to each other as 84 is to 100.

"The dolomite of this district is a great deal purer than the limestone. The foreign matter of the former does not exceed 2 per cent. while of the latter an average is at least 4 per cent. To determine the value of a stone as a flux we must deduct the impurities it contains, plus as much of the base as is necessary to flux these impurities. Taking the limestone as a 96 per cent. lime carbonate, and deducting 8 per cent. to take care of its own impurities we have left 88 per cent. of lime carbonate as available flux. Taking the dolomite to contain 2 per cent. of impurities and 43 per cent. of carbonate of magnesia, with 55 per cent. of carbonate of lime, we have left, after deducting 4 per cent. of the carbonate of lime to take care of the impurities, 43 per cent. of magnesia carbonate and 51 per cent. lime carbonate. The fluxing powers of the two carbonates are to each other as 84 is to 100, so reducing the magnesia carbonate to its equivalent in fluxing power of lime carbonate we have

$$\frac{43 \times 100}{84} + 51 = 102.19.$$

"Therefore the relative values of the two fluxing materials of this district are to each other as 88 is to 102.19."

In other words the dolomite flux is preferred because of its greater purity; but this objection to limestone will not apply to the waste limestones of the Southern Indiana quarry district, as none of the dolomites used for flux are any more free from impurities than the Oolitic limestones which often carries as high as 98.5 per cent. calcium carbonate. The overlying Mitchell limestone is, if anything, purer than the Oolite stone.

Another argument in favor of dolomite fluxing stone is that it gives a more liquid slag than a limestone.

In this regard I would say that very liquid slags are only necessary where the ore used contains a large amount of impurities. The only blast furnaces that could use our waste stone, on account of the high freight rates, are located around Gary and Chicago and use much higher grade ores than those needing very liquid slags.

Dolomite can not be used as a slag when the ores run high in sulphur. The lime carbonate is better than magnesium carbonate because the calcium has a greater affinity for sulphur than magnesium.

Since most of the ores now used from the ore fields of Michigan and Minnesota are high grade ores and carry some sulphur the demand for limestone slag is sure to increase even if the tendency to produce blast furnace cement does not increase, which it seems sure to do. This industry is developing rapidly in many foreign countries and seems almost sure to increase here, as the cost of such manufacture is very small and also offers an opportunity for the removal of a large amount of waste material.

Waste stone has been sent out of the Southern Indiana quarry district for use as flux in the steel mills of Gary and Chicago for a long time; but the amount has been small and the profit from this source to the quarrymen has amounted to little more than a method of getting the waste piles out of the way. This condition results from the excessive rates charged on such shipments by the railroads, or, at least, the conditions under which such shipments must be made. As soon as the railroad officials realize the amount of this material that could be carried if more favorable rates were made there will be a tendency to make better terms and provide better conditions.

One thing that has held back the development of this outlet for the waste stone of the district is the fact that in the past many quarry operators have adopted the practice of giving the waste stone to the railroads if they would remove it, even going so far as to load the material free of cost. Under such circumstances the profit, if any, has gone to the railroads and it has consequently been to their interest to charge relatively high rates on shipments of this material by individuals.

The total amount of limestone used for fluxes in the United States in 1913 represented a value of $11,103,989, of which Indiana produced $199,995, ranking ninth in the industry. This represented a production of 22,620,961 long tons at an average price of forty-nine cents per ton.

The production in 1912 was 20,190,554 long tons with a value of $9,937,772.00 with an average price of 49 cents per ton.

LIMESTONE AND LIME IN THE MANUFACTURE OF GLASS.

"Glass is an amorphous, transparent or translucent mixture of silicates, one of which is always that of an alkali." The above definition of glass is taken from a work on industrial chemistry. The present paper is concerned only with the glass that contains calcium as the alkali metal. In the technical discussion of glass two general classes are recognized: lead glass and lime glass. The lime glass is most widely used, harder, cheaper, less fusible and has greater brilliancy than the lead glass. The essential materials for the manufacture of lime glass are silica; an aklali such as soda or potash; and lime or limestone. In the manufacture of glass materials free from iron or iron compounds must be used. The alkalies most commonly used are the carbonates or sulphate of sodium or potassium. The carbonates fuse more easily but the sulphates being cheaper are more commonly used. With the sulphate powdered carbon must be used as a reducing agent, the reaction being as follows:

$$2Na_2SO_4 + 6SiO_2 + C = 2(Na_2O, 3SiO_2) + 2SO_2 + CO_2.$$
$$2Na_2SO_4 + 2SiO_2 + C = 2Na_2SiO_3 + 2SO_2 + CO_2.$$

Common salt as a source of sodium in the manufacture of glass has not yet reached any extended use, but some method whereby it can be used economically is sure to be perfected. Lime, or more properly calcium, is obtained from limes or finely ground limestone. The lime has been used much longer than the limestone but has always given more or less trouble on account of the fact that it changes in volume, as it takes up carbon dioxide from the air. And this makes it difficult to mix the constituents of the glass in the correct proportions. The fact that the only form in which the limestone can be used is as a finely ground powder makes this a very good way for the plants turning out ground limestone for fertilizing purposes to dispose of their product during the dull season. The one plant already turning out ground limestone in the quarry district disposes of a large amount of its surplus product in this way.

The ground limestone can be used at the same mesh for glass manufacture as it is turned out for fertilizer, thus doing away with the necessity of installing extra screens. The manufacture of glass in this country has greatly increased during the last year or so and is sure to grow to a great industry in the next few years.

The chemical composition of the limestones of the Southern Indiana quarry district makes them very well adapted to the manufacture of glass, as they are very high in calcium carbonate and contain only traces of iron and aluminum. The demand for the ground limestone of this district is sure to grow when it becomes generally known that the chemical composition of the stone is so well adapted to this industry.

The final reactions in the manufacture of lime glass are as follows:

$$Na_2CO_3 + CaCO_3 + 2SiO_2 = Na_2Ca(SiO_3)_2 - 2CO_2.$$

Or,

$$Na_2Sio_3 + CaCO_3 + SiO_2 = Na_2Ca(SiO_3)_2 + CO_2.$$

Data on the amount of stone used for the purpose of glass manufacture in this country are not at present available, since the government reports on the amount of stone used give the stone used in glass factories, paper mills, carbonic acid plants, and for fertilizing purposes in one group, and it is impossible at present to get separate data on the subject.

MINOR USES OF WASTE LIMESTONE.

LIMESTONE IN THE LEBLANC PROCESS OF SODA MANUFACTURE.

As a result of chemical experiments stimulated by the offer of a large prize by the French Academy of Science in 1775, Nicholas LeBlanc patented the process of soda manufacture which remains in use to the present time. The only other process at present in competition with it is the Solvay process, which will be mentioned later The LeBlanc Process consists of treating common salt with sulphuric acid to produce hydrochloric acid and acid sodium sulphate, or at higher temperature the normal sodium sulphate. The first reaction is as follows:

$$2NaCl + H_2SO_4 + 2HCl + Na_2SO_4.$$

The sodium sulphate is mixed with limestone and coal or charcoal and calcined in a reducing flame, forming a mixture of calcium sulphide and carbonate of soda. This reaction takes place as follows:

$$Na_2SO_4 + 2C + CaCO_3 = Na_2CO_3 + CaS + 2CO_2.$$

The sodium carbonate and calcium sulphide can be readily separated by leaching with moderately warm water as the sulphide is practically insoluble while the carbonate is easily soluble. This industry has been able to hold its own with the newer processes on account of the fact that hydrochloric acid and bleaching powder are produced as by-products of the process. At least one-half the world's supply of carbonate of soda is produced by the LeBlanc Process at the present time.

The manufacture of lime chloride, or muriate of lime, can be carried on along with the process of soda manufacture, as the only chemicals needed are limestone and weak solutions of hydrochloric acid. When limestone is treated with a dilute solution of hydrochloric acid and the solution concentrated by evaporation and allowed to cool, crystals of lime chloride will be deposited. These crystals will have the composition ($CaCl_2$, $6H_2O$), but when they are heated they will lose two-thirds of the water, leaving a porous lime chloride which has a wide use as a drying and dehydrating agent in chemical laboratories. At the present time, a large supply of this compound is produced as a by-product of the Solvay Process of soda manufacture.

THE SOLVAY PROCESS OF SODA MANUFACTURE.

The reactions of the ammonia process, later known as the Solvay Process, were first discovered by Dyar and Hemming in 1838, but no use was made of them till Solvay, a Belgian, constructed an apparatus for their use in 1863. Its advantage over the LeBlanc Process lies in the fact that there are no troublesome by-products, such as "tank waste", formed. No hydrochloric acid or chlorine is formed in the process, as these all pass into the form of calcium chloride. The process depends on the fact that sodium bicarbonate is but slightly soluble in cold ammoniacal solutions of common salt. The most important part of the process depends upon a careful regulation of temperature. The chemical reactions involved in the process are as follows:

$$NaCl + NH_3 + H_2O + CO_2 = NaHCO_3 + NH_4Cl,$$

which is salt, plus ammonia, plus gas, plus water, plus carbon dioxide, equals sodium bicarbonate plus ammonium chloride.

The carbon dioxide is obtained by burning limestone in a specially constructed kiln so arranged as to save the carbon dioxide. This gas is forced upward through a tower in which a concentrate brine of common salt charged with ammonia is flowing down. The temperature of the whole is kept at 35 degrees Centigrade. The sodium bicarbonate, being less soluble than the other constituents, is separated from them on filters. The bicarbonate is readily changed to carbonate by heating. The liquor which passes the filters is treated with the lime formed in the production of the carbon dioxide gas used in the tower, and the following reaction takes place:

$$2NH_4Cl + CaO = 2NH_3 + CaCl_2 + H_2O.$$

The liquor will contain calcium chloride and some sodium chloride. These are separated by crystallization, since the salt is more soluble and remains in solution. The ammonia and salt solution can be used again, so there is no waste. The limestone used in either this or the LeBlanc Process must be very pure, as the presence of iron, silica or magnesia interfere with the reactions and the purity of the product.

Carbon Dioxide Recovery.

In the manufacture of lime there are large quantities of carbon dioxide driven off. This gas is now used extensively for charging mineral waters and in the manufacture of paints. It is usually made for these industries by the action of weak acids on lime carbonate, using marble or a limestone in the operation. Since this gas can be condensed to a colorless liquid under a pressure of 50 atmospheres and easily handled it seems like an unnecessary loss to allow it to escape in the manufacture of lime, and then produce it as it is needed in other industries.

This recovery of CO_2 is already in operation in England, and the more progressive lime plants of this country are sure to install it in the near future.

Limestone in Lead Smelting.

The Savelsburg process of lead smelting consists of heating an intimate mixture of galena or (lead sulphide) with limestone and water, in a reverberatory furnace in a strongly oxidizing atmosphere. The resulting mass contains the lead in the form of an oxide and calcium sulphate, from which the lead can be removed by any of the ordinary methods of shaft furnace purifying. This process is often carried on with lime instead of limestone. These methods are giving way to direct blast furnace oxidation as this can be accomplished if the temperatures are carefully regulated.

Office of State Supervisor of Natural Gas,
Fortville, Ind., April 1, 1915.

Hon. Edward Barrett, State Geologist, Indianapolis, Ind.:

Dear Sir—I am sending you today the manuscript of the Annual Report for the 39th Annual Report of the Department of Geology.

Thanking you for the valuable suggestions and assistance I have received from you, I am

Very truly yours,

Floyd E. Wright,

State Supervisor of Natural Gas.

Report State Supervisor of Natural Gas.

The gas of the Indiana part of the field known as the Lima-Indiana has been failing for the last few years until it has gotten so weak in places that it is being replaced by gas piped into the State by the Logan Natural Gas and Fuel Company, of West Virginia. The gas is pumped into the State and reaches it with a pressure of about 125 pounds, but is reduced to a few ounces before being turned into the city lines. The following towns are using West Virginia gas:

Muncie, Anderson, Elwood, Alexandria, Fairmount, Hartford City, Marion, Newcastle, Richmond, Noblesville, Tipton, Lynn and Middletown.

The gas is being used mostly for domestic purposes, very little being used for manufacturing, and is sold to the consumer at from 30 to 40 cents per thousand.

While much gas is being piped into Indiana, there still remain 2,295 gas wells that are producing some gas and are supplying a great many of the smaller towns and farmers, on whose farms they are located, with gas. In Tipton and Howard counties, the Indiana Natural Gas and Oil Company has a great many wells, the gas from which is being piped to Chicago. There were 64 new wells drilled in the year of 1914, and 147 old wells abandoned.

The Sullivan County oil field produces enough gas in addition to that used in the field for power, to supply about 80 consumers in Sullivan.

The Oakland City oil field produces enough gas to supply Oakland City and Winslow with gas.

The remaining gas wells in Indiana have an average pressure of 74.4 pounds, and the average price per thousand for which it is sold is $0.327.

The remaining gas wells and mains, not including the plants supplied with West Virginia gas, represent an original investment of about $20,000,000, but in their present condition would be worth about $1,000,000.

The Indiana portion of the Lima-Indiana oil field for the year of 1914 produced 508,987 barrels of oil from 3,796 wells; the Princeton and Oakland City field produced 151,441 barrels from 285 wells; and the Sullivan County field produced 859,500 barrels from 415 wells, making a total production for the State of 1,519,-

928 barrels from 4,496 wells, showing an increase over the production of 1913 of 549,848 barrels.

The price of oil for the last year has been such that it has not offered a very great inducement to oil operators to try to open any new fields, or to properly develop the old ones.

There are a great many counties in Indiana which oil men think are underlaid with oil, but they are waiting for the price to advance a little so that the chances for gain will be greater. Among other places looked upon with favor is the territory around Birdseye, Jasper County; Gentryville, Spencer County; Foltz, Jefferson County, and Wilkinson, Hancock County. Near Birdseye and Gentryville there were a few wells drilled a few years ago, in which there was a good showing of oil, but for the want of capital at that time there was no more drilling done. In Hancock County the oil for several years has been showing up in the old gas wells, and there have been several thousand acres leased recently with the expectation of drilling deeper for oil.

In Jefferson County there was a strong gas well drilled, considering its depth, near Foltz. The rock producing the gas is thought to be the Niagara limestone, which in itself may not be of much importance but may be an indication of something deeper at that point.

There were a few fair oil wells drilled in Shelby County, on the west edge of the old gas field in that county.

Illinois geologists claim to have traced an anticline southeast through eastern Illinois to the Indiana line, and Kentucky geologists claim to have traced one northwest through Kentucky to the southern Indiana line, and that being the case it is very evident that it will cross the southwestern corner of Indiana, covering some points already mentioned as being productive of oil.

In the territory mentioned, near Bruceville, in Knox County, there have been some light gas wells producing for several years; the Princeton field in Gibson County has been a very productive oil field; the Oakland City and Petersburg fields in Pike County have been producing oil for several years; and in Spencer County, near Gentryville, several years ago one oil and one gas well were drilled in which showed a fair flow of oil and a good volume of gas, but were not developed further for the want of capital at that time. While Warrick County is in line of the same anticline, no drilling has ever been done.

The above counties will doubtless be developed as soon as the price of oil is sufficient to offer the proper inducement to operators.

The San Pierre Oil Field.

The San Pierre Oil Field, so-called in this report, includes a strip of country about twenty-five miles in length by about fifteen in width. The field proper starts south of Kouts in Porter County and extends south to the White County line, taking in parts of Porter, Laporte, Starke, Pulaski, and Jasper counties. The main field at this time is located three miles west of Wilder, part of the field being in Laporte County and part being in Porter County. This is the only part of the field that is being worked at this time. There are about twenty-five wells in this field that are being pumped, the wells being owned by one man, Mr. C. E. Russell of Laporte.

Since the beginning of the oil and gas industry in Indiana there has been more or less drilling in this field. One of the first gas wells in the State was drilled near Francesville in Pulaski County, which is in the southern part of this field. The Gifford field was at one time well known to all oil men of the State for the quality of oil found there. This field was extensively exploited in 1902–03 and was pumped for a short time, but due to the expense of operating the pumps by steam the wells failed to be a paying proposition and were abandoned in 1905 altogether.

The field now operated by C. E. Russell south of Kouts and west of Wilder was formerly drilled and a few good producing wells pumped in 1904 by an eastern oil company who abandoned their lease in 1906 due to the fact that it became too expensive to pump the wells for the output. Later Mr. Russell took up the lease and drilled a few new wells and cleaned out some of the old ones and began pumping these in July, 1914. The wells at first pumped water, but since the water is beginning to be decreased the wells are pumping a small amount of oil each day and it is expected that they will begin to be a paying proposition. At the beginning these wells pumped about 1,500 barrels of water in ten hours giving about half a barrel to a barrel and a half of oil in ten hours, compared to about 600 barrels of water with a barrel and a half to two barrels of oil in eighteen hours at the present time.

All the wells in this field are very shallow, ranging from 95 to 150 feet south of Kouts to four and six hundred feet in the southern part of the field around Medaryville, Francesville and Gifford. There have been a few deep holes drilled in Trenton rock, ranging from nine hundred to twelve hundred feet in depth.

The oil secured from these shallow wells is heavy and black and makes a very good lubricating oil as it is, as it comes from the well, but due to the small production of each well it has never been thought to be profitable to pump these wells, yet since the gasoline engine has become such a factor in the power world it may be that these wells can be profitably operated with this kind of power, and are at the present time being used in the pumping of the wells on the Hayman lease now operated by Mr. Russell.

The Gifford field, located about two miles north and east of Gifford in Jasper County, was thought at one time to be a very valuable field, so valuable that an asphaltum company located there to manufacture asphalt. The company built a large plant and worked the field until the supply of oil became inadequate for their purpose, when the plant was abandoned. The field was first worked by several different companies but was finally consolidated into one company by Wm. Budge, who operated the field until it was finally abandoned.

There were no records kept of these early wells in this county or practically any of the wells drilled in this part of the State. The companies that were responsible for the drilling of most of the wells in this territory have long since gone out of existence and it is impossible to secure any information, as all of the records that they might have kept at that time have long since been destroyed.

Practically all wells that have ever been worked at all have been shallow wells and very light producers, very few if any at any time producing over five barrels per day. The great amount of water encountered in pumping the wells has been the cause of several of the wells being abandoned.

A Supplemental Check List of Indiana Mollusca, with Localities and Notes.

By L. E. Daniels.

PREFACE.

In the 27th Annual Report of the Department of Geology and Natural Resources of Indiana, 1902, I published a Check List of Indiana Mollusca with localities. Since that time I have continued collecting and have added 40 species and 36 varieties to the former list, many of which are new to science.

In the following pages I give the names of these additional species, together with the locality in which each was taken. A few species are included on the authority of others, and in those cases the locality is followed with the name of the collector, in parentheses. In most of these cases I have received specimens from the collector.

I include the names of two species, viz., *Helicina occulta* Say and *Lymnæa galbana* Say, neither of which are known to be now living in the State but are found sub-fossil in the marl beds of Posey County, which is the type locality of "H" *occulta*. "H" *occulta* Say ranges from western Pennsylvania to Minnesota, south to Tennessee. Distribution markedly discontinuous and local.—Pilsbry and Johnson: Catalogue American Land Shells.

"L" *galbana* Say is not found at present farther south than the Transition life zone, though it ranges north well into the Boreal life zone. The marl deposits, however, show that in post glacial times it ranged south in Indiana (Upper Austral) and extended as far north as the arctic circle. It is exceedingly abundant in the marl deposits of New Jersey, New York, Michigan and Indiana, and must have been at one time one of the commonest of the smaller *Lymnæas*.—Baker, Lymnæaidæ of North America. These two species having been heretofore published are here included because they were not printed in my former list. They are not included in the total number.

Rolling Prairie, Laporte County, Ind.,
December 1, 1914.

CHECK LIST.

Helicina occulta Say.

Sub-fossil. New Harmony and Grand Chain, Posey County, abundant.

Vallonia excentrica Sterki.

Laporte, Waterford, Little Kankakee and Hunt's Lake, Laporte County; Bass Lake, Starke County; Walkerton, St. Joseph County.

Polygyra albolabris dentata (Tryon).

Mitchell, Lawrence County.

Polygyra multilineata algonquinensis Nason.

Marsh near Lake Maxinkuckee, Marshall County.

Polygyra tridentata discoidea Pilsbry.

Aurora, Ohio County; Charlestown Landing, Clark County; Leavenworth, Crawford County; Cannelton, Perry County; Mt. Vernon, Posey County. These localities are all on the Ohio River.

Vertigo ventricosa (Morse).

Marsh west side of Lake James, Steuben County.

Vertigo ventricosa elatior Sterki.

Marsh west side of Lake James, Steuben County.

Mesomphix lævigata perlævis (Pils.).

Laurel and Brookville, Franklin County; Lawrenceburg, Dearborn County. (A. C. Billups.)

Vitrea multidentata Binney.

Stoners Woods, Wills Township, Laporte County.

Euconulus chersinus dentatus Sterki.

Wyandotte, Crawford County; New Albany, Floyd County; and Medora, Jackson County.

Euconulus chersinus polygyratus Pils.

Bass Lake, Starke County.

Gastrodonta gularis (Say).

"The Knobs" one mile southwest of New Albany, Floyd County. Two specimens not quite full grown. Pilsbry writes that these are the first specimens he has seen from north of the Ohio River, and that this very late northern form is the *typical gularis*.

Limax maximus L.

Indianapolis. Rare.

Limax flavus color form *maculatus* Kal.

New Albany, Floyd County. Abundant.

Pyramidula cronkheitei albina (Mse. Ckll).

Little Kankakee near Laporte pumping station, Laporte County.

Succinea indiana Pils.

New Harmony, Posey County. I found this species in 1904 just south of New Harmony on the hillside facing the west between the marl cliffs and the highway. This place is less than a mile from the house where Thomas Say, the father of American Conchology, lived while at New Harmony.

Succinea ovalis optima Pils.

Waterford, Laporte County; Winona, Starke County; Lafayette, Tippecanoe County; Hillsdale, Vermillion County; Vawter Park, Kosciusko County. All of the Indiana specimens in my cabinet of *Succinea ovalis* was submitted to Dr. H. A. Pilsbry and he writes "that all of the Indiana specimens I have seen are *Succinea ovalis optima* Pils. Probably *typical* ovalis does not occur in the State, though it may be in the northern border. Until you find a colony of the thinner, greenish form, all of the smaller size, you may safely call all Indiana specimens *optima*. The *typical* ovalis is what is described by Binney and others as *totteniana*; the latter being a synonym."

Succinea aurea Lea.

Jeffersonville, Clark County. Rare.

Succinea avara form *vermeta* Say.

Tippecanoe Lake, Kosciusko County; Lake Maxinkuckee, Marshall County; Stone, Pine and Clear Lakes, Laporte County.

Succinea retusa magister Pils.

Carr's Slough near Brookston, White County.

Succinea retusa peoriensis Wolf.

Waterford, Laporte County.

Lymnæa columella casta Lea.

Bass Lake, Starke County; Lily and Stone Lakes, Laporte, Laporte County.

Lymnæa columella chalybea Gould.

Grassy Creek, Kosciusko County; Calumet River at Millers, Lake County. The typical columella is found at "The Channel", Laporte, Laporte County.

Lymnæa elodes Say.

Millers and Roby, Laporte County (Baker); Tippecanoe Lake, Kosciusko County; Brookston and Carr's Slough, White County; Laporte, Laporte County; Cypress Swamps, Knox County.

Lymnæa exilis Lea.

George Lake, Lake County (Woodruff).

Lymnæa dalli Baker.

Lake James and marsh west side of Lake James, Steuben County; Lake Wawasee, Kosciusko County; Lake Maxinkuckee, Marshall County; Little Kankakee River and Waterford, Laporte County. Abundant.

Lymnæa galbana Say.

Sub-fossil. Three-fourths mile southwest of Stewartsville, Posey County; one and one-half miles northwest of Petersburg, Pike County; marl deposits, New Harmony, Posey County.

Lymnæa obrussa exigna Lea.

Lake Maxinkuckee and Lost Lake, Marshall County; Lily, Clear and Stone Lakes, Laporte County; Little Kankakee River, Laporte County; marsh west side, and spring east side of Lake James, Steuben County.

Lymnæa parva Lea.

Bass Lake, Starke County; spring east side Lake James, Steuben County; Tippecanoe Lake, Kosciusko County; Little Kankakee, Laporte County.

Lymnæa parva sterkii Baker.

Cypress swamps, Knox County; Lake Maxinkuckee, Marshall County.

Lymnæa humilis modicella Say.

Lily Lake, Clear Lake, Pine Lake, Hudson Lake, Lost Lake, Waterford, all in Laporte County; Walkerton, St. Joseph County; Round Lake, Whitley County; Calumet River near Millers, marl deposits (Stewartsville, Posey County; west of Mounds, Gibson County; Fuller & Clapp).

Lymnæa humilis rustica Lea.

Marsh west side of Lake James, Steuben County.

Lymnæa reflexa walkeri Baker.

George Lake, Lake County (Baker). Hessville, Lake County (Walcott).

Lymnæa palustris blatchleyi Baker.

Turkey Lake (Lake Wawasee), and Tippecanoe Lake, Kosciusko County.

Lymnæa danielsi Baker.

Lake Maxinkuckee, Marshall County. Abundant.

Planorbis dilatus Gould.

Blue Lake, Whitley County.

Planorbis crista cristatus Drap.

Marsh west side of Lake James, Steuben County.

Planorbis trivolvis macrostomus Whiteaves.

Millers, Lake County.

Segmentina crassilabris Walker.

Vincennes; cypress swamps, Knox County; Walkerton, St. Joseph County; Brookston, White County.

Ancylus fucus engraptus Pils.

Head of Calumet River at Millers, Lake County.

Ancylus walkeri Pilsbry & Ferriss.

Pond at "Camp Colfax", Lily Lake and Clear Lake, all near Laporte, Laporte County.

Ancylus kirklandi Walker.

Head of Calumet River at Millers, Lake County; Lake Maxinkuckee, Marshall County.

Gundlachia meekiana Stimpson.

Marsh west side of Lake James, Steuben County.

Pleurocera subulare intensum Reeve.

Lake Maxinkuckee, Marshall County.

Pleurocera troostii Lea.

Wabash River, East Mt. Carmel, Knox County; "The Chains", Posey County.

Anculosa trilineata viridis Lea.

Ohio River, New Albany.

Somatogyrus strengi Pilsbry & Walker.

Wabash River at "The Chains", Posey County. (Hinkley.)

Somatogyrus currieranus Lea?

Wabash River at the Old Dam below New Harmony. (Hinkley.)

Pomatiopsis cincinnatiensis Lea.

Michigan City and Waterford, Laporte County.

Pyrgulopsis wabashensis Hinkley.

Wabash River at the "Old Dam" below New Harmony and "The Chains", Posey County. (Geo. Hinkley.)

Valvata bicarinata connectans Walker.

Lake Michigan near Michigan City.

Valvata bicarinata perdepressa Walker.

Lake Michigan at Michigan City, and at Millers, Lake County.

Valvata lewisii Currier.

Lake Wawasee, Tippecanoe Lake, and Grassy Creek, Kosciusko County.

Anodontoides modestus Lea.

Little Kankakee River five miles east of Laporte, near the city pumping station.

Unio gibbosus delicatus Simpson.

Tippecanoe River, Carroll County.

Sphærium tenue Prime.

Lake Maxinkuckee, Marshall County. (Evermann.)

Sphærium lineatum Sterki.

Lake Wawasee, Kosciusko County.

Sphærium ohioense Sterki.

Blue River, Wyandotte, Crawford County; Ohio River, Cannelton.

Sphærium emarginatum Prime.

Lake Michigan, Pine, Laporte County.

Sphærium emarfiinatum Prime.

Lake Michigan, Pine and Millers, Lake County; Michigan City, Laporte County.

Musculium ryckholti Norm.

Lake Maxinkuckee, Marshall County. (Evermann.)

Musculium jayanum Prime.

Long Lake at Millers, Lake County; Pond "Camp Colfax", Laporte County.

Musculium lacustre Müller.

Pond at "Camp Colfax", Laporte, and pond one mile west of Laporte, Laporte County.

Musculium sphæricum Anthony.

Pond one mile west of Laporte, pond at "Camp Colfax", Pine Lake; Clear Lake, "The Channel"; Lily Lake, all near Laporte, Laporte County; Saugany Lake, Rolling Prairie, Laporte County.

Musculium orbiculare Sterki.

Hammond, Lake County; Stone Lake near Laporte, Laporte County. Rare.

Musculium parvum Sterki.

Hammond, Lake County. Rare.

Pisidium compressum lævigatum Sterki.

Calumet River and pond near Millers, Lake County; Bass Lake, Starke County; Lake Wawasee, Kosciusko County; Lake Maxinkuckee, Marshall County.

Pisidium compressum rostratum Sterki.

Clear Lake, Steuben County.

Pisidium walkeri Sterki.

Culver Inlet to Lake Maxinkuckee, Marshall County.

Pisidium mainense Sterki.

Clear Lake, Steuben County; Lake Maxinkuckee. (Evermann.)

Pisidium trapezoideum Sterki.

Marsh west side of Lake James, Steuben County.

Pisidium noveboracense quadrulum Sterki.

Bass Lake, Starke County.

Pisidium idahoense indianense Sterki.

Lake Maxinkuckee, Marshall County. Abundant.

Pisidium punctatum simplex Sterki.

"The Chains", Wabash River, Posey County. (Hinkley.)

Pisidium abditum subrotundum Sterki.

Long Lake, Millers, Lake County; pond at "Camp Colfax", Laporte, Laporte County; Lake Maxinkuckee, Marshall County.

Pisidium pauperculum crystalense Sterki.

Lake Maxinkuckee, Marshall County; Lake Wawasee, Kosciusko County.

Pisidium milium Held.

Lake Maxinkuckee, Marshall County. (Evermann.)

Pisidium glabellum Sterki.

Lily Lake, Laporte County; Lake Wawasee, Kosciusko County.

ADDITIONAL LIST OF LOCALITIES.

Since the publication of my former Check List in 1902 I have added many localities to the list, and I take this as an opportune time to put those of the rarer species on record and thus be of some aid to future workers.

Vallonia costata (Müll.).

Laporte, Laporte County.

Polygyra leporina (Gld.).

Princeton, Gibson County; Vincennes, Knox County.

Polygyra stentotrema (Fer.).
Charlestown Landing, Clark County; Cannelton, Perry County.

Bifidaria procera Gld.
Upton and New Harmony, Posey County. (Hinkley.)

Bifidaria corticaria (Say).
Mitchell; Vincennes; New Albany; Shoals, Martin County.

Vertigo Gouldi Binn.
Clear, Pine and Stone Lakes, Laporte, Waterford, Laporte County.

Omphalina friabilis (W. G. B.).
English and Wyandotte, Crawford County; Grand Chain, Posey County; Medora, Jackson County; Vincennes, Knox County.

Omphalina lævigata (Pfr.).
Madison, Jefferson County; Charlestown Landing, Clark County; Medora, Jackson County; Wyandotte, Crawford County.

Omphalina inornata (Say).
Charlestown Landing, Clark County.

Vitrea capsella (Gld.).
Vincennes, Knox County.

Zonitoides milium (Morse).
Little Kankakee, five miles east of Laporte.

Gastrodonta ligera (Say).
New Albany, Floyd County; cypress swamps, Knox County.

Limax flavus L.
Charlestown, Clarke County; Indianapolis.

Punctum pygmæum (Drap.).
Wyandotte, Crawford County; New Albany, Floyd County.

Sphyradium edentulum (Drap.).
Corydon, Harrison County.

Carychium exile H. C. Lea.
Lake James, Steuben County; Waterford, Laporte County.

Goniobasis depygis Say.
Blue River, Wyandotte, Crawford County.

Goniobasis indianensis Pilsbry.
Silver Creek, Floyd County.

Amnicola limosa porata Say.
Lake Maxinkuckee, Marshall County; Millers, Lake Michigan.

Amnicola walkeri Pils.

Lake James, Steuben County; Lake Maxinkuckee, Marshall County.

Amnicola cincinnatiensis Anthony.

Upton, Posey County. (Hinkley.)

Amnicola emarginata Kuster.

The Chains, Posey County. (Hinkley.)

Paludestrina nickliniana Lea.

Little Kankakee River at the old mill dam five miles east of Laporte, Laporte County. Abundant.

Pomatiopsis lapidaria Say.

New Albany; Waterford, Laporte County.

Valvata bicarinata Lea.

Cedar Lake, Lake County.

V. bicarinata normalis Walker.

Cedar Lake, Lake County.

Pisidium virginicum Bourg.

Lake Maxinkuckee, Marshall County; Lake James, Steuben County; Lake Michigan at Millers and Pine.

Pisidium danielsi Sterki.

Clear Lake, Laporte, Laporte County.

Pisidium politum Sterki.

Bass Lake, Starke County; Lake Maxinkuckee, Marshall County.

Pisidium vesiculare Sterki.

Lake Maxinkuckee, Marshall County.

Lampsilis lienosus Con.

Eel River, North Manchester.

Quadrula cooperiana Lea.

Ohio River near Cannelton.

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