THE LIME INDUSTRY IN INDIANA.

By W. S. Blatchley.

Lime or quicklime has been manufactured and used in Indiana since the days of the pioneers. The first settlers with their rude log cabins, whose chimneys were formed of sticks and mud, of necessity did without it; but as soon as more substantial log and frame buildings with chimneys of stone or brick were erected, lime for mortar and plaster became necessary. At first rude kilns were constructed in each locality, where stone or marl could be readily secured, and in these lime was burned for neighborhood use. From these first crude stone or "ground-hog" kilns, erected on the side of a bluff or hill and operated by a single man, to the great plants of the present day, with their dozen or more large steel kilns and hundreds of workmen, is a notable advance—in keeping with a similar advance in other and kindred industries of the State. But little or nothing concerning the lime industry in Indiana has heretofore appeared in the reports of this Department. The present importance of that industry, due largely to the many and varied uses to which lime is now being put, is reason sufficient for the preparation of the present paper.

Calcium carbonate, or carbonate of lime, is one of the most abundant chemical compounds occurring in a natural state. Shells of oysters, clams, snails, and all other land and water mollusks are mainly composed of it, as are also those coral reefs which cover thousands of square miles of the ocean's floor. All the larger and purer beds of limestone which form a great portion of the surface or crust of the earth are also made up of carbonate of lime. They were formed of the framework and shells of mollusks, corals and other marine animals which existed in untold numbers in the seas, on whose floors or bottoms the sediment of the limestone was first deposited. Oölite, chalk, marble, travertine, tufa and calcareous marl are but names of other forms of carbonate of lime.

Calcium carbonate, when pure, is composed of one part of calcium (Ca) combined with one part of carbon (C) and three parts of oxygen (O_3), the chemical formula of the compound being $CaCO_3$. If this carbonate of lime be roasted or subjected to great heat it is split up into a gas and a new solid. $CaCO_3 = CO_2 + CaO$. The gas, carbon dioxide (CO_2), escapes and the solid, calcium oxide (CaO), is left behind as the unslacked lime or quicklime of commerce.

It is a common belief among masons, architects and others that the best lime is produced only from the purest carbonate of lime. Statements to that effect are also often found in text-books on chemistry. Experience has proven that such beliefs and statements are wholly erroneous. Some of the best lime in Indiana is made from stone containing a high percentage of magnesia. The Delphi and Huntington limes are burned from this magnesian limestone, analyses of which show the presence of 44 per cent. of magnesium carbonate as against 53 of calcium carbonate. When burned, the magnesium carbonate is reduced to magnesium oxide and the resulting lime is a mixture of magnesium and calcium oxides. These magnesium limes are preferred by many masons, as they claim that the mortar made from them is "cooler" and sets more slowly. Mortar made from pure lime is, in their language, too "hot" and "quick setting." It is also claimed that the magnesian limes have better cementing qualities.

Lime is a brittle, white, light gray or cream colored solid with a specific gravity of 2.3 to 3. It is one of the most infusible compounds known, withstanding the extreme heat of the oxyhydrogen blowpipe, but when exposed to it giving off a light of such exceeding brilliancy as to be almost unbearable to the eye. Lime has a very strong attraction or chemical affinity for water, uniting with it with such vigor as to generate great heat. This process is called slacking or slaking. When the freshly burned lime is exposed to the atmosphere for any length of time, this affinity for water causes it to absorb moisture, or "air-slack." It then crumbles into a white powder and loses much of its usefulness for certain purposes. A sample left in this office for a week and then analyzed was found to contain 8.5 per cent. of moisture which it had absorbed in that time. On account of this attraction for the mois-

ture of the air, lime is termed a perishable product, which should be used as soon as possible.

When water-slacked, pure lime swells very much and ultimately falls into a snow-white powder. Lime (CaO) + water (H_2O) = the calcium hydrate ($Ca(OH)_2$) of chemists; the latter being the white powder. If more water is then added, what is called the "milk of lime" is formed. This is composed of particles of calcium hydrate suspended in water. When this milk of lime is exposed to the air the extra water evaporates, and the calcium hydrate slowly absorbs carbon dioxide from the air and changes into calcium carbonate. Calcium hydrate ($Ca(OH)_2$) + carbon dioxide (CO_2) = calcium carbonate ($CaCO_3$) + water (H_2O).

Uses of Lime.

The most important use of lime is in the production of mortar and plaster. For that purpose it has been used by all modern and most ancient civilized nations. In the earliest masonry of which any remains have been found, as the Etruscan, that of the Island of Cyprus and ancient Troy, walls were laid up with large stones without mortar ("cyclopean" masonry), or with smaller ones packed in clay; but by the Egyptians, Hebrews, Greeks and Romans, the use of lime for mortar was universal.

In the preparation of mortar, sand is added according to the richness or "fatness" of the lime—that is, according to the fineness and uniformity of the powder into which the lime falls when water-slacked. Where the resulting powder is very fine it makes with the water a milk of lime or lime paste which will penetrate the minute spaces between the grains of sand, however closely they may be crowded. The thinner the film of paste between the grains of sand, the stronger their adhesion will be in the future. Hence the value of a lime is roughly measured by the quantity of sand it will serve to unite—the better the lime, the greater the quantity of sand which it will bind together to form mortar or plaster.

As the lime in the mortar gradually hardens by absorbing carbon dioxide from the air, it also unites with the sand to form calcium silicate or silicate of lime. This is one of the important constituents of hydraulic cement and by its formation the strength of the mortar is still farther increased. The latter often continues

to absorb carbon dioxide and by its aid form calcium silicate for hundreds of thousands of years before being saturated. Hence the great tenacity of old mortar, that in the Egyptian pyramids being as hard as the stone it joins together. Chemical analyses clearly prove that in these old mortars the silicate of lime is much greater in quantity than in those more recently made.

The great increase in recent years in the number of brick and stone buildings, due largely to the disappearance of our forests and a consequent rapid advancement in the price of lumber, has led to a greatly increased demand for lime for mortar making. Probably 70 per cent. of that produced in Indiana is used for this purpose alone.

Whitewash, much used instead of paint as a surface covering for outbuildings and fences in the country, and also as a purifier and disinfectant, is simply "milk of lime" mixed with a little glue. Much lime is also used in making "bleaching powder" or chloride of lime. This is formed by passing chloride gas into leaden chambers containing slacked lime which absorbs the gas very rapidly. Chloride of lime is a dry white powder which smells faintly of chlorine and has a strong taste. It dissolves partially in water and the solution is much used for bleaching cotton goods.

Lime acts on the skin like a caustic alkali and is therefore used by tanners for removing hair from hides and by glue manufacturers in the making of glue from scraps of hides and hoofs. It is also necessary in the manufacture of caustic soda and caustic potash, and large quantities are used for this purpose. These caustic alkalies are much used in soap manufacture, so that the soap industry depends indirectly upon that of lime making.

Lime is also extensively used in glass making, and as a flux in smelting iron. It is customary, however, to use finely ground limestone for glass manufacture and chunks of pure limestone in blast furnaces. During the melting of the glass ingredients or the smelting of the iron ores the limestone gives up its carbon dioxide and is changed into quicklime, the latter serving as the fluxing agent in both cases.

Large quantities of lime are also used in paper manufacture, especially in strawboard works. Pure lime to the amount of 1,500 or more pounds, is first placed in a large rotary and steam turned in until it is thoroughly slacked. The hot slacked lime is then

blown into another rotary containing the straw which it bleaches and aids in reducing to a pulp. In the making of paper from rags, milk of lime and water are added to a rotary boiler which is filled with rags. The boiler is then slowly revolved, steam being admitted under pressure. This cooking thoroughly softens the grease or any dirt remaining in the rags, at the same time rendering them more easily reduced to paper pulp.

The making of a "sand brick" from sand and lime has lately come into vogue and promises to cause a demand for quite a quantity of lime in the near future. Three large factories are already in operation in Indiana and several others will soon be erected. In the making of these brick from eight to twelve per cent. of unslacked lime is used. This is ground fine and mixed intimately with the proper amount of clean, pure sand, and the mixture is then put through a pressed brick machine. The brick as they issue from the machine are piled on iron cars and wheeled into large air-tight steel cylinders, which, when full, are closed and sealed. The brick are then subjected to a high steam pressure for 12 to 15 hours, when they are ready for the market. They are of a white or cream color, and are used the same as ordinary brick for building purposes. Some care must at first be taken in handling and laying them, but they soon harden and in time become more firm and solid than the ordinary kiln-burned clay brick. The reason for this gradual hardening is the same as for that of mortar, viz., the combining of the slacked lime with a portion of the silica of the sand to form a calcium silicate which, in time, binds or cements the particles of sand firmly together. Where the right kind of sand is plentiful and lime can be had for a reasonable price, sand brick can be made very cheaply, as there is a great saving in time and in the amount of fuel required for their manufacture.

Much lime is used either as a fertilizer for soils or as a means of improving the mechanical condition of soils. It can only be used as a fertilizer with profit where the soil is lacking in calcium, as that is the only element of plant food which lime contains. Most soils contain lime enough for practical use, as a lime content of one per cent. in a soil is always sufficient. When the amount falls below one per cent. the application of lime fertilizers is occasionally beneficial, and always so when only one-quarter to

one-half per cent. of lime is present. When less than one-quarter of one per cent. of lime is found in the soil, liming is absolutely necessary. Caustic lime or quicklime is the most concentrated form of lime which can be applied as a fertilizer. The finer the state of division it is in when applied the quicker and more direct will be the benefits derived. The hydrated lime manufactured at Milltown, Indiana, especial mention of which will be made on a subsequent page, is for this reason extensively used as a top-dressing for soils.

The use of lime "as a means of improving the mechanical condition of soils" is a very important one, and is worthy of more general practice than it has received from farmers in the past. A soil may contain all the elements or ingredients necessary for the production of a certain crop and yet, on account of its mechanical condition, its extreme looseness or porosity, or its compactness, plants can not grow in it. By the application of certain materials, one of the best of which is quicklime, these unfavorable physical properties of the soil are often modified or broken up, so that the plants can avail themselves of the store of fertility in the soil, and a good crop is the result.

Many clay soils, when wet by rains, are not porous enough to allow the water to pass through them with sufficient rapidity. As a consequence they become water-logged and the air which is necessary for the healthy growth of the plant roots is excluded. In time of drought such soils cake readily, thus forming large clods, and becoming more difficult to till and less adapted to the sustenance of the growing plant. Some compound of lime, when applied in sufficient quantity, will prevent this puddling or caking, thus allowing the water, air and heat to thoroughly permeate the soil. The texture of the soil will also become more suitable for the easy penetration of the roots and rootlets of the plants.

Lime Making Materials in Indiana.

Indiana is rich in materials suitable for the making of lime. Moreover, they are widely scattered throughout the State. In the southern part the Mitchell and Bedford limestones furnish an abundance of the purest carbonate of lime. In the northern part

the Niagara limestone in its outcrops along the valley of the Wabash and its tributaries, has long been the source of a fine grade of magnesian limestone which is noted for the excellence of its lime product. The marl deposits scattered about the lakes and marshes of the northern third of the State, furnish also a good lime-making material which was once quite extensively utilized for that purpose, and could be again if necessity required.

THE MITCHELL LIMESTONE.—This is one of the Lower Carboniferous limestones, which immediately overlies the Bedford limestone and forms the surface rocks in an area three to 25 miles in width in an irregular strip extending from the Ohio River northward to near Crawfordsville, Montgomery County, where it disappears beneath the drift. The area covered by the Mitchell limestone thus embraces parts of the following counties: Harrison, Crawford, Floyd, Washington, Orange, Martin, Lawrence, Monroe, Owen, Morgan, Putnam and Montgomery. In this area the Mitchell limestone has been utilized for making lime on an extensive scale at Milltown, Mitchell, Limedale and Okalla; while at numerous places throughout the area isolated kilns are or have been in operation for burning lime for local use.

The Mitchell limestone varies much in structural character and appearance. In most places it is a fine-grained, crystalline or sub-crystalline stone which is quite hard. In the southern part of its area there are found in a number of localities near the top of the Mitchell and between the beds of grayish stone, layers having an oölitic structure, nearly pure white in color and much softer than the gray. This "oölite" outcrops at Milltown, Marengo, and numerous other localities in Crawford County; at the Stockslager quarry in Harrison County; in Madison and Posey townships, Washington County, and at numerous places along the French Lick Branch of the Monon Railway west of Paoli, in Orange County. Both it and the more common gray Mitchell limestone comprise the purest forms of carbonate of lime found in the State.

The following table of analyses shows the composition of the Mitchell limestone from four widely separated localities:

ANALYSES OF MITCHELL LIMESTONE FROM SOUTHERN INDIANA.

Source of Sample.	Calcium Carbonate ($CaCO_3$).	Magnesium Carbonate ($MgCO_3$).	Ferric Oxide and Alumina ($Fe_2O_3+Al_2O_3$).	Insoluble Residue (Silica, etc.).	Total.	Authority.
Oölite from Eichel Quarry, Milltown, Ind	98.91	.63	.15	.48	100.17	W. A. Noyes.
Gray stone from Mitchell Lime Quarry, Mitchell, Ind	96.65	1.20	.27	1.57	99.69	— ——
Gray stone from South of Harrodsburg, Ind	97.64	.....	.32	.82	98.74	T. W. Smith.
Gray stone from land of J. B. Lyne, Monroe County	99.04	.....	.09	.80	99.92	T. W. Smith.

The last analysis given is from a ledge of the gray Mitchell limestone on the land of J. B. Lyne, in the southeast quarter of section 32 (8 N., 1 W.), five miles south of Bloomington, Indiana. This showed the highest per cent. of carbonate of lime of any Indiana stone whose analysis has been seen by the writer.

The above analyses show that the Mitchell limestone is a remarkably pure carbonate of lime, in every way suitable for making the purest of quicklime, not only for mortar-making purposes but for chemical and other uses where great purity of the raw ingredient is necessary. Farther analyses of the Mitchell stone will be given in connection with the descriptions of the plants now making lime from it in southern Indiana.

The Bedford Oölitic Limestone.—This is the best known limestone in the State, being the formation so extensively quarried for building and ornamental purposes. It is one of the Lower Carboniferous limestones, and forms a portion of the surface rocks in a narrow irregular strip from two to 14 miles in width, extending a distance of 110 miles from near Greencastle, Putnam County, to the Ohio River. Its outcrops occur in Putnam, Owen, Monroe, Lawrence, Washington, Floyd and Harrison counties. Numerous quarries have been opened throughout this area for building stone, and lime has been burned at a number of points, but nowhere on as extensive a scale as at Mitchell and Milltown, where the Mitchell limestone is used. The Bedford oölitic stone ranges from a creamy white to a dark drab in color. It is very

uniform in grain and quite soft when first quarried. Under the microscope it is seen to be made up of the globular shells of minute one-celled animals. These are composed of carbonate of lime and are cemented together by the same material, so that the rock is a very pure limestone, ranking close to the Mitchell stone in chemical composition. From a number of analyses of the Bedford stone made by Dr. Noyes for the Twenty-first (1896) Report of this Department the following are taken to show its composition:

ANALYSES OF BEDFORD OÖLITIC LIMESTONE FROM SOUTHERN INDIANA.

Source of Sample.	Calcium Carbonate ($CaCO_3$).	Magnesium Carbonate ($MgCO_3$).	Ferric Oxide (Fe_2O_3).	Insoluble Residue (Silica, etc.).	Total.
Bedford, Indiana, Stone Quarry, Lawrence County	98.27	.84	.15	.64	99.90
Hunter Bros. Quarry, Monroe County.....	98.11	.92	.16	.86	100.05
Romona Oölitic Stone Company, Owen County	97.90	.65	.18	1.26	99.99
Twin Creek Stone Company, Washington County ..	98.16	.97	.15	.76	100.04

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 oölitic stone for making a very pure quicklime; and the practical burning of the lime at Salem, Bedford and other points proves that fitness. For some reason, however, the lime industry in the oölitic 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 southwest of Bedford, and three south of the same place along the Monon Railway, and in Owen County at Romona. Prof. T. C. Hopkins, in a chapter on "The Commercial Features of the Bedford Oölitic Limestone," comments on the lack of use of the Bedford stone for lime making, and gives, doubtless, the real reasons for the neglect of the industry in the area. I quote from him as follows:*

*21st Ann. Rep. Ind. Dept. Geol. and Nat. Res., 1896, p. 337.

"To see the great quantity of waste rock on the dump piles about the oölitic quarries one wonders why more of it is not burnt into lime, and no satisfaction 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 it had ever been tried, or would make lime at all. One only needs to look at the table of analyses of the stone to see that it would make a fat or rich lime, but that should not be a serious objection, as for many purposes a rich lime is preferred to any other. The reason that more of it has not been burnt may be due to a number of causes: 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 the quarries 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. The last is probably the most important reason."

THE NIAGARA LIMESTONE.—This limestone is the principal formation representing the Upper Silurian Period in Indiana. It forms the surface rocks over a wide area of the eastern and northern portions of the State and also over an irregular narrowing strip, 30 miles to one in width, extending southward from Newcastle, Henry County, through portions of Wayne, Rush, Fayette, Franklin, Decatur, Ripley, Jennings, Jefferson and Clark counties to the Ohio River near Jeffersonville. Through this narrow strip the rock is close to the surface, but in the larger area north of Newcastle it is nearly everywhere covered with deep drift. However, in the valley of the Whitewater and its tributaries in northern Wayne County, at Portland, Jay County, and along the Wabash River in the vicinity of Bluffton, Huntington, Wabash and Logansport it comes to the surface, as also in isolated areas near Delphi, Monon and Kentland. At a number of these localities and also near Utica, Clark County, the Niagara stone has for years been burned into a high grade of lime; and it is probable that at nearly every point where it outcrops it will be found suitable for lime making.

The Niagara limestone ranges from nearly white through buff to blue in color and from a hard, subcrystalline stone to a soft,

shaly one in structure. In Decatur, Franklin and Wabash counties it is, in places, especially hard and compact, of even texture and color, and often occurs in thin, easily separated layers, usually from three to 12 inches thick which are largely quarried for flagging, curbing and similar uses. In other places it is known as "cliff rock" owing to the fact that the thick, uppermost layers withstand the action of the weather and form steep cliffs and bluffs along the ravines and lines of outcrop.

The chemical composition of the Niagara limestone varies greatly. In southern Indiana it usually contains only from 6 to 10 per cent. of magnesium carbonate, but the outcrops along the Wabash River contain 40 per cent. or more of this compound. This is especially true of certain outcrops in the vicinity of Huntington, Wabash and Delphi, where the Niagara stone seems to have passed through an upheaval, the strata being tilted in various directions, sometimes at an angle of 45 degrees or more. Near Delphi, Monon, and Kentland, Newton County, the Niagara comes to the surface in isolated islands in which the layers show this same tilted condition. Dr. E. M. Kindle has studied carefully the outcrops and stratigraphy of the Niagara through this region and has an interesting paper concerning it on subsequent pages of the present volume. The following table shows the variability of the Indiana Niagara limestone in chemical composition:

ANALYSES OF INDIANA NIAGARA LIMESTONE.

Source of Sample.	Calcium Carbonate ($CaCO_3$)	Magnesium Carbonate ($MgCO_3$)	Ferric Oxide and Alumina ($Fe_2O_3+Al_2O_3$)	Insoluble Residue (Silica, etc.)	Sulphuric Anhydride.	Total.	Authority.
Consolidated Lime Company, Huntington	53.22	44.96	.23	.59	.11	99.11	R. E. Lyons.
Harley Bros. Quarry, Delphi, Carroll Co.	54.53	43 92	.51	.19	.18	99.33	R. E. Lyons.
Greensburg Stone Company, St. Paul, Decatur Co	74.02	10.35	6.20	5.90	.90	97.37	E. T. Cox.
Scanlan's Quarry, Flat Rock Creek, Decatur Co	83.00	6.3	2.50	5.30	1.00	98.10	E. T. Cox.

The limestones from Huntington and Delphi, whose analyses are given, have long been used in making the magnesian limes for

which those two points are famous. These limes are "cooler" or more "slow-setting" than those from the purer Mitchell and Bedford limestones and for that reason are preferred by many masons and builders. There is little doubt but that as good lime can be made from the Niagara stone at a number of other points along its outcropping horizon in Huntington, Wabash, Miami and Cass counties as at Huntington and Delphi. While analyses are not available, it is believed that the stone at Monon and near Kentland will also make a good grade of lime. The analyses of the Niagara stone in the southern part of its area show that a lime intermediate in character between that made at Delphi and Huntington, and that from Mitchell and Milltown could be produced. Large quantities are at present burned at New Paris, Preble County, Ohio, but six miles east of Richmond, Wayne County, Indiana, and for years kilns were in operation at Cox's Mills, five miles northeast of Richmond, and near Laurel, Franklin County. At these localities the Niagara limestone, similar to that at Decatur and St. Paul is or has been in use. A fine grade of lime has also been manufactured for years from a gray, crystalline, Niagara limestone in the vicinity of Utica, Clark County. Prof. W. W. Borden, in 1873, wrote of the industry in this vicinity as follows:* "The lime burned and sold under the name of the Utica lime has acquired by long use a high reputation, and where known is used in preference to all other brands. J. Speed, Esq., has erected at Utica two of Page's patent kilns, each producing 120 barrels of lime per day. At Robinson's landing, a few miles above Utica, Mr. Jacob Robinson burns of the same stone ten thousand barrels per year. The fuel employed is wood and requires four cords to burn one kiln. The Utica Lime Company use a mixture of wood and coal, and have two kilns, each producing 90 barrels of well burned lime per day. The Louisville Cement and Lime Company, and the Utica Lime Company, and Mr. J. Robinson burn 125,000 barrels of lime per year, employing in the business a large number of hands."

On account of a lack of proper transportation facilities at Utica, where shipment is possible only by boat on the Ohio River, the industry has gradually dwindled to about 8,000 barrels per year.

*5th Ann. Rep. Geol. Surv. of Ind., 1873, p. 145.

MARL AS A SOURCE OF LIME.—About the existing lakes, and the extinct lakes and marshes of the northern third of Indiana are many extensive deposits of marl or "merl" as it is called in the country. This marl is a soft, earthy material composed principally of an amorphous form of carbonate of lime. Its color varies with the percentage of impurities which it contains, from a milky white to a dark brown when wet; and from a white or cream to a slate color when dry. The grains or particles composing the dry mass cohere very slightly and vary in size from coarsely granular to fine powder. They effervesce very freely and in time wholly disappear in cold muriatic acid, which is the principal test for carbonate of lime. These marls were deposited in the still waters of the lakes of the region, the original source of the marl material being the glacial clay and rock flour which formed a large part of the till or drift of the region surrounding the lakes. Percolating through the deposits of glacial clays and limestone debris, rainwater has, for centuries, dissolved and become saturated with the carbonate of lime. It has then flowed onward underground until it issues forth in the form of a spring, either bubbling up from the bottom or flowing in from the side of the basin in which the lake is located. In the warmer waters of the lake, the carbonate of lime has then been deposited until it has formed the vast beds of so-called marl.*

Several hundred deposits of marl occur in the lake region of the northern part of the State. These vary in size from an area a rod or two square and a foot or two deep, up to hundreds of acres, twenty or thirty feet or even more in depth. In the report cited, are full descriptions of thirty-two deposits which contain a body of marl equal to 160 acres in area and ten feet thick. The following are analyses of average samples of marl from five of these deposits, made by Dr. W. A. Noyes for the 1900 Report. From them one can judge as to the chemical composition of the average deposit in the State:

*For a full account of the Lakes of Indiana and their accompanying marl deposits, as well as for detailed information regarding the formation, deposition, properties and uses of marl, see the paper by Blatchley and Ashley, in the 25th (1900) Report of this Department, pp. 31-321.

ANALYSES OF INDIANA MARLS.

Origin of Sample.	Calcium Carbonate ($CaCO_3$)	Magnesium Carbonate ($MgCO_3$)	Ferric Oxide and Alumina ($Fe_2O_3+Al_2O_3$)	Insoluble residue (silica, etc.)	Organic matter.	Total.
Lake James, Steuben Co	92.41	2.38	.29	1.16	1.97	98.36
Tippecanoe Lake, Kosciusko Co	90.67	2.42	.32	2.48	2.87	98.76
Manitou Lake, Fulton Co	87.65	2.60	.49	6.39	2.88	100.01
Maxinkuckee Lake, Marshall Co	85.38	3.50	.38	6.40	3.15	98.98
Chain and Bass Lakes, St. Joseph Co	87.92	2.64	.30	3.10	4.18	98.37

In the early settlement of northern Indiana much quicklime was made from these deposits of marl. No one of the counties in which the principal deposits occur has outcrops of limestone, and hence the marl was used, being burned in rude kilns erected for the purpose. Richard Owen, in his report on St. Joseph County, says: "Beneath the swamp-muck beds in the Kankakee marshes near South Bend, a shell marl, three to ten feet thick, is obtained. At many places this is dug and moulded into brick-shaped masses of considerable size, so as to be readily piled in a kiln, burnt and used for all purposes to which lime is usually applied, being of an excellent quality and white color. An extensive manufacture of this kind is also carried on near the fine Catholic College of Notre Dame, beautifully situated a mile or two north of South Bend."*

Other localities where the marl lime was made, were near Rochester, Fulton County; Lime Lake, Steuben County; Albion, Noble County, and Silver Lake, Steuben County. The lime from the marl was snow-white in color, and very perishable owing to its fine mechanical condition. As much of the mortar made from the burned marl did not endure exposure to the weather (probably on account of too small an amount of sand being used in its composition), the use of marl as a lime material was discontinued when railways were constructed which brought in from Wabash, Delphi and Huntington a superior lime. The manufacture of quicklime from the marl for use in mortar will, however, probably never be renewed, as the quality of the lime produced at the lime burning

*Report of a Geological Reconnaissance of Indiana, 1859, p. 200.

cities along the Wabash, taken in connection with the present cheap and rapid means of transportation, will not justify its renewal.

The Burning of Lime.

As has been stated, quicklime is produced from limestone by calcining or roasting the latter. In this process the carbon dioxide gas is expelled, and the solid quicklime of commerce remains. This burning, roasting or calcining is effected in kilns of various kinds. The kilns used at local points for burning lime for neighborhood use are or were intermittent kilns of stone. In them the fire was allowed to go out after each burning, to be started again after the kiln was recharged with stone. These cheaper, temporary or "ground-hog" kilns were rudely constructed of stone,

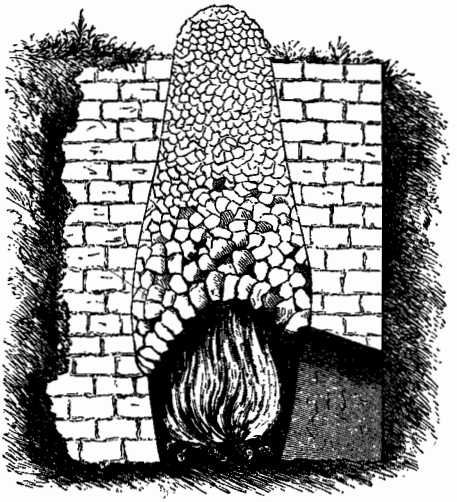


Fig. 1. Old-fashioned "ground-hog" or temporary lime-kiln.

and were located on the side of a hill, so that the top was easily accessible for charging the kiln with stone, and the bottom for supplying fuel and drawing out the lime. In charging, the largest pieces of limestone were first selected and formed into a rough, dome-like arch with large open joints springing from the bottom of the kiln to a height of five or six feet. Above this arch the kiln was filled with fragments of limestone from the top, the larger

pieces being used in the lower layers, these being topped off with those that were smaller. A fire of wood was then started under the dome, the heat being raised gradually to the required degree in order to prevent a sudden expansion and consequent rupture of the stone forming the dome. Should this happen, a downfall of the entire mass above would take place, thus putting out the fire and causing a total loss of the contents of the kiln. After a bright heat was once reached through the mass of stone, it was maintained for three or four days to the end of the burning. This was indicated by a large shrinkage in the volume of the contents, the choking up of the spaces between the fragments and the ease with which an iron rod could be forced down from the top. The fire was then allowed to die out and the lime was gradually removed from the bottom. It was in this manner that all the lime used in Indiana for many years was burned, and in some localities these temporary intermittent kilns are still in operation. The process of burning is simple and cheap, the only expense being for blasting the stone and preparing the fuel. Possibly but one or two kilns were necessary to supply a neighborhood for a year. These were burned in a week or two when required, the kiln remaining idle for the remainder of the time.

As the population increased, the demand for lime became greater, and in many places permanent kilns lined with fire brick were erected. These were the old fashioned stone "pot kilns" of a quarter of a century ago. On the inside they were usually circular in horizontal section, tapering slightly, by a curve both up and down from the circle of largest diameter, which was from four to six feet above the bottom. A kiln 10 to 11 feet in greatest diameter, was 25 to 28 feet high, five to six feet in diameter at the top and seven to eight feet at the bottom. There was an arched opening on one side at the bottom, five to six feet high, through which the wood was introduced and the burnt lime removed. A horizontal grating on which the fire was built was usually placed one or two feet above the bottom. In all these intermittent kilns there was an enormous loss of heat at each burning, for the quantity of fuel, necessary to raise the contents of the kiln and the thick stone and brick walls to the degree of heat necessary to form the lime, had to be repeated each time the kiln was charged. Moreover, the

stone nearest the dome-arch in the kiln was liable to become injured by over-burning before the top portions were thoroughly calcined.

As wood became scarcer and the demand for lime increased, these intermittent kilns gave way to continuous or perpetual burning kilns, usually of stone, in which the lime was burned by coal without intermission in the fires. In the first styles of these, some of which are still in use, the kiln was filled with alternate layers of coal and limestone and then fired from below with light wood. As the burning was completed in the lower portion of the kiln the finished lime was drawn out from time to time, usually twice each 24 hours, allowing the entire mass above to settle down. New layers of fuel and stone were then added at the top.

These old style perpetual kilns have mostly been replaced by cylindrical steel kilns, 35 to 40 feet in height and six to eight feet in inside diameter. These kilns have two (sometimes four) furnaces, one on either side, situated at about one-third of the height from the bottom. In these the fires are kept perpetually burning, wood, coal, oil or gas being used as fuel. The limestone is elevated in steel cars by means of a tramway to the tops of the kilns and dumped into them until they are full. The flame and heat from the fires in the furnaces pass up through the limestone and thoroughly roast it, so that by the time it has descended to near the level of the furnaces, it has been deprived of all its carbon dioxide gas and converted into lime. The latter is then drawn out at the bottom, the drawing taking place about once every six hours. The limestone for burning should be broken into pieces not exceeding four to six inches in diameter, else the inside of them is liable to remain unburned. More or less trouble is experienced at all kilns with these "cores" or unburned centers, as the pieces of lime containing them have to be sorted from the shipment.

The steel perpetual kilns are a great improvement over the old stone ones in which the coal was mixed with the fuel, as the resulting lime is cheaper and purer, and much less fuel is necessary. All modern lime-making plants are equipped with them, most of those in Indiana being of the Monitor pattern, costing about $1,500 each.

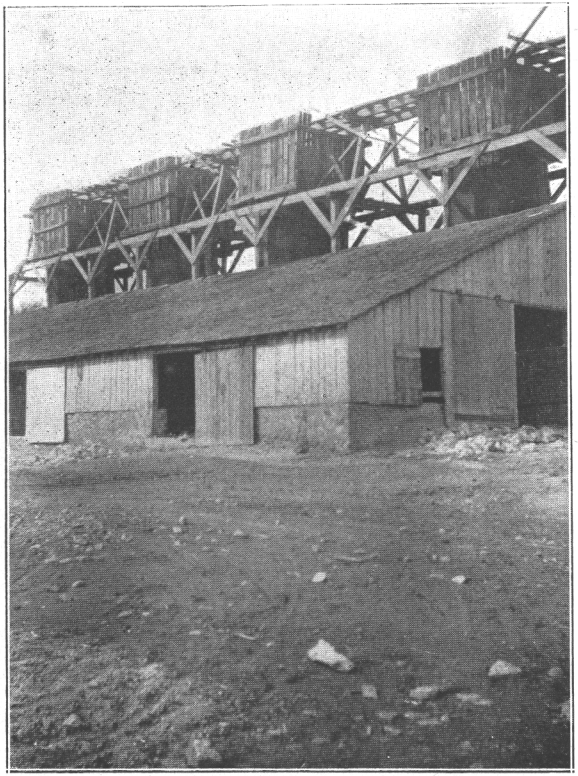
THE MANUFACTURE OF LIME IN INDIANA.

At Delphi, Carroll County.

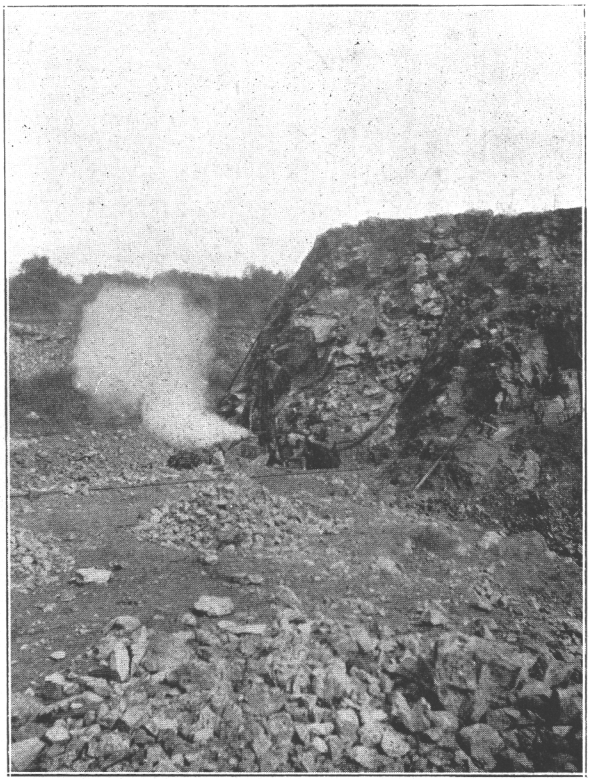
Delphi, the county seat of Carroll County, is a city of 2,500 population, located at the junction of the C. I. & L. (Monon) and Wabash railways, 72 miles northwest of Indianapolis and 112 miles southeast of Chicago. The city is picturesquely located on the high banks of Deer Creek, near the junction of that stream and the Wabash River.

The lime industry in the vicinity of Delphi has been an important one for many years; the "Delphi lime" having a wide reputation for the excellence of its quality. The first kilns, as in other localities, were of a very crude, temporary nature, in which only lime sufficient was burned to supply the local demand. However, the quality of the lime began to attract attention in other places and in 1858 the firm of E. W. Hubbard & Co., composed of E. W. Hubbard, E. R. Harley and Robert Mitchell, was organized for burning lime for shipment. Their principal outlet was along the old Wabash and Erie Canal, as long as that waterway was in operation. The larger part of the output was shipped to Covington, Ind., and from there hauled in wagons to points in Illinois and western Indiana. The old-fashioned intermittent stone "pot kilns" were used until 1870. These held from 1,000 to 1,200 bushels of lime. They were filled one day, burned two and a half to three days, and emptied in a day or two. There was much waste of fuel, due to the necessary cooling at the end of each burning. About 20 of these kilns were operated by the company.

By 1870 several other firms had started in the business. In that year there was a combination of all of these and the pioneer company under the name of "The Delphi Lime Company." The old stone intermittent "pot kilns" were soon replaced by more modern steel ones in which the burning was continuous. The old company operated the plant until 1891, when it was sold to a Mr. Cartwright, who controlled it until 1902. For a year after his death the plant was closed, but a new company was organized under the old name, and the plant was again opened in September, 1903.



KILNS OF DELPHI LIME CO., DELPHI, IND.



QUARRY OF DELPHI LIME CO., DELPHI, IND

THE DELPHI LIME COMPANY.—The present location of the Delphi Lime Company's kilns is about one mile north of the city limits of Delphi. No railway switch is connected with their plant, the lime being hauled in wagons to the city and there loaded on cars. The company owns twenty acres of limestone land, about half of which has been quarried out to a depth of 15 to 25 feet. In one place a pond, whose water is 12 to 15 feet in depth, fills an abandoned quarry several acres in area. The stone used is of the same character and quality as that burned by the other lime companies at Delphi, being a Niagara limestone, rich in magnesia. It is part of an island or uplift of rock, which was forced above the sea toward the close of the Niagara period. This island is remote from outcrops of the main body of Niagara limestone in the State, and forms the surface of an area of about 600 acres north and northwest of Delphi. As in other isolated deposits of Niagara in this portion of the State, the strata are much tilted, the main dip being 20° to 30° towards the northeast. The stone is, in places, very much shattered, and presents other evidences of a true upheaval.*

The kilns of the Delphi Lime Company are of the Monitor pattern and four in number, one large one being eight feet, the others six feet, in inside diameter. But one of these was in operation at the time of my visit, October 3, 1903. These kilns were among the first of their kind erected in the State, and differ from most others in having at the base four arches or furnaces instead of two. These are about ten feet above the bottoms of the coolers or pits to which the lime passes when thoroughly burned. Each of the smaller kilns produces about 200 bushels and the larger one 240 bushels of lime in 24 hours. Wood, costing $2.50 per cord, was being used for fuel, but on account of its scarcity it will soon be changed to coal. The superintendent claims that with wood, a fourth more lime can be gotten from the same amount of stone, than with coal, and that it can be burned in less time. The trade of the Delphi Lime Company had been largely lost by their year's shutdown, but it was hoped that it would soon be regained. The lime produced is similar to that of the Harley Bros. Lime Company, described later, brings the same price and is sold mainly for builders' use and for paper manufacture.

*See the paper by E. M. Kindle in another part of the present volume for further information concerning these "islands" of Niagara stone.

HARLEY BROS. LIME COMPANY.—The Harley Bros. Lime Company, composed of C. and G. P. Harley, began the burning of lime at Delphi in 1875. Their first kilns were located on a small tract of Niagara limestone land near the northern limits of the present city, but in 1891, having secured possession of a larger tract of stone land, they moved to their present location, one-eighth of a mile farther north. A switch from the Monon Railway runs to their plant. About $10,000 is invested, exclusive of the stone land, and their output of lime is the largest of the three plants located at Delphi. The three kilns operated by the company are of stone and are seven feet in inside diameter, with an output of 225 bushels each per day. The burning is by the continuous process, coal and a small amount of wood being used as fuel. The plant is operated the entire year, with the exception of a few weeks of the coldest weather—May, September and October being the months in which there is greatest demand for the product. In these months 35 men are employed in quarrying stone and operating the plant. Ordinary laborers and quarrymen receive from $1.50 to $1.60 per day; while burners, of which there are two to each kiln, receive $12.25 each for seven days' work.

Harley Bros. own 40 acres of stone land suitable for the burning of lime, their quarry being located just north of the kilns. From 12 to 18 inches of stripping is removed and the stone is then used to a depth of 16 feet. When exposed, the stone in many places is found to be very much broken, the fragments being often raised up in small dome-like arches. The appearance of one of these, in the words of one of the owners, is like that of a pot of hot mush which has been suddenly cooled off. Where layers of any area are found in this particular quarry, they dip 10° to 15° to the southeast. An analysis of this stone, made by Prof. R. E. Lyons for this paper, shows its composition to be as follows:

ANALYSIS OF STONE FROM HARLEY BROS.' QUARRY, DELPHI, IND.

Calcium carbonate ($CaCO_3$)	54.53
Magnesium carbonate ($MgCO_3$)	43.92
Ferric oxide and alumina ($Fe_2O_3+Al_2O_3$)	.51
Insoluble residue (silica)	0.19
Sulphuric anhydride (SO_4)	.18
Total	99.33

HARLEY BROS. KILNS, DELPHI, IND.

HARLEY BROS. QUARRY, DELPHI, IND.

The analysis shows the stone to be very rich in magnesia. The sum of the magnesium and calcium carbonates, both of which go to form lime, is 98.45 per cent., so that the amount of impurities is very small.

When blasted and broken to the proper size, the stone is loaded into steel cars holding one and a quarter yards, and hauled up a tramway to a point above the kilns where, by an ingenious arrangement, the cars are automatically dumped. A load of stone, so dumped, is converted into lime in about 36 hours. From 50 to 60 bushels of lime are drawn from the bottom of each kiln every six hours.

The Delphi lime, when fresh, is of a dirty brownish color, but when slacked bleaches out as white as any other. It is a "cool" lime which sets slowly. For this reason a much larger amount can be strewn with the trowel along a row of brick; whereas with a "hot" lime but enough can be scattered to lay three or four brick before it begins to set. It is on account of this property that it is so highly esteemed by masons. It is also claimed for it that it has better cementing qualities than a "hot" lime, requiring more sand to form a perfect combination and forming in time a very hard mortar joint. For paper manufacture Delphi lime is said to be superior to a pure calcium lime, as it does not clog the cloth or "felt" as rapidly as does the purer lime, hence the labor of cleaning the "felt" is lessened.

An analysis of the lime burned by Harley Bros. was made for the firm by Dr. J. N. Hurty, of Indianapolis, who reported its composition to be as follows:

ANALYSIS OF HARLEY BROS.' DELPHI LIME.

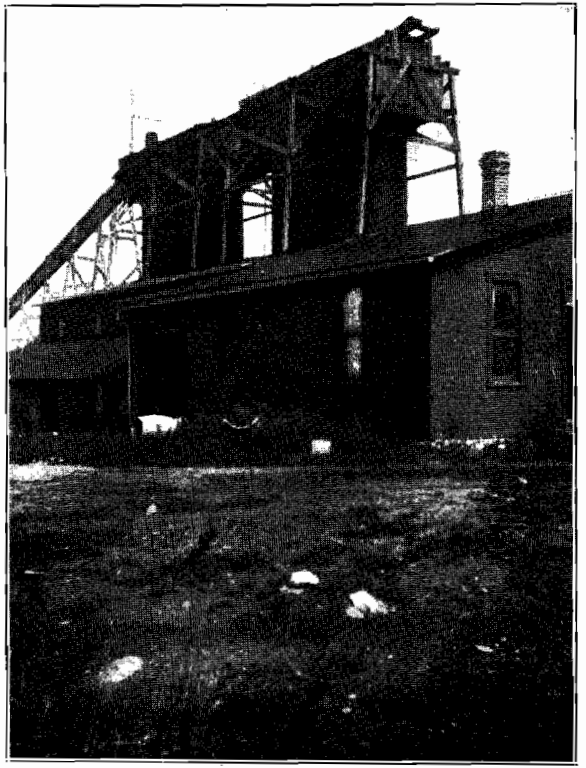
Calcium oxide	38.59
Magnesium oxide	31.76
Clay	26.63
Silica	.14
Loss	2.88
Total	100.00

In October, 1903, the Delphi lime was bringing 13 cents per bushel of 70 pounds, or 60 cents per barrel, in car load lots, f. o. b. at Delphi. An ordinary car holds 550 bushels. The cost of man-

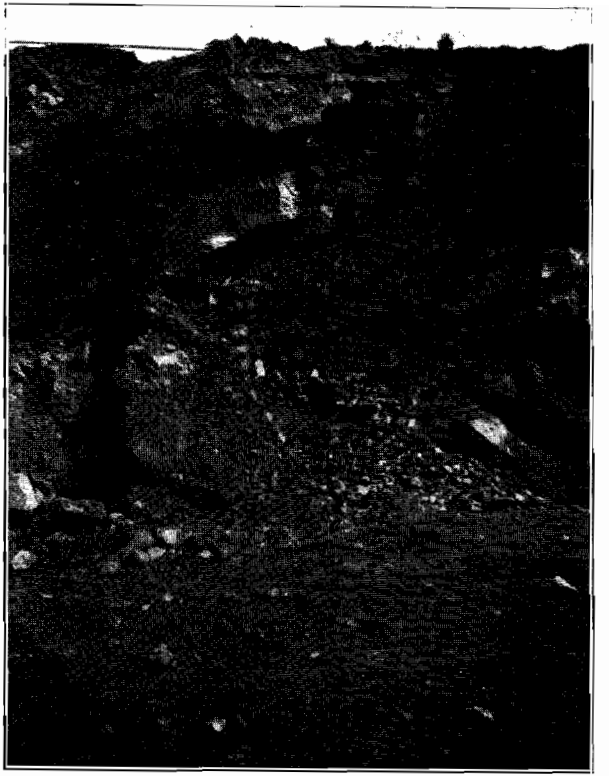
ufacture is said to be about 7½ cents per bushel. That made by Harley Bros. is sold mainly for building purposes, though quite a quantity goes to paper factories. The most of it is used in Indiana and northern Illinois. About ten per cent. is shipped in barrels, the remainder in bulk. On account of the great increase, in recent years, in the cost of barrel making materials, most lime manufacturers are trying to reduce the barrel shipments to a minimum. Each lime plant of any size has its own cooper shop. The cost of a barrel at the Delphi plants, in October, 1903, ranged from 23 to 26 cents, of which amount four or five cents went to the cooper, the rest for material. Indiana bituminous "mine run" coal is used for fuel and was being laid down at the plants for $2.40 to $2.70 per ton. Care must be taken to secure a coal as free from sulphur as possible, else a brownish crust will be formed on the lime during burning which will prevent it from properly water slacking.

The Coble Lime Company.—In 1902 a number of Delphi and Frankfort citizens organized a new company for the purpose of burning lime at Delphi, and incorporated under the name of the Coble Lime Co. During the first year they burnt quite a quantity of lime in old-fashioned pot kilns, but in the spring of 1903, an up-to-date plant was erected at a cost of $12,000, about one mile north and a little east of the courthouse, and about half way between the two plants already described. Here the company owns 22½ acres of excellent stone land, which cost them $7,500. Four steel kilns were erected, each having a capacity of about 200 bushels daily. The kilns are a little smaller than the average, in order to burn the lime thoroughly with coal. A 20-horsepower gasoline engine furnishes power for hoisting stone and compressing air for drilling in the quarry. The kilns are filled twice each day, and the lime is drawn at intervals of six hours. Eighteen men were employed at the time of my visit, the average wages paid being $1.50 per day. The company had found a ready market for all the lime burned since June 5th, when the plant was first opened for business.

In the quarry just north of the kilns the stone is in places broken and upheaved, as in the other quarries in the vicinity. The dip of the strata in place is to the north. The lime produced is similar in appearance and quality to that made by Harley Bros. An



KILNS AND STOREHOUSE OF COBLE LIME CO., DELPHI, IND.



QUARRY OF COBLE LIME CO., DELPHI, IND.

analysis of a freshly burned sample, made for the company by T. W. Smith of Indianapolis, showed its chemical composition to be as follows:

ANALYSIS OF LIME FROM COBLE LIME CO, DELPHI, IND.

Calcium oxide (CaO)	90.20
Magnesium oxide (MgO)	6.08
Iron and aluminum oxides (Fe_2O_3+Al_2O_3)	1.70
Potassium and sodium (K_2O+Na_2O)	1.54
Silicon oxide (SiO_2)	.15
Moisture	0.30
Total	99.97

In October, 1903, no switch was as yet completed to the plant of the Coble Co., though a line for one had been surveyed. When it is finished the company will have every facility for producing lime at a minimum cost, as the plant was arranged with an especial view to convenience and economy. With a constantly growing demand for good lime and with the widely known reputation of the Delphi product behind it, there is every reason to believe that a profitable business will soon be established.

At Huntington, Huntington County.

Huntington, the county seat of the county of the same name, is a city of 10,000 population, located at the junction of the Wabash and Chicago & Erie railways, 142 miles east of Chicago and 12 miles southwest of Fort Wayne. Huntington has, for more than a half century, ranked as the principal lime producing center in Indiana. There, as elsewhere, the first kilns were temporary ones of the ground-hog pattern. In 1845, or thereabouts, the first permanent kilns were erected by Louis Gephardt about one mile east of the city. Other intermittent burning kilns of the same kind were from time to time built by other parties, both east and west of the city, at points indicated by the abandoned quarries on the accompanying map. A number of these quarries furnished stone for much of the lime shipped for years on the old Wabash & Erie Canal. Those west of town were located along its margin, and are almost continuous, the separating strips being no more than 15 or 20 feet across.

About 1868, when the first perpetual burning kilns came into use, several larger companies were organized and the industry rapidly grew in importance. In 1875 Prof. E. T. Cox visited the county and made a brief report upon its general geology. In this he wrote of the lime industry as follows: "The greatest development of the Niagara limestone is seen along the banks of Little River above and below Huntington. The most easterly outcrop is on John McCarty's land on section 18, township 28, range 10, about three and a half miles from Huntington. Lime kilns have been established all along the outcrop and the burning of lime constitutes one of the chief industries of the county. Thirty-one kilns were in active operation making caustic lime at the time of my visit. Eight of the number are perpetual kilns, the remainder are occasional kilns which require to be completely discharged and cooled before refilling.

"The annual make of lime amounts to about 617,000 bushels, and the consumption of wood to 12,260 cords; being an average of nearly 400 cords of wood and 20,000 bushels of lime per kiln, and an average of 50 bushels of lime for each cord of wood consumed. This lime is held in high estimation and meets with a ready market, not only in Indiana, but in Ohio and Illinois as well."*

The companies then in operation were gradually combined until in time but three remained. These were the Baltes & Martin Company; the Huntington White Lime Company, and the Beck and Purviance Company. They operated individual plants until 1887, when their interests were pooled under the name of the Western Lime Company.

THE WESTERN LIME COMPANY.—This is the largest lime producing company in the State. It owns four large plants in the vicinity of Huntington, three of which were in operation in October, 1903. As shown on the accompanying map, these are located on switches of the Wabash Railway, about one and a quarter miles east of Huntington, in the northwest quarter of section 13 and the southwest quarter of section 12 (28 N., 9 E.). The closed plant (No. 4) is located about a third of a mile farther east, by the side of the main line of the Wabash Railway. It is the one formerly operated by the "Huntington White Lime Company,"

*7th Ann. Rep. Geol. Surv. of Ind., 1875, p 121.

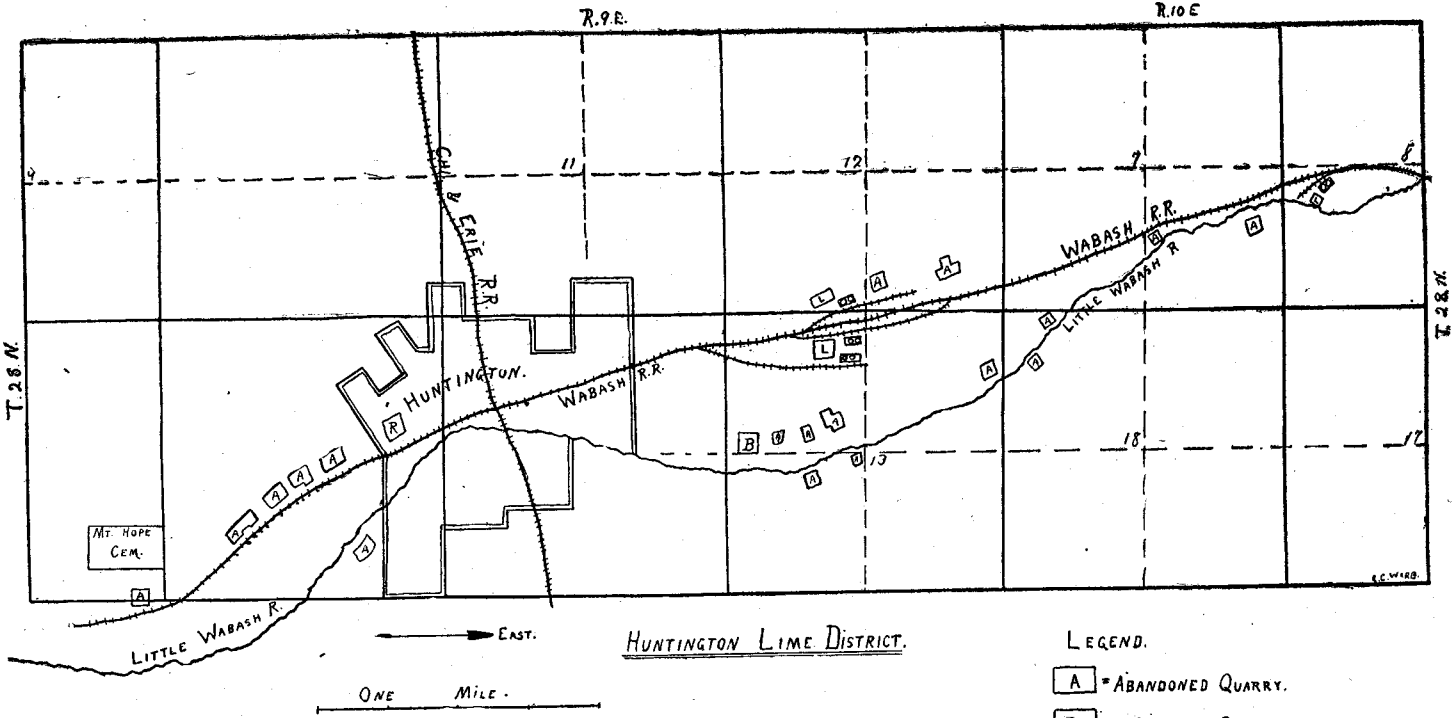
No. 2. Plant of Western Lime Co., Huntington, Ind.

and has eight kilns, six of steel and two of stone. It has not been operated for several years. One reason given for its closing was that the thick ledge near the top of the quarry from which stone was obtained was not so good as the underlying ledges, being shelly and fossiliferous. A mixed grade of lime was the result unless the stone was sorted. Another reason was that the output of the other three plants nearer town equaled the demand, and in closing one of the plants the one farthest distant was selected.

The active plants are equipped with 24 steel kilns, 20 of which were burning lime on the date mentioned. These steel kilns are of the Monitor continuous burning pattern, about 11 feet in outside diameter and 40 feet in height. Their output is about 200 bushels each per day. On account of greatly decreased demand for lime in the winter months but six to eight kilns are operated during that season. From 140 to 200 hands are employed from April 1st to November, the wages paid grading from $1.40 to $2.00 per day. For a number of years all the lime produced was burned with natural gas, but on account of the greatly decreased supply of that fuel it is now only used in part of the kilns during the summer months, and is then supplemented by wood. Hocking Valley, Ohio, coal is the principal fuel used in the winter and spring.

The rock used in making lime in the vicinity of Huntington is a magnesian Niagara limestone, very similar in appearance and chemical composition to that used at Delphi. In regard to the dip of the stone, Mr. L. C. Ward, who prepared for me the accompanying map of the Huntington Lime District, writes: "As to the dip of the rock in the different quarries, nothing definite in the way of figures can be given. Even in the same hole, the dip may vary widely in pitch and in direction. All those west of town dip toward the south and southeast, the pitch varying between 3° and 30°. The latter number is for the quarry marked R, within the city limits. For the neighboring quarries, 3° to 15° are the prevailing dips.

"In the quarries east of town, a greater degree of regularity is noticeable. The quarry marked B has level strata, the dip being considerably less than 1°. All the other quarries in sections 13, 12 and 7 have their strata dipping to the northwest, or northwest by north. The average dip is 12°; it sometimes reaches 15°



HUNTINGTON LIME DISTRICT.

LEGEND.

A = ABANDONED QUARRY.

L = LIME QUARRY

R = ROAD-MATERIAL QUARRY

B = BUILDING-STONE

000 = ACTIVE KILN.

and rarely drops to 10°. In the large quarry marked L, section 13, the dip in the northern part of the hole is 15° to the northwest; in the southern part, 12° to the southwest. In section 8, the strata in the quarry marked L have a dip of 10° to the north and northeast. These great variations in dip point to a greatly complicated set of folds or faults, or both. The overlying mantle of drift, however, precludes any closer study of the strata relations underneath."

In the main quarry, L. (n. w. quarter section 13) used by the Western Lime Company, about 36 inches of stripping is removed and the stone then quarried to a depth of 53 feet. There is no waste except some fine material which accumulates on the bottom and which would choke the kilns if used. The quarry covers several acres and the stone, after being blasted and broken to the required size, is loaded into cars and then hauled by horse-power along temporary tramways to the foot of an incline from which it is raised by steam-power to a platform above the kilns. The cars hold 30 cubic feet of stone, and 26 of them are required to make 450 bushels of lime.

The lime made by the Western Lime Company is a magnesian lime, much the same in character as that burned at Delphi. For mortar making it is "cool" and slow-setting, and where used in paper factories it is claimed that it does not gum the cylinders as does a lime made from pure calcium carbonate. For that reason it is sold to a number of the larger paper and strawboard factories of Indiana and adjoining states. About 35 per cent. is shipped in barrels, the remainder in bulk. The price at the kilns in October, 1903, was 13 cents per bushel or 60 cents per barrel; in car-load lots it brought about two cents less per bushel. An analysis of the lime made for the company in March, 1897, by T. W. Smith of Indianapolis, showed its chemical composition to be as follows:

ANALYSIS OF LIME FROM THE WESTERN LIME CO., HUNTINGTON, IND.

Calcium oxide (CaO)	63.03
Magnesium oxide (MgO)	34.15
Ferric oxide and alumina (Fe_2O_3+Al_2O_3)	2.62
Silica (SiO_2)	.07
Moisture	.13
Total	100.00

The combined calcium and magnesium oxides, which form the quicklime, show it to be 97.18 per cent. pure lime.

THE CONSOLIDATED LIME COMPANY.—The plant of this company is located on a switch of the Wabash Railway, two and a half miles east of Huntington, in the northwest quarter of the southwest quarter of section 8 (28 N., 10 E.). (See accompanying map.) The first kilns, two in number, were erected in 1893, and two more were built in 1894. These were stone pot kilns. In March, 1903, the company replaced these by three steel kilns of the latest pattern, and in October had the foundations in and the steel ordered for three additional ones. The capacity of the six kilns will be 1,500 bushels each 24 hours. The kilns are 10 feet in outside diameter by 42 feet in hight, 8 feet of the latter dimension being taken up by the cooling and drawing pit. When the new kilns are completed the company will have about $30,000 invested. Twenty men are employed, the burners and drawers receiving $12.00 per week of seven days; the quarrymen, $1.50 per day. "Black Hawk" bituminous coal from southern Indiana is used as fuel. Firing is done every three-quarters of an hour, and the lime is drawn every four hours, 30 to 40 bushels to the kiln, the amount depending upon the draught or indirectly upon the density of the air.

The Consolidated Lime Company owns 24 acres of limestone land in the immediate vicinity of the plant, the quarry being just south of the kilns on the bank of the Little Wabash River. Two or three feet of stripping is removed and all the stone is then used; the quarry being opened to a depth of 18 feet. The strata have a decided dip of 10° or more to the north and northeast. The stone is a grayish to buff magnesian limestone whose chemical composition, according to R. E. Lyons, is as follows:

ANALYSIS OF LIMESTONE FROM QUARRY OF CONSOLIDATED LIME CO., HUNTINGTON, IND.

Calcium carbonate ($CaCO_3$)	53.22
Magnesium carbonate ($MgCO_3$)	44.96
Ferric oxide and alumina ($Fe_2O_3+Al_2O_3$)	.23
Insoluble residue (silica, etc.)	.59
Sulphuric anhydride (SO_2)	.11
Total	99.11

The stone is hauled up an incline by steam-power and dumped into kilns. It burns into a grayish lime which is said to slack quicker than that produced by the Western Lime Company. In plastering 100 square yards of surface, three barrels of the lime is sufficient.

An analysis of an average sample of this lime, made by Dr. R. E. Lyons, showed its constituents to be as follows:

ANALYSIS OF LIME FROM CONSOLIDATED LIME CO., HUNTINGTON, IND.

Calcium oxide (CaO)	59.20
Magnesium oxide (MgO)	38.38
Ferric acid and alumina (Fe_2O_3+Al_2O_3)	.49
Insoluble residue (silica, etc.)	.35
Moisture	1.80
Total	100.22

The combined calcium and magnesium oxides which form the lime show a percentage of 97.58, thus proving the purity and excellent quality of the lime. The latter has, up to the present, been sold for building purposes alone and the demand has exceeded the supply. The price in October, 1903, was 12 cents a bushel, or 58 cents a barrel, f. o. b. the cars at the kiln. The market is at present principally in Indiana, but when the new kilns are in place, the company hopes to extend the trade into adjoining states. The quality of the lime produced will, without doubt, aid them in realizing their expectations.

At Markle Huntington Co., Ind.

Markle is a town of 750 population, located in Rock Creek township, Huntington County, nine miles southeast of Huntington on the Chicago & Erie Railway. The most eastern outcrop of Niagara limestone in Huntington County is just south of Markle, on the Wabash River. It has a blue-green color, is irregular in fracture, and usually occurs in four to six-inch layers. The strata have a local dip of 20° to the southeast. The outcrop may be followed for two or three miles up and down the stream. An analysis of the stone, made by E. T. Cox,* showed its chemical composition to be as follows:

*7th Ann. Rep. Geol. Surv. of Ind., 1875, p. 119.

ANALYSIS OF NIAGARA LIMESTONE FROM MARKLE, IND.

Lime	37.56
Magnesia	7.58
Carbonic acid and combined water	48.50
Iron and alumina	2.50
Insoluble matter	2.25
Moisture	.75
Sulphuric acid	.27
Total	99.41

The Markle stone was first used for lime in 1888. The kilns, located just south of the corporate limits, were operated for a few years and then closed down until 1902, when the present proprietor, Mr. E. S. Wheeler of Huntington, assumed control. Three stone pot kilns of the intermittent pattern are used, their capacity being 1,000 bushels each. Wood costing $1.75 per cord is used for fuel, the lime being sold as "Wood-burnt White Lime." The proprietor claims that the lime rock contains less sand than that used at Huntington; that it will yield more lime and that the latter will slack quicker than the Huntington lime. About $3,000 is invested in the plant. In 1903, 35,000 bushels of lime were produced, which sold for 12 cents per bushel, or about $4,000. The plant is operated ten months in the year and employs six men.

At Keesport, Cass County.

Keesport is an abandoned station on the Wabash Railway, four miles east of Logansport, the county seat. Large outcrops of a very pure limestone occur along the Wabash River in the immediate vicinity. The burning of lime from one of these deposits was begun by A. B. Keeport & Co. in 1868, and was continued until 1901, when the industry was abandoned, on account of the deposit of stone owned by the firm becoming exhausted. Four continuous burning stone kilns were in use, the capacity of the plant being 1,000 bushels per day. From 1892 to 1896, 220,000 to 250,000 bushels of lime were burned each year. The output was an excellent quality of white lime, which was sold mainly for building and chemical uses. An analysis of the stone made for the firm by Dr. J. N. Hurty showed its composition to be as follows:

ANALYSIS OF LIMESTONE FORMERLY BURNED INTO LIME AT KEESPORT, CASS COUNTY, INDIANA.

Calcium carbonate ($CaCO_3$)	96.02
Silica (SiO_2)	1.02
Alumina and iron oxide ($Al_2O_3+Fe_2O_3$)	2.00
Magnesium carbonate ($MgCO_3$)	1.04
Total	100.08

Near Ingalls, Madison County, Ind.

Ingalls is a town of 600 population, situated 23 miles northeast of Indianapolis, on the Cleveland Division of the Big Four Railway, in the southeastern corner of Madison County.

Beds of a very pure limestone outcrop at a number of places north and northeast of Ingalls. At a point about three-quarters of a mile north of the town the Ingalls Lime and Stone Company erected two modern steels kilns in 1891 and began the burning of lime, with natural gas as fuel. The industry was discontinued in 1894, as no switch had been put in and the lime had to be hauled to Ingalls in wagons and there loaded into cars. The product was a "short," quick-slacking lime. It was sold to glass and strawboard manufacturers and for building purposes, and gave good satisfaction wherever used.

The company owns 66 acres of land about the quarry from which the stone for lime making purposes was taken. The stone lies within two feet of the surface over most of this tract. It is at present quarried and ground for glass making purposes and for a fertilizer. It is mostly in thin layers, which break into fragments when blasted. An analysis of it made by Dr. W. A. Noyes, shows its composition to be as follows:

ANALYSIS OF LIMESTONE FROM NEAR INGALLS, IND.

Silica (SiO_2)	5.85
Alumina (Al_2O_3)	0.77
Ferric oxide (Fe_2O_3)	0.16
Calcium carbonate ($CaCO_3$)	93.17
Magnesia (MgO)	0.25
Combined water (H_2O)	0.08
Total	100.28

On account of the low percentage of magnesia present the stone is very suitable for making Portland cement.

Near Utica, Clark County.

Utica is a town of small size located on the Ohio River in the southern part of Clark County six miles above Jeffersonville. Thick outcrops of Niagara limestone occur near the town, and lime was first burned from these in temporary kilns by M. H. Tyler and H. C. Emmericke in 1868. In 1871, J. B. Speed & Co. leased some of the stone land and erected three permanent kilns of 800 bushels capacity. These they have since continued to operate, but at present use only one kiln having 300 bushels daily output. This is located about a quarter of a mile northeast of Utica. The stone used is a very fine magnesian carbonate which burns into a lime of high repute for mortar and plaster. Pittsburgh nut and slack coal is used for fuel. The lime is marketed at Louisville and Ohio River points above Utica. In 1903, 13,385 barrels of 2¼ bushels each were produced, but the average annual output for the last seven years has been but about 8,000 barrels. The Union Lime and Cement Co. also operated several kilns near Utica up to about 1900, when they discontinued, mainly on account of lack of transportation facilities.

At Milltown, Crawford County, Ind.

Milltown is located 34 miles northwest of Louisville, on the St. Louis Division of the Southern Railway. The town has a population of about 450 and is situated on Blue River, which here forms the line between Harrison and Crawford counties. The river at that point is about 225 feet wide and between there and its mouth at the Ohio River has a fall of 89 feet, or about seven and a half feet to the mile. Many places are available for impounding dams, which could be built from 20 to 40 feet high. The stream thus furnishes one of the best unutilized sources of water-power in southern Indiana.

J. B. Speed & Co.—This company, whose main office is at Louisville, Kentucky, has been making lime at Milltown since 1887. The plant is located on the west side of Blue River, in

Crawford County, and is operated in connection with a large rock-crushing plant whose output is used for ballast and macadam. In the lime plant, four kilns are in use, two of steel and two of stone, the total capacity of which is 1,500 bushels of lime per day. The burning is by the older style of the continuous process kiln in which both fuel and stone are put into the kiln in alternate layers, from the top. The greatest diameter of the stone kilns is about one-third their height above their base. From this they taper gradually down to the "eye" or draw pit. Their capacity is about 375 bushels per day, that of the steel kilns being a little more. Indiana coal from the Ayrshire mines near Oakland City, is used as fuel. Each draw of stone requires from 36 to 48 hours to convert it into lime.

The stone used is Mitchell limestone from certain beds of the quarry which is operated for crushed stone. A detailed section of this quarry is as follows:

SECTION EXPOSED AT J. B. SPEED QUARRY, MILLTOWN, IND.

		Feet.	*Inches.*
1.	Buff, weathered limestone	1	8
2.	Coarsely crystalline limestone, with numerous crinoid stems	2	0
3.	Pure white oölitic limestone, with few fossils	4	0
4.	Light buff to drab lithographic limestone	5	0
5.	Greenish shale	0	4
6.	Gray lithographic limestone	0	10
7.	Greenish-gray shale, intercalated with bands of lithographic limestone, two to eight inches thick	0 to 1	6
8.	Gray, lithographic limestone	7	0
9.	Soft, granular, buff magnesian (?) limestone	.3 to 4	0
10.	Lead gray, fine-grained, crystalline limestone	.3 to 4	0
11.	Pure white oölitic limestone	5	0
12.	Calcareous shale	.2 in. to 0	4
13.	Gray oölitic to sub-oölitic limestone	4	6
14.	Limestone with black chert	.1 in. to 0	8
15.	Drab colored, impure limestone	4	0
16.	Bluish gray lithographic limestone	0 to 0	10
17.	Dark gray, sub-oölitic to sub-crystalline limestone	8	0
18.	Very soft, drab colored, magnesian limestone	6	0
19.	White oölitic limestone	6	0
20.	Gray limestone	.16	0

The beds used for lime are Nos. 3, 11 and 17. Nos. 3 and 11 are composed of oölite or oölitic limestone of very great purity.

They correspond to similar beds in the Eichel quarry across the river, a chemical analysis of which showed the presence of 98.91 per cent. carbonate of lime.

The stone, after being blasted and broken to the proper size, is loaded into cars and hauled by steam-power up an incline to the top of the kilns; 26.4 cubic yards constituting what is termed a draw or one day's burning. This produces 375 bushels of lime. On account of the process of burning in use, quite a good deal of trouble is experienced with "cores" or centers of the larger pieces of stone which pass through the kilns unburned. Two men are required to separate these when the product is shipped in bulk.

The lime made from beds Nos. 3 and 11 is very white; that from No. 17 is a darker gray in color. The lime is termed "hot" or quick-setting by masons. An analysis of an average sample, made by Messrs. Burk & Arnold, of Louisville, Ky., showed its composition to be as follows:

ANALYSIS OF LIME FROM J B SPEED & CO., MILLTOWN, IND.

Calcium oxide (CaO)	98.24
Magnesium oxide (MgO)	.56
Ferric oxide and alumina (Fe_2O_3+Al_2O_3)	.42
Insoluble residue (silica, etc.)	.30
Moisture	.54
Total	100.06

The lime is sold mainly in southern Indiana, Illinois, Ohio and West Virginia. In September, 1903, it was bringing 12½ cents per bushel, or 60 cents per barrel at retail at the plant. Fifty per cent. was being shipped in barrels, the remainder in bulk in carload lots. About ten per cent. went to paper manufacturers, the remainder being sold for building purposes. Forty men were employed in the lime industry by the company. Their wages ran from $1.30 per day for the quarrymen to $2.00 per day for experienced burners. The plant is run the year around, but with a decreased output in the winter months. The lime has a wide reputation for purity and, in the region where sold, is preferred to the slower setting limes made from the Niagara limestone.

Besides the ordinary quicklime, the J. B. Speed Company make a hydrated lime of two grades, the best of which is sold under the

name of "White Rock Finish." A separate plant a few rods north of their kilns is used in its preparation. The No. 1 grade of hydrated lime is made from ordinary quicklime by first crushing, then grinding to extreme fineness. The ground product is then mixed with a certain quantity of water, after which it is passed through a fine bolting cloth. As it issues from this it resembles a very fine flour, but is much lighter, bulk for bulk. It is sold in sacks of two sizes, either cloth or paper, which hold 40 pounds or 100 pounds.

When mixed with water, this hydrated lime is ready for immediate use, and possesses all the qualities of lime putty. It does not air slack and can be applied to almost any purpose for which lime is commonly used, being especially suitable in those lines of manufacture where a dry, inert, carefully seasoned preparation of lime is required. In its use for mortar making, a saving both of time and of water is effected.

In the making of No. 2 hydrated lime an inferior grade of quicklime is used, the same being air-slacked lime from the kilns and portions which have become fused with cinders while passing through them. The process of manufacture is the same as for the No. 1 grade, except that it is not passed through the bolting cloth. It brings $2.50 per ton and is sold in bulk as a top dressing for soils, mainly to Illinois farmers. It is not used as a fertilizer, but as a material for improving the mechanical condition of soils.* The J. B. Speed Company has the only plant for making hydrated lime in the State, and has made quite a success of the business. Similar plants are said to be in operation in northern Ohio.

Eichel Lime and Stone Co.—The plant of this company is located on the east side of Blue River, in Harrison County, about one-quarter of a mile east of the Speed plant. As with the former, the lime industry is carried on in connection with that of preparing crushed stone. The company began the burning of lime in 1903. Three steel kilns are in operation, each of which is 36 feet in height and 20 feet in outside diameter. The process of burning is the same as that of the Speed Company, the kilns being charged at the top with alternate layers of stone and coal. The latter is shoveled in in such a manner as to spread evenly over the center

*See "Uses of Lime," on p. 216.

of the kiln. The outer edge of the layer of coal should not be nearer than one foot to the inner edge of the kiln; otherwise the latter is apt to become too hot, thus causing the partially burned lime to stick to it. If the coal is heaped in the center of the kiln, it is apt to smother down the fire. Ayrshire coal is used as fuel, it being as free from sulphur as any obtainable along the Southern Railway.

The stone used is of the same nature as that used by the plant across the river, the Eichel Company owning 26 acres of stone land surrounding their quarry. A section down the face of the quarry showed the presence of the following beds:

SECTION AT EICHEL QUARRY ON EAST SIDE OF BLUE RIVER, OPPOSITE MILLTOWN, IND.

		Feet.	*Inches.*
1.	Light drab and light brown lithographic limestone	7	0
2.	Light and bluish drab calcareous shale	1	3
3.	Light drab, lithographic limestone, slightly cross-bedded, with thin lines of coarse sand grains especially toward the top	12	0
4.	Light gray limestone	9	0
5.	White to dark gray oölitic limestone, oölitic structure not distinct	13	0
6.	Hard blue, sub-crystalline, sub-oölitic limestone, (crowfeet)	6	8
7.	Bluish green shale	0	2
8.	Light gray, granular limestone, one notable crowfoot near the middle, accompanied with some green matter	5	0
9.	Shale parting	0	1
10.	Interlayered gray crystalline and oölitic limestone	3	9
11.	Lithographic limestone in thin layers, with shale partings	2	0
12.	Drab lithographic limestone, with calcareous bands and nodules	3	6
13.	Gray crystalline limestone	0	2-6
14.	Lithographic limestone, with numerous flint bands and nodules	7	0
15.	To river, about	10	0

The main bed used for lime is No. 5 of the above section. With it is combined portions of Nos. 3, 6, 8 and 10 of the section; in all about 38 feet. An analysis of the oölite from bed 5, made for this Department by Dr. W. A. Noyes, showed its chemical composition to be as follows:

ANALYSIS OF OÖLITE USED IN LIME MAKING AT EICHEL QUARRY, MILLTOWN, IND.

Calcium carbonate ($CaCO_3$)	98.91
Magnesium carbonate ($MgCO_3$)	0.63
Ferric oxide and alumina ($Fe_2O_3+Al_2O_3$)	0.15
Insoluble in hydrochloric acid	0.48
Total	100.17

Another analysis showing the average composition of six limestone beds of the quarry, including the oölite bed, resulted as follows:

ANALYSIS OF AVERAGE SAMPLES FROM SIX BEDS OF EICHEL'S QUARRY.

Calcium carbonate ($CaCO_3$)	96.87
Magnesium carbonate ($MgCO_3$)	1.19
Silica (SiO_2)	.51
Alumina (Al_2O_3)	.37
Total	98.94

The stone is loaded at the quarry into steel cars, which are drawn up an incline to the top of the kilns, where they are dumped automatically. About 20 cubic yards are used for a draw of 360 bushels. Each draw is about four days in passing through the kiln, but is in actual contact with the fire about 36 hours. The oölite stone loses fully half its weight while being changed into lime.

The Eichel lime, like that from the Speed kilns, is a hot lime, which slacks very quickly. It is also termed a "strong" lime; i. e., a bushel of it will, it is claimed, make more mortar than that produced farther north. About eight per cent. is sold to paper manufacturers, and quite a quantity is ground and goes to glass works, especially to bottle glass factories. The greater quantity is sold for mortar and plaster; the principal markets being in Indiana, Illinois, Kentucky and Missouri. The retail price is the same as at Speed's kilns, the wholesale price not being given. The plant is operated throughout the year. Twenty hands are employed in the quarry and at burning, at wages ranging from $1.30 to $2.00 per day. Besides these, five coopers are engaged in making barrels, for which they receive four cents apiece; an average of 50 being completed in a day by each man.

At Salem, Washington County.

Salem, the county seat of Washington County, is a town of 2,000 population, located on the C., I. & L. (Monon) Railway, 41 miles northwest of Louisville, Kentucky. The quarries of Bedford oölitic limestone near which the limekilns are situated, are in the northwest quarter of section 19 (2 N., 4 E.) one mile west and a little south from the courthouse. They were first operated under the name of the "Salem Stone & Lime Co.," and then for a time under that of "The Salem-Bedford Stone Company." In 1896 Mr. Hopkins wrote of them as follows: "These quarries were for many years worked quite extensively and produced some excellent building stone which went into fine buildings. The Georgia statehouse is constructed of this stone, as is the Salem courthouse, one of the neatest courthouses in western Indiana. There are a half dozen different but closely adjoining openings along the bluff running south from the railway on the west side of the branch road made by the company. The bottom of the stone is concealed either by water or debris at present, so that the total thickness of the stone is not shown. The walls show from three to five channel cuts, or from 20 to 30 feet, with three to 20 feet of rock and soil stripping. The stone has a medium fine grain; no large fossils were observed. The greater part of the stone is buff, yet in a few places a little blue stone occurs. There is a large stone mill and a number of limekilns at the quarry, but the mill is now idle. Most of the channelers have been removed and there appears to be very little dimension stone being quarried.

"A unique feature of this quarry is the absence of the large dump piles of waste stone, the universal accompaniment of the quarries elsewhere. The explanation of this is found in the limekilns at the quarry, where all the waste stone is burned to quicklime and marketed in that form. The only stone that is being quarried at present (July, 1896) is the broken stone for lime burning."*

The Union Cement and Lime Co.—The first lime was burned from the Bedford oölitic stone at the Salem quarries about 1884.

*"The Bedford Oölitic Limestone of Indiana," in 21st Ann. Rep. Ind. Dept. Geol. and Nat. Res., 1896, p. 394.

In 1898 the property passed into the control of the Union Cement and Lime Company, whose main offices are at Louisville, Kentucky. This company at present controls 50 acres of stone land in the immediate vicinity of their plant. The latter is located on a spur of the Monon Railway, a dummy engine, owned by the company, doing the switching.

Five continuous process kilns are used in burning the lime, three of which were in operation in October, 1903. Four of the kilns are of stone; the other of steel. The dimensions of the stone kilns are, base, 22 feet square; top, 18 feet square; height, 38 feet above the drawpit. The stone kilns have a capacity of 250 bushels each and the steel kilns 175 bushels, per day. Wood, oil and coal have all been used as fuel, the use of the first two having been abandoned on account of increase in cost. The coal used in 1903 was nut and slack from Wolfman's mine near Huntingburg, Dubois County, and cost $1.40 per ton, delivered at the plant. The firing is done in furnaces located at the base of the kilns, above the drawpit. Blowers are used in all furnaces to increase the draught.

The quarry from which the stone is at present obtained is located just back of the lime plant, and disclosed the following section:

SECTION OF QUARRY NEAR KILNS OF UNION CEMENT AND LIME CO., SALEM, IND.

1.	Soil, surface clay and weathered stone (stripped)...	5 feet
2.	Buff to gray oölitic limestone.....	8 feet
3.	Bastard oölitic stone.....	10 feet
4.	Buff to blue oölitic limestone (massive).....	30 feet

The stone used in making lime is from beds 2 and 4 of the section. The bastard stone, bed 3, burns into a yellow lime, which makes a tough putty-like plaster, hence the whole ledge has to be discarded and hauled to one side thus increasing the cost of the lime produced. The stone is first blasted and then broken by sledge or squib blast into small pieces. That from ledge No. 2 is hauled up an incline to the top of the kilns, while that from the deeper ledge, No. 4, is raised by derricks. The latter will be abandoned as soon as room enough is afforded for an incline to the bottom of the quarry. No analysis of the stone used for lime was available, but it is very similar in composition to that from the Twin Creek quarries, about seven miles northwest, whose analysis

showed the presence of 98.16 per cent. of carbonate of lime, .97 per cent. of carbonate of magnesia, and only .91 per cent. of impurities. The kilns are filled by day and topped up for night burning. Bins at the top hold stone enough for two or three days' burning when severe weather is experienced. The plant is operated all the year, except for two or three weeks in midwinter. But little trouble is experienced with "cores."

The lime is drawn every eight hours, the output for the three kilns in operation at the time of my visit being 750 bushels daily. It is at first rather dark in color, but becomes pure white when slacked. It is a "hot" lime, which slacks quickly and is evidently very pure in composition. It is used mainly for mortar and plaster, though large quantities are sold to tanneries and paper mills. It is shipped wholly in bulk, and goes mainly to Louisville, from which point it is distributed by the company. At Salem, where there is no competition, it is retailed at 20 cents per bushel. The cost of production is estimated at about 9½ cents on board cars. The company refused to give information regarding the wholesale selling price, or to furnish analysis of either lime or stone, but an analysis of the lime made by Chauvenet & Bro., of St. Louis, showed its constituents to be:

Calcium oxide (CaO)	96.93
Magnesium oxide (MgO)	.85
Silica (SiO_2)	2.22
Total	100.00

Twenty men are employed in and about the plant, their wages ranging from $1.25 for quarrymen to $1.60 per day for foremen and chief burners.

At Mitchell, Lawrence County.

Mitchell, a town of 2,500 population, is located in the southern part of Lawrence County at the junction of the C., I. & L. (Monon) and B. & O. S. W. railways, 67 miles northwest of Louisville, and 127 miles west of Cincinnati. The Mitchell limestone, of which mention has been made a number of times in this paper, takes its name from the town, which is located on this stone.

Lime has long been burned from the Mitchell limestone in the vicinity of the town. The first kilns were of the temporary ground-hog pattern. They were in time replaced by the more permanent intermittent burning stone pot kilns. One of the first men in the region of Mitchell to make the burning of lime his principal industry was Asa Erwin, who operated several of these pot kilns 40 or more years ago. John Collett, in his report on the Geology of Lawrence County, published in 1873, makes mention of Erwin and his industry as follows: "Mitchell lime is favorably known to the trade. Asa Erwin, on a branch of Rock Lick Creek, N. E. quarter section 24 (4 N., 1 W.), uses a common kiln, capable of burning one thousand bushels at a time. His annual product is seventeen thousand five hundred bushels, which sells at twenty cents per bushel delivered on the cars. The product is a white lime, which works 'hot,' and is found to be nearly equal to cement for foundations. He makes use of the *Vermicular* stratum, a bluish gray limestone, massive, but traversed in every direction irregularly by tubular canals, from one-eighth to one-half inch in diameter. The stone, on account of its porous nature, is found to burn and slack with great certainty. The waste lime from this kiln has been used with remarkable profit as a manure, and the result invites further experiment."*

The Big Four Lime Company, also operated for a number of years, six or more pot kilns on the main fork of Rock Lick Creek in the northwest quarter of section 30 (4 N., 1 E.), about two miles southeast of Erwin's location. In 1895 the Mitchell Lime Company was organized and by purchase or lease secured possession of both the plants then in operation and all the adjacent stone land suitable for making lime.

THE MITCHELL LIME COMPANY.—This company now owns two large plants on or near the sites of the older pot kilns above mentioned. The larger one of these is the Monon or Rabbitville plant, located on a spur of the Monon Railway, two and a half miles north of Mitchell. The company owns 178 acres of stone land immediately surrounding the plant. On a portion of this the town of Rabbitville, consisting of about 20 neat frame houses and a good brick schoolhouse, is situated. In them live the workmen em-

*5th Ann. Rep. Geol. Surv. of Ind., 1873, p. 302.

ployed about the kilns and quarry. Six modern steel kilns, of 250 bushels capacity each are in use at this plant. The actual output of each kiln averages 200 bushels daily. Both wood and coal are used for fuel. The coal usually comes from Greene and Daviess counties, Indiana. In October, 1903, however, only Daviess County coal was being used, and it was being hauled by wagon from cars at Mitchell and cost about $2.00 a ton laid down at the plant, as against $1.70 for the same coal delivered at the other plant, the difference in cost being due to switching charges by the Monon Railway.

The quarry of Mitchell limestone, from which the stone for burning is obtained, is located just southeast of the kilns. After one to five feet of stripping, composed of soil and bluish outcropping stone, is removed, the face of this quarry discloses nine ledges of stone which are used for lime. These ledges vary in thickness from 10 inches to five feet, and comprise a total thickness of 26 feet. Below the lowermost of these and between it and the Bedford oölitic stone is a ledge 16 feet thick, which is composed of about 80 per cent. lime and 14 per cent. silica. The top of this ledge forms the floor of the quarry and is kept clean of all rubbish and broken stone by the superintendent in charge. All the strata in the quarry dip to the southwest at the rate of one foot to 100 feet, or 52 feet to the mile.

The company has had made an analysis of each of the nine ledges used for lime making. These analyses show a very close uniformity in composition, the carbonate of lime ranging only from 95.73 to 97.51 per cent. An average of the nine analyses was as follows:

AVERAGE ANALYSIS OF NINE LEDGES OF STONE USED FOR LIME MAKING AT THE MONON PLANT OF THE MITCHELL LIME CO.

Calcium carbonate ($CaCO_3$)	96.65
Magnesium carbonate ($MgCO_3$)	1.20
Ferric oxide and alumina ($Fe_2O_3+Al_2O_3$)	.27
Insoluble residue (silica, etc.)	1.57
Total	99.69

On the eastern side of the quarry, a ledge eight feet from the top, and the fourth in serial order, is more of a bluish hue than the others. It is 30 inches in thickness and is burned separately,

the resulting lime being sold for chemical uses only. The analysis of this particular ledge showed its composition to be:

ANALYSIS OF LEDGE NO. 4, AT QUARRY OF MONON PLANT OF MITCHELL LIME CO.

Calcium carbonate ($CaCO_3$)	96.46
Magnesium carbonate ($MgCO_3$)	0.00
Ferric oxide and alumina ($Fe_2O_3+Al_2O_3$)	0.16
Insoluble residue (silica, etc.)	2.46
Total	99.70

The stone from the quarry is raised by an inclined tramway and dumped into bins at the top of the kilns. From these bins it gradually finds its way down through the kilns, about four days elapsing before it is drawn out as lime. The drawing takes place every four hours. The pieces of lime produced are larger than the average, but contain few cores. The waste is said not to exceed five bushels to the car load.

The second or "Rock Lick Plant" of the Mitchell Lime Company, is located about one mile northeast of Mitchell, near the sites of the former kilns of the Big Four Lime Company, and on a switch of the B. & O. S. W. Railway. A rock-crushing plant is operated in connection with the lime making industry, the two being carried on in separate buildings, but a few feet apart and alongside the same switch. The company owns 149 acres of stone land in the near vicinity. Five steel kilns of the same size and pattern as those at the Monon plant are in use for burning lime.

The quarry from which the stone is obtained is opened to a depth of 30 feet, the upper 14 feet being used for lime, the lower 16 feet for crushed and ground stone. The stone used for lime contains a little more silica than that burned at the Monon plant, but otherwise is quite similar.

The lime made at Mitchell has a wide reputation for strength and purity. It is claimed by the company to be "the strongest white lime on the market." It is said to be a quick slacking, and cool working lime which, when slacked, increases largely in bulk, so that 100 pounds will make mortar enough to lay 1,000 brick.

An analysis of a freshly burned sample of the lime from the Monon plant, made by E. F. Buchanan, the chemist of the Colonial Salt Company, of Akron, Ohio, showed its composition to be as follows:

ANALYSIS OF MITCHELL LIME FROM MONON PLANT.

Calcium oxide (CaO)	97.712
Magnesium oxide (MgO)	1.150
Ferric oxide and alumina (Fe_2O_3+Al_2O_3)	.328
Insoluble residue (silica, etc.)	.418
Carbonic oxide (CO)	.319
Undetermined	.073
Total	100.00

On account of its purity, a large amount of the lime is sold in Chicago and Cincinnati for chemical use, caustic and soap manufacture, etc. Quite a quantity goes to paper factories, and the remainder for mortar and plaster. About 20 per cent. is shipped in barrels. The cost of barrels made at the plants was 28 cents apiece, of which amount the coopers received 3½ cents. The principal markets for the lime are in Indiana, Ohio, Michigan and Illinois. In October, 1903, the price at the kilns was 13 cents per bushel, or 60 cents per barrel of 185 pounds. In carload lots it brought about two cents less per bushel.

The Mitchell Lime Company is incorporated for $50,000, and has about $30,000 invested in the lime industry. Seventy-five men are employed, most of whom do piece-work. The wages of the burners and drawers average $14.00 per week of seven days. Quarrymen receive $1.25 to $1.50 per day, and common laborers 13 cents per hour. Five cars of lime and 10 to 12 cars of crushed and ground stone were being shipped each day from the two plants of the company in October, 1903. The plants are operated the year around, but with a decreased output in the colder months.

Near Bedford, Lawrence County.

Bedford, the county seat of Lawrence County, is a city of 7,000 population, situated on the C., I. & L. (Monon), Southern Indiana, and a branch of the B. & O. S. W. railways, 77 miles northwest of Louisville. It has long been the center of the Oölitic Stone Industry of the State, the largest and oldest worked quarries being in its immediate vicinity. Lime has been burned from the oölitic stone at a number of localities about Bedford, but not in recent years; the burning having been done in temporary kilns for local

use in the days when transportation facilities were meager. About every oölitic quarry of any size in Lawrence and Monroe counties there are dump or "grout" piles containing thousands of cubic yards of refuse stone. This stone is as pure chemically as any sold for building purposes but on account of some flaw, such as a small crack or "crowfoot," is unsalable.

THE HORSESHOE LIME AND CEMENT COMPANY.—In 1902, the Horseshoe Lime and Cement Company was organized for the purpose of utilizing by burning into lime the spalls and waste stone which had accumulated for years at the P. M. & B. quarry, about five miles northwest of Bedford. This quarry is located on a spur of the Monon Railway in the southwest quarter of the northeast quarter of section 33 (6 N., 1 W.). The spur leading to it leaves the main line of the Monon a short distance north of the famous horseshoe curve or bend, hence the name adopted by the company. The quarry was first opened in 1889, and, having been continuously operated, the grout pile is therefore a very large one.

The kilns of the lime company, three in number, of the continuous burning pattern, are located near the center of the excavated portion of the quarry. They are of stone and are 18 feet square at the base, 4 feet at the top, and 40 feet in height. The capacity of each kiln is 250 bushels per 24 hours. The furnaces are especially arranged for burning slack coal, being enclosed like a regular boiler front. The Dorrance shaking grate, having 66 per cent. air space, is used in the furnace, and the slack coal is burned successfully without artificial draught of any kind. The fire is kept low, being not over six inches high at any time and the grate can be cleaned in a minute or two. The furnace is at no point within three feet of the body or center of the kiln, there being a four-foot arch leading back from the fire box to the kiln. The coal used comes from Linton, Indiana, and costs $1.75 per ton, laid down at the mine. This is a high price for "slack," but it is said that the freight rate on coal from Linton to Bedford, a distance of 49 miles, is the same as from Linton to Chicago, 213 miles. It is thus that the railways foster the infant industries which spring up along their lines.

The spalls or refuse stone used for lime by the Horseshoe Company are in large pieces, some of them containing 200 cubic feet. These are blasted to the required size and hauled up an incline

plane to bins or cribs six feet high on the top of the kilns. From here the stone gradually descends through the kiln, taking on an average two and a half days before issuing as lime.

Being burned from stone wholly free from dirt, and in kilns whose construction keeps it separated from all cinders, the lime made by the Horseshoe Lime Company is noted for its purity. On this account it is sold mainly to the chemical trade. It is shipped wholly in bulk in carload lots, and goes to Indianapolis, Chicago and points north and northeast. Quite a quantity is furnished to a large paper mill at Lafayette and to the Illinois Steel Company for use in the manufacture of steel Puzzolana cement. This cement is a mechanical mixture of blast furnace slag and lime slacked with a solution of soda.

Except while undergoing repairs the three kilns have been continuously in use since they were built and the demand for the lime is said to have exceeded the supply. A new kiln of the same capacity as those existing will be erected in 1904. Two analyses of the lime, made for the company, No. 1 by Chauvenet & Bro., of St. Louis, and No. 2 by T. W. Smith, of Indianapolis, showed its chemical composition to be as follows:

ANALYSES OF LIME FROM THE HORSESHOE LIME AND CEMENT CO., BEDFORD, IND

	No. 1.	*No. 2.*
Calcium oxide (CaO)	98.40	97.80
Magnesium oxide (MgO)	.10	.18
Ferric oxide and alumina (Fe_2O_3+Al_2O_3)	.52	.62
Insoluble residue (silica, etc.)	.78	1.38
Total	99.80	99.98

For building purposes the Horseshoe lime is a "hot," strong lime, which combines with a large amount of sand in making mortar and plaster. It slacks out very fine and makes an excellent skim coat.

The fact that the Bedford oölitic limestone has long been used in lime making at Salem, coupled with the recent success of the Horseshoe Company at Bedford, should be sufficient proof of the fitness of that stone for a high grade, chemically pure lime. Immense quantities of spalls, already quarried, free from dirt and other foreign matter, exist about all the larger quarries of the region. As the demand for a pure lime increases, there is little

doubt but that much of this refuse stone will be used for lime making in kilns which will be hereafter erected.

Near Laurel, Franklin County.

Laurel is a town of 650 population, situated in the northern part of Franklin County, on the Whitewater Division of the Big Four Railway, 54 miles northwest of Cincinnati, Ohio. The town is located near the eastern horizon of the Niagara limestone, and the stone from the vicinity has long been quarried for curbing, flagging, foundations, abutments and similar purposes.

Between 1870 and 1885 lime was burned quite extensively in the vicinity of Laurel for the Wawasee Paper Mill, which was then located on the Whitewater River, three miles above Laurel. Many farmers in the vicinity added not a little to their income by burning lime in temporary kilns for the use of the mill. When, about 1885, the latter burned, the industry was discontinued. A number of local kilns were also from time to time burned about three miles east of Laurel, but for a number of years the lime used at Laurel, Brookville and neighboring towns has been shipped in from New Paris and Springfield, Ohio, where extensive kilns are in operation.

In 1903, the Laurel Steam Stone Company, which controls the output of a large quarry near Derbyshire Falls, in section 20 (12 E., 12 N.), erected near the quarry a temporary kiln and burned two kilns, or 5,000 bushels of lime. According to John O'Hair, the president of the company, the stone used is a ledge immediately underlying the Clinton limestone, and contains 93 per cent. of carbonate of lime. The burning was done more as an experiment to determine the fitness of the lime for use in the large paper mill at Brookville, ten miles below Laurel. The lime was burned with wood, in 72 hours' time, and gave excellent satisfaction at the mill, where it was all sold. This mill uses from three to five carloads a week, and has heretofore been getting it in Ohio and northern Indiana at a cost of 13 cents or more per bushel. The Laurel Steam Stone Company say they can burn it for seven cents or less, and expect to put in a modern plant in 1904 for that purpose. Several good gas wells are located in the near vicinity, and gas will be used for fuel as long as it lasts.