THE NATURAL RESOURCES OF THE STATE OF INDIANA.

By W. S. Blatchley.

The natural resources of the State of Indiana, as of any other restricted area of the earth's surface, may be classified into two great groups. The first of these consists of those forms of matter which have stored within themselves potential energy in the form of heat. When this is set free by combustion and then controlled by some device of man, it is used by him to perform the work of the world. Such natural resources are called *fuels,* the most important of which, as found in Indiana, being *coal, petroleum* and *natural gas.*

The second group of natural resources consists of those forms of matter which are devoid of any kind of stored energy which may be set free by combustion, but which are themselves used by man for varied and important purposes. They comprise the *raw materials,* which he fashions into varied forms for the use of the world. The most valuable members of this group found in the State are *limestones, sandstones, clays* and *marls.* Other and less important members are sands, iron ores, mineral paints, etc.

Fuels of the State.

At the present time the relative importance of any State or Nation in the world is very largely determined by the amount of available fuel which that State or Nation possesses. The fuels of Indiana, viz., *coal, petroleum* and *natural gas,* are valuable only for the stored energy which they contain. How came that energy within their matter? When was it there confined? Let us try to answer briefly these two questions.

Matter and energy are the two things which comprise the universe. *Matter* is anything which occupies space, as stone, water, gas. *Energy* is that which produces, changes or destroys motion in matter. In other words, it is the power of doing work. Energy exists in a number of different forms, as heat, light, electricity, gravitation, etc.

About the year 1800, man began to study more closely than ever before both matter and energy, and as a result he made, during the nineteenth century, many important discoveries concerning them. The two greatest of these discoveries, which, more than anything else will make that century famous throughout all time—are embraced in those grand natural laws known as the "Law of the Indestructibility of Matter," and its correlative, "The Law of the Conservation and Correlation of Energy."

The first of these laws merely asserts that "*Matter cannot be created, cannot be destroyed:*" that the same amount, the same number of tons, pounds, ounces, yea, even grains, exists in the universe to-day as existed at the beginning of time. If the reader can bring himself to understand this great law and all that it embodies; to feel and know that every particle of soil, clay, stone or coal on, or in the earth has been formed from matter already in existence; that every living plant or animal is made up of matter which has existed for thousands, aye, millions of years, and much of which has been used over and over again in the structure of previously existing animals and plants, he will have gotten the main idea of this law, and will be the better able to understand many of the statements in the pages which are to follow.

The law of conservation and correlation of energy asserts: "*That energy, like matter, cannot be created, cannot be destroyed, but that one form can be changed into any other form.*" In speaking of the natural fuels of the State, it is this law which we must ever bear in mind, as stored in these fuels is found the heat or energy which will drive the engines and turn the wheels for future generations. Man can invent no new forms of energy, nor can he produce a single iota of energy. He can only devise machines for setting free, and transmuting or changing forms already existing into other and more available forms.

Another great truth which has become fully understood only in recent years, but which is very important in this connection, is that the *sun is the source of all the energy used in performing the work of the world.* From the sun comes heat and light which fall upon the grass and grain and trees of the earth and furnish the power or force necessary for their growth. The plants use the heat and light to assimilate their food and promote their powers of vegetation, and at the same time they store up these forms of energy within their cells.

Suppose, for example, that 1,000 calories (heat units) of heat are used in producing an ear of corn. When the ear is mature, that amount of heat, no more, no less, is stored up within its cells. This heat can be made available to perform work for man in two ways; (a) By burning the corn in a furnace, when the heat will be freed and can be used to generate steam which in turn will cause wheels to revolve. (b) By feeding the ear of corn to a horse, in whose body the heat will be changed into muscular energy which can be exerted in turning wheels or in pulling loads. Or man himself can eat the corn, and the heat which is stored up in it will in his body be changed into muscular and mental energy. Thus the muscular force with which these words are written and the mental energy necessary to evolve the thoughts which they comprise, can be traced back to the sun's heat, which somewhere, in days gone by, fell upon and was stored up by plants, which directly or indirectly have formed the recent food of the writer. In other words we move muscles and think thoughts with the energy derived from the sun's heat and light.

The falling waters pulled by the force of gravitation down to the level of the sea, and on their way doing work for man by turning the wheels of many forms of machinery, were raised from the ocean by the heat of the sun; while the winds which bore those waters in the form of clouds to the higher levels of the land also owe their power of movement to the unequal heating of the atmosphere by the sun's rays. Every ounce of steam and every current of electricity utilized by man is therefore derived from or produced by the sun's heat.

Plants alone have the power of thus storing up the energy of the sun's light and heat. Animals are wholly lacking in this power, and can only utilize the energy so stored by plants. The vegetable cell is thus a storer of power, a reservoir of force. It mediates between the sun, the sole fountain of energy, and the animal life on the globe. The animal cannot use an iota of power that some time, either directly or indirectly has not been stored in the plant cell. This storage is forever going on. Of the vast floods of energy that stream forth from the sun's disk in the form of heat and light, an insignificant fraction is caught up by the earth as it revolves in its orbit. Of the little fraction that the earth thus arrests an equally insignificant part is used directly in plant growth. Yet the entire productive force of the living world turns on this insignificant fraction of an insignificant fraction.

Bearing in mind this great truth, we can better understand how in ages past the sun's light and heat were locked up in the cells of those plants which flourished in the swamps of the old Carboniferous age. For thousands of years it accumulated within their stems and leaves and spores, and when, by the processes of nature, the plants were changed into coal, it still remained, a most valuable heritage for future man.

In the same way the heat stored up in the petroleum and natural gas of the Trenton rocks came from the sun and was stored in the cells of those countless smaller forms of plants which grew on the margins or in the waters of the ancient Silurian seas. Animals used these plants for food, and so received the heat, and when they died, by a process of slow destructive distillation, the carbonaceous matter within their bodies was changed with its imprisoned heat into the gas and oil now so valuable as fuels.

We have thus seen that a fuel is but a form of matter containing within itself a stored supply of potential energy in the form of heat. This stored energy is the richest inheritance which has come down to man from the ages past. Millions of years have been necessary for its accumulation. At the present rate of consumption a few thousand will suffice for its total dissemination. We are drawing upon it with a lavish hand. It came to us without great labor, as comes oftentimes the accumulated riches of a toiling and thrifty parent to a spendthrift son and, as with the latter, "come easy, go easy," seems to be our motto.

The most important thing to remember in treating of these natural fuels is that *no coal, no oil, no natural gas is being formed beneath the surface of our State to-day.* Our present supply of each of these fuels will never increase, but ever diminish. Each constitutes a great reservoir or deposit of reserve energy upon which the people of the present generation are daily drawing without adding thereto. Like a bank account under the same conditions, it is only a question of time until it will become exhausted.

Coal.—Seven thousand square miles, or nearly one-fifth of the area of the State of Indiana, is underlain with coal.* This area is found in the western and southwestern parts of the State, and ranges from ten to sixty miles in width. It lies west of a line passing through Williamsport, Greencastle, Paoli and a little to the east of Cannelton. There are between 20 and 30 horizons at which coal occurs, of which five contain workable coal over large areas, and not less than seven others contain work-

*For a detailed account of the coal fields of Indiana, with maps and charts showing the distribution and thickness of the different veins, full analyses, etc., the reader is referred to the "Coal Deposits of Indiana," by Dr. George H. Ashley, published in the 23d (1898) annual report of this Department.

able coal over small areas. The workable coal runs from three to ten feet in thickness. The upper beds or "bituminous" coals average between four and five feet thick, while the lower or "block or semi-block" beds average three feet one inch. The upper beds occur in large basins, often hundreds of square miles in area, through which they often maintain great uniformity of thickness and minor detail. The lower beds are characteristically in small basins, often of only a few acres, but some with an area of several square miles. The coal in these basins is thick in the center and thins toward the edges.

The Indiana coal field is a part of what is known as the *Eastern Interior Coal Field,* which comprises 46,000 square miles, in central and southern Illinois, northwestern Kentucky and southwestern Indiana. It occupies an elliptical basin with a center in southeastern Illinois toward which the different layers of rock slope or dip from every direction. The Indiana field being on the eastern edge of the basin, all the coal and other rocky beds tend to dip or get deeper toward the southwest or center of the basin. The result of this is that along the eastern edge of the Indiana field only the lowest coal bed is found. Going westward, this descends at the rate of about 24 feet to the mile, and gradually the other beds set in, until, along the Wabash River, the lowest bed may be 700 or 800 feet below the surface, and as high as 16 other beds have been found above it in a single drilling, the total thickness of the coals in this case being over 32 feet. As a rule, not more than one or two workable beds will be found at any locality, and at many points, constituting together perhaps one-fourth of the field, none of the underlying beds are workable. In a few cases three or more beds are workable at a single point.

For convenience, the Indiana coal field may be considered as occupying four belts or areas which merge one into the other. The eastern edge of the field includes eastern Fountain and Parke; western Putnam and Owen, and the eastern four-fifths of Greene, Martin, Dubois, Orange, Crawford, Spencer and Perry counties. Most of this area is hilly, and contains but limited quantities of workable coal. The lower, pockety coals are nearing outcrop, so that most of the mines are small and worked by drifting. These coals tend to be block or semi-block in character.

West of this belt is another from 10 to 20 miles broad, where the coals are still shallow, the mines seldom reaching a depth of 100 feet. The coals are block or semi-block and, though in pockets, are largely workable. The surface of this belt is flat or rolling. It crosses western Fountain, central Parke and Clay, western Greene, central Daviess and eastern Pike and Warrick counties.

Still west of this is a third belt, 10 to 20 miles wide, where the upper coals are near outcrop and are extensively mined. The coals in belt two are here deeper and, as a rule, not workable. Most of the larger mines of the State are in this and the preceding belt. This third belt covers Vermillion, southwestern Parke, Vigo and western Clay, eastern Sullivan and Knox, western Daviess, Pike and Warrick counties.

Gibson, Vanderburgh and Posey and western Sullivan and Knox counties comprise a fourth belt or area, where the upper coals are generally workable but deep; the mines, as a rule, being 250 feet or more in depth. The lower coals are here usually thin. On account of the surface rocks in this area showing little or no coal, the impression is general that there is but little coal in this belt. The data at hand lead to the conclusion, however, that not only is this view erroneous, but that this area will some day prove the richest part of the Indiana field.

The most active mining regions at present are in Clay and Vigo, southern Parke and Vermillion, eastern Sullivan, western Greene and northeastern Knox counties. The quantity of coal in Clay and Greene is not great, but will yet last for many years. Parke and Vermillion counties have somewhat larger quantities. The coal of Vigo and Sullivan counties, though long and extensively mined, has hardly as yet been touched. This is still more true of Knox, Gibson and Vanderburgh counties. Pike County has a bed of unusual thickness outcropping or very near the surface, but as yet hardly touched. The same bed is present in Warrick County, though not covering as large an area. Daviess County still has much workable coal, but in thin beds. Limited areas of unmined block coal exist in southeastern Parke and western Clay counties, and near Patricksburg, Owen County.

The presence of a hitherto unknown basin of block coal comprising some 12,000 to 14,000 acres in southern Clay County, was proven by sixteen test bores and a shaft sunk in 1906. This basin lies near Howesville, and is penetrated by the new division of the C. I. & L. (Monon) railway, which extends from Quincy to Linton. The bed runs from three and a half to four feet in thickness, and the coal is said to be up to the average of the best Brazil block coal in quality.

The block coal, wherever found, is one of the most valuable fuels in the State. It possesses a laminated structure, and is composed of alternate thin layers of vitreous, dull black coal and fibrous mineral charcoal. It can be mined in blocks as large as it is convenient to handle. These blocks split readily in the direction of the bedding plane, but in the opposite direction are broken with difficulty.

It is as pure as splint coal, is almost free from sulphur or phosphorus, and has the softness and combustibility of wood. In burning it swells so little that its expansion is scarcely perceptible, does not change form, and never cakes or runs together; hence, it is a most valuable fuel for the blast furnace and the cupola of the iron founder.

For steam and household purposes it has an unrivaled reputation. It burns under boilers with a uniform blaze that spreads evenly over the exposed surface, thus securing a more uniform expansion of the boiler plates. Its lack of sulphur also causes it to have but little detrimental effect upon the boiler, grates or fire boxes. In household grates it burns with a bright and cheerful blaze, like hickory wood, making a very hot fire which, for comfort and economy, cannot be surpassed by any fuel except an abundant supply of natural gas.

The bituminous coals of the State, which far outrank the block coals in abundance, are also of excellent quality. Realizing some years ago that the natural gas supply of the State was going to fail, and wishing to retain as many of the factories in Indiana as possible, I had average samples of coal collected from 19 of the leading mines of the State. These were sent to Dr. W. A. Noyes, of the Rose Polytechnic Institute at Terre Haute, who made a complete chemical analysis of each and at the same time determined its heat value and steam producing value. Seven samples of Pittsburg and West Virginia coals were also secured from the Marmet Coal Company, of Cincinnati, Ohio, and the same facts concerning them were determined in order that a comparison could be made of analyses determined under the same conditions. The results of these analyses are herewith given as follows:

ANALYSES OF INDIANA COALS.

Number.	COUNTY.	NAME OF COAL AND OWNERS.	Total Combustible Matter.	Volatile Combustible Matter.	Fixed Carbon.	Moisture.	Ash.	Sulphur.	Heating Effect—Calories per Kilogram, Calculated.	Heating Effect—Calories per Kilogram, Berthier's Test.	Evaporative Effect—Pounds of Water per Pound of Coal.
1	Vanderburgh.........	Sunnyside Coal and Coke Company, Evansville (V)...................	86.73	38.59	48.14	6.44	6.83	1.85	6,924	6,759	12.9
2	Warrick.............	Deforest mine (V)..	84.16	39.09	45.07	6.08	9.76	2.14	6,705	6,339	12.5
3	Knox...............	Edwardsport Coal mine Edwardsport Coal and Mining Co. (VI).......	82.03	36.00	46.03	8.75	9.22	3.08	6,495	6,345	12.1
4	Knox...............	Bicknell mine, Bicknell Coal Company (VI).........................	83.76	35.22	48.54	7.61	8.63	1.67	6,692	6,489	12.5
5	Daviess.............	Cabel & Kauffmann (V)..	87.15	37.99	49.16	6.50	6.35	1.85	6,958	6,981	13.0
6	Sullivan............	Star City (VI)..	87.30	38.53	48.77	9.40	3.30	1.23	6,995	7,002	13.0
7	Sullivan............	Alum Cave (V)..	84.77	42.60	42.17	6.49	8.74	3.18	6,712	6,894	12.5
8	Greene..............	Buckeye or Fluhart, Linton Coal and Mining Company (IV)..........	86.79	35.69	51.10	7.81	5.40	0.72	6,974	6,618	13.0
9	Greene..............	Summit mine, Dugger and Neil Coal Company (IV)..................	87.54	35.30	52.24	7.44	5.02	0.61	7,041	6,852	13.1
10	Greene..............	Island City mine No. 1, Island City Coal Company (IV).............	86.47	35.97	50.50	7.12	6.41	0.84	6,944	6,819	13.0
11	Vigo................	Ray mine, Seeleyville, Vigo County Coal Company (VI).............	84.46	40.25	44.21	7.57	7.97	4.01	6,656	6,762	12.4
12	Clay................	Gart No. 5 shaft, Brazil Block Coal Company (III).................	85.27	36.11	49.16	11.20	3.53	0.62	6,856	6,774	12.8
13	Clay................	Brazil Block No. 1 shaft, Brazil Block Coal Company (III)............	85.12	45.16	49.96	13.82	1.06	1.47	6,810	6,888	12.9
14	Clay................	Eureka mine No. 1, Carbon, Eureka Block Coal Company (III)........	86.74	36.32	50.42	9.80	3.46	0.34	6,985	7,050	13.1
15	Clay................	Crawford No. 3 mine, Crawford Coal Co. (III).......................	84.58	36.34	48.23	11.26	4.16	0.56	6,803	6,858	12.7
16	Clay................	Columbia No. 2 mine, Teller, McLelland & Co. (III).................	89.52	36.75	52.77	7.47	3.01	0.57	7,202	7,344	13.4
17	Owen...............	Lancaster No. 4 mine (III)..	83.85	36.45	47.40	12.73	3.42	0.55	6,744	6,636	12.6
18	Parke...............	McIntosh No. 1 mine, near Diamond, I. McIntosh & Co. (III).........	87.70	36.69	51.01	8.21	4.09	0.95	7,039	7,008	13.1
19	Parke...............	Cox No. 3 shaft, "bituminous," Brazil Block Coal Co. (VI)...........	88.33	41.88	46.45	6.49	5.18	2.93	7,009	6,897	13.1
20	Pittsburg coal.......	Beck's Run, first pool, Hays Coal Company.........................	96.06	36.01	60.05	2.09	1.85	0.64	7,726	....	14.6
21	Pittsburg coal.......	Anchor, fourth pool, Beaumont Coal Company......................	89.84	35.30	54.54	1.30	8.86	0.45	7,230	....	13.5
22	Pittsburg coal.......	Caledonia, fourth pool, T. J Wood..................................	90.26	35.22	55.04	1.35	8.39	0.69	7,256	....	13.5
23	Pittsburg coal.......	Stony Hill, fourth pool, John D. Nixon.............................	92.74	35.46	57.28	1.11	6.15	0.56	7,462	....	13.9
24	Pittsburg coal.......	Little Redstone, fourth pool, Little Redstone Coal Company..........	91.08	35.88	55.20	0.98	7.94	0.82	7,316	....	13.7
25	West Virginia coal...	Raymond, Marmet Smith Coal and Mining Company..................	91.16	40.14	51.02	3.20	5.64	2.25	7,266	....	13.6
26	West Virginia coal....	Belmont, Belmont Coal Company, Belmont, W. Va..................	90.04	37.84	52.20	1.45	8.51	0.46	7,248	....	13.5
		Average of Indiana Coals..	86.36	38.22	48.14	8.45	5.61	1.52	6,879	......	12.8

A comparison shows the quality of the Indiana coals to be much better than expected; the average steam producing value, or evaporative effect, of the nineteen samples being 12.8 pounds, as against 13.7 pounds, the average for the foreign coals. The small value of .9 pound in favor of the Pittsburg coals is more than offset by their additional cost of transportation.

In 1898 Dr. George H. Ashley, after a careful survey of the coal area of Indiana, estimated that there were 40 billions of tons of coal in the State, of which one-fifth, or eight billions of tons, were workable under present conditions. The distribution of this coal by counties was given by Dr. Ashley as follows:

DISTRIBUTION OF AVAILABLE COAL IN INDIANA BY COUNTIES.

COUNTY.	Number of Coals Contained.	Greatest Thickness Recorded.		Area Underlain by Coal, in sq. miles.	Area Underlain by Workable Coal in square miles.	Estimated Total Tonnage of Coal.	Estimated Total Tonnage of Coal removed or rendered Unworkable.	Estimated Total Tonnage of Workable Coal Left.
		Ft.	*In.*					
Warren	4	4	2	300	30	472,000,000	60,000	43,500,000
Fountain	7	8	+	325	75	500,000,000	2,733,000	128,750,000
Montgomery	1	....		½	0	100,000	0	0
Putnam	2	3	0	C.M.100	¾	56,000,000	25,000	1,800,000
Parke	11	7	6	C.M.470	100	1,000,000,000	12,000,000	424,000,000
Vermillion	11+	7	0	250	100	1,457,600,000	5,350,000	441,000,000
Owen	4	6	1	125	30	67,000,000	600,000	15,000,000
Clay	14	8+		250	100	1,000,000,000	50,000,000	150,000,000
Vigo	11	7+		400	300	3,375,000,000	6,500,000	1,000,000,000
Greene	9	7		300	50+	1,000,000,000	4,000,000	150,000,000
Sullivan	9+	9+		440	365	4,650,000,000	9,000,000	950,000,000
Martin	7?	4		175	14	330,000,000	300,000	20,000,000
Daviess	15	7	3	400	200	2,378,000,000	5,250,000	320,000,000
Knox	15	6+		540	300+	7,000,000,000	760,000	950,000,000
Orange	2	2	8	1	¼	840,000	200	200,000
Crawford	3	4		12	½	9,200,000	None?	400,000
Dubois	9	5		300	40	947,000,000	87,000	52,500,000
Pike	10+	10	2	330	200	1,836,000,000	1,293,000	630,000,000
Gibson	10+	7	7	450	400	6,675,000,000	66,000	1,175,000,000
Perry	7	5	8	30	6	36,500,000	3,400,000	8,750,000
Spencer	7	5	10	300	25	1,000,000,000	200,000	50,000,000
Warrick	8	9	0	356	175	2,000,000,000	2,000,000	345,000,000
Vanderburgh	7+	4	6	240	200	2,258,000,000	3,000,000	835,000,000
Posey	6+	2	6	420	200	1,600,000,000	None	400,000,000
Total	27‡	10	2	6,508	3,051	39,618,240,000	106,024,200	8,090,900,000
Approximately	27+	10		6,500	3,000	40,000,000,000	100,000,000	8,000,000,000

Total area surveyed, about 9,000 square miles.*

*Ashley, 23 Rep. Ind. Dep. Geol. and Nat. Res., 1898, p. 1422.

It was estimated that up to the year 1899, 100 million tons, 1-400 of the total amount, or 1-80 of the workable amount had been mined.

Since that date 70,213,404 tons have been mined, the output for each year to January 1, 1907, being as follows:

Year.	*Tons produced.*
1899	5,864,975
1900	6,283,063
1901	7,019,203
1902	8,763,197
1903	9,992,563
1904	9,872,404
1905	10,995,972
1906	11,422,027

It was estimated by Dr. Ashley that if the past rate of increase of production be maintained, the coal supply of Indiana would last not less than three hundred years. Owing to the rapid failure of natural gas the rate of increase of production was greatly enlarged, fully seven-tenths as much being mined in the last eight years as in the previous fifty years. During the past four years the output has been more steady, averaging a little above ten million tons per annum, and from now on a smaller and more regular rate of increase will doubtless be maintained. In the words of Dr. Ashley: "Constantly improving methods will tend to lengthen the life of the field by securing a larger proportion of the coal in a given area and by rendering workable much coal now considered unworkable. On the other hand, changes and exhaustion of competing fields and the invention of better methods of utilizing the Indiana coal, by increasing the demand, will tend to shorten the life of the field. On the whole, it seems safe to assume that the life of the Indiana coal field is at least 300 years, and probably more."

Finally, it may be said that the human mind cannot conceive the vast amount of energy at present locked up in the coal fields of the State, nor place anything like an accurate value upon it. The richest men of the nation to-day are those who have utilized the stored energy found in coal in years gone by; who have bought this energy at low prices, and either sold it in the form of manufactured articles at many-fold its cost price, or used it in transporting, for hire, man and his products to the four quarters of the globe.

Not being familiar with the production and use of "producer gas," I asked Mr. W. H. Duncan, Secretary of the Terre Haute Commercial Club, to prepare a brief statement regarding such gas for this paper, as at Terre Haute such gas is made and used in quantity in the glass furnaces. He kindly agreed to do so, and has furnished the following statement, which is herewith printed just as handed in by him:

Producer Gas.—Producer gas was first brought into use some thirty years ago, and has been applied with such marked economy for so many purposes that it is now considered essential to the prosecution of many lines of industry, notably steel works, rolling mills, smelting furnaces, glass works and chemical works. During the life of the natural gas fields producer gas received little attention in Ohio and Indiana, though used to considerable extent in Pennsylvania and Illinois. However, since the failure of natural gas manufacturers everywhere realize that the only staple and reliable source of heat on a large scale is coal, and that the most satisfactory method of utilizing its heat is to first convert it into gas.

The manufacture of producer gas is by no means difficult. A gas producer is perhaps the simplest of all metallurgical furnaces; in fact almost any vessel capable of containing a deep bed of incandescent coal through which a current of air, or air and steam, can be forced or drawn is a good producer. In the gas producers as they are now constructed the fixed carbon is consumed in the producer. The volatile matter, together with a certain portion of the fixed carbon, in the form of carbon monoxide, is conveyed to the melting furnace, where it is desired to utilize the fuel. As producer gas is not a fixed gas it must be used while hot; it cannot be carried to exceed 1,000 feet from the producer to the furnace.

Until quite recently anything in the form of a closed box with a grate under it was considered good enough for a gas producer—in fact this was the only kind used in Indiana previous to the failure of natural gas. After that came a change, and now there are a dozen or more styles made by as many different firms, each having its friends.

The ordinary gas producer used for operating glass, iron or steel furnaces consists of an iron shell made of sheet iron, measuring ten feet in diameter and twelve feet in height. It is lined with fire brick, having a suitable grate in the bottom and cast iron plates covering the top, with hoppers for receiving the coal. A bed of fuel is maintained from three-and-a-half to four feet in height above the grate. A steam injector is used for forcing air and steam through the grate at the bottom, and the coal is fed through the hopper at the top in small quantities, at short intervals, the object being to consume a portion of the fixed carbon in order to maintain sufficient heat to distill the volatile gases as the coal is deposited on top of the fuel bed. The gas is led up through an opening in the side of the producer near the top, where the pipes connect to convey the gas to the furnaces. The producers are usually constructed in batteries, and a number of producers can be connected with one main gas flue. The operation is simple, no purifying process being used, and the soot and tar which accumulates in the pipes must be cleaned out once a week. The cost of producers varies from $1,000 to $1,800, exclusive of outlet and steam connections, according to make and size. A good one which will consume twelve tons of run-of-mine coal per twenty-four hours will cost $1,400, and one of fifteen tons capacity will cost $1,600.

The results obtained vary according to the producer and the coal used. With the old style producer still used in Indiana thirty tons of Indiana coal make producer gas sufficient to heat 100 tons of iron for rolling purposes, the heat required being 2,700 degrees. An authority on producer gas says that in the glass business the manufacturer can count on three-fourths of a pound of coal per pound of glass. (In this connection it may be mentioned that the melting point of silver is 1,733°; gold, 1,913°; copper, 1,929°; cast iron, white, 2,075°; cast iron, gray, 2,228°; glass, 2,390°; steel, hard, 2,570°; steel, mild, 2,687°.) Thirty tons of coal to 100 tons of iron is 600 pounds per ton of iron, while, as above stated, glass men can figure on three-fourths of a ton of coal to each ton of glass in the melting process. But the latest producers bring ample proof that they can accomplish 50 per cent. better results than can be obtained by the old process, which means that with thirty tons of our Indiana coal they can make a sufficient quantity of gas to heat 150 tons of iron—400 pounds of coal per ton of iron, which is certainly cheap enough with run-of-mine coal a dollar per ton delivered on the cars at the factory.

The amount of gas produced from a ton of coal varies with the composition of the coal, and also largely with the proportion of steam used in blowing the producer. On the average it is assumed that in Pennsylvania one ton of anthracite buckwheat coal produces about 170,000 cubic feet of gas, containing 138,000 heat units per 1,000 cubic feet. The volume of producer gas from bituminous coal is about the same, but it runs 157,000 heat units per 1,000 cubic feet. One thousand cubic feet of natural gas contain 1,100,000 heat units, which, in point of strength, would make one foot of natural gas equal to seven feet of producer gas. The analyses of the Pennsylvania coals from which these results are taken make the following showings: Fixed carbon, 57 to 60 per cent.; volatile matter, 33 to 38 per cent.; ash, 3 to 5 per cent.; sulphur, 1 to 1¾ per cent. Taking the analyses as a criterion the coals of Indiana are much better than those of any other portion of the west, and compare very favorably with those of Pennsylvania. The Indiana coals contain a higher percentage of volatile matter than those of Pennsylvania, and are somewhat lower in fixed carbon, while in sulphur much of the Indiana coal is superior to that of Pennsylvania. Recently a Pennsylvania producer gas expert came out to Indiana on a tour of investigation. He had never seen any of the Indiana coals before, and after having spent several weeks in various portions of the State, went away with a high opinion of our products. The Greene County, Sullivan County, a portion of Parke and Vigo County coals he pronounced equal to any he had seen anywhere for producer gas purposes, and said they were all far superior to any other found in the west.

Not only are the Indiana coals of good quality for producer gas purposes, but can be converted into a quality of fixed gas which can be used to great advantage in operating machinery. At a recent trial at the government testing plant at St. Louis, it was demonstrated that 2,575 pounds Vigo County coal, converted into fixed gas, operated to its fullest capacity for ten hours continuously a gas engine of 240 horse power.

Petroleum.—Crude petroleum, one of the most valuable of natural fuels, has been produced in commercial quantities in Indiana since 1890, when the first producing well was sunk near Keystone, Wells County. From that time to the present the area of the main Indiana oil field has gradually increased until now it covers an area of 1,280 square miles in the south half of the northeastern fourth of the State.

Throughout this area the oil occurs in porous strata or "pay streaks" of the Trenton limestone at depths ranging from 900 to 1,350 feet below the surface. From this limestone there was produced in the sixteen years from 1891 to 1906, inclusive, the enormous total of 85,109,048 barrels, which sold for $70,999,592, or an average of $4,437,474 per year.

The low average price, the discovery of oil in large quantities in Illinois, and other minor reasons, caused the output of Trenton rock petroleum in Indiana in 1906 to decrease, the output being but 7,762,825 barrels, or 3,129,613 barrels less than in the year preceding. This brought, on the market, $6,877,863, an average of 88 3-5 cents per barrel.

The causes above mentioned prevented the sinking of as many wells in 1906 as in the year previous, there being but 1,132 new bores put down as against 1,882 in 1905. Of these 124 were dry. Of the producing wells, the average initial output was 14.6 barrels to the well, as against 20.6 in 1905.

In addition to the Trenton rock petroleum, there is produced from a limited area about Princeton, Gibson County, in the southwestern corner of the State, a crude petroleum from the Huron sandstone, one of the Lower Carboniferous or Mississippian formations. The output of the Princeton field in 1906 was 103,843 barrels, valued at $81,771.

A few wells in or near Terre Haute, Vigo County, also yield crude petroleum from the Corniferous limestone of the Devonian formation. The output of these wells for the year was 7,269 barrels, valued at $8,456.

Unless the area of production be much increased, the output of petroleum from the Indiana fields will from now on gradually dwindle, as several thousand new bores are necessary each year in order to offset the decrease in output of those already producing. These are possible only when the market price is such as to stimulate the producer and guarantee him a fair profit on his capital invested. Whether or not any new productive area of consequence will be added to that already known only the future use of the drill will show; since the great depth at which the oil bearing strata lie makes it imposible to guage from the surface their area and content.

Natural Gas.—One of the most valuable and convenient fuels known to man is natural gas, the volatile part of crude petroleum. During the ages which have elapsed since the petroleum was formed in the depths of the Trenton and other rocks of Indiana, large portions of it volatilized or changed into gas. Wherever possible, this gradually rose and passed into the higher porous portions of the limestone, where it was held by either petroleum or salt water behind it. From its discovery in Indiana in 1886 the field was gradually developed until it reached an area of approximately 2,500 square miles, embracing part or all of seventeen counties near the center of the eastern half of the State. The original rock pressure was 350 pounds and some of the wells yielded 12 to 14 million cubic feet per day.

In the early history of the field there was an enormous waste, some of the wells being turned on full blast and allowed to burn as an advertisement. It was estimated that in the last six months of the year 1887, fifteen billion cubic feet of gas, worth, at an extremely low estimate, $1,500,000, was wasted in this manner in the Indiana field.

So greedy was the citizen of the gas belt in those days, so ignorant of the real value of this gaseous fuel and the manner of its formation, so reckless in its consumption, that at the end of a score of years there remains only the dregs of the plenty that has been.

The value of the gas produced in the State slowly increased until 1900, when it began to decrease. The output had begun to dwindle several years before this, but about 1898 it began to be sold by metre measurement. Under this system the producer received about five times as much per thousand for his gas as under the old flat rate system everywhere in vogue during the palmy days from 1887 to 1900. As a consequence, while the production has fallen off very greatly, the total value still represents a considerable amount.

The following table shows the value of natural gas produced in Indiana during the 20 years from 1886 to 1905, inclusive:

VALUE OF NATURAL GAS PRODUCED IN INDIANA, 1886–1905.

Year.	Value.	Year.	Value.
1886	$300,000	1897	$5,009,208
1887	600,000	1898	5,060,969
1888	1,320,000	1899	6,680,370
1889	2,075,702	1900	7,254,539
1890	2,302,500	1901	6,954,566
1891	3,942,500	1902	7,081,344
1892	4,716,000	1903	6,098,364
1893	5,718,000	1904	4,342,409
1894	5,437,000	1905	3,094,134
1895	5,203,200		
1896	5,043,635	Total	$88,234,440

At the present time there are but few attempts made at drilling for gas exclusively, the greater proportion being secured while drilling in search of oil. The majority of the manufacturing plants in the "Gas Belt" of the State have been forced to abandon natural gas as fuel and to substitute coal, wood or manufactured gas, or seek new localities where cheaper fuel is available. Occasionally a fair gas well is found where a limited reservoir has escaped previous notice, but the lives of such wells are usually short, owing to the limited area upon which they have to draw.

Pumping stations which artificially exhausted the gas and thereby created a vacuum in the porous strata, thus allowing the water to flow in and drown out the fuel, have caused the abandonment of much territory which would otherwise be still productive. The poor plugging of abandoned wells has also been a partial cause of failure of the supply in many parts of the field.

Every one will admit that the highest use to which natural gas can be put is that of household consumption, especially in cook stoves. With no kindling, no replenishing, no ashes, no soot, the duties of the housewife are decreased many fold. For this reason every effort should be made to husband the present supply by stopping at once all unnecessary use or wanton waste. Any attempt to evade the law relative to the waste of gas should be promptly reported to the proper officers. Even yet an occasional oil operator is found who pipes the gas into a pile of brick and burns it, hoping thereby to keep himself within the pale of the law. All such persons are wholly lacking in public spirit, and devoid of every feeling which tends to advance the interests of humanity.

It must also ever be remembered that with both natural gas and petroleum we are drawing upon stored products which are not being increased a single iota, and that therefore the end of the supply of both is sure to come.

RESOURCES OTHER THAN FUELS.

LIMESTONES.

*The Indiana Oolitic Limestone**.—For her output of building and ornamental limestone Indiana far outranks any other State in the Union. The Indiana oolitic limestone, otherwise known as the Bedford Oolitic Limestone, the Salem Limestone, etc., has long been known among architects for its strength and durability. Within the past decade the demand for it has been rapidly increasing, and it is now in use in twenty-nine states, and three foreign countries. Four State capitol buildings, those of Indiana, Illinois, Georgia and New Jersey, have been constructed wholly or partly from it, as have also 31 court houses in Indiana, and numerous custom houses, postoffices, hotels and other public buildings throughout the United States. The Soldiers' and Sailors' Monument, at Indianapolis, with its magnificent carved groups of statuary, is composed wholly of it. In New York and other eastern cities it is also used extensively in the construction of the private residences of many of the more wealthy citizens. Its wide reputation is due to its general usefulness in masonry, ornamentation and monuments; its abundance; the ease with which it can be quarried and dressed, and its pleasing color and durability.

*For a detailed account and maps of the area containing the oolitic stone, and also full data relative to its production for the market, the reader is referred to the paper by Messrs. Hopkins and Siebenthal in the 21st (1896) Annual Report of this Department.

This stone is geologically a member of the Mississippian or Lower Carboniferous formation and occupies a strip of territory from two to 14 miles in width which extends from Greencastle, Putnam County, to the Ohio River. It occurs in a stratum varying from 25 to nearly 100 feet in thickness. This stratum is massive in many places, being without bedding or lamination planes from top to bottom, so that the size of the blocks which may be quarried is limited only by the capacity of the quarry machinery and transportation facilities. There are, however, in many quarries and all outcrops one or more systems of vertical or nearly vertical joint seams, which occur 20 to 40 feet apart. These and the presence of peculiar suture joints, known as "stylolites," "crow feet," "toe nails," etc., often cause a great deal of waste and annoyance in quarrying.

The principal working quarries of the oolitic stone are located near Romona, Owen County; Stinesville, Ellettsville, Bloomington and Sanders, Monroe County; Oolitic, Dark Hollow and Bedford, Lawrence County; Salem, Washington County and Corydon, Harrison County. Within the past five years many quarries have been opened along Clear Creek in the southern part of Monroe County, and this region has become one of the richest productive areas of oolitic stone in the State.

Few building stones are more accessible than the Indiana oolitic limestone. Occurring as it does in an almost horizontal position and in the driftless portion of the State, it outcrops over a comparatively large area, with either no covering at all or one so light that it can be readily removed.

The C. I. & L. (Monon) Railway traverses the area from north to south over its most productive part, and there are also three east-west railroads and a short line known as the Belt, which serves to connect many quarries around Bedford with the other roads. There are also short branch roads, making switch connections with one or more of these roads, running into each of the quarries. The Indianapolis Southern Division of the Illinois Central Railway recently completed, will soon construct a spur from Bloomington south into the main quarry district of Clear Creek Valley.

The oolitic stone is a granular limestone, or calcareous sand rock in which both grains and cementing principle are carbonate of lime. In the common sandstones of the State the grains are hard and nearly angular. In the oolitic stone they are always soft and either round or rounded, and the cement is harder than the grains. In color the stone is either buff or blue. Its specific gravity is about 2.47, and its weight about 152 pounds per cubic foot. In chemical composition it is nearly pure carbonate of lime, the *average* of eight analyses of specimens from eight of the leading quarries showing the following percentage composition: Calcium carbonate, 97.62; magnesium carbonate, .61; iron oxide and alumina, .36; insoluble residue, .91. The crushing strength of 50 specimens ranged between 4,500 and 13,200, with an average of 7,000 pounds per square inch.

The fire resisting properties of the oolitic stone are also very great, as a series of experiments on one-inch cubes by this Department has proven. Heated to 1,000° F., and plunged into cold water, the cubes were not affected. Heated to 1,200° F. and plunged into cold water, the cube crumbled slightly along the lower edges. Heated to 1,500° F. and cooled in air, the cubes retained their forms intact, but were calcined in a marked degree. This shows that the stone will withstand the effects of fire to the point of calcination.

On account of its softness when first quarried, the oolitic stone can be readily sawed or carved into any form desired, and the larger companies now operate one or more saw mills in connection with their quarries. The saws in use at the various mills are largely the common gang saw with long iron blades made to swing to and fro across the stone, sand and water being fed under each saw automatically. In a number of the mills what is known as the "diamond saw" is now used to do the cutting. A heavy steel blade 10 to 12 feet in length and a foot or more wide, has its lower edge set with steel blocks about an inch square and a little thicker than the blade. Attached to each of these blocks are small black diamonds that do the cutting. No sand or other abrasive is used with this saw, and it cuts at the rate of about 30 inches per hour, as against three to four inches by the ordinary gang saw.

The larger part of the oolitic stone which is quarried is used for fine dimension stone for buildings, both for face work and trimming. It is also much used for monumental purposes, either as bases for monuments or for the shafts or both. Large quantities are used for pavements, curbing, sewer piers, abutments, etc. It makes a strong and durable pavement, and does not wear slippery. Its use for curbing for cement walks is increasing year by year in many of the larger towns of Indiana and adjoining states. Large quantities of the spalls and waste pieces from the quarries are also used annually for railway ballast.

The oolitic stone is too soft for use as macadam material on roads which are much traveled or where heavy traffic is necessary. On such a road it grinds easily into a dust which is very disagreeable in summer and full of chuck holes in winter and spring. It is by far the most valuable stone in Indiana, and many good deposits are as yet undeveloped.

In the year 1905, the output of rough building limestone from the oolitic quarries was valued at $1,155,728, while the dressed building stone from the same quarries was valued at $1,337,232, making a total of $2,492,960 for the oolitic stone industry of the State.

The Niagara Limestone.—This limestone comprises 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 south and southwestward from Newcastle, Henry County, to the Ohio River near Jeffersonville. In the vicinity of Osgood, Ripley County; Westport, New Point and St. Paul, Decatur County, and Laurel, Franklin County, are important beds of Niagara limestone, which for many years have been extensively quarried. This is locally known as the Laurel limestone, since the stone is typically exposed and has been longer worked near the town of that name.

This stone can be quarried more easily and at less expense than any other stone of a similar nature in the State; the natural seams and even bedding doing away largely with the necessity for drilling and blasting. The stone occurs in natural slabs of a uniform thickness—two to 20 inches—and with the upper and lower surfaces very even, so that for many purposes tool dressing after quarrying is not necessary. It is of a handsome color, very hard and durable, and is used extensively for bridge abutments, flagging and curbing, and to a less extent for window sills, window caps, range stones, ashlar, doorsteps, foundations, street crossings, gutter stone, pier footings, etc. For many of these uses it is better suited and can be furnished more cheaply than either the Indiana oolitic limestone or the Berea (Ohio) sandstone, the two materials with which it comes in closest competition. Across Fall Creek at Indianapolis, some of the most handsome and durable bridges in the State have recently been constructed almost wholly of this stone.

A somewhat similar stone, well fitted for curbing, flagging and paving, and occurring, as does the Laurel limestone, in layers of variable thickness, has been quarried in the immediate vicinity of Wabash, Wabash County. The deposits are large, easily and cheaply quarried, and worthy of much more extensive development.

Macadam and Concrete Stone.—Limestone well adapted for macadam and concrete making purposes occurs in many localities in central, eastern and southern Indiana.* A large number of tests made in the U. S. Road Laboratory at Washington in 1905, show that, named in the order of their superiority, the Mitchell, Huron and Niagara limestones of the State rank best for road making purposes. The Devonian limestones are in many places too soft and, as already noted, the Indiana oolitic limestone should not be used for the same reason.

The Mitchell limestone is a heavy bed of compact limestone and chert, intercalated in places with thin layers of limey shales. It is one of the divisions of the Lower Carboniferous or Mississippian formation, and its exposures occur over an irregular area three to 25 miles in width, extending through the central part of southern Indiana from the Ohio River in Harrison County, north and northwestward to the southwestern corner of Montgomery County, where they disappear beneath the drift. Chemically it is a very pure carbonate of lime, one analysis of a sample from Monroe County showing 99.04 per cent. of that compound.

The Mitchell limestone is quarried in large quantities and used for road metal, wagon roads or railways, for flagstones, for paving and curbing, for burning to quicklime and for building stone. It is one of the best road metal stones in the State of Indiana, comparing favorably with the Niagara limestone of Silurian age in this respect, but it is harder and generally superior, since the Niagara in many places has thin layers of intercalary shale which, if not separated in the quarrying, will quickly form mud on the roads.

This limestone has been used quite extensively, especially during the last few years, in macadamizing the roads in the area where it occurs. Many small quarries have been opened from which the stone has been obtained for local use. A number of large railway quarries, where the stone is taken out extensively for railway ballast or road material, are also scattered throughout its area. Each of these quarries is capable of turning out from ten to 30 carloads of crushed limestone per day.

The Huron limestones lie just west of the Mitchell, and like it belong to the Mississippian formation. There are three of these limestones with two beds of sandstone intervening. The lower Huron limestone is a compact, smooth-grained, ash-gray to blue limestone, which runs five to eight feet in thickness. In structure it is a close, fine grained, non-crystalline stone, breaking with a subconchoidal fracture. This structure renders it well fitted for mac-

* For a detailed account of the macadam industry in Indiana, see the paper entitled "The Roads and Road Materials of Indiana," in the 30th (1905) Report of this Department.

adam stone, for which purpose it has been used locally in a number of places.

The middle Huron limestone is usually a close textured, semi-crystalline, gray fossiliferous limestone, which varies in thickness from five to 30 feet, averaging about 16 feet. It also has been recently used for road material in Orange, Martin and Greene counties.

The upper limestone averages about 15 feet in thickness, is more crystalline in structure, varies from dark to light gray in color and contains many crinoid stems and remains of bryozoa. It takes a fine polish and resembles marble when so treated, but does not hold the polish when exposed to the atmosphere. On account of its crystalline structure it is not so well suited for road material as the finer grained, harder rocks of the middle and lower beds. It, however, is far better than any sandstone for road purposes, though sandstone has been used in some localities where the upper limestone was available.

The Niagara limestone already mentioned has been used more extensively for road material than any other limestone in the State. This is on account of its wide distribution rather than for any special fitness which it possesses. Numerous tests show it to rank below the Mitchell limestone in resistance to wear, though its cementing qualities are better.

The use of crushed stone for macadam and concrete work is constantly growing, and the business of preparing the stone for such uses will, in the near future, become a more important industry in many localities of the State than at present, as there are many places where the limestones outcrop in quantity close to a railway and offer excellent sites for the investment of capital. In 1905 the value of crushed stone manufactured in Indiana was $336,812, divided as follows: for road making, $222,441; for railroad ballast, $84,007; for concrete, $30,364.

Large and permanent plants for preparing material for macadam concrete, and railway ballast from the Niagara and Mitchell limestones are already located at a number of places throughout the southern two-thirds of the State. Each of these plants is situated on a spur of some railway and the stone dumped directly into the cars from storage bins. The following list of companies, with location and kind of rock crushed, is given for the benefit of those interested:

A LIST OF THE PERMANENTLY LOCATED STONE CRUSHING PLANTS OF INDIANA.

Name of Firm.	Location.	Kind of Stone.
W. F. Goff Stone Co.	Kentland, Newton County	Niagara.
Edw. Hely	Monon, White County	Niagara.
Casparis Stone Co	Kenneth, Cass County	Niagara.
Thos. Bridges' Sons	Wabash, Wabash County	Niagara.
Wabash Stone Co	Wabash, Wabash County	Niagara.
Erie Stone Co	Huntington, Huntington County	Niagara.
Keefer & Bailey	Huntington, Huntington County	Niagara.
F. A. Brickley	Markle, Huntington County	Niagara.
Shoemaker Bros.	Bluffton, Wells County	Niagara.
Meyer Stone Co	Bluffton, Wells County	Niagara.
J. S. Bowers Co	Decatur, Adams County	Niagara.
E. Woods & Co	Pleasant Mills, Adams County	Niagara.
Portland Stone and Lime Co	Portland, Jay County	Niagara.
Baltes Stone Co	Montpelier, Blackford County	Niagara.
Marion Stone Co	Marion, Grant County	Niagara.
Chaffin Bros. Stone Co	Kokomo, Howard County	Niagara.
Leach & Co	Kokomo, Howard County	Niagara.
Wilson Stone Co	Kokomo, Howard County	Niagara.
Deffenbaugh & Co	Kokomo, Howard County	Niagara.
Interurban Stone Co	Kokomo, Howard County	Niagara.
Delphi Crushed Stone Co	Delphi, Carroll County	Niagara.
Pierce Stone Co.	Delphi, Carroll County	Niagara.
Armfield & Cartwright	Ridgeville, Randolph County	Niagara.
Mock Stone Co	Muncie, Delaware County	Niagara.
Eaton Stone Co.	Eaton Delaware County	Niagara.
L. C. Nicoson	Alexandria, Madison County	Niagara.
David V. Miller	Ingalls, Madison County	Niagara.
J. D. Torr	Oakalla, Putnam County	Mitchell.
A. & C. Stone & Lime Co	Greencastle, Putnam County	Mitchell.
Big Four Stone Co	New Point, Decatur County	Niagara.
Greensburg Limestone Co	Greensburg, Decatur County	Niagara.
Westport Stone Co	Westport, Decatur County	Niagara.
St. Paul Stone Quarry Co	St. Paul, Decatur County	Niagara.
Spencer Stone Co	Spencer, Owen County	Mitchell.
Southern Indiana Railway Co	Williams, Lawrence County	Mitchell.
Mitchell Lime Co	Mitchell, Lawrence County	Mitchell.
W. W. Franklin	West Franklin, Posey County	Carboniferous limetsone.
Marengo Manufacturing Co.	Marengo, Crawford County	Mitchell.
J. B. Speed & Co	Milltown, Crawford County	Mitchell.
Eichel Lime & Stone Co	Milltown, Crawford County	Mitchell

*Limestone for Lime Making.**—Indiana is rich in stone suitable for making high grades of lime. No purer forms of calcium carbonate occur anywhere than that furnished by the Mitchell and Bedford oolitic stone, while the Niagara limestone in places affords a magnesium-calcium carbonate which produces a lime rich in magnesium oxide.

The outcrops of Niagara limestone along the Wabash River in the vicinity of Huntington, Huntington County; Delphi, Carroll County, and Logansport, Cass County, have proven especially suitable for the production of lime for building and other purposes. At Huntington and Delphi extensive kilns are at present in active operation.

The lime made from this stone contains about 32 per cent. of magnesium oxide and is, when burned, a dirty brownish color; but

*For a full account of the lime industry in Indiana, see the 28th (1903) Report of this Department, pp. 211–257.

when slacked it bleaches out as white as any other. It is what is termed a "cool," slow setting lime. Where used in paper factories it does not gum the cylinders or clog the cloth or "felt," as does a lime made from pure calcium carbonate. Large deposits of this magnesian stone are yet available in Huntington, Wabash, Miami, Cass and Carroll counties and offer excellent sites for new kilns.

At Mitchell, Lawrence County, and Milltown, Crawford County, large plants are engaged in burning lime from the Mitchell limestone which is the purest form of calcium carbonate in the State. The lime from this stone runs from 97.7 to 98.2 calcium carbonate, and is a quick slacking, strong lime. On account of its purity, large quantities are sold for chemical use, caustic and soap manufacture, etc.

At Milltown a hydrated lime is made from ordinary quick lime 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. 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.

The Mitchell limestone outcrops in fifteen or more counties in this section of the State, and everywhere furnishes a very pure and easily obtained material for lime manufacture.

At Salem, Washington County, and near Bedford, Lawrence County, large kilns are burning lime from the Bedford oolitic stone, the spalls and waste stone from the oolitic quarries being mostly used. As it is burned from stone wholly free from dirt and in kilns so constructed as to separate it from all cinders, the lime made from the spalls of the oolitic stone is noted for its purity and is sold mostly to the chemical trade. For building purposes it 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.

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.

The total value of the lime manufactured in Indiana in 1905 was $366,866.

Limestone for Fluxes.—Large quantities of Indiana limestone are either crushed or ground fine and then sold for fluxes. The magnesium-calcium carbonate or dolomite, quarried at Kenneth, Cass County, is used extensively as a flux by the Illinois Steel Company at South Chicago.

At Mitchell, the Mitchell limestone is ground into a fine powder and sold in quantity for glass making, bringing $1.50 per ton in car load lots at the plant. Any one of the three main limestones of the State, viz., Mitchell, Oolitic and Niagara, can be used in making fluxes, and the growth of this industry will doubtless largely increase as soon as the new steel plants now being erected at Gary, Lake County, are in operation.

The value of the limestone fluxes sold in the State in 1905 was $117,790.

Limestone for Mineral Wool.—The upper layers of the Niagara limestone at Alexandria, Madison County, are being utilized by the Hoosier Rock Wool Company in the making of a mineral or "rock wool." The stone so used runs from three to ten feet in thickness, and is composed of a mixture of silica, alumina, lime, and magnesia in the right proportions to make it fibrous on being subjected to jets of superheated steam while in a melted condition. The result is a mineral fibre resembling cotton in appearance, and called rock wool, which is said to be much superior to the ordinary mineral wool made from steel slag. In the process of manufacture the material increases in bulk twelve times, which shows that the original stone has enmeshed a quantity of air equal to eleven times its own bulk. It is this that makes rock wool one of the most perfect non-conductors of heat and cold known, and it is also fire proof.

The uses of this material as shown from its nature are at once apparent. The covering of boilers and steam pipes in order to retain the heat; for fire proofing; for insulating and lining cold storage plants, refrigerator cars, packing houses, breweries, creameries, hotels and residences; in fact, for all purposes where perfect insulation is desired.

The utility of mineral wool in building as a deadener of sound and as a sheathing in place of building paper is now also generally recognized. The material is also manufactured in felt and board in thicknesses to meet the different requirements of the trade. The many valuable uses to which rock wool may be put and its comparative cheapness make it one of the future valuable mineral resources of the State.

The value of limestone produced in Indiana from 1900 to 1906 was as follows:

1900	$2,344,818	1903	$2,935,274
1901	2,993,186	1904	3,140,679
1902	2,865,691	1905	3,189,259

The following table shows the production of limestone in Indiana in 1905 and the uses to which it was put:

USES AND VALUE OF INDIANA LIMESTONE IN 1905.

Uses.	*Value.*
Rough building	$1,155,728
Dressed building	1,337,232
Flagging	29,699
Curbing	134,898
Paving	5,421
Lime burners, sold to	193
Road making	222,441
Railroad ballast	84,007
Concrete	30,364
Rubble and riprap	43,422
Flux	117,790
Miscellaneous	28,064
Total	$3,189,259

SANDSTONES.

Sandstones of good quality occur in great abundance at a number of localities in western and southwestern Indiana. On account of the wide distribution of excellent limestones in the State they have not as yet received the attention and development which their quality and availability merit. The Indiana sandstones may be classed under three heads, viz., the Mansfield sandstone, the Knobstone sandstones and the Coal Measure sandstones.*

The Mansfield Sandstone.—This is a bed of coarse-grained sandstone and conglomerate that lies at the base of the Coal Measures. It outcrops over a strip from two to 20 miles in width, extending from the north part of Warren County 175 miles in an east of south direction to and beyond the Ohio River. It thus forms a dividing belt between the Lower Carboniferous limestones on the east and the coal producing beds on the west. While the Mansfield sandstone when first quarried is soft, friable and easily worked, it

*For full information concerning Indiana sandstones, see the paper entitled "Carboniferous Sandstones of Western Indiana." by T. C. Hopkins, in the 20th (1895) Report of this Department.

hardens by exposure and becomes in time one of the most durable rocks in the State.

In this sandstone the mass of the rock is made up of white or colorless quartz grains embedded in a matrix or cementing substance consisting almost wholly of iron oxide. When this iron oxide is a hematite or anhydrous in its character, the stone is a handsome *dark brown* in color and is especially suited for business blocks, and for the lintels and cornices of buildings whose fronts are constructed of pressed brick. The rain never discolors small portions of such stone, and the brick walls are therefore permanently free from those unsightly, mouldy looking streaks which soon appear where limestone is used for finishings.

This brown variety of the Mansfield sandstone has been quarried at Hillsboro, Fountain County; near Green Hill, Warren County; Mansfield, Judson and Portland Mills, Parke County, and St. Anthony, Dubois County. Good brown stone in suitable position for quarrying, but not yet developed, occurs near Bloomfield, Greene County, and on Rocky Fork and Sugar Mill creeks in Parke County. Smaller outcrops of less importance occur elsewhere.

Specimens of this brown stone from six of the leading deposits in the State have been analyzed by this Department, and their *average* composition was found to be as follows:

	Per cent.
Insoluble residue (silica)	90.39
Alumina	.49
Iron oxide	7.41
Lime	.08
Carbonic acid	.09

When the iron oxide in the cementing material is a limonite or hydrous form, the color of the sandstone is a buff or gray. Ledges of such stone are more common than the brown variety, and are well fitted for bridges, foundations, retaining walls or, when of the best quality, for fronts of business blocks. These buff and gray varieties of the Mansfield sandstone have been quarried at and near Williamsport and Kickapoo, Warren County; Attica, Rob Roy, Stone Bluff, Hillsboro, Wallace and elsewhere in Fountain County; Guion, Judson, and several different localities along Raccoon and Sugar creeks in Parke County and at numerous small quarries throughout the area farther south. Where the Mansfield sandstone occurs of a homogeneous texture and free from impurities, it will furnish a stone of superior quality for building purposes.

Knobstone Sandstones.—The Knobstone rocks of Indiana comprise one of the uppermost members of the Mississippian or Lower Carboniferous formations. They form the surface rocks over a strip of territory three to 38 miles in width, extending from the Ohio River southwest of New Albany in a west of north direction to a point a few miles south of Rensselaer, Jasper County. In central and southern Indiana the group may be divided into (1) the New Providence shales at the base or eastern side, overlain by (2) the Upper Knobstone shale and (3) the Knobstone sandstone. The two shales will be mentioned on another page under the head of clays, to which they properly belong.

The sandstone of the Knobstone group has been extensively quarried at Riverside and Independence, near Attica, Fountain County. Small quarries to supply a local demand have been operated near Raccoon and Bainbridge, Putnam County, and at several points in Brown and western Jackson counties.

The stone at Riverside is very fine grained. It takes a smooth finish and is light blue or drab in color, and well adapted for delicate carving and ornamentation. It has a crushing strength of 6,000 pounds per square inch, and a chemical analysis shows its percentage composition to be: Silica, 93.16; alumina, 1.60; iron oxide, 2.69. It has been largely used at Lafayette and neighboring towns.

In general, the Knob sandstone is not a very durable building stone, especially in the presence of moisture, and hence is not well adapted to foundations and bridges, where it has been too frequently used. In the walls of buildings above the foundations, or as trimmings for brick or stone buildings, it is quite serviceable if quarried and selected with some care. It has a fine grain and generally uniform color, either yellowish buff, as generally found in the top layers, or a blue gray in the deeper unoxidized layers. The fineness and evenness of grain, the uniformity in color, the ease with which the stone can be cut and carved are all strong points in its favor as a building stone. If the stone is selected with care and quarried and dressed with proper precautions and laid in proper position in the wall, it can be used safely and with good architectural effects.

Coal Measure Sandstones.—In the upper Coal Measures, overlying or at a horizon above that of the Mansfield sandstone, are several beds of sandstone which are extensively quarried in the coal bearing counties of the State. In composition these Coal Measure sandstones are finer grained than the Mansfield sandstones, and the cementing matrix is more complex, being composed of a mixture of clay, silica, decaying feldspar and iron oxide. These stones are buff, blue or gray in color, and have proven durable wherever used. The largest quarries are at Worthy, Vermillion County, and Cannelton, Perry County. The stone from Worthy has been used extensively in Chicago for wall fronts and trimmings, and from it public buildings in several towns in Illinois have also been built.

The oldest and largest sandstone quarries in the State are those near Cannelton. The stone varies in color from a lemon yellow to a light or dark gray. Its percentage composition is as follows: Silica, 96.18; iron oxide, 1.56; alumina, .54; lime, .15. It has proven very durable but its color is not an attractive one for fine buildings, owing to the iron oxide weathering to a rusty yellow tint. It has been extensively used for building purposes at Cannelton; in the locks on the canals at Louisville, Kentucky, and on the Green River, Kentucky; and for wharves, retaining walls, etc., at many places along the Ohio River.

Other deposits of sandstone which have been quarried on a small scale, occur near Rockport, West Baden, Paoli, Brazil, Coxville and Covington. Some of these, as well as many hitherto undeveloped deposits, are sufficient in quantity and in quality suitable to merit the careful attention of capitalists in search of good investments.

*Sandstone for Whetstones and Grindstones.**—Certain sandstones in Orange and Martin counties have long been used in the manufacture of abrasive materials. Two grades of whetstone rock are used. One, known as the "coarse whetstone bed," is a portion of the upper Huron sandstone, which occurs in massive beds 20 to 35 feet thick. Of this, but five or six feet is suitable for whetstones. This is a white, coarse grained, friable sandstone, free from iron nodules and concretions, and which under the lens resembles loaf sugar. It occurs in quantity along the valley of French Lick Creek in Orange County. After being blasted out of the ledge in blocks, this coarse sandstone is sawed into slabs the thickness of the finished whetstone, usually by a gang saw operated by horse power. The whetstones made from it are well adapted to produce a harsh, coarse edge, and are largely used for shoemakers' and fishermen's knives.

The Hindoostan or fine-grained whetstone rock is found in a bed about 25 feet thick, which comprises a portion of the Mansfield sandstone and occurs from 60 to 100 feet above the base of that formation. It is found most abundantly northwest of French

*For a detailed account of the Whetstone and Grindstone rocks in Indiana see the paper by E. M. Kindle in the 20th (1895) report of this Department.

Lick in the northwestern part of Orange County, and along the southeastern margin of Martin County. All the operated quarries are in the former county. This stone varies much in color, the best grades being creamy white. It is composed of very fine quartz grains which average about .02 of a millimeter in diameter. Most of the whetstones from it are manufactured at small mills situated near the quarries and run by horse power, though one or two steam power mills are operated. Since the whetstone rock occurs in thin layers, these mills are chiefly used in grinding the whetstones smooth on a rub wheel. The whetstones made from it are chiefly "slips," axe stones, glass makers' files, hacker stones, etc. They bring a much higher price than those made from the coarse-grained whetstone rock.

But few grindstones are at present made in Indiana, although sandstones which are capable of making a fine quality of such stones occur at a number of localities in western Orange, northeastern Dubois and southeastern Martin counties. About 35 years ago grindstones were made extensively in this region and sold throughout Indiana and adjoining states. As the work was done by hand and there was great lack of transportation facilities, the industry gradually dwindled until only enough are made to supply the local demand. The Orange County stone is just as good, if not better, than that used at Berea and Amhurst, Ohio, where the leading grindstone industries of the world are located.

Both the Upper and Lower Huron sandstones, and also the Mansfield sandstone, afford an abundance of good grindstone "grit" at many localities in the three counties above mentioned. The French Lick and Jasper Railway now building will soon be completed, and will furnish the long needed transportation facilities. It runs through the center of the region furnishing the grit, and there is therefore no reason why several large steam plants for making both grindstones and whetstones would not prove a profitable investment in this region.

Clays and Clay Industries.*

The clays of Indiana rank in value next to coal and petroleum among the natural resources of the State. A dozen years ago the term "shale" was almost unknown among such resources. Those great beds of soft, blue-gray, thin-layered rock which occur over vast areas in the coal bearing counties were then looked upon as a

*For a detailed paper on the Clays and Clay Industries of Indiana, see pp. 13 to 657 of the 29th (1904) report of this Department.

wholly valueless nuisance, which had to be removed or tunneled through before the underlying veins of coal could be reached. Today the smoke is pouring forth from hundreds of kilns where these shales are being burned into sewer pipe, hollow block, conduits, paving brick, pressed front and ordinary brick, drain tile, etc. It is only within the past ten years that capitalists have come to realize to some extent the vast possibilities which the clays and shales of western Indiana present for manufacturing purposes. Even yet but few of the main deposits are being worked, and there is room for five times as many factories as are now in operation. During the past five years all factories have had many more orders than they could fill and, on account of the rapid advance in the price of lumber, the future of the clay industry is a most promising one.

Not only have the Carboniferous shales been proven in the highest degree suitable for the best of vitrified wares, but the Knobstone shales, which were accounted even more valueless than those of the Carboniferous age, are in several places now being utilized for vitrified, pressed front and ordinary brick, and in three of the largest factories of the State as the clay ingredient of Portland cement. The factories now utilizing them are but the pioneers or forerunners of many yet to be; for these hitherto ignored Knob shales possess almost unlimited possibilities of service for practical use.

At the present time Brazil, Terre Haute, Clinton, Veedersburg, Crawfordsville, Montezuma, Cayuga, Hobart and Porter are the principal seats of clay industries in the central west and northwestern parts, while important factories are located at Brooklyn, Martinsville, New Albany, Huntingburg and Evansville in the center and southwest. In the eastern half of the State there are few, if any, clays suitable for other purposes than ordinary brick and drain tile.

Each of the principal classes of clay in the State will now be taken up in order, and its distribution and uses briefly stated.

Kaolin of Lawrence and Martin Counties.—The purest clay in Indiana is the kaolin of Lawrence and Martin counties. The best grades of it are pure white, and show a chemical analysis of 98.61 per cent. silicate of alumina, and but 1.47 per cent. of fluxes. The poorest grades are yellowish brown in color, but even they contain no more than three per cent. of iron oxide and but 5 or 6 per cent. of all impurities combined.

The great drawback to this kaolin is its lack of plasticity. Otherwise it would be in every way suitable for the best grades of porcelain ware. It is, however, suitable in the highest degree for the manufacture of alum salts for the sizing of the finer grades of wall and letter paper. Its refractory properties are also very great, and for that reason, if mixed with a small percentage of the under-clays of the nearby Coal Measures to render it more plastic, it can be used for making the finer grades of refractory wares, such as retorts, glass pots, glass tanks, etc. Ground fine with a bond clay and pressed dry, it will make the highest grade of fire brick. The best flint clays of Ohio and Kentucky, from which the high grade refractory products of those states are made, are, like the Lawrence County kaolin, wholly non-plastic, and have to be mixed with a plastic under-clay before they can be burned into fire brick and similar products. Recent experiments have proven this kaolin also suitable for making a filler for furniture and buggies; for cosmetics and for ultramarine.

At the largest known deposit, four miles north of Huron, Lawrence County, thousands of tons of this purest of clays can be seen, comprising a stratum five to 11 feet in thickness; yet, since 1891, not a pound has been put to use. The deposit is not a local one, covering a few rods or acres, but square miles, as evinced by outcrops which are known. There is enough in sight in the mines at this one deposit to last an average factory a hundred years, and not one one-thousandth of it has been exposed to view. There it lies, a great mineral resource of untold value, unworked, unutilized, awaiting only the coming of energy and capital to make it up into many kinds of products which are now brought into our State from distant lands.

Fire-Clay of Vermillion County.—Next to the kaolin in purity is the fire-clay of Vermillion County, found just west of Montezuma and north of Hillsdale, in the hills bordering the Wabash River. It is a whitish, silicious under-clay, showing 98.24 per cent. of clay base and sand, and but 1.79 per cent. of fluxes.

From this it will be seen that the clay is of high refractory grade, and moreover, very pure. It contains less fluxes than any plastic under-clay so far discovered in Ohio, and lacks but .02 per cent. of being as pure as the Mineral Point flint clay of that State, which is largely used in making high grade refractory materials, such as glass pots and kindred products. The only objection to the fire brick made from this clay is that for some purposes they are too friable, or easily crumbled. This is due to the small amount of bonding material present, and can be readily overcome at any time by mixing with a small per cent. of a more plastic high grade under-clay, such as occurs at Mecca and many other points in the coal areas to the south. In Ohio, non-plastic flint clays constitute the body mixture of all the refractory wares made in the State, but it is necessary to use plastic under-clays with all of them to act as a bond material.

The Vermillion County fire-clay occurs in a stratum five to seven feet in thickness which underlies an area a mile or more wide, extending from Hillsdale almost to Newport. Coal of good quality both overlies and underlies the fire-clay, the latter outcropping on the sides of the ravines. It is at present worked by six companies whose plants are located along the C. & E. I. Railway, between the points mentioned. Four or five of these grind and ship large quantities of the under-clay, receiving therefor an average of $1.25 a ton on board the cars. This is used for making mortar for laying and setting the parts of kilns, for rock and adamant plaster, for lining ladles and making molds, and many other purposes.

Fire-brick made from this clay by the Burns & Hancock Company of West Montezuma have been used for years in the iron and steel furnaces at Birmingham, Alabama; Atlanta, Georgia, and as far west as Montana, and the Illinois Steel Company at South Chicago uses large quantities of both the brick and the unburned clay as a lining for their furnaces. The six-pound fire-brick sell for $12.00 per thousand, and other sizes by weight at the same proportion, on board the cars at the plant.

A number of sites are yet available where large plants can be located for the manufacture of this clay into many kinds of refractory products. Taking into consideration its quality and the facilities of fuel and transportation, there is room for an investment of large capital in its development, with the assurance of a handsome profit in the future.

Potters' Clays.—Potters' clays of good quality are found in a number of localities in the coal bearing counties; notably near Huntingburg, Dubois County; Cannelton, Perry County; Loogootee and Shoals, Martin County; Clay City, Poland and Brazil, Clay County; Coal Bluff, Vigo County; Annapolis, Parke County, and Stone Bluff, Fountain County. All of these deposits have been tested in a small way in manufacturing pottery for the local markets, and all have given excellent satisfaction.

The best known deposits and the ones heretofore most extensively worked are those at Huntingburg and Cannelton. The clays from these two points show the presence of 95.16 per cent. of clay base and sand, and 5.20 per cent. of fluxes. The average analyses of the clays used in the great potteries at Akron and Zanesville, Ohio, give 94.65 per cent, of clay base and sand, and 4.54 per cent. of fluxes. The potters' clays of Indiana are thus shown to be as good as those of Ohio, and the fuel supply and transportation facilities are, in many localities, better.

The deposit at Huntingburg is known to underlie an area one mile wide and three miles long between Huntingburg and Holland, and it also occurs in quantity north and northeast of the former place. It is a soft, light gray, plastic material, free from all grit and impurities, and a high grade clay in every particular. Besides stoneware, it can be made into terra cotta, sewer pipe, hollow brick and all kinds of hollow vitrified wares. For a number of years large quantities of it have been shipped to potters at Evansville, New Albany, Louisville and other points along the Southern Railway, and for twenty-seven years it has been used in a pottery at Huntingburg. The bed runs five to seven feet in thickness, and the clay at present brings $1.25 per ton on board the cars. The stoneware made from it at Huntingburg and Evansville is strong, durable, and takes an excellent glaze. It does not air-crack in drying or in cooling after being removed from the kilns.

A good slip clay for glazing pottery occurs in abundance along Rocky Run, four and a half miles west of Rockville, Parke County, and another deposit which has been recently put on the market is found along the St. Joseph River, just west of Elkhart.

Under-Clays and Shales of the Coal-bearing Counties.—Millions of tons of shales and under-clays, well fitted for making the best grades of vitrified products, exist in the coal bearing counties of Indiana. These clays lie in the closest proximity to the fuel necessary to burn them; the shales immediately overlying, and the under-clays, as their name denotes, underlying the veins of coal.

The relation of the *under-clays* to the coal shows plainly that the former may be regarded as having formed the soils of the ancient Carboniferous marshes, and that from them sprang that luxuriant vegetation which in time was changed into coal. The under-clays, then, are the mother soils of the coal seams. They are usually from one to six feet in thickness, and composed of a soft, homogenous clay, whitish or gray in color, highly plastic and, when sufficiently free from the fluxing elements, capable of withstanding in a remarkable degree the action of heat. These clays are best fitted for the making of sewer pipe, conduits, drain tile, flue linings, chimney tops, hollow building block, fireproofing, and all hollow products of similar grade. Of the wares mentioned, the sewer pipe, conduits and hollow building brick are vitrified in the making. The others are burned at a lower temperature, generally for a shorter time, and are not salt-glazed, as are the vitrified products. A number of large factories in the State are engaged in making these hollow wares, and have proven by years of practical experience that the under-clays of the Coal Measures furnish a raw material which can not be excelled for that purpose.

The blue, drab and gray *shales* comprise the greater part of the Coal Measure rocks of Indiana, and, taken as a whole, are the most valuable clay deposits occurring in the State. They are not closely related to the strata found above or below them, and their thickness and composition varies exceedingly and is dependent entirely upon the character and source of those streams of water which flowed into the old lakes in which the shales were formed.

When freshly exposed these clay shales are usually hard and tough and more or less massive, requiring to be blasted or worked much as the seemingly harder rocks. As soon as exposed to the weather they soften and crumble into a mass of more or less plastic clay. This is commonly called "slacking," more properly "slaking." Some shales, when weathered, divide into thin flakes or leaves, when they are called "fissile shales." Others break up more or less into little cubes. Of these two, the latter are generally more suitable for making clay wares. The very plastic shales, other things being equal, are best adapted for making stoneware and sewer pipe; those of moderate plasticity find their application in the manufacture of paving brick, while the lean or sandy ones are used mostly for dry pressed and common brick.

The argillaceous or clayey shales, in which clayey material (silicate of alumina) largely predominates, are usually drab or blue in color, though yellow and buff shades are not of uncommon occurrence. They are almost free from "grit" and are often soft and unctuous or greasy to the touch. In the country they are almost universally known as "soapstones," but this term rightfully belongs to the mineral steatite or talc, a magnesian silicate which does not occur in Indiana. Sometimes, however, the shales are quite hard and tough, yielding but little to the pick and requiring the use of explosives for their removal. But whatever their character when first mined, upon exposure to air, rain and frost, they quickly disintegrate into soft, plastic, fine-grained clays of large, commercial importance.

These shales are most useful for the making of vitrified and other brick. No more durable material for the making of pavements can be used than vitrified brick, provided sufficient care be taken in the structure of the foundation upon which the brick are placed. Such a pavement comes nearer than any other to a typically perfect pavement, i. e., one which is reasonable in first cost; low in cost of maintenance, and easy of repair; durable under heavy traffic with reasonable freedom from noise and dust; free from decay, water-proof and non-absorptive; of low tractive resistance and furnishing a good foothold for horses. The making of paving brick is an industry yet in its infancy in Indiana, for the time will come, and that before many years, when not only the streets of every town of two thousand or more inhabitants within our State will be paved with brick, but also many of our country roadways in those regions devoid of gravel and other road material.

On January 1, 1907, there were in Indiana six large factories using Carboniferous shales for making paving brick, while 13 others, among which are the largest clay-working industries in the State, were making hollow wares from either the shales or the under-clays of the Coal Measures. These do not include numerous factories making stoneware, drain tile, building brick and many other products from the shales which a dozen years ago were practically unused and despised.

Undeveloped deposits of shale and under-clay which offer promising sites for great factories are so numerous in the coal-bearing counties that space can not here be taken for their enumeration, and parties interested are referred to the Twenty-ninth (1904) Report of this Department, where the advantages of each are set forth in detail.

Shales of the Knobstone Area.—As already mentioned, the Knobstone area comprises a strip of territory three to 38 miles in width, extending from northwest to southeast near the center of the State. Its eastern or basal division, known as the New Providence or Lower Knobstone shale will, wherever it is exposed, be found suitable for paving brick, pressed front and ordinary brick and the clay ingredient of Portland cement. When properly ground it becomes plastic enough to form a good sewer pipe clay, but when utilized for that purpose, some difficulty is experienced in glazing the product. Otherwise it is of excellent quality. It is already being utilized on a large scale at New Albany for the making of both ordinary stiff mud and dry pressed brick.

The middle division of the Knobstone, known as the "Upper Knobstone shale," consists of a series of soft, light gray or greenish shales, which vary in composition from soft clay shale towards the bottom to an impure, fine-grained sandstone at the top. It has a thickness of 200 to 250 feet, and extends from the East Fork of White River in Jackson County north to Rensselaer. At Blue Lick, Jackson County, this Upper Knobstone shale is quarried in quantity and shipped to Mitchell, where it is used as the clay ingredient of Portland cement at the two large factories of the Lehigh Portland Cement Company.

That the same shale is in every way suitable for brick making is proven by the practical use of it at the large plant of the Adams Brick Company, at Martinsville, Morgan County, where 40,000 ordinary soft mud brick are made from it each working day in the year; and at Crawfordsville, Montgomery County, where from it the same number of stiff mud paving blocks are made daily. It is probable that this upper Knobstone shale will in many places be found too "lean" to be made into sewer pipe and drain tile, though at Brooklyn, Morgan County, a large factory for making drain tile from it has been in successful operation since 1904. By mixing two parts of the shale with one of a more plastic clay, such as one of the under-clays of the Coal Measures, it will, without doubt, make the best of such products.

In locating a large factory for clay products in any part of the Knobstone area care should, of course, be taken to select a locality where the shale is not too sandy and has the proper composition. Then with a man in charge who is experienced in manipulating and burning clay wares, as good, if not better, products can be made from the Knobstone shales as from the more widely known Carboniferous shales which have come into such extensive use during the past decade.

Clays for Terra Cotta Lumber.—In the northern third of the State, near Brook, Newton County; Hammond and Hobart, Lake County; Chesterton, Porter County; Michigan City, South Bend and other points, are extensive deposits of a silty or marly clay, which is peculiarly fitted for the making of terra cotta lumber. These clays were deposited in bays, lakes or harbors, in still water. Much "rock flour" containing a large percentage of kaolin was produced by the passing of the glaciers over beds of shale. This was held in suspension by the glacial streams and finally deposited in the bays and lakes of that epoch. These marly clays are, in general, composed of very fine grains, and are usually in thin layers, separated by a coating of sand. They contain a large percentage of finely disseminated lime and magnesium carbonates, and for that reason products burned from them are usually cream colored or whitish in hue.

The terra cotta lumber for which they are principally used is made by mixing one part of sawdust with three parts of clay, and then forming a hollow brick a foot square and two, four or six inches in thickness. After burning, the ware is left very light and porous, but strong and wholly fire-proof. It can be sawed like a pine board, is easily penetrated by nails, and on it plaster can be spread without intervening laths, or to it wooden finishing can be readily united. It is coming into rapid demand for wall partitions in fire-proof buildings. Floor arching, wall furring, column and girder covering and under-roofing to which slate or roofing tile can be nailed, can also be made of this same porous material. One factory has been making these products at Hobart for 20 years, and the average profits of the owner have been $20,000 or more per annum. Capital invested at any of the points mentioned will realize a handsome profit in the making of porous fire-proof products, the demand for which is increasing every year.

Clays for Ordinary Brick and Drain Tile.—Clays suitable for burning ordinary building brick and drain tile occur in quantity in almost every county in Indiana. In the northern and eastern parts of the State they are largely of drift origin, and some care has to be taken to choose those free from limestone pebbles. The surface of a large area in southwestern Indiana is covered with a very fine grained, clayey buff or brown silt, known as "common loess." It contains but a small percentage of lime, rarely effervescing with acid. Lime pebbles are very scarce, and where found are generally of small size. Other pebbles do not occur except where the sheet of loess is so thin that roots penetrate to the underlying drift and, on the felling of the tree, pull the pebbles up into the loess. Being very uniform in composition, and free from foreign impurities, these common loess clays are much better suited for ordinary brick making than the pebbly drift clays of other sections of the State.

Within the past few years large factories have been erected near Cayuga, Martinsville, Montezuma and Brazil, for making ordinary brick from shale. These factories have been successful from the start, and in 1906 could not supply the demand for their output.

The following table, extracted from the Annual Report of the Mineral Resources of the United States for 1905, shows the value of the clay products of Indiana for the six years, 1900 to 1905, inclusive:

CLAY PRODUCTS OF INDIANA, 1900–1905.

PRODUCT.	1900.	1901.	1902.	1903.	1904.	1905.
Brick.						
Common—						
Quantity	274,383,000	315,966,000	305,233,000	294,890,000	294,409,500	279,073,000
Value	$1,391,873	$1,624,133	$1,710,385	$1,697,190	$1,725,162	$1,630,072
Average per M	$5.08	$5.14	$5.60	$5.76	$5.86	$5.84
Pressed—						
Quantity	19,084,000	27,293,000	24,866,000	24,742,000	29,606,000	22,212,000
Value	$172,752	$234,775	$215,202	$232,487	$240,670	$231,353
Average per M	$9.05	$8.60	$8.65	$9.36	$8.03	$10.42
Vitrified—						
Quantity	30,326,000	31,468,000	45,933,000	47,864,000	49,305,000	43,573,000
Value	$331,276	$320,221	$441,494	$482,967	$545,721	$474,600
Average per M	$10.92	$10.18	$9.61	$10.09	$11.06	$10.89
Fancy or ornamental, value	$7,310	$8,160	$10,398	*	*	$15,520
Fire, value	$40,976	$51,526	$66,725	$115,526	$128,760	$163,728
Drain tile, value	$674,602	$772,241	$807,516	1,014,706	$1,023,571	$1,267,691
Sewer pipe, value	$279,719	$253,626	$311,223	$363,212	$417,260	$430,680
Fireproofing, value	$116,581	$91,081	$342,854	....	$165,000	$393,985
Tile, not drain, value	$343,985	$478,130	$579,896	$463,082	$450,000	*
Earthenware and stoneware, value	$48,544	$54,371	$28,780	$73,160	$88,780	$74,462
Miscellaneous*, value	$450,732	$578,190	$769,260	$1,252,295	$1,300,500	$1,817,482
Total value	$3,858,350	$4,466,454	$5,283,733	$5,694,625	$6,085,424	$6,499,573

*Included in miscellaneous are ornamental terra cotta, yellow and Rockingham ware, C. C. white graniteware, sanitary ware, porcelain electrical wares, glass pots, hollow building block, conduits, and all products not otherwise classified.

Although the above table shows a steady growth in the annual value of the clay products of Indiana, yet, taking into consideration the clay resources, the cheapness of fuel and the transportation facilities of the State, the output is not what it should be. There is room for five times as many clay factories as now exist without over-crowding or overdoing the business, for the number and variety of clay products is increasing at a marvelous rate, while the growth of the country and the rapid disappearance of the forests is ever widening the demand and opening up new markets.

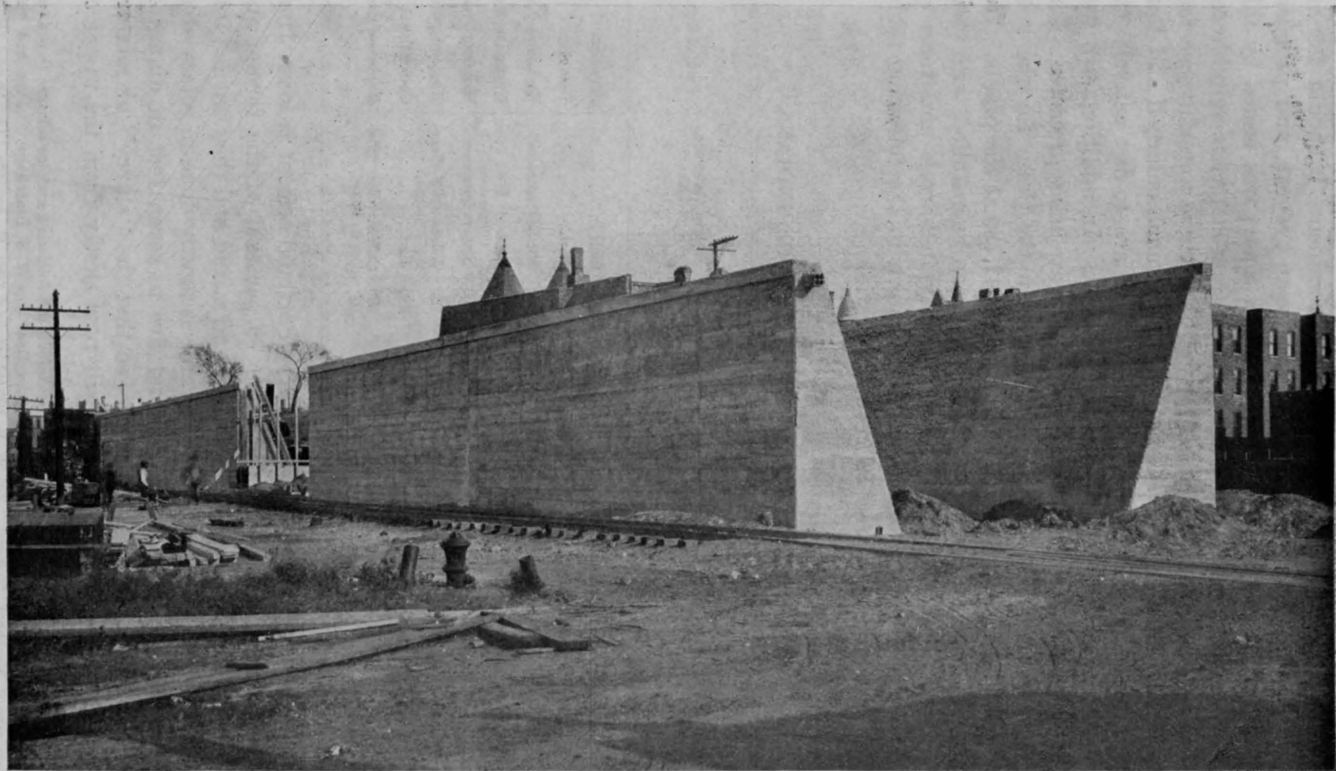
CEMENT RESOURCES.

Portland Cement.

No mineral industry in the United States has grown more rapidly during the last fifteen years than that of the manufacture of Portland cement. In 1890 there were but sixteen plants making such cement in the United States. Their output was but 335,600 barrels, while 1,940,186 barrels were imported. In 1905 the number of plants in the United States had increased to 89 while their output reached the enormous total of 35,246,872 barrels for the year.

Portland Cement Industry in Indiana.—While the making of

Plate II.



Illustrating the Use of Portland Cement in Elevating Railways.

Portland cement has not reached the prominence it should assume in Indiana, the industry is increasing year by year, and promises much for the future. In 1901,* when a report was issued by this Department showing the location of the raw materials suitable for such cement in many portions of the State, there were but two factories in operation. These have since been much enlarged and four additional ones have been erected, which are to-day actively engaged in turning out the finished product. In addition, two factories were built during 1906, while others are being promoted. The total output of the operating factories in the State for the year 1906 was 3,867,427 barrels, valued at $4,947,180 at the plants. The factories now in operation or which will soon be installed, with their location, number of kilns, daily capacity in barrels and form of carbonate of lime and clay used, are shown in the following table. The first seven are now in active operation.

PORTLAND CEMENT FACTORIES OF INDIANA.

	NAME OF FIRM.	Location.	Number of Kilns.	Daily Capacity, Barrels.	Form of Carbonate of Lime.	Form of Clay.
1	Sandusky Portland Cement Co.	Syracuse, Kosciusko County.	14	1,800	Marl	Silty clay.
2	Wabash Portland Cement Co.	Stroh, Lagrange County.	10	1,500	Marl...............	Drift clay.
3	Lehigh Portland Cement Co.	Mitchell, Lawrence County.	18	5,000	Mitchell limestone...	Knobstone shale.
4	United States Cement Co.	Bedford, Lawrence County.	6	1,200	Bedford Oölitic limestone.	Knobstone shale.
5	Universal Portland Cement Co.	Buffington, Lake County.	16	4,500	Niagara limestone...	Slag from Steel Works.
6	Louisville Cement Co.......	Speeds, Clark County	2	700	Jeffersonville limestone.	Knobstone shale.
7	Art Portland Cement Co.	Kimmel, Noble County.	1	250	Marl...............	Carboniferous shale.
8	Standard Portland Cement Co.	Charlestown, Clark County.	1	300	Jeffersonville limestone.	Knobstone shale

Ingredients of Portland Cement.—Portland cement is made from carbonate of lime and clay—about 78 per cent of the former and 22 of the latter—intimately ground and mixed and then burned into a clinker and reground. The burning is mostly done in rotary steel kilns, 60 to 80 feet in length and five to seven feet in diameter, which are set at a slight incline, so that the "slurry" or mixture of carbonate of lime and clay will pass slowly from the upper or

*The 25th report, issued in June, 1901, contained the following articles relative to the subject: "Portland Cement; Its Manufacture and Use," by W. S. Blatchley; "Lakes and Marl Deposits of Northern Indiana," by W. S. Blatchley and Geo. H. Ashley; "Oolite and Oolitic Stone for Portland Cement Manufacture," by W. S. Blatchley.

stack end to the lower or fire end. Into the latter end the fuel—now mostly dried and powdered bituminous coal—is forced with a blower and burns with a very hot flame similar to that produced by natural or other gas. From the lower end the clinker, the size of a walnut or smaller, emerges. This is then ground to a fine powder in either the Griffin or other ball and tube mills, from which it emerges as the cement of commerce. A plant with an output of 500 barrels daily, complete with machinery up to date, will cost approximately $200,000, while one with a capacity of 2,000 barrels costs $550,000 or more.

The carbonate of lime used in the production of Portland cement is either marl or limestone. Both of these forms occur in great abundance in Indiana; marl of excellent quality being found only in the northern third of the State, while the limestones abound in the southern half.

Marl for Portland Cement.—Marl, or "merl" as it is commonly called in the country, is a soft, earthy material, composed principally of an amorphous form of carbonate of lime. It occurs only in or about the margins of lakes or marshes, either present or extinct. In color it varies with the percentage of impurities which it contains. In the wet or damp state in which it occurs in lakes or marshes, it ranges from a milky white through varying shades of brownish-yellow to a dark brown, which may finally grade over or merge into the overlying or adjacent muck. After exposure to the air a short time a wet marl that at first may seem almost white turns a bluish or drab color, on account of some chemical change which takes place. In drying, the color of marl tends to lighten again, but seldom gets beyond a light dove color, and is generally a decided drab, running from a light drab to a slate color. The purer forms, however, when dry, are white or slightly cream color. The grains or particles composing the dry mass cohere very loosely and vary in size from coarsely granular to fine powder.

A careful study of the deposits of marl in northern Indiana, made by this Department in 1899 and 1900, led to the following conclusions regarding its origin:

First.—That the marl deposits of Indiana have been formed in the still waters of lakes now in existence, or in former lakes, now extinct.

Second.—That the original source of the marl material is the glacial clay in the region surrounding the lakes.

Third.—That the deposition of the marl is caused by the loss of carbon di-oxide from the sub-aqueous spring waters which bear the marl material into the lakes.

Fourth.—That the loss of this carbon di-oxide is for the most part caused in three ways, viz.:

(a) By the increase in temperature of the incoming spring water.

(b) By the decrease in pressure as the spring water rises to the surface of the lake.

(c) By the action of different aquatic plants in abstracting the carbon di-oxide for food.

In the Portland cement industry, a cubic yard of marsh marl, of the consistency of soft putty, is used in making two barrels of cement. Where the marl is dredged from a lake, and contains much water, this proportion is necessarily greater. Careful estimates go to show that an acre of marl three feet in thickness will make 10,000 barrels of cement. From this data the length of time necessary to exhaust any deposit can be readily computed. At the present time a factory with an output of 500 barrels of cement each 24 hours is considered of only medium size. As the process is a continuous one, with no stop for Sundays or holidays, such a factory will use a bed of marl nine acres in area and six feet in thickness each year.

The following table gives approximately the length of time which deposits of varying thickness and area will last a factory whose output is 500 barrels of cement daily:

Area in Acres.	*Thickness in Feet.*	*Barrels of Cement.*	*Time*
1	3	10,000	20 days.
1	6	20,000	40 days.
1	12	40,000	80 days.
1	18	60,000	120 days.
9	6	180,000	1 year.
40	12	1,600,000	8.9 years.
120	12	4,800,000	26.5 years.
135	12	5,400,000	30 years.
160	10	5,333,000	29.6 years.
200	10	6,666,000	36.5 years.
90	18	5,400,000	30 years.
270	6	5,400,000	30 years.

Since a modern cement factory with a capacity of 500 barrels daily costs in the neighborhood of $200,000, the company erecting it wish a deposit of marl in sight which will last at least 30 years. From the table we note that a deposit equal to 160 acres ten feet in thickness will last almost 30 years.

During the investigations made by this Department, 32 deposits of the size mentioned were located in northern Indiana, and fully described in the report for 1900. Of these but three are as yet utilized for the making of cement.

In quality the marls of Indiana rank up with those of Michigan and Ohio, where they are being put to much more extensive use. The following analyses made for the report of 1900 are herewith given, that persons interested may know where the best deposits occur:

ANALYSES OF INDIANA MARLS.

ORIGIN OF SAMPLE.		Calcium Carbonate ($CaCO_3$).	Magnesium Carbonate ($MgCO_3$).	Alumina (Al_2O_3).	Ferric Oxide (Fe_2O_3).	Calcium Sulphate ($CaSO_4$).	Insoluble Inorganic (Silica, etc.).	Organic Matter.	Total.	Authority.
Lake.	County.									
Hog Lake	Steuben	90.42	2.88	.14	.28	......	.68	4.13	98.53	W. A. Noyes.
Lime	Steuben	86.00	9.42	......	1.16	......	1.08	2.32	99.98	Chas. R. Dryer.
Deep and Shallow	Steuben	93.29	2.67	.04	.12	......	.47	1.56	98.15	W. A. Noyes.
James	Steuben	92.41	2.38	......	.29	.15	1.16	1.97	98.36	W. A. Noyes.
Silver	Steuben	84.00	6.46	......	1.34	......	4.52	3.68	100.00	Chas. R. Dryer.
Turkey Lakes	Lagrange	91.14	2.75	.61	.25	......	.85	......	95.60	W. R. Oglesbey.
Loon	Whitley and Noble	82.07	2.63	.41	.42	.22	5.95	6.71	98.41	W. A. Noyes.
Mud	Elkhart	82.89	2.04	.41	.23	......	7.94	3.67	97.18	Osborn Engineering Co.
Cooley	Elkhart	88.21	4.78	.52	.36	......	1.42	2.58	97.87	Osborn Engineering Co.
Syracuse	Kosciusko	88.49	2.71	.90	.31	1.58	1.78	4.23	100.00	S. B. Newberry.
Dewart	Kosciusko	92.35	3.54	.37	.16	......	2.00	2.12	100.54	A. W. Burwell.
Dewart	Kosciusko	84.24	2.85	.18	.30	......	4.52	5.02	97.11	W. A. Noyes.
Tippecanoe (James Basin)	Kosciusko	90.67	2.42	.06	.26	......	2.48	2.87	98.76	W. A. Noyes.
Tippecanoe	Kosciusko	91.02	2.28	......	.29	.05	2.92	2.10	98.66	W. A. Noyes.
Little Eagle	Kosciusko	84.75	2.84	.15	.35	.07	4.61	5.69	98.46	W. A. Noyes.
Manitou	Fulton	87.65	2.60	.19	.30	......	6.39	2.88	100.01	W. A. Noyes.
Maxinkuckee	Marshall	85.02	3.85	.12	.33	.17	5.67	3.21	98.37	W. A. Noyes.
Maxinkuckee	Marshall	85.38	3.50	.05	.33	.17	6.40	3.15	98.98	W. A. Noyes.
Houghton and Moore	Marshall	89.22	2.73	.04	.20	......	2.02	4.15	98.36	W. A. Noyes.
Notre Dame	St. Joseph	91.62	4.02	.05	.07	.14	.19	2.25	98.34	W. A. Noyes.
Chain and Bass	St. Joseph	87.92	2.64	.10	.20	.23	3.10	4.18	98.37	W A. Noyes.
Kankakee Marsh Deposit	St. Joseph	91.30	2.90	......	.08	.22	.82	3.88	99.20	W A. Noyes.
North Judson Marsh Deposit	Starke	89.92	2.46	.45	.74	......	1.56	4.51	99.64	W. A. Noyes.

In addition to the deposits mentioned in the table of analyses the following were included among the workable deposits investigated by the Department:*

Gage and Lime lakes, Steuben County; Shipshewanna, Cedar, Grass, Libey and Fish lakes, Lagrange County; Waldron, Jones, Steinbarger, Eagle and Deer lakes, Noble County; Crooked Lake, Whitley County; Indiana and Long lakes, Elkhart County; Turkey, Barbee, Center, Pike, Eagle or Winona lakes, Kosciusko County; Hudson and Fish lakes, Laporte County.

Limestones of Indiana for Portland Cement Manufacture.—The Oolitic and Mitchell limestones of Owen, Lawrence, Monroe, Washington, Crawford and Harrison counties have been found to make Portland cement of a superior quality. The oolitic stone contains from 93 to 98 per cent. carbonate of lime, and is almost free from magnesia, the element most harmful in the manufacture of cement. Millions of tons of spalls and refuse pieces of this stone, unfit for building purposes but in every way suited for cement manufacture, are thrown aside yearly from the leading quarries. The stone, when first quarried, is soft and much more easily ground than is generally supposed. At Bedford, Lawrence County, this stone is being used in the large plant of the United States Cement Company.

The Mitchell limestone has been in use three or more years at the largest cement plants in the State, namely, those of the Lehigh Portland Cement Company, at Mitchell, Lawrence County, and their product has everywhere given the best of satisfaction. This stone occurs in quantity in a dozen or more counties, and runs from 96 to 99 per cent. carbonate of lime. Large beds of oolite, which is whiter and much softer than oolitic limestone, occur as component strata of the Mitchell limestone at Milltown and Marengo, Crawford County, right by the side of the Southern Railway. The bed at Milltown as exposed is 13 feet thick and 1,500 feet in length, when it disappears in the bluffs of Blue River. An analysis showed the oolite to contain 99.18 per cent. carbonate of lime. It is, therefore, purer than oolitic limestone and, being softer, the expense of the preparatory grinding will not be so great.

Clays for Portland Cement Making.—In the northern part of the State beds of drift clay of sufficient purity to utilize with the marl occur in many of the counties. A full account of their distribution, extent and properties will be found in the Twenty-ninth (1904) report of this Department.

*In a number of instances the marl in two or three lakes, lying close together, was treated as one deposit.

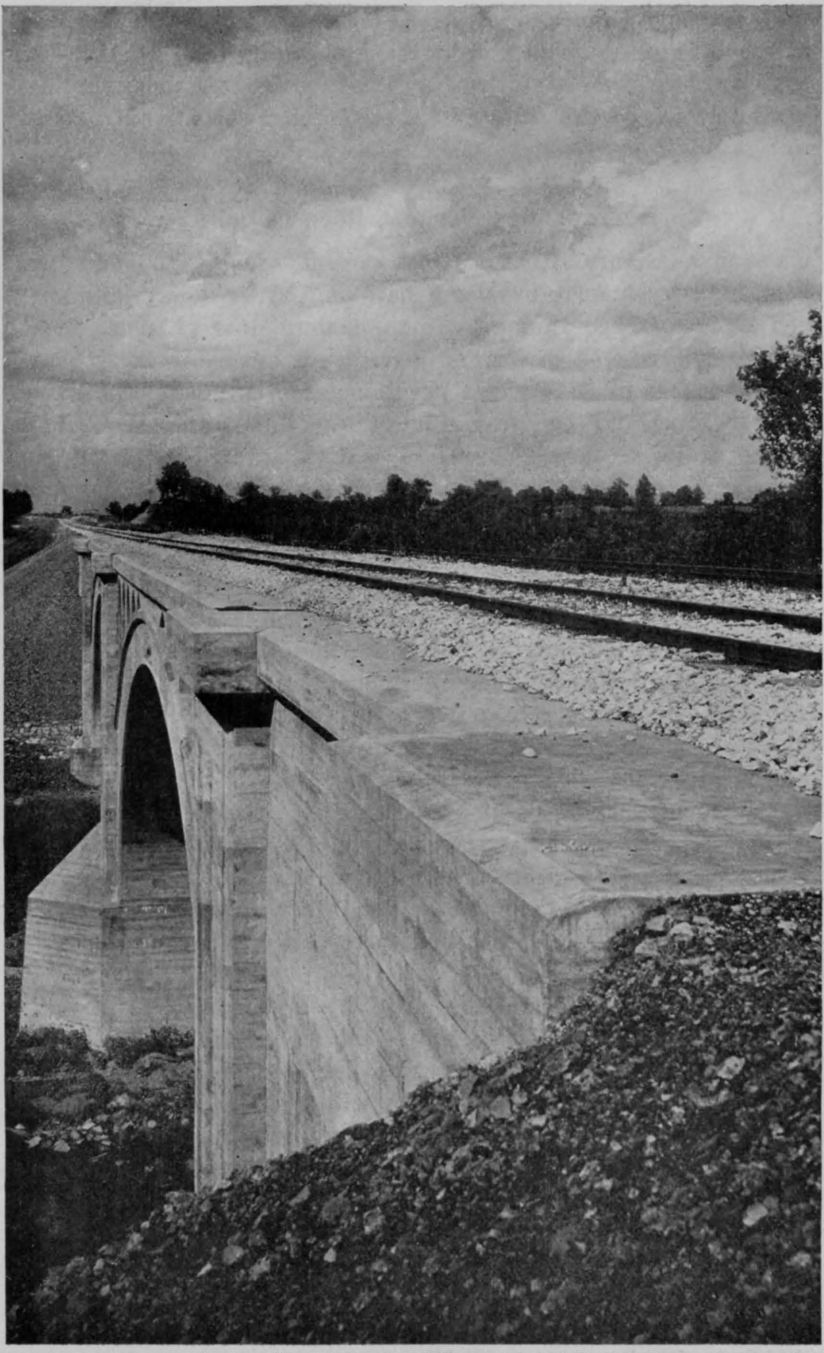
At both the Bedford and Mitchell plants in southern Indiana Knobstone shale from Jackson County is utilized as the clay ingredient, and has proven highly fitted for that purpose. There is no apparent reason why this same shale from numerous other parts of the Knobstone area should not be used for the same purpose. Points that should lead to the increased use of the Knobstone shale in cement making are (1) its proximity to the excellent limestone beds overlying it, and its short distance from the coal fields; (2) uniformity in composition, and (3) ease of quarrying and preparation. The shales may be a little harder to pulverize and mix with the lime ingredients than the softer clays that are sometimes used, but this is more than counterbalanced by the greater uniformity of composition and great thickness of the beds. The clay at Huntingburg, mentioned above under the head of "Potters' Clays," will furnish an abundance of the best of material for use with any deposit of limestone which may be utilized along the Southern Railway. The Coal Measure shales at Loogootee and other points are also well fitted for the purpose.

Lying, as it does, adjacent to fuel and the shales and other clays of the Knobstone and coal bearing counties, there is no reason why this Mitchell and Ooolitic stone region should not become the center of the Portland cement industry in Indiana.

A large Portland cement plant was erected by the Illinois Steel Company at Buffington, Lake County, in 1904, and was started up in January, 1905. It has 16 rotary kilns, each 80 feet long by 7 feet high at the fire end, and 5 feet 6 inches at the stack end, capable of turning out sufficient clinker to make 4,500 barrels of Portland cement per day. Power for the electric motors is supplied from the South Chicago works, 10 miles distant, at less than a 4 per cent. loss. The current is supplied by two 2,000-kilowatt generators, and steam is furnished by boilers fired with waste gases from the blast furnaces in South Chicago. As in the company's slag-cement factory at North Chicago, Illinois, and its Portland cement plant at South Chicago, Illinois, the raw materials used are obtained in the State of Illinois, the same quarry furnishing limestone for all three of the plants. Slag from the steel funaces at South Chicago is used with the limestone in place of clay or shale. The output of this factory in 1906 was 1,529,000 barrels, valued at $2,140,600. The product is now sold under the name of Universal Portland cement.

The building of the Panama Canal, which will require more than 12,000,000 barrels of cement; the re-building of the cities of Balti-

Plate III.



Illustrating the Use of Portland Cement in Viaduct Building.

more and San Francisco, especially along their water fronts; the enormous increase in the consumption of cement caused by its use in the various forms of concrete construction, and the increasing demand throughout this country for cement sidewalks, point toward a bright outlook for the Portland cement industry in the future.

Hydraulic or Natural Rock Cement.*

The manufacture of natural rock cement, which is the oldest cement industry known, has for a half century or longer been carried on in southern Indiana. In the manufacture of such cement there is no artificial mixing of ingredients, but the rock as quarried is crushed to small pieces, then burned in ordinary continuous up-draft kilns, and then ground into the cement of commerce. This simple process lessens the cost of manufacture very greatly, so that the cement is much cheaper than Portland cement, the ingredients of which must be artificially mixed in certain proportions. The hydraulic cement is well suited for lining cisterns and cellars, and for all underground work which is protected from frost, but will not stand freezing as will Portland cement.

In southern Indiana the rock used in its manufacture is the Silver Creek Hydraulic Limestone, one of the formations of the Devonian age. This rock outcrops in Clark and Scott counties, but is utilized for cement making only in the former, where it occurs in great quantity. It is a homogeneous, fine grained, bluish to drab clayey magnesian limestone, five to 16 feet in thickness, the calcined form of which has the property of *hydraulicity,* or setting or hardening when in contact with water. Its average chemical analysis shows about as follows: Calcium carbonate, 53 per cent.; magnesium carbonate, 31 per cent.; silica, 10 per cent.; iron oxide and alumina, 5 per cent.

There are 13 mills with 116 kilns in this district which were built to make cement from this hydraulic limestone. For several years most of them have been idle, owing to the formation of a company to control the manufacture and the selling of the cement, and to regulate the quota assigned to each mill. In many cases the quota of smaller factories is made for them by one of the large plants, in which event the small place is not started up at all.

For a number of years, between 1895 and 1900, the Indiana plants made two to three million barrels of natural rock cement yearly,

*For a full account of the hydraulic cement industry in Indiana, see the paper entitled "The Silver Creek Hydraulic Limestone of Southeastern Indiana," by C. E. Siebenthal, in the 25th (1900) Report of this Department, pp. 331–389.

but on account of the great activity in the Portland cement industry, that of the hydraulic cement has dwindled until in 1905 but 527,600 barrels, valued at $211,040, were produced. The deposits of limestone are as abundant, and the transportation facilities better than ever, yet it is very doubtful if the industry soon again reaches the proportions it held a decade and more ago.

Mineral Waters.

The mineral waters occurring in Indiana comprise one of the important natural resources of the State which, in the future, will be much more appreciated than in the past. In the report of this Department for 1901, 80 springs and 86 wells which yield mineral waters within the State were fully described and, in many instances, chemical analyses of the waters were given.

These wells and springs are distributed among 52 of the 92 counties of the State. At a number of them large hotels and bath houses have been erected for the accommodation of guests. Those of two or three localities have already become so noted as to attract many thousands of visitors each year from all parts of the United States. A number of other springs and wells of the State have waters which are as valuable and worthy of increased public patronage as those of these better known resorts.

Among those little known which will well repay the investment of capital in their development are (*a*) the Lodi well near Silverwood, Fountain County, drilled in 1865 to a depth of 1,155 feet. It has an output of 30,000 barrels of saline-sulphuretted water per day. This water is fully equal in medicinal properties to that at French Lick and West Baden; (*b*) King's, Payne's and other mineral springs in Clark County; (*c*) the artesian well at Worthington, and (*d*) those at Spencer; (*e*) the mineral spring near Corydon; (*f*) the Zorn and Blair mineral wells near Michigan City; (*g*) the Feldun Fields wells near Avoca, Lawrence County; (*h*) the artesian well at Shoals, and (*i*) the one at Winamac; (*j*) the Mudge artesian well near Medarysville, and (*k*) Snowden Springs, near Bainbridge. At the most of these the surroundings are or can be easily made picturesque, while facilities for recreation can be readily established.

It is the writer's opinion, based on personal experience, that the change of surroundings and diet, the increased amount of recreation and exercise, obtained by a few weeks spent at the sanitariums and resorts, have quite as much to do with bringing about a cure of many patients as does the water itself. There are many ordinary springs of pure water, i. e., water containing only a few grains of lime or iron salts per gallon, located near villages in this State, which are claimed by the inhabitants to possess remarkable curative properties. Old persons who seldom get ten rods from their homes, and business men who are kept indoors most of their time, begin to visit such springs, and once or twice a week walk or drive quite a distance to bring home a jug full of the water. The increased amount of exercise thus obtained, as well as the change of scenery, however limited, and perhaps the drinking of an extra amount of water each day, are the causes of the improved health rather than any curative properties possessed by the water.

From 23 of the more important and best known mineral springs and wells in the State the water is bottled and sold. This industry is constantly increasing, the sales for 1905 amounting to $435,182 as against $376,485 in 1904. The water of several of these springs is not at all mineral in character, yet they have been utilized for medicinal purposes and are highly recommended by some physicians. Many of the so-called "potable water" or "pure water" springs of the State are as worthy of development for medicinal purposes as those better known as real "medicinal springs." Proper advertising and the expenditure of some capital in furnishing means of recreation is about all that is necessary to make of them "noted health resorts."

Iron Ores.

Limonite or brown hematite, siderite and pyrites are the ores of iron occurring in Indiana.*

Limonite.—Limonite or brown hematite, commonly called bog iron ore, is found in largest quantities in Green, Martin, Monroe and Perry counties in the south, and in the swamps of Lake, Porter and St. Joseph counties in the northwest. In general, it is too siliceous to compete with the richer hematites of the Lake Superior, Missouri, Tennessee and Georgia iron regions. As a proof of this it is only necessary to state that of fourteen blast furnaces which were erected in the State in the past to use these bog and other iron ores, not one is in operation at the present. Most of them have long since gone to ruin, and of those still standing, the last one went out of blast in 1893.

The most extensive deposits of limonite are those in Martin and

*For a detailed account of the distribution, extent and character of the principal deposits see the paper by Chas. W. Shannon in another part of this volume.

Greene counties. An average analysis of seven samples from these counties, made by Dr. Lyons for this report, showed the presence of 45.1 per cent. metallic iron; the range being between 36.6 and 51.5 per cent.

The old Richland furnace, which was located two miles southeast of Bloomfield, was used in reducing the ores of Greene County between the years 1841 and 1858. About nine tons of pig iron were produced daily. The closing down of the old Wabash and Erie canal left the furnace thirty miles from the nearest transportation point, and so caused its final abandonment. A semi-block coal of good quality is found in veins two to three and a half feet thick in the immediate vicinity of this iron ore. The Bloomfield branch of the C., I. & L. (Monon) Railway is distant to the southward about two miles, while the Indianapolis Southern division of the Illinois Central passes close to the principal deposits.

In Martin County extensive deposits are found within one to four miles of the B. & O. S. W. Railway. Within the past two years about 50 carloads of the ore have been shipped from Martin County to Jackson, Ohio. This brought $2.00 per ton on board cars at the point of loading. The unprecedented demand for manufactured iron and the use of slag as a by-product in making cement has caused a demand for a low grade iron ore formerly considered worthless. If this demand continues, the deposits of Greene and Martin counties will have a commercial value which will yield a fair profit to those who may undertake their development and shipment.

Present conditions of transportation and demand for pig iron would doubtless justify the erection of two or three good blast furnaces in the vicinity of the principal iron ore deposits of Greene and Martin counties. Limestone for fluxing is abundant in the near vicinity, and the Indiana block coal, which can be used without coking, would furnish a cheap and easily obtained fuel.

Siderite.—Siderite, or carbonate of iron, often called kidney iron ore, is found associated with the overlying shales in most of the coal bearing counties. In western Vigo and Vermillion counties it is especially common in the shales overlying coal VII. Large quantities were formerly used in the blast furnace at Terre Haute, and in the old Indiana furnace on Brouillet's Creek, about eight miles to the northwest. It is a low grade ore, yielding usually about 35 per cent. of iron. At the present price of iron ores it would doubtless pay for collecting and shipping.

Pyrites.—Pyrites, or iron sulphide, known also as "fools' gold," is the most widely distributed ore of iron in the State. Where free from rock or other impurities its constituents are iron, 46.7 per cent.; sulphur, 53.3 per cent. It is probably to be found in greater or less quantities in every county. It occurs most abundantly associated with coals V and VI, the thickest veins of bituminous coal mined in the State. Hundreds of thousands of tons of pyrites have been thrown out on the dumps of the mines of these veins of coal between Edwardsport, Knox County, and Coxville, Parke County. Within the past few years this pyrites has greatly increased in value on account of the rapid rise in the price of sulphur. The pyrites is used mainly in the manufacture of copperas, or iron sulphate, and sulphuric acid; 100 tons of the pyrites being used in making 50 tons of the acid. It is also used in the manufacture of fertilizers and in the wood pulp industry. The deposits in the United States do not begin to supply the demand, and there is annually a greater quantity imported from Spain, Portugal and New Foundland than is produced in this country.

As usually thrown on the dumps, the pyrites is mixed too largely with coal and other impurities for use. A plant or separator for freeing it from impurities can be erected for about $2,500, and the pyrites will then bring $3.75 or more per ton. In 1905, 253,000 tons of pyrites, valued at $938,492, were produced in the United States, while 511,946 tons, valued at $1,774,379, were imported. The value of that produced in Indiana for the year was $11,491.

Sulphuric acid is by far the most important chemical compound known to man. Sodium nitrate and pyrites are the two ingredients used in its making. The nitrate for any factory in the United States has to be imported from South America. With the pyrites and fuel present in large quantity, western Indiana offers a most excellent site for a great sulphuric acid factory.

TRIPOLI.

Tripoli or infusorial earth occurs at a few localities in Indiana. A large deposit which was formerly somewhat extensively worked occurs near Ferdinand, Dubois County, on the land of Joseph Brinkman. It is a fine grained, highly siliceous product of excellent quality, but lack of capital and transportation facilities have put a stop to its development. Another extensive deposit, darker in color and showing the presence of 83.71 per cent. of silica, 8.92 per cent. of alumina, and 1.54 per cent. of iron oxide, is found on the farm of A. H. Harbaugh, near Freetown, Jackson County. Other deposits occur near Mooney, Jackson County, on the land of Mrs. Elizabeth Clampett; in Lawrence County, on the farm of Hugh S. Bass of Bedford; near Merom, Sullivan County, on the land of W. P. Sparks, and near Bartle, Washington County.

Tripoli is formed from the siliceous shells of diatoms and other minute species. It is used mainly as a polishing powder for brass, silver and other metal work; also as an absorbent of nitroglycerine in the manufacture of dynamite, as a protective packing about steam boilers, as a base for fire and heat retarding cements, and in the manufacture of scouring soap and filters. It brings about $6.00 per ton on the market. Ten thousand nine hundred and seventy-seven tons, valued at $64,637, were produced in the United States in 1905.

"Drift marl," a very fine grained, silty clay containing 40 per cent. or more of calcium carbonate, and valuable as a polishing powder, occurs in quantity on the farms of M. W. McCann, near Rushville, and D. B. Wilson, Carbon, Clay County; also near Gosport, Owen County, and Boone Grove, Porter County.

Mineral Paints.

Minerals suitable for making paints are found in quantity in several places in southern Indiana.

In section 6, Pierson Township, Vigo County, there is a large deposit of very fine grained, grayish shale, known as the "Paint Mine." For a number of years this was ground and shipped in barrels to be used as a body for paints. It served the purpose admirably, and a lack of capital and transportation facilities have alone prevented the development of the industry on a larger scale.

On the land of Chas. Grimes, Section 20 (9 N., 5 W.), Jefferson Township, Owen County, three miles east of the E. & I. Railway, is a large deposit of iron oxide suitable for a mineral paint. A similar deposit of finer texture occurs near Worthington, Greene County.

One mile west of Dover Hill, Martin County, is a bed of ferruginous shale and clay, 15 and more feet thick, which furnishes umber and red and yellow sienna of excellent quality. When Dover Hill was the county seat of Martin County, this deposit was extensively worked, but on account of a lack of transportation facilities it has, for many years, remained untouched.

Near Ferdinand, Dubois County, in the south half of section 34 (3 S., 4 W.), are extensive beds of red oxide of iron and clay, which, about 1870, were worked on a large scale. Paints of a dozen or more different colors were made which were highly esteemed for their beauty and durability. A lack of capital and shipping facilities, however, in time put a stop to the enterprise. Large deposits of ochre and other paint clays are found farther south in the same region.

Deposits of a ferruginous clay suitable for umber also occur in quantity on the land of W. C. Stevenson, near Dillsboro, Dearborn County.

Glass Sands.

Sand suitable for glass making occurs in quantity at a number of localities in Indiana. Extensive deposits near Pendleton, Madison County; Montpelier, Blackford County, and Lapel, Hamilton County, were formerly largely used by the glass factories in the gas belt. A large deposit near Wolcott, White County, has been used for some years by the American Window Glass Company.

On section 15 (14 N., 8 W.), one-half mile east of Coxville, Parke County, is also a large deposit which in the past few years has been shipped in quantity for use in window and bottle glass making at Terre Haute, Muncie, Orestes, and other points. A switch from the T. H. & L. Railway is laid to the deposit, and a branch of the C. & E. I. runs within a half mile. At the point where produced, this sand is 40 feet thick. The deposit extends a mile or more along the bluffs of Raccoon Creek and is, in most places, underlain with a four-foot vein of good coal.

On the northwest quarter of section 20 (21 N., 7 W.), near the station of Rob Roy, Fountain County, there is a valuable deposit of glass sand which, for several years has been extensively worked by the Western Silica Company. A switch from the C. & E. I. Railway has been laid to the plant, erected on the banks of Shawnee Creek. The stratum of sandstone which is crushed and washed, reaches a thickness of 16 feet. This sand has had a large sale to points west and north.

Other noteworthy deposits of glass sand occur near Hillsboro, Fountain County; Johnstown, Greene County, and Loogootee, Martin County.

The manufacture of glass requires a purer sand than that used for any other purpose, and glass sand is, therefore, higher priced than other sands. The chief impurities are iron, alumina and clay, which color the glass or give it a cloudy appearance. These impurities are removed by washing and sometimes, in the case of iron, with a magnet. The purity of the sand used is regulated by the quality of the glass desired. Glass sand is mined in a more or less pure state from deposits of sand, and it is also obtained as a rock easily disintegrated when exposed to the air, or from hard sandstones, which have to be crushed before being used.

The following table shows the chemical composition of a number of the sands above mentioned:

ANALYSES OF INDIANA GLASS SANDS.

Location.	Silica (SiO_2).	Alumina (Al_2O_3).	Iron Oxide (Fe_2O_3).	Lime (CaO).	Magnesium (MgO).	Loss by Ignition.
Wolcott, White County	99.08	.59	.23	.10	trace.	....
Hillsboro, Fountain County	97.25	1.35	1.38	trace.	trace.	....
Rob Roy, Fountain County	97.84	1.38	.10	....	.03	.32
Coxville, Parke County	98.77	....	.68	.43	.11	....
Johnstown, Greene County	97.38	1.81	.16	.06	....	.57
Loogootee, Martin County	96.26	2.50	.92	....	.16	....

Molding Sand.

Molding sand for use in foundries occurs in a number of places in northern and central Indiana. The best known and most widely used deposit is on the land of the Bradford Sand Mining Company, near Centerton, Morgan County. A switch from the I. & V. Railway extends to a screening and loading plant near the principal beds, and during the year 1906, 16,100 tons, valued at $12,825, were shipped, principally to points in Indiana and Illinois. The sand is graded as per long established foundry rules and usages, into grades Nos. 0, 1, 2, 3, etc., which mean very fine, fine, medium and coarse. Each grade is then divided into three or more grades (as for instance, No. 0 strong, No. 0 medium, No. 0 open), thus making 20 or more grades. As almost every foundry makes a special kind of work, each requires a different kind or grade of sand suitable to their work, according to the mode of molding, kind of iron or metal used, etc.

Other beds of molding sand which are extensively used in Chicago, are located near McCool, Porter County, and four miles southeast of Valparaiso, in the same county. Near Hobart, Lake County, is a fine deposit eight and a half feet thick and covering a large area, which is, as yet, unworked. Other good deposits are found near Gosport, Owen County; Salem, Washington County, and Rockport, Spencer County. A large deposit has also been recently discovered on the land of Lewis Taylor, near Newburgh, Warrick County.

Sand Lime Brick.

The manufacture of brick from a mixture of sand and lime is a rapidly growing industry in Indiana. Four large factories are already in operation in the State, 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 usually 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. The sand-lime brick industry will grow most rapidly in northern Indiana, where sand is plentiful and good clay for ordinary brick making scarce. The Lake Michigan sand deposits of Lake, Porter and Laporte counties offer an abundance of material, and the pioneer plants in Indiana were located at Michigan City. The value of the sand lime brick produced in Indiana in 1905 was $65,905.

Gold and Diamonds.

For a half century or longer it has been known that free gold in the form of minute grains and flakes occurs in a number of Indiana counties. Moreover, the natives of Brown and Morgan counties have, while washing gold, happened upon a dozen or more small diamonds, most of which have been found in the past ten years. This gold and the diamonds have from time to time been the subject of numerous articles in the newspapers, and public curiosity and attention have therefore been drawn to them. Many letters and inquiries relative to them have been received at the office of the State Geologist, and a large number of persons have called there tc secure information regarding the distribution and quantity of gold in the State.

*For a detailed paper on the occurrence of gold and diamonds in Indiana, see pp. 11 to 47, inclusive, of the 27th (1902) Report of this Department.

Gold.—All gold found in the State up to the present time is "free" or "placer" gold, the particles ranging in size from those too small to be seen with the naked eye up to nuggets whose value was five to six dollars. Occasionally a piece of quartz or other igneous rock is found which contains particles of gold, but in each instance this quartz is a pebble or boulder of drift origin. In one or two places, horizontal strata of a conglomerate occur, which have been said to show gold upon assay. This gold, if present, has found its way into the conglomerate through interstices in the overlying strata, or was a component part of the sedimentary material which originally formed the conglomerate. The rocks underlying the surface of Indiana are all of them sedimentary limestones, shales or sandstones. No igneous dikes or vertical veins are known in the State, and no quartz, slate, schist, granite, gneiss, mica or other igneous rock with which native gold is found associated, occurs except in the form of boulder or pebble of glacial origin. Taking into consideration the above facts, there remains but one conclusion as to the origin of the gold, namely: *It was brought in by one or more slow moving glaciers from some point far to the north or northeast and deposited by the melting of those glaciers on or near the places where it now lies.*

Although this placer gold is known to occur in twenty or more of the drift covered counties of the State, especially in those which are just within or along the border of the drift-covered area, it has as yet been found in commercial quantities only in Brown, Morgan, western Johnson and northern Jackson counties. Here, along the lowlands of the stream valleys, it is found associated with a black magnetic iron ore sand, numerous minute garnets, and a mineral known as menaccanite. The quality of the gold found is of the best, as it will average 22 or more carats, as against 16 to 18 for California gold, and 14 to 16 for Klondike gold.

Along each side of the streams in the counties mentioned is a strip of bottom land of varying width, composed of gravel, clay and soil, the gravel resting upon the bed rock, which is the blue Knobstone shale. It is this gravel, next to the bed rock, that is richest in gold. Most of the surface of these strips is cultivated. and the owners will not allow the "gold hunters" to pan except in the beds of the streams. These beds have most of them been washed many times in succession, a new supply of gold being eroded during each freshet from the gravel beds along the banks. These beds, which form the base of the lowlands or cultivated bottom lands of the valleys, were formed during the melting of the glacier, when the streams flowing through the valleys were much wider and stronger than now. The gravel and sand composing them was then deposited and the soil, for the most part, has been formed since then by decaying vegetation and annual overflow.

After every freshet the children of the vicinity seek gold along the rocky bottom of each rill and stream and often find pieces worth 25 to 40 cents. Much of this is found lodged in minute crevices at the bottoms of small waterfalls. A few of the natives do little else than pan gold for a livelihood. One of them, Uncle John Merriman, of Brown County, has panned more or less every year for 53 years, and has done little else for the last quarter century. The largest nugget he ever found was taken on Bear Creek, and weighed 132 grains, valued at $5.50. He has found a number of pieces which ran as high as $1.00 to $1.25 in value; but most of what he secures is in the form of "colors" or minute flattish particles. He estimates that the gravel beneath the soil of the lowlands will average 25 cents per cubic yard in gold.

On two different occasions Mr. Merriman has kept a careful account of the results of a month's work—Sundays excluded. One month yielded him $34.00, the other $40.00. He claims that he can average $1.25 a day during the panning season, which runs from March to November, except in time of summer drought. During his panning he has found several small diamonds.

Practical tests have been made of the lowland material in a number of places in northern Morgan County. These have proven that it runs from 30 to 80 cents per cubic yard in gold. The most thorough of these tests was made on the land of Dr. Clark Cook, section 30 (13 N., 1 E.), just north of the postoffice of Brey. Here 25 holes were dug through a strip of lowland to bed rock, the average depth being three feet, nine inches. From each of these holes 75 pounds of gravel was carefully panned, one-third being taken from the top, one-third from the middle and one-third from the bottom of the gravel stratum. In addition, miscellaneous gravel from the holes was added to bring the total up to 2,000 pounds. From this, gold to the value of $1.54 was secured. Allowing 3,000 pounds as the weight of a cubic yard of gravel, and deducting two-thirds for soil and clay, which were barren of gold but must be handled, the tests showed 77 cents per cubic yard for the matter composing the lowland. There is probably an aggregate of ten to twelve square miles of the gold-bearing lowlands in the four counties above mentioned.

The most serious problem to be solved in the working of these placer deposits on a large scale is that of a permanent water supply, as most of the streams are dry several months in summer. By constructing permanent dams in several of the valleys enough water could probably be conserved to tide over the dry season. There is no doubt but that large quantities of gold exist in the area mentioned. Only a person experienced in hydraulic and placer mining who is conversant with the latest improved machinery for that purpose, will be able to state whether the process of its separation can be made a profitable one. One company with a large amount of capital at its disposal could, with a plentiful supply of water and machinery, which would save 90 per cent. of the gold, perhaps make money in the thorough washing of these placer deposits, but everyone is warned against investing money in small stock companies, several of which have been promoted for that purpose in the last few years.

Diamonds.—While panning gold from the gravel and sand in the beds of the streams of Brown and Morgan counties, a number of small diamonds have been found by the gold seekers. Their discovery, however, is only of scientific interest, as they are far distant from their original home. It is only by chance, at long intervals, that one is happened upon, and a search for one would be like seeking the proverbial "needle in the haystack."

I have seen nine of these diamonds and have credible information concerning several others. The ones which have come to my notice were small stones, one-eighth to five carats in weight. The colors were variable, brown, yellow, pink or bluish. Most of the stones were clear and flawless, their gem value running from $5.00 to $200.00.

Source of the Gold and Diamonds.—From a careful study of the minerals found associated with the Indiana gold and diamonds, and from what is known regarding the source of the glaciers which brought them into our State, it is believed that their original home was somewhere in British America, probably to the west or southwest of James Bay. The Director of the Geological Survey of Canada has become interested in the subject, and has begun the mapping of the Canadian wilderness in this region, in order to determine more definitely the source and direction of the ice movement. The new National Transcontinental Railway, from Quebec to Winnipeg and the great wheat region of Manitoba, will traverse much of the country whence the gold and diamonds have probably come, and the Canadian Government is also sending out numerous survey parties for exploration along its route. It is not improbable that within the next quarter century a real El Dorado will be discovered among the igneous rocks of this far northern region, which will be as rich in gold and precious stones as any heretofore known to man.

Other Minerals and Ores.—With the exception of the placer gold above mentioned, no gold, silver or other precious metal occurs in the State. Much money has been foolishly spent and time wasted by people who have thought otherwise; but they have ever had their labor for their pains.

In many of the northern counties small pieces of "black jack" or zinc blende, galena or lead sulphide, and native copper ore, are occasionally found, and give rise to much local excitement and speculation. It is needless to say that the specimens of copper and lead were also brought in by the drift or by the Indians; and the blende, while possibly of native origin, is, on account of its small quantity, utterly valueless. In almost every county one also hears tales of reputed silver and lead mines, which in the days of long ago were secretly worked by the Indians. Many well informed people yet believe these tales, and have spent days in fruitlessly searching after imaginary mines, where enough silver may be had to pave the streets of their native towns, or where lead ore exists without limit.

While Indiana is thus lacking in the precious and other useful metals, her deposits of coal, clay, stone, petroleum and cement resources are far more valuable, and are bringing more wealth into the State than if, instead of them, rich mines of gold and silver had been found within her bounds. Higher grades of labor, and more stable industries are based upon such resources, for few, if any, large factories utilize gold and silver in quantity as a manufacturing resource.