SHALE BLUFF ONE MILE SOUTHWEST OF VEEDERSBURG, FOUNTAIN COUNTY, INDIANA. WORKED BY WABASH CLAY CO.

INDIANA.

. . . DEPARTMENT . . .

. . . OF . . .

GEOLOGY

—AND—

NATURAL RESOURCES.

TWENTIETH ANNUAL REPORT.

W. S. BLATCHLEY,
State Geologist.

1895.

INDIANAPOLIS:
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THE STATE OF INDIANA,
EXECUTIVE DEPARTMENT,
January 16, 1896.

Received by the Governor, examined and transmitted to the Secretary of State for publication upon the order of the Board of Commissioners of Public Printing.

MYRON D. KING,
Private Secretary.

Filed in the office of the Secretary of State of the State of Indiana, January 16, 1896.

WILLIAM D. OWEN,
Secretary of State.

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THOS. J. CARTER,
Clerk Printing Bureau.

State of Indiana,
Department of Geology and Natural Resources,

INDIANAPOLIS, IND., January 15, 1896.

HON. CLAUDE MATTHEWS,
Governor of Indiana:

SIR:—In compliance with section 5715 of the Revised Statutes of Indiana, I herewith submit to you the Twentieth Annual Report of the Department of Geology and Natural Resources. The contents of the report pertain almost wholly to economic geology, and show the results of the work accomplished by the different divisions of the Department during the calendar year, 1895.

Very respectfully,

W. S. BLATCHLEY,
State Geologist.

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Note.—Acknowledgments are due Mr. T. A. Randall, of the "Clay-Worker," for the half-tone engraving for Plate V, and to the proprietors of the "Daily Times," Brazil, Ind., for those for Plates III and VII. Those for the other plates, as well as the etchings for all figures, were made especially for this report. A number of other parties were requested to send in photographs of quarries, factories, etc., for plates, but they either failed to comply with the request or sent such poor ones that they could not be used.

INTRODUCTORY.

The Department of Geology was primarily instituted to determine the location and extent of those natural resources of the State which are of economic importance, and to make known to the world at large the leading facts concerning their accessibility and value for commercial, agricultural or manufacturing purposes. A secondary duty which falls to the Department is the gathering and disseminating of accurate knowledge concerning the origin or formation of such resources, and the publishing of descriptions of such fossils and objects of natural history as are found to accompany them, or as are of general scientific interest.

Such information is presented to the public in annual reports issued by the chief or director of the Department. Five thousand copies of these reports are printed and distributed gratuitously to those persons who are especially interested in promoting the material development of the State, or who are seeking locations for the investment of capital. The present volume is the twentieth in the series of reports so issued, and gives the general results of the work accomplished by the Department during the calendar year, 1895.

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, which may be set free by combustion and then be controlled by some device of man and used by him to perform work. Such natural resources are called *fuels*, the most important of which, as found in Indiana, are COAL, NATURAL GAS and PETROLEUM.

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. The most valuable members of this group found in the State are SOILS, BUILDING STONES and CLAYS. Other and less important members are sands, iron ores, marls, etc.

Taking up separately these different resources, let us briefly notice, in this introductory part of the report, their general distribution, abundance and value.

THE NATURAL FUELS OF THE STATE.

The fuels of the State, Coal, Natural Gas and Petroleum, are valuable only for the stored energy which they contain. Energy and matter 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.

Since the year 1800, man has studied more closely than ever before both matter and energy, and as a result has made many important discoveries concerning them. The two greatest of these discoveries—which more than anything else will make the nineteenth 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 can not be created, can not 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 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 be better able to understand many of the statements in the pages which are to follow.

The law of the conservation and correlation of energy asserts, "*That energy, like matter, can not be created, can not 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 transmuting or changing forms already existing into other and more available forms.

But the question naturally arises, how came this heat to be stored in the coal and other fuels? This question brings up another great truth which has become fully understood only in recent years, namely, 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. First, 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. Second, 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 directly 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 sunlight.

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 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 derived from or produced by the sun's heat stored in some kind of fuel.

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. This fact has been well portrayed by Prof. Edward Orton, in the following words:

"The remarkable office of the vegetable cell is thus brought to light. It is a storer of power, a reservoir of force. It mediates between the sun, the great fountain of energy, and the animal life of the world. The animal can use no power that has not been directly or indirectly stored in the vegetable cell. This storage is forever going on. Of the vast floods of energy that stream forth from the great center of our system, an insignificant fraction is caught by the earth as it revolves in its orbit. Of the little fraction that the earth arrests, an equally insignificant part is used directly in plant growth. But 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 natural gas and petroleum 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 destructive distillation, the carbonaceous matter within their bodies was changed with its imprisoned heat into the gas and oil now so valuable as fuels.

The most important thing to remember in treating of these natural fuels is *that they are not being formed in our State to-day.* No coal, no gas, no oil, is being made in Indiana by nature's processes, either in the bowels of the earth or above it. Our present supply of each will never increase, but ever diminish. It is a great reservoir or deposit of reserve force 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 one-fifth of the area of the State of Indiana is underlaid with coal. This area is found in the western and south-western part of the State, and ranges from ten to sixty miles in width. It extends from Warren County southward 150 miles to the Ohio River, where it is widest in extent, stretching across the counties of Vanderburgh, Warrick, Spencer, and part of Perry. Workable veins are found in nineteen counties in the area mentioned and thin outcrops occur in three additional ones. At least seven distinct veins of workable thickness occur in the State. These vary from three to eleven feet in thickness, and aggregate in a few places from twenty-five to twenty-eight feet. The area of greatest development of the seams is embraced in the counties of Clay, Sullivan, Greene, Daviess and Pike; though Parke, Vermillion, Vigo, Owen, Warrick and Spencer rank as close seconds.

The coals of the State are of two varieties, which in places merge into one another. These are the non-caking or block coal and the caking or bituminous coal. The former is one of the most valuable fuels found in the United States. It has a laminated structure and in the direction of the bedding lines it splits readily into thin sheets, but breaks with difficulty in the opposite direction. It can be mined in blocks as large as it is convenient to handle, whence its common name of "block coal." It is remarkably free from sulphur or phosphorus, and when burning it does not swell out nor does it form a cake by running together. It leaves no clinkers, the only residue after combustion being a small quantity of white ashes. Ordinary bituminous coals have to have their volatile constituents driven off and be changed into coke before they can be utilized in the making of iron products. The sulphur which they contain, if allowed to remain, would destroy the tenacity and malleability of the iron. Their tendency to cake or become packed under the weight of the overlying mass in the blast furnace prevents the free passage of the heat through all portions of the molten iron. The block coal, on account of its freedom from sulphur and phosphorus and its non-caking properties, can be used without coking and thus becomes a most valuable fuel for the blast furnace and the cupola of the iron founder.

For steam and household purposes it likewise 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 boilers, grates or fire boxes. In household grates it burns with a bright, cheerful blaze like hickory wood, making a very hot fire, which for comfort and economy can not be surpassed by any fuel except an abundant supply of natural gas.

The block coal area lies mainly in Clay, western Owen and southeastern Parke counties, though small deposits are found in other sections. A number of analyses of block coal from Clay County were made by Dr. G. M. Levette for the reports of the Geological Survey published in 1869 and 1870. The average of ten of these is given as follows:

Fixed carbon	56.83	
Ash	1.66	
Solid or coke producing matter		58.49
Gas	36.50	
Water	5.00	
Volatile		41.50

The following table shows also the average of the same ten in regard to the points mentioned:

Specific gravity	1.234
Pounds, weight of one cubic foot	77.16
*Units of heat	7983.00
*Steam value	1481.00

The bituminous or non-caking coals found in Indiana vary much in purity and character, but their average will compare favorably with that of those found in any other State. They are far more abundant than

*The "units of heat" show the number of pounds of water that one pound of coal will raise from 39° to 40° F. The "steam value" shows the number of gallons of water that one ton of coal will raise from 100° F. to steam, at atmospheric pressure. These computations were made by Dr. Levette and published in the Report of the Geological Survey for 1883.

the block coals, occupying an area of almost 6,500 square miles. Four workable seams are known, the maximum aggregate thickness of which is 20 feet, and the average aggregate thickness, over the greater part of the district, 11 feet.

The average analysis of ten of these coals, from Vigo, Daviess, Knox, Pike, Greene and Sullivan counties, is as follows:

Fixed carbon	53.89	
Ash	3.00	
Solid or coke-producing matter		56.89
Gas	38.67	
Water	4.4	
Volatile		43.07

The average of the other more important points is as follows:

Specific gravity	1.265
Pounds, weight of one cubic foot	77.85
Units of heat	8003.00
Steam value	1471.00

Comparing with these figures the following averages of four samples of Pittsburgh coal, as given in the Second Report of the Pennsylvania Geol. Survey:

Fixed carbon	59.46	
Ash	5.45	
Solid or coke-producing matter		64.91
Gas	32.57	
Water	1.06	
Volatile		33.63
Units of heat		7825.00
Steam value		1451.00

it will be seen that the average Indiana bituminous coal is slightly superior to the average Pittsburgh coal in heat and steam-producing power.

The Indiana coal fields are as yet in the infancy of their development, yet last year, according to careful statistics gathered by the State Mine Inspector, Mr. Robert Fisher, and published in another part of this volume, 4,202,084 tons were mined from them. It has been computed that a ton of good coal used in a good engine will perform the same amount of work as 1,300 horses in a day of ten hours. The amount mined in Indiana last year had, therefore, stored up within it and capable of utilization, power or energy equal to that exerted by 14,966,325 horses working 10 hours a day for an entire year.

The human mind can not 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 by the ton 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 corners of the globe.

But little has been done by the Department of Geology since 1878, towards the development of the coal fields of the State. Between 1869 and 1878, Prof. E. T. Cox, then State Geologist, issued seven reports which dealt largely with the facts concerning them, and in which their area was fairly circumscribed, but no complete survey of the area as a whole was ever attempted.

Since 1878 thousands of bores have been put down to prove the presence of coal in workable quantities, and hundreds of shafts have been sunk to the veins which were close to railways. Much information has thus become available concerning the area covered by each seam, which, if properly gathered, could be used in the proper correlation of the seams in isolated areas.

Letters are constantly being received at the office of the State Geologist, asking for information concerning portions of the coal fields in which operations have been recently begun. To these no definite answers can be given, because no accurate survey has been made of such areas. The time has come when an accurate survey of the entire field is imperatively demanded, for the coal area of the State is bound to become its greatest manufacturing area. The cost of such survey, if conducted in a proper and thorough manner, has been carefully computed and found to be not less than $10,000 per year for two years. Other States with much smaller coal areas have given from $20,000 to $50,000 per year for four to six years. The last Legislature was asked to appropriate $8,000 per year for conducting a coal survey. It gave, instead, $3,800 for carrying on the entire work of the Department and State Museum. This sum became available in November, 1895, and in March, 1896, it is the intention of the Chief of the Department to begin a survey of the coal area, and to carry it on in such a manner and to such an extent as the small sum appropriated will permit.

The report of the State Mine Inspector, Mr. Robert Fisher, for the year 1895, is unusually full and complete. It shows that 664,851 more tons of coal were mined in 1895 than in 1894. Nearly 8,000 men are employed in the mines operating more than ten men, and if to these the number employed in the smaller mines be added, the total number will reach nearly 10,000.

A number of statistical tables are given, which are different from any that have appeared in previous reports.

Mr. Fisher has visited many of the mines twice, or even three times, and has seen to it that all things needed to insure, in the fullest degree, the safety and comfort of the men employed therein were provided by the operators.

PETROLEUM.—Within the past two years the production of petroleum has attained enormous proportions in Indiana. The area in which the oil is found has steadily increased, and to-day comprises parts of Adams, Wells, Huntington, Grant, Blackford, Jay, Randolph and Delaware counties. In addition, a few flowing wells are in operation in the city of Terre Haute, but repeated drilling has failed to locate any extensive field in Vigo County.

During the year 1895, 2,711 new oil wells were completed in the State. Of these 754 were dry. The aggregate initial output of the productive wells finished during the year was 46,342 barrels daily. If this initial output had kept up for a year, it would have resulted in the enormous total of 16,914,830 barrels. But, as noted below, the spouting of an oil well soon ceases, and the average output is thereby rapidly diminished.

In the following table will be found a statement of the production of petroleum in Indiana from 1889 to 1895, inclusive:

Production of Petroleum in Indiana, from 1889 to 1895.

	1889.	1890.	1891.	1892.	1893.	1894.	1895.
Total production (barrels of 42 gallons)	33,375	63,496	136,634	698,068	2,335,293	3,688,666	4,380,000
Total value at wells of all oils produced, excluding pipage	$10,881	$32,462	$54,787	$260,620	$1,050,882	$1,774,260	$3,109,800
Value per barrel	$0.32⅝	$0.51⅛	$0.40	$0.37	$0.45	$0.48	$0.71*

The probabilities are that the area of territory productive of oil will continue slowly to spread to the west and south until it finally embraces the greater part of the area at present yielding natural gas. This has been, in general, the history of other gas and oil fields, and there is no known reason why the one of Indiana should prove an exception. The oil, on account of its much greater specific gravity, underlies the gas in the area where the two are found together. As the pressure of the gas gradually decreases on account of a diminution of the supply, the hydrostatic pressure of the oil in time overcomes that of the gas, and a spouting or flowing well of oil results.

How much oil there is beneath the surface of Indiana is a question that no man can answer. How long the supply will last depends wholly upon its amount and the average daily or yearly drain therefrom. Suffice it

*This is the average of the 36 different prices at which oil sold during the year.

to say *that the supply is limited and will never be increased.* The age of a productive oil well in the United States does not generally exceed five years and is very often much less. A spouting oil well does not continue to gush forth for many weeks if allowed to flow freely. It soon degenerates into a flowing well and then into a pumping well, whose production dwindles away and finally ceases to be remunerative, so that unless new wells are continually being developed the output must fall off and finally cease entirely. However, there is no danger of the supply beginning to fail in Indiana for some years to come, as it has as yet been drawn upon for too short a time. True, some of the older wells have ceased to yield, but for every one so abandoned a dozen productive ones have been opened up; and this will continue to be the case until the total oil area, which can only be circumscribed by the future use of the drill, is fully developed.

NATURAL GAS.—During the past nine years natural gas has done more to advance the material interests of the State of Indiana than any other two resources within her bounds. Millions of dollars of capital have been invested within the gas field and thousands of people have flocked thereto attracted by ready employment at good wages. As a consequence both the wealth and population of the area in which gas has been found have increased many fold.

Originally that area embraced part of or all of seventeen counties lying northeast of the center of the State and comprised on the whole about 5,000 square miles. On account of the encroachment of salt water and petroleum, this area has become gradually reduced until to-day the main gas field contains an approximate area of 2,500 square miles. This, however, is larger than has ever been possessed by any other State in the Union.

The average initial or rock pressure of the entire field in 1889 was 325 pounds to the square inch. To-day, according to careful measurements made during the past season by Mr. J. C. Leach, the State Natural Gas Supervisor, it is 230 pounds to the square inch over the main field. There is no doubt but that one-half of the supply has been nearly or quite exhausted, and as there can be no increase of it, the pressure will decrease more rapidly in the future than in the past. How long the supply will last no man can tell. Too many varying factors, as the daily amount necessarily consumed for fuel and heat, the different pressures at which salt water and petroleum overcome the gas pressure—and more than aught else—the future percentage of waste, enter into the consideration of such a question. If the waste could be entirely shut off, the supply in the heart of the field, where much undeveloped territory has been held in reserve, would probably last for a number of years. It is in cities like Indianapolis and Richmond, which receive their supply through pipe lines, that the diminution in pressure is most noticeable; and there is no doubt but that their supply will become completely exhausted some time before that of the cities which lie wholly within the field. For the main facts concerning the present condition of the field the reader is referred to the report of Mr. Leach for the year 1895, which is found in another part of the present volume. No report for 1894 was submitted to me by the former inspector, Mr. E. T. J. Jordan.

RESOURCES OTHER THAN FUELS.

SOILS.—Indiana is preëminently an agricultural State. Her soils constitute by far the most valuable of her natural resources. More people are dependent upon them for a livelihood than upon all the rest of her resources and manufacturing establishments combined. Ranking in area of square miles but thirty-fourth among the forty-five States of the Union, the census of 1890 shows that she stood second in the production of wheat,* seventh in the production of corn, and eighth in the value of her live stock.

This magnificent showing is due to two things: first, the excellent, average fertility of her soils; second, the high degree of intelligence manifested by her farming population, in the cultivation of the soils.

In the production of any cereal nothing new is created, but forms of matter already existing in the earth, air and water are utilized by the growing plant. Taking wheat, for example, besides the carbon, hydrogen and oxygen, which make up the greater bulk of the straw and grain, and which are abundant enough in the air and water, potash, nitrogen, phosphoric acid, magnesia, lime, sulphur, chlorine and silicon are absolutely essential constituents. If any *one* of these is lacking in the soil, or is present in a form not available by the wheat roots, the plants will not flourish and the soil will be worthless for wheat production. Such a soil may, in most cases, be made to produce a crop of grain by adding to it the constituent which is lacking, but if this can not be done except at a prohibitory cost, or one at which more fertile ground can be procured, the soil may be regarded as "worn out" or barren.

The drift soils, which cover the northern and central portions of Indiana, derived, as they were, from various primary and igneous rocks in the far north—ground fine and thoroughly mixed as they were by the onward moving force of a mighty glacier—are usually rich in all the above named necessary constituents of plant food and do not require a large annual outlay for artificial fertilizers as do the soils of southern Indiana, over which the drift of the glacial period did not extend.

While the methods of soil cultivation in vogue in Indiana are, perhaps, above the average, too many of the farmers of the State never stop to

*Illinois was first, with 37,389,000 bushels; Indiana, a very close second, with 37,318,000 bushels.

consider that in the growth of a crop absolutely nothing is created. With no knowledge of chemistry they do not understand that the tons of grain, straw and stalks, which their fields produce, are only transformations of materials which existed in other forms either in the earth or air.

Too many of them go on year after year, taking from their fields all the products, grain, straw, and everything, and giving nothing back. They do not realize that those vast freights of grain and meats which tax our means of transportation to the utmost, are great streams of the elements of fertility flowing from their fields to the towns and cities of this continent, and to the marts of the Old World never to return. They never think of that law of compensation which asserts that we can not supply in one place without removing from another. As a consequence their lands become, after a time, deficient in one or more of the necessary grain constituents and therefore comparatively worthless. Then they allow those lands to remain idle or else begin to buy fertilizers in a reckless manner, knowing nothing of the chemical composition of that which they buy, or whether it contains the elements of plant food which are lacking.

Thus hundreds of thousands of dollars are annually spent for fertilizers which are worthless to the persons buying them, because they do not contain the constituents needed; and thousands of acres of land are left untilled, or are tilled at a loss, because of a lack of a certain element of fertility which is unknown to the owner and therefore not supplied by him.

Constituting as they do the most valuable of our natural resources it can be readily seen that the study of the origin, distribution and constituents of the soils of the State falls naturally to the Department of Geology. Many facts concerning them which would be eminently useful to the farmer are now entirely lacking, and can be gained only by a careful and systematic study of the soils in the different localities of the State. Complete analyses of soils from every county, showing the proportions of phosphates, nitrates and other necessary elements of vegetation, should be made. From them the farmer could determine what constituent of his soil, if any, is deficient, and could supply the same in suitable quantities and in an available form. From them, also, it would be possible to specify the localities where the different staple crops could be most advantageously grown, instead of compelling the farmers to learn the peculiarities of their lands by experiments which necessarily consume time and exhaust the soil. While such a study of the soils would undoubtedly result in a large annual increase of the agricultural products of the State, it can not be undertaken until the Legislature becomes more generous in the appropriation allotted to carry on the work of the Department of Geology.

BUILDING STONES.

LIMESTONES.—No State in the Union possesses better stone for building purposes than Indiana. The oölitic limestone from Lawrence, Monroe and other counties has long been noted among architects for its strength and durability. It is of a uniform rich gray color and close texture, and on account of the ease with which it can be quarried, sawed and dressed for builders' use it can be sold with profit for a less sum per cubic foot than any other stone in America.

The best grades of it contain 97 per cent. of carbonate of lime, which is practically indestructible by ordinary atmospheric influences. It contains of iron oxide and alumina, two of the most damaging constituents of such stone, less than one per cent., thus showing a remarkable degree of purity.

The average crushing strength of twelve samples of tool dressed oölitic stone, as determined by Maj.-Gen. Q. A. Gilmore for the Board of State House Commissioners in 1878, was 7,857 pounds per square inch, while that of four samples of sawed oölitic stone was 12,675 pounds per square inch.

The best deposits of the oölitic stone are found in a narrow strip of territory extending from Greencastle, Putnam County, to Salem, Washington County, a distance of 110 miles. The width of this strip varies from three to ten miles, and the stone throughout its full length is found very close to the surface.

Since the building of the Court House and the State House at Indianapolis from this stone its use for public and private buildings has steadily increased, especially in the East and South. A number of the private residences of the richer citizens of New York City have been recently constructed from it, while its use in such important public buildings as the Custom House at New Orleans, the Auditorium at Chicago, and many court houses in the counties of adjoining States has served to bring it more prominently before the attention of the public. During the year 1895 the quarries in operation in the oölitic district had an output of more than 15,000,000 cubic feet, the most of which was shipped to points outside of Indiana.

While much has been published in the previous reports of this Department concerning the oölitic limestone, it has been of a general nature, and no careful detailed survey of the limited area in which it is found has ever been made. It is my intention to begin such a survey as soon as the season opens in 1896, and to have prepared an accurate map showing the exact limits of the more valuable deposits found therein.

Besides the oölitic limestones a number of crystalline limestones or so-called "Indiana marbles" are found in the State. These admit of a fine polish and make most handsome mantels and other interior decorations; while some of them are close textured, strong and durable enough to be well fitted for masonry. One of the most valuable of these deposits is found in the southern part of Fayette County, and belongs to Hon. J. N. Huston of Connersville. Others occur on Pipe Creek in Miami County, and at English, Crawford County.

Besides the above, which are limestones largely or almost wholly composed of calcium carbonate, numerous quarries are worked in the State in which magnesium carbonate is a leading constituent of the stone. These are found, for the most part, in the eastern half of the State, and belong to the Silurian formations. As a rule they are not building stones of a high grade. They are darker than the oölitic stone and more apt to crumble after years of exposure, as they contain a larger percentage of iron oxide. The magnesia present also causes them to blacken and disintegrate more or less readily, especially in cities where the atmosphere contains large amounts of sulphurous fumes derived from the burning of soft bituminous coals. However, much of the magnesium limestone quarried in Indiana will compare favorably both in texture and durability with many of the stones used for building purposes in other States.

SANDSTONES.—"The Carboniferous Sandstones of western Indiana," is the title of an extensive paper which was prepared for the present volume by Mr. T. C. Hopkins, the chief assistant to the State Geologist.

Mr. Hopkins is a trained geologist, who for a number of years was connected with the Geological Survey of Arkansas, and prepared the volume on the building stones of that State. He is a specialist in that particular subject, and his report on the sandstones of western Indiana, will be found thorough, accurate and valuable.

He spent the season of 1895 in the field, and made a personal investigation of the leading outcrops and worked quarries of sandstone in the area shown on the two map sheets accompanying his report. The Conglomerate or Millstone Grit, in which these sandstones mostly occur, is a great formation lying at the base of the Coal Measures of the State. It is wholly useless to look for coal east of the eastern horizon of this formation.

Mr. Hopkins found that in a number of localities the sandstones comprising the so-called Conglomerate are valuable commercial stones, easily worked and of great durability. In several places, notably at St. Anthony, Dubois County; Bloomfield, Greene County, and Portland Mills, Parke County, the stone is of a handsome brown color, and compares favorably in appearance with the brown sandstones of the Lake Superior region which are so much used for the fronts of business blocks in Chicago, Milwaukee, and other cities of the Northwest.

One use to which this brown sandstone is peculiarly well fitted is for the lintels and cornices above the windows and doors of those buildings whose fronts are composed of dry pressed brick. Where limestone is used for the lintels, the rain, dashing against it, is sure to dissolve out a small portion of the stone which flows down over the brick and gives them a mouldy, streaked appearance. Where the brown sandstone is used no such streaking is seen on the brick beneath the windows and archways. The color of the sandstone also harmonizes better with that of the brick than does that of the limestone.

Large quarries of buff and gray sandstone have been in successful operation for a number of years at Attica, Williamsport and Riverside, and at Cannelton, on the Ohio River. Other localities where such stone can be quarried to advantage are noted in the report of Mr. Hopkins, and it is hoped that his report, being by far the most complete which has ever been issued on the sandstones of Indiana, will do much toward leading to the development of these sandstones, which form an important but hitherto much neglected resource of the State.

WHETSTONE AND GRINDSTONE ROCKS.

It is perhaps not generally known that Indiana is the second State of the Union in the production of whetstones and grindstones. The fine-grained silicious rock found in Orange and Martin counties has long been used for such purpose, but no detailed survey of the region in which it is found, or report on the industry, has been heretofore made.

Mr. E. M. Kindle, formerly Assistant Professor of Geology in the State University, was employed for the season of 1895 to make such a survey, and his report of the work accomplished, together with an accurate map of the region, is included in the present volume.

Full details concerning the various deposits of stone (found in the area mapped) suitable for manufacturing into abrasive materials are given, together with the methods of manufacture as carried on at the present time. A lack of capital and railway facilities has hitherto undoubtedly kept this industry from assuming those proportions which the abundance and quality of the raw material would seem to merit.

CLAYS.

Among the most valuable of the undeveloped resources of the State are her clay deposits. In one form or another they are found in every county, but the largest and most valuable ones occur in the western and southwestern parts of the State, where the coal measures exist, for the coal measures of the State are preëminently its clay measures. Every seam of coal is normally underlain with a bed of fire clay, and above the coal there are almost always beds of shale. These coal shales a few years ago were thought to be worthless, but experiment has proven that they are excellently adapted to the making of paving brick, roofing tile, sewer pipe and many similar products. In Ohio, where forty-four paving brick factories turned out 298,000,000 paving brick in 1894, 80 per cent. of the best grades were made of the carboniferous shales which ten years ago were wholly unused.

So much of the field season of 1895 as could be spared from routine office work was devoted by the State Geologist in person to a detailed study of the different clays of the coal bearing counties, and to an investigation of the methods used in the clay working factories found within their bounds. The results of such study and investigations are incorporated in the accompanying paper, entitled, "The Clays and Clay-working Industries of the Coal-bearing Counties of Indiana." Complete analyses of twenty-eight clays have been made especially for this paper by Profs. W. A. Noyes and Robert Lyons, and will be found in a table at the end of the second chapter. From them much can be learned concerning the fitness of the clays for especial products.

The clay-working industries of the State have grown apace in the last five years, and full statistical tables showing their present state of development are given on later pages. No hesitation is felt in prophesying that within the next ten years they will become the leading manufacturing industries of western Indiana. Raw material and fuel, both of excellent quality, are found associated together in enormous quantities in many places which are accessible to transportation; and where the three elements of fuel, raw material and railways are thus combined, capital in time is sure to locate and utilize the natural resources. The larger clay industries already in existence in the vicinity of Brazil, Terre Haute and other places, are all of them flourishing; the demand for their products in many instances being greater than the possible supply. They have proven by practical experience that the shales and underclays of the coal measures are in every way fitted for manufacturing purposes. The analyses given in this report but add additional testimony.

Most of these clay industries, as well as the larger coal, stone, natural gas and oil interests, are owned by outside capital. The people of the State, for some unknown reason, seem reluctant to invest money in the resources found within her bounds. Outside capitalists have no such reluctance, and their investments have almost universally proved to be winning ones. While much capital is thus brought into the State, thereby increasing its total wealth, the profits, which in time aggregate far larger sums, are removed as fast as made. With local capital invested the profit would remain and the wealth upon which the taxes are based would increase much more rapidly.

One of the chief beneficial effects which the development of the clay-working industries will bring about, will be the increasing of the available amount of coal in the State. Many seams now thought to be too thin to work will be utilized in connection with the associated shales and fire clays. The minimum thickness of a workable seam of coal will, therefore, be greatly reduced, and many veins which have long been allowed to pass unnoticed will be mined with profit.

IRON ORES.—Limonite or bog iron ore ($2\ Fe_2O_3+3H_2O$), and siderite or kidney iron ore ($FeCO_3$), are found abundantly in several counties of Indiana. The former occurs notably in Greene, Martin and Perry counties, and in the swamps of the Kankakee region; the siderite in all of the coal bearing counties. Experience has proven, however, that these ores are too silicious to compete with the rich beds of hematite of Missouri, Tennessee and Georgia. As a proof of this it is only necessary to state that of fourteen blast furnaces which have been erected in the State in the past, 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.

SANDS.—White sand, suitable for glass making, occurs in quantity in the vicinity of Pendleton, Madison County; Montpelier, Blackford County, and Lapel, Hamilton County. Near Salem, Washington County, and Centerton, Morgan County, are found large deposits of a fine grade of moulder's sand, suitable for foundry use. Sand suitable for building purposes occurs in all parts of the State.

MARL.—The use of marl for making hydraulic and Portland cement, and as a disinfectant and deodorizer, is constantly on the increase. Deposits of this resource which are close to railways will undoubtedly prove of much value in the future. The largest at present known are found in the vicinity of Silver Lake, Dekalb County; Lime Lake, Steuben County, and near South Bend and North Liberty, St. Joseph County.

OTHER MINERALS AND ORES.—With the exception of small quantities of drift gold, in the form of minute grains and scales, which are found in the sands and gravel beds along the streams of Brown, Morgan and other counties near the southern limit of the drift area, 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 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, natural gas and petroleum are far more valuable, and will in time bring 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.

NATURAL HISTORY.

While this Department was primarily originated to gather and disseminate information concerning the mineral resources of the State, the existing flora and fauna present interesting scientific problems which to the earnest student of nature are ever worthy of careful study. Valuable papers on the flora of different counties and on the reptiles and fishes of the State, have appeared in some of the previous reports. In this one is found a paper on "The Crawfishes of Indiana," by W. P. Hay, formerly a resident of Irvington, Ind., now Professor of Natural History in the Central High School, Washington, D. C. Professor Hay has made for a number of years a special study of the crustaceans of Indiana, and the present paper embodies the results of a large amount of original research.

The crawfishes inhabit every running stream and lake in the State. They form much of the food of the larger fishes, and are themselves most valuable scavengers, so that the paper, dealing as it does in part with questions of distribution and habit, has an economic as well as a purely scientific side. The students of our colleges and high schools interested in zoölogy will, I am sure, welcome the appearance of such a paper. In it every species of crawfish inhabiting the State is carefully described, and the descriptions are preceded by analytical keys and accompanied by drawings of the more important specific characters, so that with a little careful attention the identity of any species at hand can be readily determined.

THE STATE MUSEUM.

The museum connected with this Department has become a center of attraction to many of the people of the State who come to Indianapolis. An average of three hundred persons visit it each day, and its educating effect can hardly be overestimated. The time of the State Geologist during the winter season, when field work can not be done, is largely taken up in connection with work pertaining to it. A thorough rearrangement of its contents on an accurate scientific basis is being made, and a catalogue prepared, so that future incumbents of the office may know what ought to be therein. According to the 12th Annual Report of the Department, issued in 1882 (p. 7), there were then 100,000 specimens in the museum. If that statement be accurate many of them have since disappeared, for no more than 60,000 are on hand to-day. No record of additions or catalogue of contents having been kept, it is impossible to determine the locality or history of many of the specimens which are unlabeled, and much of their value is therefore lost.

The museum should contain, in addition to specimens of archæology and paleontology, examples of the different objects of Natural History found within the State. Many of our birds and mammals are rapidly becoming extinct, and while to-day they can be procured at a nominal sum, in ten years they can not be had at any price. A number of mounted birds and a large collection of fishes and reptiles were secured the past season, and it is the intention to add to the collection of such objects as rapidly as the means available will permit.

The case-room for specimens is exhausted, and the new ones received have to be stored in out-of the-way places until a sum is appropriated for additional cases. Those provided for the battle-flags are wholly inadequate for the proper display and preservation of the flags. The latter are so crowded that the ones belonging to the different regiments can scarcely be distinguished.

OFFICE WORK.

One object of the founders of the Department of Geology was undoubtedly to establish a bureau where official information could be secured at all times by the citizens of Indiana, or by the public at large, concerning the resources of the State. During the year 1895 more than 1,900 letters of inquiry concerning such resources have been answered by the Geologist. In addition to this, information was given concerning the character and value of 840 specimens of minerals and objects of Natural History which were sent to him for examination. Persons who seek advice from the Department are often restrained from sinking thousands of dollars in useless search for minerals, gas and oil in localities where there is not one chance in a thousand of finding the object sought.

A PRELIMINARY REPORT ON THE CLAYS AND CLAY INDUSTRIES OF THE COAL-BEARING COUNTIES OF INDIANA.

BY W. S. BLATCHLEY.

CHAPTER I.

GENERAL USES OF CLAYS—DEFINITION OF CLAYS—PROPERTIES OF CLAYS—ORIGIN AND CLASSIFICATION OF CLAYS—IMPURITIES OF CLAYS.

No mineral resource of the earth has been longer used or has been made into such varied products for the benefit of the human race as clay. Found in all countries, easily obtained, and, when moistened, readily molded into any shape which the fancy can invent, it is no wonder that prehistoric man, emerging slowly from that animal stage in which for thousands of centuries he had existed, made early use of it. To his undeveloped mind no better form of amusement probably presented itself than that of dabbling in mud and molding it into fantastic shapes—just as on the borders of many a pond or stream "mud pies" are made by the youthful progeny of the nineteenth century. Some of his rude products—sun-dried—became permanent, were used by him as drinking vessels, and so begat in his crude mind an impression of their usefulness. He began to fashion them, not for amusement but for use, and the clay industry of the world had begun. From such a beginning, into what enormous proportions has it grown!

Clay products, when properly made and cared for, are among the most lasting works of man. Wind or rain, frost or fire, has little effect upon them. The most ancient remains of man's industry are the pieces of pottery vessels picked up on the sites of his former habitations, or removed from his burial mounds. The oldest buildings on earth are those made of sun-dried brick. From these rude vessels, relics of man's first handiwork, to the delicate and costly china ware of our shops—from the adobe walls on the plains of Persia and Mexico to the magnificent fronts of pressed brick and terra cotta of our present cities—what steps of human progress—what proofs of man's advancement in the art of clay working!

GENERAL USES OF CLAY.

No natural material can be so easily and cheaply made into the finished product as clay. It enters more largely into the necessities of our every day life than does any other mineral resource; and the ultimate value of its products are greater than of any other, except iron. The following are some of the uses to which materials made of clay are put in Indiana:

1. Domestic.—Utensils, porcelain ware, china ware, granite or ironstone ware, yellow ware, earthen ware, fire kindlers, etc.
2. Structural.—(*a.*) For buildings: Brick, common, front or pressed, ornamental, hollow, glazed; terra cotta, roofing tile, drain tile, door-knobs, puddling. (*b.*) For roadways: Vitrified brick.
3. Agricultural.—Drain tile, soil tile, soil tempering, barn flooring.
4. Hydraulic Structures.—Water conduits, reservoir lining, sewer pipe, "stone" pumps.
5. Sanitary Engineering.—Granite ware, urinals and water-closet bowls, earthen ware, sewer pipe, absorbent brick, drain tiles, ventilating flues.
6. Industrial Arts.—China clay, chemists' crucibles and other apparatus, wall and writing paper filling, refractory clay, lime, cement and pottery kilns, puddling hearths, reverbatory and other smelting furnaces, glass pots, assaying furnaces, gas retorts, stove and furnace linings, saggars, plugs, models, alums, etc.
7. Ornamental and Æsthetic Uses.—Tiling, ornamental pottery, terra cotta decoration, artists' molding clay, base for retaining pigments.
8. Imitative Uses.—Food adulterants, paint adulterants.*

The above materials, to the value of more than twenty millions of dollars, are annually used in our State, while heretofore less than five millions of dollars' worth have been produced within her bounds. Yet, with the exception of some of the clays used in the making of encaustic tile, porcelain and china ware, Indiana contains, as I shall endeavor to show in a subsequent chapter, the raw material in abundance to manufacture every one of the above mentioned articles.

DEFINITION OF CLAYS.

The term clay is, in popular language, given to a large number of widely different materials. To most persons it calls to mind any soft, structureless, earthy matter, which, when moistened with water, will become plastic and sufficiently firm to be fashioned into any desired form.

*Adapted from a table given by Robert T. Hill, Vol. VIII, Mineral Resources of United States, 1891, 475.

To the manufacturer it may be either the above or an artificial mixture of several or many constituents, ready to be turned, molded or pressed, and then burned or baked to the required hardness.

To the chemist and geologist it has a far wider meaning including all rocky material whose chief constituent or "clay base" is composed of the three elements,* silicon, aluminum and oxygen, joined in chemical union, and holding more or less water in combination with themselves. To this clay-base has been given the name "kaolin" or "kaolinite," and its chemical formula has been found to be:

$$Al_2O_3 2SiO_2+2H_2O$$

or

$$Al_2Si_2O_7+2H_2O,$$

which shows that it is composed of two parts of aluminum, two of silicon, and seven of oxygen chemically combined and united with two parts or molecules of water.

When pure its percentage composition is as follows:

Silica (SiO_2)	46.3
Alumina (Al_2O_3)	39.8
Water (H_2O)	13.9

In other words kaolin is what chemists call a hydrated silicate of alumina; *i. e.*, a silicate of alumina combined with water. This kaolin may, and often does, as we shall hereafter see, exist in an almost pure state, but in most cases it is found mixed with numerous other minerals, such as free silica or sand, oxides of iron, lime, mica, magnesia, etc., in greater or less proportions.

To these mixtures (as well as to the pure kaolin itself) the general term "*clay*" rightfully belongs, whether they appear in incoherent masses, as those to which the name is most commonly given, or in a more consolidated and finely laminated condition—the so-called "*shales*;" or in the still more thoroughly consolidated "*slates*." Finally, from the above, it may be readily perceived that the greater the amount of kaolin or clay-base in the mixture the purer is the clay. Still, the name of clay is given to the mixture if it contains no greater amount than 10 per cent. of the kaolin.

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*For those who have little or no knowledge of chemistry I have thought it best to give here a definition of the word "element," as it will be hereafter used on numerous occasions. An *element* is one of the seventy primary forms of matter which make up the universe. It is a substance which has never been separated into anything simpler. Two or more elements united together form a *compound*. There are millions of compounds, but only seventy elements. For example: Wood is a compound, which in the chemical laboratory can be separated into three substances, carbon, hydrogen and oxygen, but no man has as yet been able to separate carbon, hydrogen or oxygen into anything simpler than themselves. Hence they are elements. The seventy elements bear the same relation to the compounds as the twenty-six letters of the English language bear to its four hundred thousand words. Or, to state it still differently, the elements form the alphabet of the universe.

PROPERTIES OF CLAY.

The value of clay for the purposes to which it is put depends upon certain essential and characteristic properties which we shall now briefly consider. One of the most important of these is

PLASTICITY.—It is this property which causes clay when wet with water to become a tough, pasty mass, readily capable of being fashioned into any form by the hands or molds; and, when so fashioned, to retain its shape while being carried to the drying room or kiln. Very few other minerals or artificial compounds possess this peculiar and important property. Particles of iron, sandstone or limestone are almost wholly non-plastic, and, when wet, will not cohere to any great extent.

The cause of the plasticity of clays is, as yet, a mooted question among scientists. Many of the purer residual clays, *i. e.*, those which have been formed in the place where they are now found, are almost non-plastic. When examined under the microscope such clays appear to be largely made up small, six-sided crystalline plates or scales, arranged in bundles and surrounded by numerous, smaller unattached scales. When such clays are ground fine, and the crystalline structure of the plates in part destroyed, they become much more readily plastic. A re-examination under the glass then shows that the plates which still retain their crystalline form are imbedded in a matrix made up largely of the particles of those which have been destroyed.

Now our natural clays, which are most plastic, are sedimentary, or those which have been carried by water or ice to the places they now occupy. In their journeyings they have been ground and reground, their crystalline structure destroyed, and their particles reduced to a very fine condition and thus rendered more susceptible to cohesion with particles of water. It is true many of them may have been consolidated into shales and slates, but most of these by repeated grinding are again rendered plastic. *The property of plasticity, therefore, appears to depend largely upon the absence of crystalline structure in the clay-base or kaolinite, and the fineness to which the particles mixed with this have been reduced.* A further proof of this is seen in the effect produced by "weathering." Clays which are mined in autumn and exposed to rain and frost throughout the winter have the crystalline structure of their kaolin more or less broken up by alternate freezing and thawing. Their degree of fineness is at the same time increased, rendering them more highly plastic, and therefore more readily moulded into any desired shape.

That *plasticity*, to a certain extent, depends upon the presence of combined water in the clay-base, is shown by the fact that when heated to redness and this water driven off, the clay loses its plastic quality. Brick dust or burned clay may be ground fine and moistened, but unless mixed with some unburned plastic material the particles will not cohere.

Some clays possess too great a degree of plasticity and are called "lean" clays. This fault can be easily remedied by mixing with a more non-plastic clay. On the other hand, many common brick clays which are too non-plastic for use, have from earliest times been moulded with straw to give them sufficient tenacity to be handled while being placed in the kiln.

A second important property of clay is

INSOLUBILITY.—The better grades of clay are not affected by any acid or other chemical. If, for example, a few drops of either muriatic (hydrochloric) or sulphuric acid be poured upon a piece of iron or limestone, a bubbling or effervescence will take place, and, if sufficient acid be used, the iron or stone will soon wholly disappear. No such action occurs with kaolin. When, however, a clay is very impure, containing a large percentage of lime, carbonate of iron, or other deleterious matter, the same effervescence is seen when the acid is applied.

As many of the products made of clay are liable in time to be brought directly or indirectly in contact with injurious chemicals, it will be readily seen that this property of insolubility, which is possessed by the raw material and transmitted to the manufactured product, is a most valuable one. It often prevents their destruction or enables them to be put to many uses in which utter freedom from chemical action is demanded.

A third and indispensable property of clay is

INFUSIBILITY OR REFRACTORINESS.—Kaolin and many of the purer grades of fire-clay can be subjected without fusing or melting to the highest heat obtainable in the practice of metallurgy. This can be said of but few other minerals, chief among which is quartz or silica, which is one of the leading impurities mixed with kaolin to form the different kinds of clays.

This fire resisting or refractory property is one of the most remarkable and valuable which clays possess. Upon it depends their use for making that long list of materials, which of necessity must be subjected to intense heat, such as crucibles, gas retorts, glass pots, reverbatory furnaces, etc.

But it is only the purer clays, as kaolin, or kaolin mixed with silica (the so-called fire clays) that are infusible. When other substances commonly found in sedimentary clays, such as lime, potash, iron, etc., are present, a comparatively low temperature will bring about a fusion or melting. Chemical changes will result and new compounds, chief among which are complex artificial silicates, will be formed. To all such substances whose presence tends to bring about the melting of refractory material the general name of "*fluxes*" is given. Named in the order of their power to cause the fusion of kaolin the leading fluxes are potash, soda, iron, lime and magnesia. The presense of a small amount of one or more of these is sufficient to destroy the refractory property of an otherwise excellent fire-clay.

The infusibility of kaolin is chiefly due to the same property being possessed by its constituents, silica and alumina. Each can be melted only in the flame of the oxy-hydrogen blow-pipe. Combined with kaolin to form the fire-clays is almost always a large per cent. of free silica or sand, which is nothing more than small particles of quartz. This is the only impurity that can be mixed with kaolin without lessening its property of infusibility. In all the better grades of fire-clays a large percentage of this free silica is present. The Montezuma fire-clay, which has a wide reputation throughout Indiana and adjoining States for fire-resisting qualities, contains a total of 83.4 per cent. of silica; while some refractory materials are manufactured from quartzose rock, which is finely ground and then mixed with a small amount of plastic fire-clay to give it tenacity. But few large deposits of either kaolin or fire-clay free from fluxing impurities are known to exist; and such of these as are readily accessible are of great commercial value.

Another property of clay, and the last one to be here mentioned, is the power which it possesses of *hardening* when subjected to heat. No especial name has been given to this property yet its importance can scarcely be over-estimated. Without it an article fashioned from clay would be only so much stiff mud, which on exposure to rain or frost would soon crumble to dust on account of its porosity and attraction for moisture. Any clay which is plastic enough to be molded into shape can be baked and thereby made to become hard, solid, and stone-like in appearance.

The first change taking place in the clay when heated is the driving off of the water which has been added to it to make it soft and plastic. This should be done "so slowly as to allow all of this moisture to escape as vapor before the clay becomes heated above the boiling point of water, for the generation of steam would of course tend to destroy the structure which has been imparted to the clay and which is important to keep."* After this hygroscopic water has been driven off the heat may be increased more rapidly, until at about 1000° F. the ware will begin to shrink and lose weight on account of the loss of the combined water in the clay-base or kaolinite.

Thereafter the clay "will grow more hard and dense and more impervious to water, until finally, if the heat be stopped at the right point, it will have become practically impervious and very hard, strong and tough. Clay in this condition is a new chemical compound composed of a mixture of all its bases (metals) combined with all its acids, forming a mineral as nearly indestructible as any known. Small bits of pottery made in the

* Orton, Edw., Jr., Geol. of Ohio, VII, 80.

earliest times of pre-historic man come down to us as fresh and unaltered by the centuries of exposure as they were when made. Records made in hard burnt clay are imperishable, except to animate force. If the heat be continued above this most favorable point the clay begins to deteriorate in some of its qualities. It may grow harder but less strong, or it may become spongy and vesicular like lava, or it may melt into a fragile glass, but whatever the change, it is a retrogression. What the temperatures are at which these various results are obtained, depends wholly upon the nature and composition of the clay under treatment. Some clays require only a low heat to develop their best qualities, others demand the highest heats attainable in the practice of metallurgy." *

THE ORIGIN AND CLASSIFICATION OF CLAYS.

All clays, soils and sands, are, in the first place, derived from the decomposition or breaking up of different kinds of rock. I say "are derived," for the silent processes of nature to-day, as in past geological ages, are grinding rocks into clays and recementing and hardening clays into rocks. There was a time when the surface of the earth was formed of rocks and rocks only, but various natural agencies began and kept in constant action processes of slow decay, and clays, soils and sands were formed, and afterwards, as we shall see, carried as sediments into ancient seas.

The rocks that formed that first crust of the earth were largely or wholly igneous in their nature, *i. e.*, they were rocks which had been acted upon by great heat, and had not been deposited in stratified layers by water. The most common of them were the granites, gneisses and syenites. As kaolin, which is the base of all clays, may be formed from any of these three kinds of rocks, the process being essentially the same, I shall take granite and try and make plain the origin of kaolin from it.

Granite is an igneous rock composed of three minerals, quartz, mica and feldspar. *Quartz* is the most abundant of all minerals, and in one form or another comprises fully 25 per cent. of the crust or hard surface of the earth. It is composed of two elements, silicon and oxygen, united in the proportions of one part of the former to two of the latter, the chemical formula being SiO_2. The chemical name of this compound is silica and it is wholly insoluble in rain water or ordinary acids. Of *mica*, the second mineral constituent of granite, it is necessary to say nothing in this connection, except that it, like quartz, is not acted upon or decomposed by rain water.

But to *feldspar*, the third mineral found in granite, especial attention should be given since it is the source from which all kaolin, is supposed

* Orton, *loc. cit.*, 76.

to have been derived. Feldspar is the common name given to a group of very complex minerals. The most abundant of these is *orthoclase*, the kind of feldspar usually found in granite. It is composed of four elements, silicon, oxygen, aluminum and potassium, and its chemical formula is K_2O, Al_2O_3, $6SiO_2$, showing that it is what chemists call a double silicate of potash and alumina. In other words it is a silicate of potash chemically combined with a silicate of alumina—the former being soluble in rain water—the latter, as we have seen in another connection, wholly insoluble. Granite, then, may be regarded as composed of particles of insoluble quartz united to particles of insoluble mica by a cement of feldspar which is partly soluble and partly insoluble.

Now the geologist recognizes three great natural agencies as constantly acting upon the surface of the earth. One is *igneous* or the agency of internal heat, which in some place is always pushing a portion of the earth's surface upward. The second agency, and the most important one, as far as the formation of clay is concerned, is the *atmosphere*. This is composed of three gases, oxygen, nitrogen and carbon di-oxide, and in addition to these, watery vapor. Of these the nitrogen is inert or non-active and has nothing to do with the formation of clay. The oxygen, carbon di-oxide and water, either separately or combined, are universal solvents and, in time, will cause the crumbling of the hardest rocks. The oxygen unites with certain elements or minerals in the rocks to form new compounds. The particles of these compounds cohere or unite less closely than the particles of the rock before the compounds were formed, and in time lose their cohesion and fall apart. A somewhat similar action is seen when a leaden bar is melted and then stirred until all its particles are brought in contact with the oxygen of the air. A new compound, lead oxide, wholly unlike the original bar lead, is formed, which is easily reduced to a powdered state.

The watery vapor in the air when cooled, condenses and falls as rain. As it passes downward it gathers unto itself a part of the gaseous carbon di-oxide of the atmosphere and unites with it to form rain or carbonated water. When this falls upon the granite, already softened to a certain extent by the oxygen of the air, it percolates it and the carbon di-oxide (CO_2) leaves the water and unites with the potash (K_2O) to form potassium carbonate (K_2CO_3). This, being a very soluble substance, is soon washed out by the water, thus destroying the cement which held the particles of quartz and mica together. The granite, therefore, crumbles apart and there results from it a mass of *kaolin* (the insoluble silicate of alumina of the feldspar), mixed with quartz particles or sand, and numerous scales of mica. Thus is kaolin the basis of all clays, formed from granite or any rock of which feldspar is a constituent.

The clay materials resulting from the decay of feldspar may be broadly classified into two great groups—residual clays and sedimentary clays.

RESIDUAL CLAYS

are those which have remained on or very near the spot formerly occupied by the rocks from which they are derived. If these rocks contained much feldspar, or but little mica, and were covered before their decay by some permeable material such as conglomerate sandstone through which the water could easily pass, large beds of comparatively pure kaolin were formed. Such deposits are called residual rock kaolins and are among the richest and purest known to man. The kaolin deposits of Lawrence and Martin counties, Indiana—of whose especial origin more will be said hereafter—are examples of such residual clays.

If, on the other hand, the mica be present in abundance, or should there be quantities of such impurities as hornblende or iron pyrites in the rock, the resulting residual clay will be largely mixed with oxides of iron derived from the hornblende, mica or pyrite, and will be a mere red brick clay of little or no value. Thus it happens that although many localities are known where granite has decayed in great abundance, but few of them yield large deposits of a good quality of kaolin.

South of what is known as the drift area in Indiana—of which more anon—there occurs a surface clay which is also residual, being derived from the decay of the underlying limestone or sandstone rocks. During thousands of years the rainfall penetrating these rocks has carried with it well known solvent agencies derived from the atmosphere and from the vegetation on the surface. Attacking the rocks, these solvents have borne away the several ingredients which they were competent to dissolve and have left the rest behind. The result has been the production of well disintegrated earth or soil at the surface merging into clay and partly decomposed rock below. For the most part this clay is in essentially the same state as when separated from the primitive crystalline, feldspathic rocks, as the decay of the limestone or sandstone has only restored it to the condition in which it was when deposited with the sediments of which they were formed. It is composed mainly of a mixture of kaolinite, oxides of iron, and sand combined in varied proportions, the kaolinite being the silicate of alumina that was disseminated in small particles through the limestones or sandstones at the time of their formation. This residual surface clay is free from those minute angular fragments of foreign rocks which occur so commonly in most glacial or drift clays. It is never stratified like the latter sometimes are, and its texture is more homogeneous or alike throughout. For these reasons its quality for manufacturing purposes is far superior to that of most of the surface drift clays of northern Indiana.

SEDIMENTARY CLAYS

are those which have been removed from their place of origin and redeposited in water. This removal has been brought about by water either in its liquid or solid form; for the third great natural agency acting upon the surface of the earth is known as "*aqueous*" or the agency of water. This has to do, however, with the distribution rather than the origin of clays and soils. Gentle rains and earth-born torrents, little trickling rills and strong streams are ever at work tearing down the clays from every slope where feldspathic rocks have decayed and bearing them away to lower levels. While being carried onward the clay-base or kaolin, comparatively pure at starting, becomes mingled with many impurities, such as the remains of decayed limestones, oxides of iron, etc. It, as well as these impurities, are at the same time washed and ground fine by the action of the flowing water until finally the entire mixture is deposited as a bed of fine sedimentary clay at the bottom of river, lake or sea, perhaps one, perhaps a thousand miles from the home of its mother rock. Since the first rain-fall upon the primitive crust of the earth this process of disintegration and transportation of clay by water has been going on, and on it will continue until the end of time, for the forces of nature are never ceasing in their action.

As a result vast beds of sedimentary clays are found wherever lakes or seas have at some former period covered a portion of the surface of the earth. In many cases these clays have by pressure been consolidated and hardened into "*shales*." The chemist recognizes no difference between a shale and a clay, and the geologist distinguishes them only by a thin lamination, or capability of being separated into layers, which is present in the shale and absent in the clay and which is generally due to the former having been deposited intermittently in deep, still water.

Shales are classified and named according to the character of the chief impurity which is mixed with their clay-base. Thus we have silicious shales, micaceous shales, calcareous shales, bituminous shales, etc. These differ widely in their relative hardness and in the degree of plasticity which they show when ground fine and mixed with water. In general, however, they as well as the soft sedimentary clays are highly plastic on account of the constant grinding and washing which they have undergone previous to their final deposition in water.

The beds of sedimentary clay now found upon the surface of the earth are very few of them identical with those first formed after the decay of the primitive crystalline rock. That igneous force which somewhere is ever pushing the bottom of the sea upward, long ago raised those first shale beds into dry land. Rain and frost again caused their decay, and again did the agency of flowing water mix and grind and bear their particles to the bottoms of new seas and lakes. No one knows, or can ever know, how often these successive changes of elevation, disintegration, erosion and deposition have taken place in the ages past; but the clay-base in the materials of our buildings and roadways of to-day, would, if traced backwards, lead us through many a geologic change to the granites and gneisses of the old archæan times.

We shall find in Chapter II, that the most important sedimentary clays of the coal measures are the different shales which overlie the seams of coal, and farther information concerning their origin will be given there. Underlying each coal seam is almost always a bed of "*fire-clay*"—a form of sedimentary clay usually richer in kaolin and silica and poorer in the fluxes than the shales. This fire-clay had its origin in the same manner as did the shales, but its freedom from lamination is a proof that it was deposited in shallower water. Its relation to the overlying coal seam plainly shows that it once formed the soil which supported that luxuriant plant growth from which the coal was in time derived. Although the general name of "fire-clay" is applied indiscriminately throughout the coal-bearing counties to all the under-clays of the coal seams, yet but few of them, properly speaking, are refractory clays of a high grade. The majority of them contain so great a percentage of the fluxes that they fuse readily at even moderate temperatures. The origin of all is, however, practically the same, and a farther classification, based on their more valuable properties, will be given in the next chapter.

Along the lowlands of the Ohio and Wabash Rivers and their larger tributaries are found, at intervals, enormous beds of "*alluvial,*" or river-bottom clays. These are sedimentary clays of the most recent times and owe their origin either to deposition in the eddies of those streams, or to the slow accumulation of the clayey sediment during the annual overflows of the areas which they occupy. Oftentimes they alternate with strata of sand or even gravel. In some places they are 30 to 50 feet in depth and free from pebbles or coarse impurities of any kind. They are usually very plastic owing to the presence of more or less lime and iron oxides in a finely divided state. In Ohio similar clays have been used for several years in the manufacture of paving material, but in Indiana their only use heretofore has been in the making of ordinary building brick.

One other form of sedimentary clay remains to be mentioned—namely, the so-called "*drift-clays*" or "*hard-pans,*" which are the characteristic surface clays of northern Indiana. From the shales and fire-clays which, in many places, underlie them, they differ widely in the amount of lime and other foreign constituents which they contain. This difference is mainly due to the fact that they were transported to and deposited in their present resting places, not by water in the liquid form, as were the shales and fire-clays, but by a great glacier or moving sea of ice which, thousands of years ago, flowed slowly over the greater portion of our State, grooving and planing the surface of the solid rocks, strewing for hundreds of miles in its track beds of clay and sand and gravel—pushing before it the accumulated soils and clays of centuries, and mixing, transporting and changing them to such an extent as to well nigh destroy their separate characteristics and greatly increase the difficulty of their proper classification.

The climate of the region to the north of us was similar, at that time, to that of Greenland to-day, or even cooler. The snow, ever falling, never melting, accumulated there in one vast field of enormous thickness. Near the bottom of this mass a plastic, porous sort of ice was gradually formed from the snow by the pressure from above. This ice took upon itself a slow, almost imperceptible, motion down into the valleys to the southward. As it moved thus onward, dirt bands were formed along its margins; stones and great masses of partly decayed rock and clay from hillsides and jutting cliffs rolled down upon it, and were carried on and on, until, by the melting of their icy steed, they were dropped upon the clean-swept surface rock below. In this way all the beds of so called "dri t clays" were accumulated where they lie.

In Indiana they form the surface clays north of a line drawn approximately from the southeastern corner of the State to the Wabash River at a point midway between Terre Haute and Evansville. South of this line the surface clays are, for the most part, the variety of residual clays mentioned above. Transported and deposited as they were, it is no wonder that the drift clays are too impure for any use but the making of ordinary brick and drain tile, and oftentimes they contain too much lime even for this purpose, numerous analyses showing the presence of as high as 40 per cent. of calcareous material. This is due to the grinding up and mixing with the clays much of the surface limestones over which the glacier passed, as the erosion of that epoch not only removed and commingled the previously formed residual deposits, but planed away the country over a vast area to a greater depth than had been reached by any previous decay. These eroded limestones and the clays with which they were mixed were many of them ground into impalpable powder and deposited before a subsequent decay could take place, so that, as has been well said, "the drift clays are, many of them, rock flour, and not, as are the residuary clays, the products of rock rot."*

Summing up the last few pages we find, therefore, that, based either upon the relation of their present location to their place of origin, or the manner of their transportation and deposition, we have the following classification of our Indiana clays:

*Chamberlain, T. C.—Sixth Ann. Rept., U. S. Geol. Surv., p. 249.

- CLAYS.
  - *Residual.* Remaining on or near the place of their origin.
    - *Rock Kaolins* of Lawrence and adjoining counties.
    - *Surface Clays* of the driftless area of southern Indiana.
  - *Sedimentary.* Removed from their place of origin and deposited in water.
    - Transported by water.
      - Ancient or paleozoic.
        - *Shales.* Laminated owing to deposition in deep water.
        - "*Fire-Clays.*" Unlaminated; deposited in shallow lakes or marshes.
      - Recent.
        - *Alluvial.* Deposited by our present rivers and streams.
    - Transported by ice.
      - *Drift Clays.* The surface clays of northern and central Indiana.

Based upon the relative proportions of clay-base and fluxes which they contain, one of the most recent and best classifications of clays is that given by Prof. Edward Orton (Seventh Rep., Ohio Geol. Surv., 1894, p. 52), as follows:

		Uses—
High Grade Clays	1. Kaolin	Manufacture of fine ware.
	2. China clay	" " "
	3. Porcelain clay	" " "
	4. Fire clay (hard)	Refractory materials.
	5. Fire clay (plastic)	" "
	6. Potters' clay	Earthenware, etc.

		Uses—
Low Grade Clays	1. Argillaceous shale	Paving block, etc.
	2. Ferruginous shale	Pressed brick, etc.
	3. Silicious clays	Paving block, sewer pipe, etc.
	4. Tile clays	Roofing tile, draining tile.
	5. Brick clays	Pressed brick, ornamental brick.
	6. Calcareous shale	Common brick, etc.

Concerning the above classification, Prof. Orton says: "The first division comprises all clays and shales that contain in conjunction with not less than 50 per cent. of kaolin base little else but finely divided silica. The amounts of the fluxing elements are in all cases small, rarely aggregating as much as 5 per cent., and generally falling below 3 per cent. Oxide of iron constitutes much the largest single element of these fluxes. In almost every case the potash is low."

"The second division includes all ordinary clays and shales. They may range in kaolin base from 10 to 70 per cent, but they always carry a notable percentage of the fluxing elements. The alkalies generally make 2 to 5 per cent., while lime, magnesia and iron add two or three times as much more. Coarse sand and rock fragments often make a conspicuous part also. These low qualities of the clay more frequently result from a surplus of fluxing element than from a deficiency in kaolin base."

IMPURITIES OF CLAYS.

Although much has been already said, in a general way, concerning the impurities found in clays, it is thought best to make in this connection, a more detailed mention of some of them, together with their effect upon the value of the clay for manufacturing purposes.

As already noted, anything other than the silicate of alumina forming the clay base may be considered as an impurity. The impurities most commonly found in clay are as follows: Silica; various compounds of iron; lime and magnesia; the alkalies, potash and soda; titanic acid, and organic matter. True, other substances sometimes occur, such as pebbles of crystalline rocks, ores of copper and zinc, compounds of sulphur, etc., but they are found so rarely that the mere mention of them will be sufficient. Free or uncombined

SILICA (SiO_2)

in the form of sand (disintegrated quartz) is found, to some extent, in all clays. The purest residual clays contain it in minute quantities, and some of the sedimentary clays have as high as 40 to 50 per cent. mingled with their clay-base, so that it is often difficult to tell where a sandy clay ends and a clayey sandstone or "freestone" begins. Although classed as an impurity, yet in the making of most clay products this free silica is an absolutely essential part of the raw material; since its presence prevents that warping, shrinking and cracking while drying which is sure to take place in the made-up product when too great a percentage of pure kaolin is present. In many cases where the clay is too rich in alumina, sand has to be artificially mixed with it before it can be used. Whenever so mixed, the natural adhesiveness, plasticity and strength of the clay are reduced; while its brittleness, and usually its refractory property are increased.

Of the clay impurities above mentioned, the

COMPOUNDS OF IRON

are, next to silica, the most common and the most important. Pure iron does not exist free in nature, but its compounds are very abundant. Among those occurring *uncombined* in clays are the two oxides—the proto or ferrous oxide (FeO), and the per, sesqui, or ferric oxide (Fe_2O_3); also the carbonate ($FeCO_3$); the sulphide (FeS_2), and the sulphate ($FeSO_4$). In addition to these many chemists believe that most every clay has, *chemically combined* with its kaolin or clay-base, a hydrated per-oxide of iron ($2Fe_2O_3+3H_2O$), the two together forming a complex double salt of iron and alumina.

The presence of iron oxides has much to do with the colors of clays, both in the raw and the burned state, for iron is one of the great coloring agents in nature. Compounds of iron cause the green color of grass and leaves, the bright red color of the blood of animals, and the darker red of some soils, clays and sandstones. The proportionate amount of uncombined iron oxides present has little to do, however, with the color of the clay in either its burned or raw state. Experience, time and again, has proven that no one can tell by looking at a clay, or even by analyzing it, what color will be produced in it by heat. In general, however, it may be stated that the finer the particles of these oxides are, and the more evenly they are disseminated through the clay, the more uniform and certain will be the color. For this reason chemists believe that the complex double salt of iron and alumina, mentioned above, has much to do with the ultimate color of burned clays, as, of necessity, the iron oxide in this is more thoroughly and evenly distributed throughout the raw material. If the oxides occur *free* in small grains or nodules, a chemical change will be caused in them by heat, and they will be apt to form black specks, scattered irregularly through the body of the ware instead of coloring it evenly throughout. The color to which a clay burns is, moreover, determined to a large extent by the different degrees of heat to which it is subjected in the kilns.

Iron oxides, besides imparting a color to clay products, also often act as fluxing agents. This is especially noticeable in those shales and surface clays which contain from 5 to 15 per cent. of these oxides. Such clays fuse and vitrify at much lower temperatures than others which are similar in every respect, except in the quantity of iron they contain.

Pyrites, or iron sulphide (FeS_2), is probably the most harmful of all the compounds of iron occurring in clays. It is usually in the form of small crystalline nodules or grains, or in concretionary ball-like masses, one to three inches in diameter, and having the surface oxidized into a brownish shell. These are popularly known as "sulphur balls," and are found in some of the shale deposits of the Indiana coal measures. When present in any quantity pyrites causes the clay constituents to fuse at a temperature much below that at which the proper vitrifaction takes place.

Sulphate of iron, or copperas ($FeSO_4$), is often produced in clay deposits containing pyrites by the oxidation of the latter. Its presence may be known by the astringent, inky taste which it imparts to the clay, and usually by the presence of a white efflorescence upon the surface. Like the pyrites, it is a very damaging constituent, rendering the clay in which it is found comparatively worthless.

Iron carbonate, or siderite ($FeCO_3$), is also a quite common mineral in the shale beds of the Indiana coal measures. It is usually found in the form of either lenticular or kidney-shaped nodules, which contain more or less clayey matter, and are known as iron kidneys or clay ironstone. They vary much in size, and often occur in layers at regular intervals apart, making it easy for the clay miner to separate them. If too large a proportion of them are ground up with the shale they increase too highly the percentage of iron, and so reduce the fusing temperature. Otherwise they are comparatively harmless, as under the influence of heat the carbonate is decomposed into ferrous-oxide and the gaseous carbon di-oxide ($FeCO_3 = FeO + CO_2$).

Some residual and almost all sedimentary clays contain

LIME AND MAGNESIA,

one or both, in small but persistent quantities. The best clays contain less than two per cent. of these substances—though for some purposes clays, containing as high as 25 per cent. of lime, may be utilized. When present, lime and magnesia usually occur either as silicates or carbonates—more commonly the latter. Like the oxides of iron their degree of harmfulness depends largely upon their physical condition. If finely divided and intimately mixed throughout the clay they are less injurious than if in the form of small grains or pebbles of limestone. When in the latter condition, as they commonly are in the glacial or surface drift clays, the carbonate of lime ($CaCO_3$), when the clay is burned, loses carbon di-oxide (CO_2). This leaves calcium oxide or quick lime (CaO), which has a very strong attraction for water. When the finished product is exposed to the air each of these particles of quick lime will absorb moisture, and expand, bursting off pieces of the ware and so causing a defect or shallow pit in its surface.

When present in quantity, and in a finely divided state, lime and magnesia not only act as fluxes, but also combine to a certain extent with the oxides of iron and give a peculiar whitish or cream colored tint to the finished products. For this reason many of the more recent sedimentary clays—as those found along the margins of our present lakes and rivers

—although rich in iron, produce a light colored instead of a red brick. Such bricks are made at South Bend and Michigan City, Indiana, and at Milwaukee, Wisconsin.

As already stated (p 27) the alkalies,

POTASH AND SODA,

rank among the leading fluxing impurities found in clays. They occur in small quantities in almost all clays, probably as silicates in the form of undecomposed particles of mica or feldspar. These fuse at a lower temperature and unite more readily with the clay-base than do any of the other impurities (iron, lime or magnesia) above mentioned. Their presence in any quantity in clays desired for refractory purposes is, therefore, most pernicious. On the other hand, where vitrified products are to be made, it is necessary that some of these fluxes be present, that they may cause the clay constituents to begin to fuse and combine at the proper temperature; and so bring about that peculiar, non-porous, "vitrified" condition which is so characteristic of all non-absorbent clay products.

The analyses of ten shales from Ohio and six from Indiana, which are used in the manufacture of vitrified brick or sewer pipe, show an average composition of about 13 per cent. of all fluxes and 84 per cent. of kaolin and sand. Probably from 8 to 10 per cent. of the fluxes would serve all necessary purposes, but a less proportion would leave the material unvitrified and porous and therefore of too absorbent a nature for use. As potash and soda are the most powerful fluxes known, 5 or 6 per cent. of them are equal to from 8 to 10 per cent. of a mixture of all the fluxes usually found in clays. Hence it is better that no more than 2 or 3 per cent. of both be present in those clays in which vitrifaction is desired and in which the other fluxes occur. As a rule the shales now being used for making paving brick contain from 2½ to 3 per cent. of potash and less than 1 per cent. of soda.

From 1 to 2 per cent. of

TITANIC ACID

occurs in most shales and fire-clays, but as far as known it has no effect either as a coloring or a fusing agent. It usually occurs in the form of small brownish black grains of irregular shape, which are supposed to be a compound of iron and titanium. Like silica, its presence is not thought to be detrimental to the fire-clays in which it is found.

ORGANIC MATTER

often occurs in clays and shales, especially those of the coal measures. Usually readily combustible it is burned out at a temperature much below that of the fusing point. When in a very fine state of division it is a comparatively harmless constituent, but if in grains of any size it is apt to leave the ware more porous than it should be, especially if vitrifaction is to follow Many of the dark-colored shales which lie immediately above the seams of coal contain too much carbon to allow them to be put to any use.

CHAPTER II.

THE CLAYS OF THE COAL-BEARING COUNTIES OF INDIANA.

During the past decade an enormous expansion of the clay industries has taken place in the United States. The utilization of vitrified brick for roadways has created a new and distinct industry, thousands of miles of streets throughout the West having, since 1890, been paved with this material. The disappearance of our forests, and the consequent rapid advancement in the price of all kinds of lumber, has led architects and builders to investigate more carefully the value of clay products for structural purposes. These investigations have resulted in valuable discoveries concerning the chemical constituents and properties of clays—have suggested the invention of new, or the improvement of old forms of machinery and kilns for their manipulation and burning, and have proven their unexcelled fitness for many purposes to which stone, wood or other materials were previously put.

As a proof that the general public is beginning to appreciate this fitness, one has to but note the rapidly increasing use of terra cotta and pressed brick for the fronts of business blocks and the more fashionable and costly private residences; of clay shingles for their roofs, and of encaustic tiles for their floors and mantels. Indeed, all present signs point to clay—that most widely distributed and cheapest resource known on earth—as the leading factor in the future structures built by man.

That Indiana has not kept pace with her sister States in this rapid development and growth of clay industries is known to all who have given the matter any attention. Recent and accurate statistics compiled by the U. S. Bureau of Mineral Resources show that of the total value of clay products manufactured in the United States in 1894, Ohio made 16 per cent.; Illinois, 13 per cent.; Pennsylvania, 11 per cent.; New York, 8 per cent.; New Jersey, 6 per cent.; while Indiana made but 5 per cent, and they largely of the cruder kinds. The reason that this State ranks as low as it does lies not in the lack of quantity or variety of raw materials, nor in the lack of enterprise and capital among her citizens, but almost wholly because of the ignorance prevailing concerning the location and quality of its clay deposits and the uses to which they are capable of being put.

This ignorance is largely due to the fact that so little has heretofore been written on the clays occuring in Indiana. In 1874 kaolin was discovered in Lawrence County, and in the report of this Department for that year Prof. E. T. Cox, then State Geologist, devoted eleven pages to the description of this deposit and the iron ores connected therewith. Prof. John Collett, in the Reports for each of the years 1882 and 1883, had a part of a page on Indiana "Clays and Kaolin." In the Fifteenth Report, issued in 1885, Maurice Thompson published a seven-page paper entitled "The Clays of Indiana," and in the Sixteenth Report (1888) W. H. Thompson covered the same ground in four pages.*

With the exception of a few lines relating to local deposits of ordinary brick clays, which from time to time have appeared in the "geological surveys" of some of the counties, the above twenty-four pages comprise everything on the subject of clays that has appeared in the nineteen Reports of this Department issued to date.

This will appear the more surprising when we take into consideration the following remarkable statement made by Mr. Robert T. Hill, a noted authority on the clays of the United States: "Indiana is one of the few States that has appreciated the importance of making complete reports upon the geology of its clay deposits, and much can be learned from them in the publications of the State survey."†

Believing that the time had come when some more definite and accurate knowledge concerning the clay resources of Indiana should be made public, I began in April, 1895, to gather the data for this preliminary

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* In this connection it may be stated that the late Geologist, Mr. S. S. Gorby, in his introduction to the Eighteenth Report (1893), used the following language: "The State Geologist is preparing an exhaustive report on the clays of the State, which will appear in the Nineteenth Report of this Department. In preparing for this report he has collected and made analysis of about one hundred and seventy samples of clay from all parts of the State. In this work only such clays have been used as are found in commercial quantities and at available points. Some of these clays are of extraordinary value on account of their whiteness and the large proportion of alumina they contain. It is hoped that the publication of the Report will result in a widening of the market for these valuable products."

In regard to this statement I will say that on taking charge of this office I found in the State Museum 85 jars containing samples of clays from different parts of the State. Each had a label attached containing the record of an incomplete analysis. The names of the parties owning the land from which the clays were secured were also on the labels, but in a number of instances I have found that no such persons exist in the regions from which the clays are said to have come. Not a single note, record or other manuscript pertaining to these or other clays was turned over to me, nor was anything published in the Nineteenth Report concerning them.

† "Clay Materials of the U. S." in "Mineral Resources of U. S.", 1893, p. 510. On another page the same author states that the "celebrated residual porcelain clays" of Lawrence County "are used for the making of common granite ware, hollow ware, fire and paving bricks."

report. Having no information for reference except that contained in the twenty-four pages above mentioned, and no funds to hire assistance for this especial work, I was forced to limit the investigation of the season to such an area as I could visit personally during such time as could be spared from the routine work of the office. I chose, therefore, the coal bearing counties—eighteen in number—for the principle reason that the coal measures of the State are preëminently its clay measures—a coal seam wherever found having associated with it a bed of fire clay and usually one or more of shale; two forms of clay material which within the past ten years have become so noted for the making of vitrified wares.

The counties comprising the area covered by this report are, therefore, as follows: Fountain, Vermillion, Parke, Vigo, Clay, Owen, Sullivan, Greene, Knox, Daviess, Martin, Dubois, Pike, Gibson, Vanderburgh, Warrick, Spencer and Perry. Posey County, lying in the extreme southwestern corner of the State, has its surface wholly covered with the rocks of the upper or barren coal measures. Little, if any, coal is mined in the county and, therefore, a report on its clays is deferred until a future time. The limited time at my command forbade anything like a thorough study of *all* the clay deposits in these counties; and, therefore, detailed mention is made only of those which are notable for the quantity and quality of the material found in them.

Before taking up these counties singly let us briefly notice as a whole the area which they comprise and gain some farther facts concerning the origin and deposition of the shales and fire clays found therein.

The surface of the counties mentioned comprises the newest part of Indiana, *i. e.*, it was the last to be raised above the surface of the water and become dry land. The outcropping or underlying rocks of the remainder of the State were all deposited in salt water, probably at great depths, and were raised upward and became dry land thousands of years before the coal and its overlying shales were formed. They are, therefore, for the most part *limestones*, and the many fossils which they contain are mostly of marine animals. The rocks of the coal measures were mainly deposited in fresh water and are for the most part *sandstones and clays.* These contain few fossils and they are largely the remains of such plants as formed the coal.

It is most probable that at the time of the formation of the coal and its overlying shales and sandstones the area comprised in the counties mentioned, as well as a part of eastern Illinois, was a great basin or depression but little above the level of the sea, and surrounded on every side except the southwestern by the higher lands of the older formations.

By successive alternations of upheaval and subsidence—carried on through thousands of years—this depression was at times an area of the southwestern sea, again a fresh water lake, and then for a period, a vast swamp or marsh. When raised high enough to form a marsh a luxuriant vegetation sprang up from the ooze and mud at its bottom, flourished for centuries—the newer growths springing from between the fallen masses of the older as in the peat bogs of to-day—and so formed a mighty mass of carbonaceous material.

By subsidence the level of the marsh was, in time, lowered until it became a lake into which rivers from the surrounding highlands flowed, bearing with them millions of tons of clayey sediment and disintegrated quartz, the remains of the older decayed rocks. This sediment was spread out over the mass of submerged vegetation, compressing it into the hard, mineral coal; the clayey sediment itself being in time compressed into vast beds of *shale*, and the particles of quartz into sandstone. In some places a more prolonged subsidence took place, sinking the floor of the lake below the level of the sea, and allowing the waters of the latter with their accompanying marine forms of life to flow in. In time beds of limestone were then formed over those of the shale or sandstone, but none of these cover an extensive area or are of great thickness.

After each subsidence, with its resulting beds of coal, shale and sandstone or limestone, had taken place an upheaval followed. The floor of sea or lake was again raised so near the surface that the semi-aquatic vegetation for a new coal seam could spring up, and, in time, the processes detailed above were again undergone. Thus, in brief, do scientists account for the origin and formation of those seams of coal which are to-day the chief mineral wealth of our State, and of those beds of overlying shale, as yet, almost wholly undeveloped, but in time destined to become as great a source of wealth as the coal has been in the past or will be in the future.

A typical vertical section showing the arrangement of the different coal measure strata as mentioned above, and their relation to each other, would be as follows:

(1)	Soil and surface drift clay	9 feet.
(2)	Blue, compact shale	27 feet.
(3)	Dark bituminous shale	3 feet 2 in.
(4)	Coal	2 feet 7 in.
(5)	Fire clay	4 feet 4 in.
(6)	Drab silicious shale	18 feet.
(7)	Sandstone	6 feet 3 in.
(8)	Dark bituminous shale	1 foot.
(9)	Coal	4 feet 8 in.
(10)	Fire clay	3 feet 10 in.

Some of these strata are closely related. The fire clays (Nos. 5 and 10) are almost universal accompaniments of the overlying coal seams. The relation of these under-clays to the coal show plainly that the former may be regarded as having formed the soils of those ancient marshes, and that from them sprang that luxuriant vegetation which in time was changed to coal. The fire clays, then, are the mother soils of the coal seams. They are usually from one to six feet in thickness, and compose of a soft, homogeneous 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. It is important to remember that these under-clays of the coal seams are the only sedimentary clays which possess in a high degree this refractory property. Its presence in them is due to the absence of a large percentage of the alkalies and other fluxes. This absence is the more notable since all other sedimentary clays contain these fluxes in quantities sufficient to cause fusion at a comparatively low temperature. Their disappearance from the fire clays is explained by the fact that these clays formerly supported so vigorous a growth of aquatic plants; for it is a well proven fact that such vegetation, aided by organic acids which are formed in the submerged soil, has the power of absorbing from such soil all or nearly all the alkalies, iron and sulphur found therein. This leaves the soil rich in silica and alumina, which are the leading constituents of the fire clays. The absorption of the iron oxides also causes these clays to assume that ashen gray color so characteristic of them.

Few, if any, fossils are found in these under-clays. The only things approaching them are the remains of the many long, thread-like roots, or underground stems (Stigmaria) of the larger plants (*Sigillarids* and *Lepidodendrids*) of the former coal flora.

The dark bituminous shales (Nos. 3 and 8 of the above typical section) are found lying directly upon most seams of coal, and constitute the so-called "black slate" of the miners. They vary much in thickness, and are usually very complex in their composition—being nothing more than the first mass of mud, impregnated with carbonaceous matter, which was deposited on the submerged vegetable remains in the old coal swamp. This mud was compressed and hardened into its present condition by the great mass of material afterwards deposited upon it. Oftentimes these shales are very fissile, and cleave in large, flat leaves as thin as paper. Again they are massive, with no visible signs of stratification. The amount of bituminous matter which they contain is usually too great to allow them o be put to use as a clay material. Many of them contain a large percentage of oily matter, which, if necessity should arise, could probably be distilled in paying quantities.

These overlying dark shales comprise the most noted fossil bearing horizon of the coal measures. They contain by far the greater number of those handsome impressions of the leaves of ferns and closely allied plants which are so characteristic a part of the fossil coal flora. The remains of mollusks are, in some localities, also abundant in these shales—the lamellibranchs and gasteropods being the chief groups which are represented.

The blue and drab shales (Nos. 2 and 6 of the section) 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 excessively 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. If the stream was a large one and flowed for a long time with sufficient velocity to carry sediment far out into the deeper part of the lake, the bed of shale is thick, covers a large area, and is comparatively uniform throughout. On the other hand, if the stream was small and flowed slowly the shale bed is correspondingly thin, of small extent, and more apt to be varied in its composition. The kinds of rocks over which those ancient rivers flowed on their way to the lake determined the constituents of the sediment they brought down, and therefore the character and composition of the shales into which this sediment was afterward formed.

In general the shales may be classified into

(1) Argillaceous Shales,

in which clayey material (silicate of alumina) largely predominates. In color these are usually drab or blue, 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. They are then known locally 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 remova . 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.

(2) Arenaceous or Silicious Shales

are those which have a large proportion of free silica or sand mixed with the clayey material. For the most part they are drab, buff or yellow in color, though sometimes gray or even bluish. Their value for manufacturing purposes depends largely upon the character of the sand particles found in them. Sometimes these particles are so minute as to be invisible to the naked eye. The shales are then comparatively free from "grit," and are scarcely inferior to the argillaceous shales in value.

*The term "rocks," in this report, is used in its true sense, and signifies any material whether hard or soft which constitutes a portion of the crust of the earth. Thus, a bed of sand or clay is no less a rock than the hardest granite.

Again, the grains of sand are larger and plainly discernible to the sense of touch as well as sight. When of this character the deposits are rightfully known as shaly sandstones and are of little economic importance. Oftentimes scales of mica are scattered abundantly among the particles of sand, and the shales are then known as "micaceous."

Much less common in the coal area than either of the preceding are the

(3) Calcareous Shales.

These contain a large percentage of carbonate of lime ($CaCO_3$) commingled with the clayey material. Such shales may be readily known by their light grayish color and the readiness with which they effervesce with muriatic acid. Where found they are usually in close connection (either above or below) with a stratum of limestone. Oftentimes they contain remains of the shells of marine or brackish waters. Surrounded as they are by so much material of better quality these calcareous shales of the coal measures are of little commercial importance. In some of the older formations (Silurian, Devonian, etc.), where good clays are less common, they may be utilized in making bricks when the percentage of lime is not too great and is disseminated evenly throughout the shale.

At times sharp lines of division separate the varieties of shales; but generally they merge so gradually into one another that it is often difficult to say where the one ends and the other begins. Thus, by the gradual addition of fine particles of sand the argillaceous shales pass into arenaceous; these, by the addition of coarser particles, into shaly sandstones, and finally into hard and durable sand rocks.

Specimens of almost all of the deposits of clay mentioned on the following pages, as well as many samples of their burned products, are in the collection belonging to the State, and all persons interested in clays or clay manufacturing are cordially invited to call at the office of the State Geologist and examine them.

I desire at this place to express my indebtedness to the many persons residing in the counties visited, who aided me in my researches. The number is too great to allow of individual mention. Everywhere I was treated most courteously and afforded every facility for securing the knowledge which I sought. I shall long remember the favors shown me and hold myself in readiness to reciprocate whenever opportunity offers.

PARKE COUNTY.

The rocks of the Coal Measures proper cover three-fourths of the area of Parke County. The conglomerate sandstone (millstone grit), marking their eastern horizon, extends from a point near the center of the northern boundary in a southeasterly direction and touches the southeastern corner of the county. The most important clay deposits are found west of this sandstone in the northwestern, western and southern townships. The Wabash River forms the western boundary of the county and receives many important tributaries from the eastward. These and their smaller branches have, in numerous places, eroded deep beds through the surface strata exposing the latter to view and affording excellent opportunities for discovering the thickness and character of the coal measure rocks.

Parke County has long been famous for its potters clays. Since the year 1840 a clay for the making of stoneware has been obtained from land now owned by Pearly Pearson and Milton Hobson (N. W. ¼, Sec. 23, Tp. 16 N., R. 8 W.) one mile southwest of Bloomingdale. A branch of Leatherwood Creek flows through this land and at several points along its low bluffs the clay is obtained by stripping. At the time of my visit the following section was obtained at the latest pit worked on the Pearson land:

1. Soil and drift clay	3 ft.	
2. Gravel	3 ft.	4 in.
3. Coarse, silicious fire clay	3 ft.	3 in.
4. "Iron sandstone"	1 ft.	10 in.
5. Fine grained potter's clay (exposed)	8 ft.	

This potters clay (No. 5) is of a grayish or lead color, quite soft and plastic, and much more so when washed and kneaded. It contains a large amount of free silica in very fine grains and, at scattered intervals, scales of white mica are discernible. It burns to a buff or cream color, and takes a handsome dark glaze with Albany slip clay.

A sample analyzed by Dr. J. N. Hurty* showed the following percentage composition:

* All analyses credited in this report to either Dr. J. N. Hurty or J. D. Kramer are incomplete, showing the presence of neither potash nor soda. I have taken these analyses, when given, from the labels on the jars of clays mentioned in the foot note on page 41. They were made for S. S. Gorby, the former Geologist. Dr. Hurty is a reliable chemist of Indianapolis, and his analyses are doubtless correct as far as completed. Of Mr. Kramer's ability as a chemist I know nothing. Prof. W. A. Noyes, the official chemist of this Department, has made especially for this report all the analyses with which he is accredited. He is a chemist of national renown and his analyses can be relied upon in every particular. Prof. Lyons, of the State University, completed eight analyses after the burning of Prof. Noyes' laboratory in November, 1895.

Silica (total)	69.41	
Alumina	18.81	
Clay-base and sand		88.22
Magnesia	.54	
Lime	.90	
Ferric Oxide	2.64	
Fluxes		4.08
Water and volatile matter	7.65	

Compare with the second column of this the average composition of ten leading stoneware clays of Ohio: *

Clay-base and sand	94.10
Fluxes	4.44
Moisture	1.57

It is probable that some of the matter classed as volatile in the Indiana specimen comprises the undetermined potash of which from 1 to 2¼ per cent. is always present in these clays. Nevertheless, the percentage of refractory material present shows that it will stand up under heat sufficient to melt the "slip-clay" used for glazing—a fact which experience has fully verified.

This stratum of potter's clay covers a large area south and west of Bloomingdale. Its maximum thickness is not known, but Mr. Hobson reported that at a point one-quarter of a mile east of where the above section was obtained, thirty feet of it was passed through in digging a well. No charge has ever been made for it by the owners of the land; but for more than fifty years it has been washed by potters near the place where mined, and then hauled in wagons six miles to Rockville. It has also been used for five years in the pottery at Bloomingdale, and to a small extent in the one at Annapolis. Many pits have been opened along the bluffs of Leatherwood, worked back a short distance, and abandoned as soon as the stripping became in anyways heavy. In almost all of these the clay was very uniform in character and quality, though in a few, the presence of small nodules of iron carbonate detracted from its value.

The coarse silicious clay (No. 3 of above section) is used at Bloomingdale in making a cream colored drain tile. Mixed with surface clay it is also burned into a good quality of building brick. In some places, however, it contains too many pebbles of limestone from the overlying gravel to be of any value. The "iron sandstone" (No. 4) separating the two clays is a very heavy and hard, dark colored, coarse grained rock, evidently a combination of some ore of iron and sand.

One-half mile west of the pit where the above section was taken a stratum of clay outcrops a few feet above the bed of Leatherwood Creek.

*Orton, Edw., Jr.—Geol. Surv., Ohio, VII., 95.

Although possessing at this place the physical appearance of a gray silicious shale, its behavior under heat proves that it is a fire clay, as it has undoubted refractory properties and burns to a handsome buff color. Its composition, as far as determined by Kramer, is as follows:

Silica (total)	73.32
Alumina	16.06
Magnesia	.70
Lime	.70
Ferric oxide	1.10
Moisture and volatile	8.12

It is hard when first mined but soon weathers into a soft plastic mass. The thickness of the stratum has not been determined. Its known properties are such as to merit further investigation.

Three miles northwest of Bloomingdale, on the land of R. A. Coffin (N. E. ¼, Sec. 9, T. 16 N., R. 8 W.), is the head of "Coke Oven Hollow," a deep ravine, long locally noted for the quantity and variety of the clays found therein. A pottery was established in this ravine in 1866 and continued in operation until 1891. It was located on ground made vacant by the mining of fire and potters clay for shipment over the old Wabash & Erie Canal, which was connected by a feeder with the mouth of the ravine, and for use in the pottery at Annapolis.

A connected section of the strata in the upper half of this ravine is as follows:

1.	Soil and yellow drift clay	8 feet.
2.	Buff argillaceous shale	27 feet.
3.	Hard, gray silicious shale	4 feet 6 in.
4.	Coal	1 foot 3 in.
5.	Fire clay	3 feet 4 in.
6.	Blue argillaceous shale	8 feet 8 in.
7.	"Iron sandstone"	1 foot 6 in.
8.	Plastic potters clay	22 feet.
9.	Dark, hard arenaceous shale merging into sand rock	21 feet.
10.	Coal	2 feet. 8 in.
11.	Fire clay	3 feet 10 in.

The potters clay (No. 8) is, doubtless, the same stratum as the one worked at Bloomingdale; the overlying "iron sandstone" of the two being identical in appearance. In its crude form the potters clay at "Coke Oven Hollow" contains more or less impurities, but when carefully washed and mixed with about one-eighth its bulk of fire clay, it burns into that strong, gray, vitrified stoneware which, since 1841, has been made at the Annapolis pottery.

The two shales (Nos. 2 and 6 of the above section) are valuable deposits; suitable in the highest degree for paving brick, sewer pipe or other vitrified products. The fire clays (Nos. 5 and 11) are also excellent in quality. Sample brick, made from the lower clay (No. 11) have been tested a number of times and have held their own in refractory properties with the best fire brick in the market. Large quantities of this clay were formerly shipped by the canal to Toledo, Ohio, and points in northern Indiana. The arenaceous shale (No. 9) contains too large a percentage of silica and mica, in coarse particles, to be of value.

The outcrops of the lower vein of coal (No. 10) have been mined for many years. It is a bituminous coal of good quality, and, locally, much valued for smithing purposes. Taken by itself the vein is too thin for profitable working. Mined in connection with the overlying clays as fuel for their burning, a profitable industry could be started here were it not for the lack of transportation facilities. Until these are secured the valuable mineral deposits of "Coke Oven Hollow" must remain practically undeveloped.

The bluffs of Sugar Creek and its tributaries, in the northern tier of townships, contain large and numerous deposits of shales suitable for manufacturing purposes. The largest and most accessible of these are found on both sides of Sugar Creek in sections 25 and 26, Tp. 17 N., R. 7. W. For nearly two miles above the "Narrows" high shale bluffs are numerous, the exposures reaching a thickness of 75 or 80 feet. It is, for the most part, a black fissile, argillaceous shale, containing more or less iron pyrites and clay ironstones and interstratified with thin seams of coal and fire clay. In places along this bluff there is considerable sandstone in the shale, in other places there is very little.

Heavy beds of shale are also found along Sugar Mill Creek in sections 4, 10, 21, 28 and 29, Tp. 17 N., R. 7 W. The largest of these and the one in the best position for working is at "the Pinnacle," on the west side of the Creek (S. E. ¼ Sec. 21, Tp. 17 N., R. 7 W.). At this point the Creek cuts off the end of a narrow ridge 50 feet high having a narrow ledge of sandstone, 10 feet thick, on top; the lower 40 feet consisting of drab to black colored shale. The shale lies in a heavy bed in the northern part of Section 28 on the south side of the Creek, where it contains a bed of coal nearly three feet thick.

On a small tributary of Sugar Creek from the south in Sec. 8, Tp. 17 N., R. 6 W., is an outcrop of blue shale resembling that so extensively used at Veedersburg, Indiana, for making vitrified brick. This deposit varies from 20 to 40 feet in thickness along the bluff.

In the vicinity of Montezuma, Parke County, and Hillsdale, Vermillion County, are found some of the largest deposits of shale and fire clay occurring in the State of Indiana. The Wabash River, flowing north and south between the towns mentioned, forms the boundary line separating the two counties. Montezuma is situated on the eastern bank of the river, on the edge of a river terrace. This level terrace or river-plain extends eastward one and one-half miles and there meets the bluff or upland which marks the eastern bank of the old river channel. On the western side of the river a stretch of level land, overflowed during high waters, extends for three-fourths of a mile to a very narrow terrace, on which the town of Hillsdale is partly located, and from the western side of which the bluffs, marking the western bank of the old river, rise abruptly.

The deposits of shale and fire clay above mentioned are found in the bluffs on both sides of the Wabash River. The I., D. & W. Railway runs east and west through Montezuma and Hillsdale. One-eighth of a mile west of where it strikes the bluff in Parke County it is crossed by the I. & I. C. Railway running north and south. A large tract of land located in the southeastern angle of their intersection has been recently purchased by the Marion Brick Company of Marion, Indiana. A connected section obtained on the sides of the bluff and in a well at its base, on this land, and on that of Thos. Morgan (S. W. ¼ Sec. 31, Tp. 16 N., R. 8 W.) adjoining it on the south, discloses the following strata:

1.	Surface soil and gravel	8 feet.
2.	Drab argillaceous shale	12 feet.
3.	Clay ironstone	3 in.
4.	Dark bituminous shale	5 feet 4 in.
5.	Coal	1 foot 2 in.
6.	Fire clay	6 feet.
7.	Bluish gray argillaceous shale	35 feet.
8.	Blue argillaceous shale	9 feet.
9.	Dark bituminous shale	1 foot 4 in.
10.	Coal	1 foot 8 in.
11.	Fire clay	3 feet.

From the above it will be seen that not less than 65 vertical feet of workable material are comprised in the three shales (Nos. 2, 7 and 8) and the two fire clays (Nos. 6 and 11) at the points mentioned.

The bluish gray shale (No. 7) is so soft as to be easily scratched by the nail, exceedingly fine grained, and has a very smooth and unctuous feel. Where exposed vertically by erosion, it weathers at first into small quadrangular blocks a few inches in surface dimensions. These in time break up into finer particles, which are washed down and give a characteristic grayish yellow tinge to the surface of the bluff for miles in either direction. Numerous tests of this shale have been made by the Marion Brick Company, and by the Wabash Roofing Tile Company, of Montezuma. When burned to near the point of vitrifaction it becomes a bright cherry red. When vitrified it is a dark brown, but if heated beyond this point it quickly becomes black, porous and worthless. It is especially suitable for making dry pressed brick for the fronts of buildings. It also makes an excellent roofing tile, as the very thin sheets of clay, when properly prepared for the kiln, do not shrink or warp to any appreciable extent while burning. It is, therefore, the sole material used in the manufacture of roofing tile by the company at Montezuma.

This bed of shale merges gradually into the stratum of blue argillaceous shale (No. 8) at its base. The latter is a somewhat harder and tougher material and burns to a darker red. By itself, or mixed with equal parts of the overlying gray shale, it will make a most excellent vitrified brick. Occasional nodules of kidney iron ore are found in the lower part of this stratum.

The upper fire clay (No. 6), where exposed on the Morgan land, is an almost white, highly silicious deposit, remarkably free from oxides of iron and other impurities. Large quantities of it have been burned into fire bricks and saggers by the Roofing Tile Company at Montezuma. The brick were finer in texture and more compact than those made from the fire clay at Hillsdale and Highland across the river. As far as used their refractoriness has proven to be of the highest.

The bluff for two miles north and nearly the same distance south of the railroad junction is largely composed of the above mentioned shales and fire clays. On the lands of O. P. Brown (Sections 30 and 19), one-half mile east of the I. & I. C. R. R , the shales are especially notable, at one point (N. W. ¼, Sec. 30, Tp. 16 N., R. 8 W.) the exposure of the gray and blue varieties together measuring 51 feet in vertical thickness.

By the side of the Rockville and Montezuma road, on the land of Benj. Phillips, valuable deposits of similar materials also occur. A bed of buff shale 25 feet thick overlies a thin seam of coal. Beneath this is a vein of fire clay 6 feet in thickness, and lower down a deposit 12 feet thick, of superior argillaceous shale of the kind locally known as "soapstone." Both this and the upper shale are very free from impurities and weather into a very fine-grained, plastic clay. The point where they are found is one and one-half miles from the I., D. & W., and one mile from the I. & I. C. R. R.

On the east side of Troutman's Branch, west of the Hollandsburg-Mansfield road, near the middle of Section 16, Tp. 15 N., R. 6 W., is a nearly perpendicular bluff of blue-drab shale 40 feet or more in thickness, with little covering. The upper part of the bed has a dull yellow to buff color, the lower part a blue-drab. The shale is nearly uniform in texture throughout the bed, except a stretch 3 or 4 inches thick near the middle, which is a fine-grained sandstone.

A section of the bluff shows:

1. Glacial drift and soil ....2 to 3 feet.
2. Blue-drab shale, weathered buff on the surface and containing a layer of sandstone 3 to 4 inches, exposed.......................................35 feet.

The shale extends below the level of the creek, and the total thickness is unknown. Other exposures of shale occur along Troutman's Branch, but none were observed so large or so favorably situated for development as the one described above.

A more compact form of blue shale has been quarried to some extent in Section 5, Tp. 15 N., R. 6 W., for use in fire-places, because of its fire-proof qualities.

Along the bluffs of Big Raccoon Creek in Wabash Township are some of the leading clay deposits of Parke County. The most valuable of these, as far as variety, quality and accessibility of the clays are concerned, are found at Mecca, on the lands of S. L. McCune (S. E. ¼ Sec. 20 and S. E. ¼ of N. W. ¼ Sec. 20, Tp. 15 N., R. 8 W.), where the following strata are exposed in a connected section beginning near Shaft No. 2 of the Otter Creek Coal Co., and extending down the ravines in a northwesterly direction to the mouth of "Oklahoma Hollow:"

1.	Soil and drift, "hard pan,"	5 to 18 ft.
2.	Light blue arenaceous shale	20 to 35 ft.
3.	Coal—double vein with thin fire clay parting	2 ft.
4.	Fire clay—light gray	4 ft. 8 in.
5.	Drab to buff argillaceous shale	28 to 36 ft.
6.	Dark, fissile bituminous shale	1 ft.
7.	Coal	1 ft. 8 in.
8.	Fire clay—bluish gray	5 ft. 4 in.
9.	Soft, dark blue argillaceous shale	8 ft.
10.	Dark, fossiliferous limestone	4 to 10 in.
11.	Black fissile shale with large nodules of kidney iron ore	2 ft. 6 in.
12.	Coal	1 ft. 2 in.
13.	Fire clay—dark colored	1 ft. 8 in.
14.	Light gray argillaceous shale	8 to 10 ft.
15.	Dark bituminous shale with streak of coal at base	4 ft.
16.	Fire clay—light bluish gray	5 ft. 2 in.
17.	Hard, dark silicious ironstone	2 ft.
18.	Dark gray silicious shale	12 ft.
19.	Bituminous shale	4 ft.
20.	Coal	2 ft. 8 in.
21.	Fire clay—light gray and coarse grained	4 ft. 6 in.

Outcrops of all the above strata are visible along the sides of the ravines, except the last two, which are found in the bottom of the large ravine known as "Oklahoma Hollow." Of the shales and fire clays, Nos. 2, 4, 5, 8, 9, 13, 14, 16, 18 and 21, aggregating not less than 97 feet and in places 122 feet in vertical thickness, occur in the area mentioned. Of these the following are so valuable as to be worthy of more extended mention.

The light blue shale (No. 2) is located by the side of the switch running to No. 2 coal shaft and can be easily stripped and loaded directly into cars. It contains a large amount of free silica in fine grained particles. Three thin bands of kidney iron ore are found in the lower half of this stratum at intervals of two feet apart. A sample of this shale analyzed by Prof. Noyes, shows that it contains of

Clay-base and sand	85.70 per cent.
Fluxes	12.49 per cent.

According to Orton, loc. cit., p. 134, the average composition of the shales used by ten of the leading paving brick and sewer pipe factories of Ohio is

Clay-base and sand	84.78 per cent.
Fluxes	13.22 per cent.

with a variation in the ten of only 4.1 per cent. in clay and sand and 6.04 per cent. in fluxing ingredients. Taking this *as a future standard of comparison for the composition of Indiana shales suitable for vitrified products*, we find that the one under consideration ranks high and may be classed as well fitted for the making of paving brick.

The bed of drab and buff argillaceous shale (No. 5) is a most valuable deposit. It is so situated that millions of tons can be loaded directly onto the switch running to coal shaft No. 1 or onto a short spur, easily constructed. Sixty car loads of it have been shipped to Chicago Heights and used by the Ludowici Tile Company for making roofing tile. Samples have also been burned into red pressed front brick that can scarcely be equalled in quality or appearance. According to analyses made by Prof. Noyes, it contains of

Clay base and sand	87.09 per cent.,
Fluxes	13.43 per cent.,

showing that it ranks almost as close as shale No. 2 to the standard composition of material suitable for vitrified products.

Quantities of the bluish-gray under-clay (No. 8) have been shipped to the Northwestern Terra Cotta Works of Chicago and used as the body clay in the making of structural terra cotta. The upper part of the vein burns to a bright buff and the lower to a darker, almost tan color. Handsome pressed front brick of the latter tint, made from this deposit, are now in the State collection of Indiana clay products.

The analysis of a specimen of this clay shows the presence of

Clay base and sand	89.87 per cent.*
Fluxes	10.50 per cent.

The large percentage of fluxes in this underclay shows that it is not a "fire clay," properly speaking, and any attempt to make refractory

*For complete analyses of these clays see the table at the end of this chapter.

products from it would doubtless result in failure. It can be made into sewer pipe of good quality, but the use to which it is best adapted is probably that for which it has already proven its superiority—the making of terra cotta and buff front brick.

The stratum of dark argillaceous shale (No. 9) has been practically tested in the making of paving brick, 75 or more car-loads having been shipped to the Indiana Paving Brick Company of Brazil, and used for that purpose. The bricks from it were as tough and durable as any from the noted stratum of Brazil shale to be described hereafter. No. 9 shale is softer and smoother to the sense of touch than any of those overlying it in the section given. Near the bottom of this stratum are numerous nodules of kidney iron ore which can be readily thrown aside by the miner. A sample of the shale was analyzed by Prof. Noyes and found to contain:

Clay base and sand	88.64 per cent.,
Fluxes	11.51 per cent.,

showing that it falls within the limit of variation from the standard composition which a good vitrifying material may take.

Fire-clay (No. 16), outcropping beneath the switch leading to coal shaft No. 1, is another valuable deposit. It is very soft and plastic where exposed, and so light colored that it is often used by the miners for whitewashing. It burns to a handsome light buff, and a number of high grade front brick have been made from it for Mr. McCune by the Cayuga Pressed Brick Company. It contains, according to analysis:

Clay base and sand	94.12 per cent.,
Fluxes	6.35 per cent.,

showing that it is a purer and much more refractory under-clay than the one above mentioned. Its composition is very close to that of the famous stoneware clays found about Akron, Ohio.

Neither tests nor analyses have been made of the upper fire-clay (No. 4) or the lower (No. 21) of the above section; but, judging from appearances, both are typical fire-clays of high refractory properties. The lower is almost white, and in texture and general appearance resembles more closely that at Highland, from which the well-known Montezuma fire-brick are made, than does any similar deposit so far known to occur in Indiana.

The Otter Creek Coal Company mines, from the same land on which the above clays are found, a semi-block coal. It is taken from a lower vein than any given in the above section. As a fuel either for domestic or manufacturing purposes it takes a rank among Indiana coals second only to "Brazil block." At Veedersburg and Montezuma, where it has long been used in the making of paving and fire brick, it is pronounced the best fuel which can be secured for burning these products. Running to each of the coal shafts, and passing by the side of the main strata of shales and fire clays, are switches of the I. & I. C. Railroad. Raccoon Creek, with a never-failing supply of water, is within one-eighth of a mile of the leading deposits. With an unlimited supply, in great variety, of the better grades of shales and fire clays, with good transportation facilities already constructed, and with excellent fuel and plenty of water —all in one place—this is the most eligible location for a great clay industry which Parke County possesses. Indeed, few better can be found in the State.

On the western bluffs of Big Raccoon Creek similar deposits occur, but are not so extensive. The Dee Sewer Pipe Company, of Chicago, has purchased land and, during the past summer, erected a large plant on the northwestern quarter of Sec. 19, Tp. 15. N., R. 8 W., where they will soon begin the manufacture of sewer pipe and kindred products on an extensive scale. Two strata each of shale and fire clay, aggregating 45 to 50 feet in thickness, were exposed at the time of my visit. The shales had been tested and found to make a pipe of good quality. One-half mile south of the Dee factory, on the land of Solomon Dixon, the same beds of shale are exposed just west of the I. & I. C. Railway. A more extended investigation will doubtless disclose their presence over a large area of the higher land between Mecca and the Wabash River.

Four and one-half miles west of Rockville, along the stream known as Rocky Run, in the N. W. ¼, Sec. 3, and the N. E. ¼, Sec. 4, Tp. 15 N., R. 8 W., occurs a large deposit of exceedingly fine-grained sandy clay known as "slip-clay." This is a natural glaze, of a highly fusible quality, which when melted over the surface of stoneware gives to it a brilliant color and finish. The essential property of a "slip-clay" is low fusibility, for it must melt at a lower temperature than the clay used in the body of the ware, else the latter will not stand up under the heat required to melt the glaze. The best slip-clay in use among potters comes from Albany, N. Y., and costs in small lots about $2.10 per barrel. To the ware made from the potters clay found at Bloomingdale and Coke Oven Hollow this gives a brilliant, smooth, dark brown surface. The slip-clay from Rocky Run is used by the potters of western Indiana to glaze the inside of the ware. It gives a reddish-brown glaze, somewhat rougher than that produced by the Albany slip.

The Rocky Run slip-clay was analyzed by Dr. Levette and the analysis published in the Report of the Geological Survey of Indiana, 1878, p. 159, as follows:

Silica (total)	55.20	
Alumina	14.40	
Clay base and sand		69.60
Ferric oxide	9.40	
Manganic oxide	1.80	
Lime	6.12	
Magnesia	.90	
Soda	.52	
Sulphuric anhydride	.34	
Fluxes		19.08
Moisture and volatile		8.60

Comparing with the last column of these figures the following average composition of six slip-clays used in the leading potteries of Ohio—

Clay base and sand	69
Fluxes	21
Moisture and volatile	9

we see that the Rocky Run clay possesses the necessary constituents of a successful natural glaze. As such it should be more thoroughly investigated by Indiana potters.

Numerous other large deposits of shale and fire clay occur in the eastern and southern parts of Parke County, but only brief mention can here be made of a few of them, as follows:

West of Hollandsburg, along a small tributary of Raccoon Creek (Sec. 9, Tp. 15 N., R. 6 W.), is a conspicuous bluff in which 26 feet of yellow and drab argillaceous shale is exposed, and can be easily secured by stripping. On the hill north of Ferndale (Sec. 27, Tp. 15 N., R. 6 W.) is a bed of drab argillaceous shale more than 30 feet thick, overlain by a heavy bed of drift. Both of the above deposits are suitable for vitrified products.

Beds of "fire-clay," suitable for terra cotta or sewer pipe, are exposed in the N. W. ¼ Sec. 4, and in the N. W. ¼ and S. E. ¼ Sec. 14, Tp. 14 N., R. 6 W.

In the vicinity of Caseyville, near the Clay County line, thick deposits of both shale and fire clay have been exposed in mining the block coal. Switches from three railroads penetrate this region and give abundant facilities for shipping, At the "New Superior" mine (S. W. ¼, Sec. 35, Tp. 14 N., R. 7 W.), operated by the Superior Block Coal Company, of Brazil, the top vein of coal is overlain with 11 feet of dark blue argillaceous shale, and underlain with 4½ feet of a superior quality of dark, plastic "fire clay." At the time of my visit much of this under-clay was being loaded for shipment to Chicago, there to be made into terra cotta. It brought 45 cents a ton at the mine. As some of it had to be taken up to make height in the rooms and entries, a fair profit was realized at this price. Thousands of tons of it, mixed with other useless materials, were going to waste on the dump. The same stratum underlies a large area in northern Clay and southern Parke counties.

From what has been said it may be seen that Parke County abounds in clays suitable for ordinary and pressed front brick, terra cotta, roofing tile, sewer and drain pipe, paving brick, stoneware and refractory products. Only the larger and more notable deposits have been mentioned in the foregoing pages. Many others of as good quality doubtless occur. These rich resources are as yet practically undeveloped. Aside from a few small stoneware potteries and brick yards, supplying a local trade, there are but two factories for making clay products located in the county, the Dee Sewer Pipe Company, of Mecca, and the Wabash Roofing Tile Company, at Montezuma. These have been started within the past two years. They are but the forerunners of others to come, for the raw material is there, the fuel in abundance to burn it is there, four railroads pass entirely through the county and two others touch its borders, all ready to carry the completed products to the four corners of the globe. With these facilities present, capital in time will come, will be invested, and will make the county a great clay industrial centre.

FOUNTAIN COUNTY.

Two reports have hitherto been written upon the geology of Fountain County. One, by Prof. E. T. Cox, was published in 1869; the other, by Dr. R. T. Brown, in 1881. The investigations which these parties made were primarily in search of coal, and, therefore, the deposits of clay, which in time will prove of far greater value than the coal in the county, were scarcely touched upon.

The entire surface of Fountain, as of Parke County, is covered with a deposit of glacial drift—soil, gravel, sand and clay—in some places attaining a thickness of more than 100 feet On this account it is only where coal shafts or bores have been put down, or where streams have eroded ravines and gulches, that the character and value of the underlying strata can be ascertained.

The central and western townships of the county are well drained by Shawnee and Coal creeks and their numerous tributaries, as well as by a number of smaller streams which flow directly into the Wabash River. It is, therefore, in these townships that the thick deposits of shales, which underlie the greater part of the surface of the county, can be most readily obtained. The coal area is, for the most part, included in the southwestern fourth of the county, and there, of necessity, the valuable underclays are located.

Beginning in the north we find on the "Hegler farm" (W. ½ of S. W. ¼, Sec. 34, Tp. 22 N., R. 7 W.), one and one-half miles northeast of Attica, an outcrop of a bluish-gray arenaceous shale, 22 feet of which is exposed. It is found in a ravine less than one-fourth of a mile east of the main line of the Wabash Railway. The shale is overlain with from 3 to 6 feet of soil and yellow clay, and at intervals throughout the exposure are thin seams of sandstone 2 inches to 1 foot thick, there being 3 such layers in the 22 feet exposed. The shale weathers into a fine grained, very plastic clay, suitable for pressed front brick or vitrified products.

Farther northeast, at the point in Secs. 19 and 20, Tp. 22 N., R. 6 W., at which the wagon road crosses the stream known as "Turkey Run," is a bed of similar shale 30 feet thick. This is but one-third of a mile south of the Wabash Railway, and like the preceding may be gotten by easy stripping.

About two miles west of Rob Roy in the S. E. ¼, Sec. 23. Tp. 21 N., R. 8 W., Shawnee Creek has eroded a bed through a thick stratum of blue argillaceous shale. Thirty-two feet are exposed at the point mentioned, which is about one mile east of where the Attica & Covington Railroad crosses the stream. This deposit is less silicious than the ones above noted, and on that account is capable of being made into a greater variety of products. The same stratum outcrops at other points along Shawnee Creek, but this is the largest exposure which was seen.

On Rattlesnake tributary to Bear Creek (S. E. ¼, Sec. 4, Tp. 20 N., R. 8 W.) Mr. Geo. Galloway some years ago sunk a shaft in search of clays, a section of which shows as follows:

1.	Soil	3 feet.
2.	Black sandstone	4 feet.
3.	Dark, bituminous shale	1 foot 10 in.
4.	Coal	2 in.
5.	Fire clay merging into sandstone	3 feet 8 in.
6.	Light gray shale	10 feet.

The fire clay (No. 5) is light gray and very silicious. The lower part of the stratum is a peculiar mixture of fire-clay and sandstone called "gannister rock." If thoroughly tested it will doubtless be found suitable for the lining of Bessemer and other steel converters. The shale (No. 6) when weathered, is very plastic and can be made into stoneware. Its analysis, according to Kramer, is as follows:

Silica (total)	73.20	
Alumina	13.38	
Clay base and sand		86.58
Magnesia	1.01	
Lime	.97	
Ferric oxide	2.19	
Fluxes		4.17
Moisture and volatile		9.25

This clay was used in a roofing tile factory at Covington, about 1886, but, according to Mr. Donaldson, one of the proprietors, it did ~~not~~ give satisfaction, as it cracked badly when burned hard enough to withstand the action of frost. It is said to be one of the best modelling clays in the country.

Along the bottoms of Coal Creek on the land of J. W. Shuster (N. E. ¼, Sec. 19, Tp. 20 N., R. 7 W.) one-half mile southwest of Stone Bluff, is an outcrop of a light gray potter's clay of a superior quality. It is wholly free from grit and has the greasy feel which the better grades of such clays possess. Its analysis, as made for this report by Prof. Lyons, shows the following composition, which compares well with the standard average of such clays used for stoneware and similar products, as given on p. 48.

Clay base and sand	93.07
Fluxes	6.73

At the point of outcrop it is overlain with soil and yellow clay six feet in thickness; the stratum of clay being exposed to a depth of five feet, but its total thickness is as yet undetermined. In the bluffs near by it is found beneath twenty feet of soil and sandstone. The I. & I. C. Railway passes within eighty rods of this deposit. The clay is found over an extensive area north and northwest, having been exposed in wells on the lands of Wm. Mallett and Albert Boord.

On the land of Frank Landers (N. W. ¼ Sec. 19), one-half mile west of Stone Bluff, the same stratum outcrops in several places. It is known to be eight feet thick, and in some places is overlain with a thin vein of coal. Mr. Landers had a sample of the clay analyzed, with the following results: *

Clay base and sand	92.24
Fluxes	8.36

The Hillsboro Pressed Brick Co. has recently acquired a tract of land just south of the town of that name, in Sec. 12, Tp. 19 N , R. 7 W., on which is found a surface stratum of silicious, ochery clay, which is being utilized in making red front brick. The deposit is a remarkably pure one, to be found on the surface in the drift region, and resembles closely

*For complete analysis see table at end of chapter.

the residual surface clays of southern Indiana. The works of the company have been erected on a tract of low ground near the bed of Coal Creek and the clay is secured from the top of the adjoining bluff, the face of which discloses the following section:

1.	Soil and yellow ochery clay	9 feet.
2.	Drab, arenaceous shale	3 feet.
3.	Reddish sandstone	12 feet.
4.	Gray arenaceous shale (micaceous)	3 feet.
5.	Sandstone	—

The dry pressed brick made from the clay (No. 1) are a handsome shade of dark red, but are much more friable than those made by other companies from argillaceous shale.

The two shales (Nos. 2 and 4) are mixed and burned into a fair quality of buff, pressed brick. They are too highly silicious for vitrified products.

In the immediate vicinity of Veedersburg are found the most notable shale deposits of Fountain County. Before the great value of shales for making vitrified products was fully understood, the Wabash Paving Brick Company, now the largest concern of the kind in the State, had located a plant one-half mile southwest of Veedersburg (S. E. ¼, Sec. 12, Tp. 19 N., R. 8 W.), close to the lines of the T., St. L. & K. and I. & I. C. Railways. Here they began making pavers from a fire clay which outcropped in the hill to the west. This clay gradually merged into sandstone as it passed back under the hill, until finally it became too silicious for use.

The company had meanwhile experimented with shales, and finding them highly suitable for their purpose, began procuring them from two different places. Their main supply is now gotten from a bank one mile north of Veedersburg by the side of the I. & I. C. R. R., and is hauled in cars to the factory. A section at this pit shows as follows:

1.	Soil and drift clay	1 foot 6 in.
2.	Blue plastic clay	3 feet.
3.	Dove colored, rotten shale	5 feet.
4.	Blue argillaceous shale with small kidney iron nodules	11 feet 2 in.
5.	Coal	2 feet 6 in.
6.	Fire clay (exposed)	5 feet 4 in.

Of these all above the coal, except about one foot of soil, are mingled in the proportions in which they occur in the bank. Six car loads of this mixture, costing at the plant about 22½ cents a ton, together with forty or more wagon loads from the southern pit are used each day. Fire clay (No. 6) is a dark, plastic clay of fair refractory properties. It will probably be used in the future mixed with the shale, in the proportions of about 1 part to 4.

South of Coal Creek, near the middle of Sec. 13, Tp. 19 N., R. 8 W., is one of the purest beds of shale in proportion to its thickness which has come to my notice in the State. It is on the land of Richard Hetfield, and is the one from which the Wabash Paving Company draws part of their supply. (See frontispiece.) When last seen by me, in September, 1895, it had been mined back until exposed for a depth of more than 40 feet, as follows:

1.	Surface soil and drift	2 feet 8 in.
2.	Blue argillaceous shale – the upper 3 feet discolored by leachings from the soil	35 feet.
3.	Coarse grained arenaceous shale	3 in.
4.	Blue shale, same as No. 2 (bottom concealed)	2 feet 10 in.

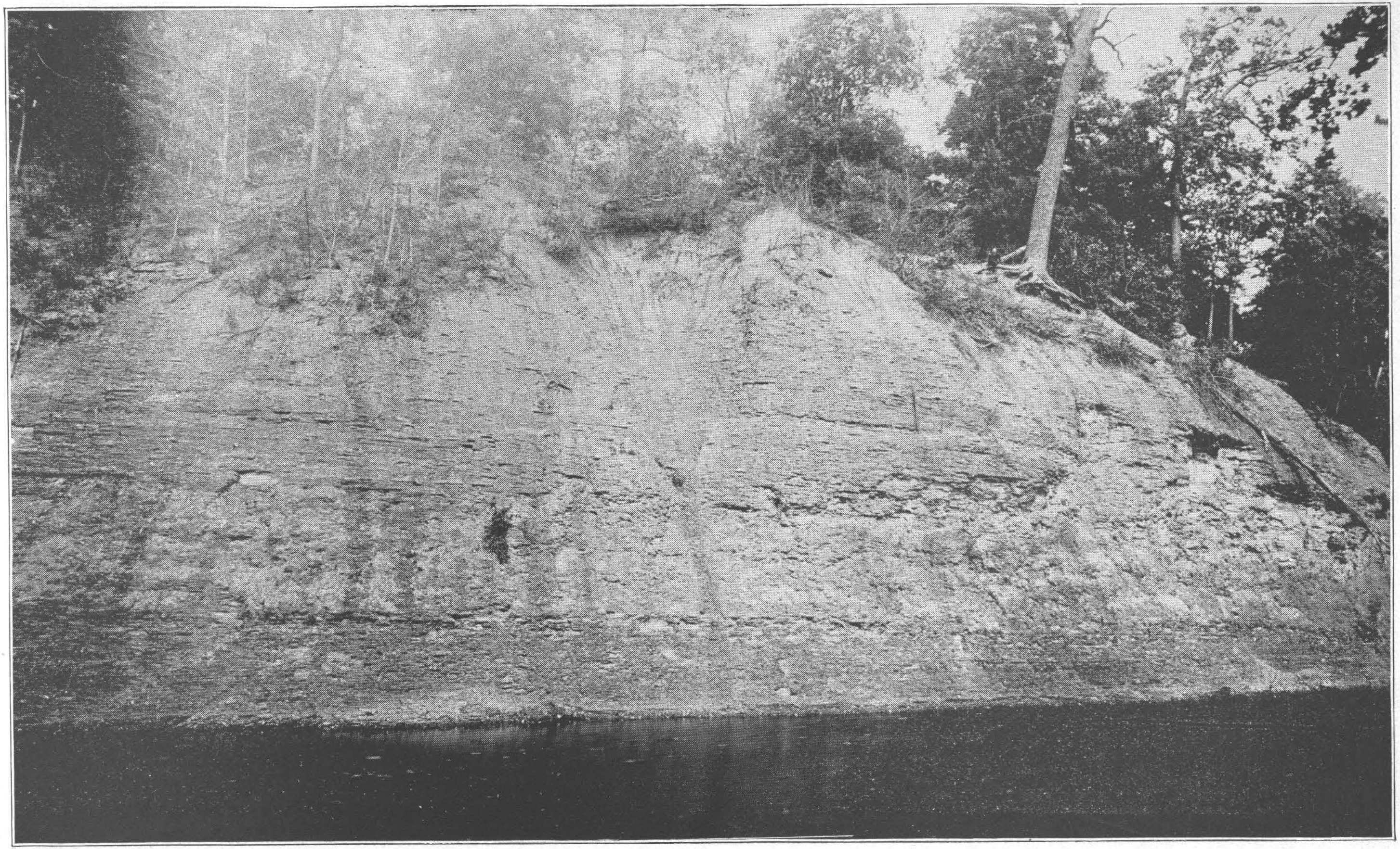
This is a rather soft, dark blue shale of very fine texture. The deposit is very homogeneous, being almost free from the concretions of iron carbonate so commonly found in such strata. But one of these was seen which had been thrown aside, and, according to the workmen, not over two a month are disclosed. The silicious band near the bottom was exposed the full length of the cliff, and was the only portion unfit for vitrified products. From the mixture of this shale with that from the bank last noted, the "Poston Block," so many of which have been used in northern Indiana during the past two years, are made. An analysis of a sample, composed of a mixture from the inside of three unburned blocks, shows the following composition of the material entering into their structure: *

Clay base and sand	82.38
Fluxes	14.73

This shows the presence of 2.40 per cent. less of refractory material, and 1.51 per cent. more of the fluxes than the standard average of Ohio shales. This is probably due to a large admixture of the surface soil and clay from the pit north of Veedersburg. Nevertheless, the mixed materials showing the above composition stand up well until thoroughly vitrified, and produce a strong and durable paving block.

Southeast of Veedersburg, on the land of Miles Marshall (N. W. ¼ Sec. 17, Tp. 19 N., R. 7 W.), a bold bluff of the same stratum of blue shale as that worked on the Hetfield land, rises abruptly from the margin of the north side of Coal Creek. The top of the bluff is covered with from 3 to 6 feet of gravel suitable for road material. The shale then sets in and is exposed for 38 feet to the water, beneath which the foot of the bluff is hidden. It is remarkably uniform in color and structure throughout the exposure, the only impurity noticeable being two thin layers of ironstone near the center. (See accompanying illustration.)

* Noyes, chemist: For complete analysis see table at end of this chapter.



SHALE BLUFF ON COAL CREEK, FOUNTAIN COUNTY, INDIANA. ONE MILE SOUTHEAST OF VEEDERSBURG.

One-fourth of a mile nearer Veedersburg, on the land of Wm. Dice (S. W. ¼ Sec. 8), the same shale is found in abundance, and can be easily secured by removing three feet of surface stripping. There is also a conspicuous shale bluff on the south side of Coal Creek near the middle of Sec. 17, Tp. 19 N., R. 7 W., and another at the mouth of Clifty Creek in Sec. 15, Tp. 19 N., R. 7 W. At the latter place the shale outcrop is 30 feet thick, and rests unconformably against a sandstone at the eastern end of the bluff.

In a ravine a short distance southeast of the shale bluff belonging to Mr. Marshall is an outcrop, three feet in thickness, of a peculiar surface drift clay. It is light brown in color, and when wet the most tenacious material I have found among Indiana clays. When dry it becomes exceedingly hard, and "sets" like plaster of Paris. It has all the properties of a most excellent modelling clay.

Numerous other deposits of clay, which are suitable for manufacturing purposes, occur in the vicinity of Veedersburg, but the above are all that can be noted in this connection. Three railroads pass through the town, connecting it directly with some of the most important commercial centers of the United States. With such superior facilities for transportation, and with an unlimited supply of excellent shales in the immediate neighborhood, nothing but a lack of energy upon the part of its people should prevent the town from becoming the seat of important clay industries.

One mile south of Covington, on the land of the Hon. Enos Nebeker (S. ½ N. W. ¼ Sec. 1, Tp. 19 N., R. 9 W.), the following strata are exposed on a hillside facing the north:

1.	Soil and drift clay	3 feet 4 in.
2.	Drab argillaceous shale	8 feet 6 in.
3.	Dark bituminous shale	2 feet.
4.	Coal	1 foot.
5.	Fire clay	1 foot 6 in.
6.	Light gray silicious shale (exposed)	8 feet.

Of these, Nos. 2 and 5 are good commercial clays and can be made into many kinds of products. No. 6 is too silicious to be used alone, but united with the others will increase their value for certain purposes.

Farther south, on land formerly owned by Monroe Carwile, potters clay of a good quality is found in an outcrop exposed for a thickness of three feet. An analysis of this clay by Kramer showed its composition to be as follows:

Clay-base and sand	91.02
Fluxes	4.90
Moisture and volatile	4.08

At an abandoned coal mine on the land of Peter Anderson (S. ½ of S. W. ¼, Sec. 12, Tp. 19 N., R. 9 W.) a deposit of blue-gray argillaceous shale five feet in thickness overlies thirty inches of coal, beneath which is a vein of fire clay the thickness of which has never been determined. Both shale and fire clay are of good quality, and mined in connection with the coal, will well repay the working.

In the S. E. ¼ Sec. 18, Tp. 19 N., R. 8 W., a blue shale comes near to the surface over a large area of land owned by J. C. Graham. It is 6 feet thick at the outcrops and according to Kramer is of the following composition:

Clay-base and sand	84.14
Fluxes	12.17

Beneath this shale are two thin seams of coal separated by a stratum of a fair quality of fire clay 3 feet in thickness.

On a small tributary of Coal Creek in Sec. 3, Tp. 19 N., R. 8 W., is an exposure of gray argillaceous shale 35 feet in thickness. Beneath this is a seam of coal 3 feet 8 inches thick, and below the coal a stratum of fire-clay of unknown depth. Both shale and clay are well suited for manufacturing purposes. Southwest of this, close to the Parke County line in Sec. 36, Tp. 19 N., R. 8 W., occurs a deposit of the better grade of potters clay.

On Sugar Mill Creek (Sec. 25, Tp. 18 N., R. 7 W.) at the lower end of the "Narrows" a blue-black argillaceous shale outcrops in places along the bluff and a well-section one-fourth mile east of the creek shows the shale to be 35 feet thick.

The above comprise all the clay deposits of note found in Fountain County of which I have a knowledge. When the means and time become available for a careful and detailed survey of each congressional township in the county others will doubtless be brought to light. Many of the above are situated by the side of or within easy reaching distance of the four railways which pass through the county. All such will soon repay the investment of capital necessary for their development, provided practical and experienced clay workers are put in charge of the plants which may be erected.

VERMILLION COUNTY

comprises a strip of territory thirty-six miles long and about seven miles wide, lying west of the Wabash River, and south of Warren County, the State of Illinois forming its western boundary. Its total area is 249 square miles, all of which is included in the *Coal Measure* formations. Of this area about one-third is taken up by the terraces and lowland bottoms of the Wabash and its tributaries. The remainder is upland, the eastern border of which is formed by the high bluffs, 120 feet or more above the level of the river, and approaching it closely between Hillsdale and Newport, the county seat.

It is along these bluffs at the point where they meet the terraces, that the largest and most available deposits of under-clays and shales are exposed. The Chicago & Eastern Illinois Railway, running north and south the full length of the county, and close to its eastern border, has its road bed within a mile and a half of all the principal clay exposures. Two other railways, the Toledo, St. Louis & Kansas City, and the Indianapolis, Decatur & Western cross the county from east to west in close proximity to large clay beds, so that the railway facilities are of the best.

Beginning with the southeastern corner of the county, we find along the bluffs between Clinton and the mouth of Brouillet's Creek in Vigo County, numerous outcrops of the same bed of shale as is worked by the Terre Haute Brick and Pipe Co. (full mention of which is made further on in the report on the clays of Vigo County.) Should a railroad ever be constructed on this side of the river these shale deposits will prove valuable. Until then, they, with the underlying coal, will remain practically undeveloped.

One and one-half miles northwest of Clinton on the S. E. ¼, Sec. 9, (14 N., 9 W.), the Clinton Paving and Building Brick Co., erected in 1893 a large factory for the manufacture of vitrified brick from the shales of the vicinity. The principal deposit of shale used lies 100 yards south of their plant, where, at the time of my visit, the following section was exposed:

1.	Soil	1 foot 4 in.
2.	Yellow drift clay	4 feet 6 in.
3.	Drab argillaceous shale	6 feet.
4.	Blue argillaceous shale	26 feet.

Of these, No. 3, while of good quality, is rotten and shelly, breaking up readily into small quadrangular pieces. The main stratum of shale (No. 4) is a soft, smooth and unctuous material, wholly free from grit, and with a smaller percentage of free silica than is possessed by the average of such shales. At a distance of twelve feet from the top of this bed is the first of five bands of rectangular pieces of iron carbonate one and one-half inches thick. These bands occur at intervals of six inches and are seen entirely around the pit. Running obliquely through the stratum of blue shale, as far as exposed, are two or three narrow curved faults or fissures, in which a material much smoother and more unctuous occurs. This corresponds to the iron sediment found in similar faults at the shale pit of the Indiana Paving Brick Co., north of Brazil, Clay County.

Brick made of the material from this pit alone are apt to shrink too much in burning and to be too brittle, owing to the lack of silica. Mixed with a more silicious material, the blue stratum is capable of being made into a strong, hard brick, with a very low power of absorption. The company formerly used the yellow drift-clay overlying the shale in another part of their yard, in the proportions of three-fourths of the shale to one-fourth of the clay. Later, they hauled from a point on Norton's Creek a shale (to be described hereafter) which they mixed in equal proportions with the No. 4 of their pit. The hauling proving too expensive they finally hit upon a shale deposit one-fourth of a mile east of their works which, when mixed with the No. 4, gives good results.

An average sample of this mixture as now used was analyzed by Prof. Noyes, and the composition found to be as follows:

Clay base and sand	84.29 per cent.
Fluxes	14.32 per cent.

This shows a very close approximation to the standard average composition* of such clays, and proves the mixture well fitted for the purpose to which it is put.

South of the plant of this company, in the N. E. $\frac{1}{4}$ Sec. 16 (14 N., 9 W.), a bore for coal was put down in the summer of 1895. The first vein, 3 feet 3 inches thick, was found at a depth of $65\frac{1}{2}$ feet from the surface. Of this thickness 41 feet was composed of shale, 32 of which was of the better quality for making vitrified products. A shaft has since been put down to the second vein of coal, which lies 142 feet below the surface and is 5 feet 10 inches thick.

On Norton's Creek, $2\frac{1}{2}$ miles northwest of Clinton, a large outcrop of shale is exposed by the side of the switch running from the C. & E. I. Railway to the mine of the Norton Creek Coal Company. This shale comes close to the surface at many places in the N. E. $\frac{1}{4}$ Sec. 5 (14 N., 9 W.) and S. $\frac{1}{2}$ Sec. 32 (15 N., 9 W.). It contains more free silica than that nearer Clinton. As mentioned above, it was for some time mixed with the blue shale at the pit of the Clinton Paving Brick Company. Care must be taken, however, in mining it, as in some places the beds contain numerous rounded nodules of iron carbonate. These, when broken open, show a formation of concentric layers, surrounding a nucleus

*See page 54.

of some foreign body, about which is more or less calcite, or crystalline carbonate of lime, and iron sulphide or pyrites. The latter impurity, when ground up with the shale in any quantity, is very harmful, causing the fluxing to take place at a temperature below that at which thorough vitrifaction occurs. If these concretions be carefully gleaned from the shale, the latter will be found in every way suitable for vitrified products. This shale lies from 10 to 12 feet below the seam of coal which has been worked to some extent in its immediate vicinity. Separating the two are 4 feet of a good quality of under-clay and from 4 to 6 feet of sandstone, the latter lying on top of the shale. A switch being already in place, this is an excellent location for a factory for vitrified brick or sewer pipe.

Farther north, along the margins of the bluff between Clinton and Hillsdale, are numerous outcrops of shale and underclay of good quality and within easy reaching distance of the C. & E. I. Railway. North of Hillsdale the bluffs come close up to the lowlands or overflowed bottoms, a narrow terrace only intervening, along which the roadbed of the railway is built.

In a ravine on the land of Jos. Burns (S. W. ¼, Sec. 26, Tp. 16 N., 9 W.), a short distance west of the station of West Montezuma, the following connected section was obtained, which shows the presence of a remarkable variety and quantity of high grade commercial clays:

1.	Soil and drift	5 to 7 feet.
2.	Sandstone	2 to 10 feet.
3.	Light gray arenaceous shale	1 to 6 feet.
4.	Coal	3 to 5 feet 6 in.
5.	Fire-clay	3 to 4 feet.
6.	Blue to drab argillaceous shale	25 to 30 feet.
7.	Concretionary iron carbonate (two bands)	6 in.
8.	Black fissile shale	2 to 3 feet.
9.	Coal	1 foot.
10.	Fire-clay (white silicious)	5 to 7 feet.
11.	Blue and drab argillaceous shale	42 feet.
12.	Black fissile shale	2 feet.
13.	Coal	1 foot 8 in.
14.	Fire-clay	8 feet.

Of these Nos. 3, 5, 6, 10, 11 and 14, aggregating from 84 to 89 feet of workable clays, and Nos. 4, 9 and 13, comprising 4 to 7 feet of fuel suitable for their burning, are found in the one place. Near the mouth of the ravine Mr. Burns, in 1872, erected a plant and began the making of fire brick from the clay No. 10. A switch from the C. & E. I. Railway runs to the plant, while the I., D. & W. Railway, one mile south, furnishes direct connection with all eastern and western points.

The gray arenaceous shale (No. 3) overlying the top vein of coal is, in places, cut out by the sandstone, the latter resting directly upon the coal. In such places the coal is much thinner than where the shale forms its roof. This shale can be made into pressed front and ordinary brick, and, mixed with some of the lower deposits, into vitrified products. The coal (No. 4) of the section has been mined at numerous places in the vicinity, and furnishes the fuel for the burning of the fire-brick at the plant below. It is a "semi-block" coal and burns into a white ash with no clinkers. The fire-clay (No. 5) is a soft, dark plastic material containing *stigmaria* and other remains of plant fossils. It vitrifies to a dark brown, and one or two kilns of sewer pipe of good quality were made from it some years ago, as an experiment, by Mr. Burns. These were sold to the I., D. & W. Railway and are now in use along that line in the vicinity of Montezuma.

Stratum No. 6 is a dark blue shale or "soapstone," which weathers to a lighter drab in places. It burns to a close textured body of a handsome dark red color. Its composition, according to analysis by Prof. Lyons, is as follows:

Clay base and sand	81.24 per cent.
Fluxes	15.91 per cent.
Volatile	2.87 per cent.

This compares favorably with the standard composition (see p. 54) of shales used for vitrified products, and shows, as far as a chemical analysis can, the fitness of the shale for making such products.

Near the lower part of this stratum of shale are the two bands of iron carbonate (No. 7 of the section), the upper being 6 inches thick and the lower 2 inches, the two being separated by a stratum of the shale 14 inches in thickness. The pieces of ironstone are quadrangular and have the appearance of bricks laid regularly in place.

Fire-clay No. 10 is nearly white and contains so large a percentage of silica that it resembles in appearance a sandstone. It is the most refractory underclay that has been discovered in the State, and the fire-brick and furnace linings made from it have been put to the most severe tests possible, and have everywhere given the best of satisfaction. Large numbers of the brick are sold annually to iron manufacturers, as far west as Montana and south to Georgia and Alabama. In a kiln at Burns' factory, which has been in constant use for 22 years, the brick of the floors and walls are of this clay and appear little the worse for wear. An analysis of this clay by Prof. Lyons shows the following percentage composition:

Clay base and sand	98.24 per cent.
Fluxes	1.79 per cent.

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 underclay 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 material, such as glass pots and kindred products. This stratum of clay underlies an area a mile wide and extending from Hillsdale almost to Newport. It is at present worked only by Burns and Hancock, and by the Hillsdale Fire Brick and Tile Company, whose plant is located one mile south, near the crossing of the I., D. & W. and C. & E. I. railways. Both companies grind and ship large quantities of the fire-clay, receiving therefor $1.50 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, and many other purposes.

Shale No. 11 is the correlative of No. 7 of the section obtained on the Morgan land across the river.* At Burns' its upper half contains much more free silica than the lower, and in places, especially farther north, is replaced by a compact gray sandstone. The lower half is the soft, unctuous, argillaceous material so well fitted for vitrified products. An analysis by Prof. Lyons of a sample of the latter shows its composition to be as follows:

Clay base and sand	88.06 per cent.
Fluxes	11.88 per cent.

This is a purer and more refractory shale than No. 6. By itself it will evidently shrink some in burning, but by mixing with the upper half of the same stratum a material can be obtained whose chemical composition is in every way suitable for making the best of vitrified products.

This stratum of shale is found exposed for a distance of twenty feet by the side and within thirty feet of the kilns of the Hillsdale Fire Brick Company. Fifty or more car loads of it were shipped from there to Chicago and made into roofing tile. It brought thirty cents a ton on board the cars.

Nos. 12, 13 and 14 of the above section are beneath the surface level at the site of the plant of the Montezuma Fire Brick Company, and were given me by Mr. Burns from a record of a well boring. One mile southwest of Hillsdale these three strata outcrop on the land of Mr. Yoke. Here the bottom of shale No. 11 rests on four feet of fissile black shale, beneath which the coal is ten inches thick. The underclay of this coal, eight feet thick, is a fine grained, light colored silicious material, which, when free from mpurities, will make good stoneware. Mr. Yoke has for some time made from it a patent "stone" fence post, and has proven the clay to be refractory enough to stand up under the heat required for glazing. Beneath this fire clay is still another vein of coal two and one-half feet thick which has been mined in a number of places southwest of Hillsdale.

Taking into consideration the quality of the fire clay (No. 10) and the variety and abundance of the shales, together with the presence of a

*See above, p. 51.

clay suitable for potter's use, and coal sufficient to burn them all, I consider the deposits at West Montezuma to be the most valuable found in western Indiana.

The sequence of the strata given above, when taken in connection with that of those found outcropping in the bluffs on the Morgan land in Parke County, show conclusively that the beds of shale, clay and coal were once continuous and unbroken across the Wabash Valley. A mighty force it has taken, acting unceasingly through hundreds of centuries, to erode this valley two and one-half miles wide to its present depth.

West of Newport, along the Little Vermillion River, outcrops of large deposits of good clay are noticeable in a number of places. In the S. E. ¼ Sec. 30, 17 N., 9 W., is an exposure of 35 feet of light gray argillaceous shale near the site of White's old mill. A short distance below this, on the north side of the stream, there is a deposit of shale that might be worked to good advantage in connection with the sandstone which lies in the shale bed. The sandstone varies from 12 to 15 feet in thickness and is overlain by 6 to 10 feet of dull gray argillaceous shale and underlain by 15 to 20 feet of a better quality of fire clay and blue shale. At the "horse shoe bend" of the same stream (Sec. 29, Tp. 17 N., R. 10 W.) are also exposures of large beds of both shale and underclay which will repay working should a railway ever be built near them.

Northwest of Newport the Wabash River terrace widens out until in places it is four miles in width with an average elevation of almost forty feet above the overflowed bottom land. Along the western border of this terrace or prairie the outcrops of shale and clay, with their accompanying coals, occur in many places. But one of these has been utilized, and that by the Cayuga Press Brick and Coal Mining Co., in the N. E. ¼ Sec. 7, 17 N., 9 W. At this point, one and one-half miles southwest of Cayuga, the largest plant now in the State for the making of pressed-front brick has been erected and a switch of the T., St. L. & K. C. Railway constructed thereto. The deposits of clay used are found seventy-five yards from the dry pans and are hauled into the sheds adjoining by tramway cars. An average section of the pit discloses the following strata:

1.	Soil and drift clay	2 feet.
2.	Pinkish shaley sandstone	5 feet.
3.	Drab arenaceous shale	5 feet 6 in.
4.	Blue arenaceous shale	7 feet.
5.	Bastard fire clay (bottom concealed)	6 feet.

The sandstone, No. 2, merges gradually into shale, No. 3, so that the latter contains a large quantity of free silica and numerous scales of mica, not enough, however, to prove harmful. The two shales, Nos. 3 and 4, are mixed together in varying proportions to form different shades of red. Average samples, taken from the centers of several unburned brick, which were made of the two shales mixed in equal proportions, were analyzed by Professor Noyes, and the composition found to be:

Clay base and sand	86.55 per cent.
Fluxes	13.78 per cent.

This mixture burns into a tough, even grained, front brick of a handsome and uniform shade. Its composition shows it to be well suited for the making of vitrified products.

Stratum, No. 5, has the general appearance of an underclay, being unlaminated, and of the light gray color usually possessed by such deposits. Its chemical analysis proves it, however, to be of low refractory power. Professor Noyes analyzed an average sample and found it to contain of

Clay base and sand	84.06
Fluxes	12.40.

This clay burns into a buff front brick of handsome appearance. Just why it should burn buff when the analysis shows the presence of 7.01 per cent. of iron oxide, is a chemical problem which is difficult to solve. At the exposure west of the plant of this company the layer of sandstone overlying the shale is much thinner, and the latter is seen to have a strong dip to the southwest and to be much contorted in the bed. One-half mile south the shale has been proven by bore to be thirty feet thick, with a surface stripping of but two and one-half feet.

The above comprise some of the more available deposits of commercial clays which came to my notice in Vermillion County. Many others doubtless exist. Those mentioned are sufficient in quantity and in quality suitable to make for centuries many of the products which are now brought into Indiana rom other States.

VIGO COUNTY,

in which the city of Terre Haute is situated, comprises an area of 400 square miles, and lies on the western border of Indiana and almost midway between the north and south boundary lines of the State. The Wabash River flows in a southwesterly direction through the county, and numerous small streams, which rise in the uplands, find their way into it in such a manner as to furnish an abundance of running water to every township. The surface of the county is practically level, the topography not being marked by any prominent hills or rugged scenery, and may be divided into three general divisions, viz.: River bottoms, prairies and uplands.

The river bottoms, which are usually overflowed each spring, are from two to four miles in width. Bordering these lowland bottoms are level river terraces or prairies varying in width from three to eight miles. Beyond the terraces are the uplands, usually more or less broken by the erosion of small streams. These extend to the confines of the county and are underlaid with coal. With the exception of the recent sedimentary clays of the river bottoms, all the commercial clays of the county are found in the uplands, or outcropping along the hillsides where the river terraces meet the uplands.

The largest and most available deposits are found in an area (two miles wide) of the upland on the west side of the Wabash River and north of the old National Road.

The following section, obtained at Broadhurst's mine, one mile west of Macksville, in the S. E. ¼ of the S. E. ¼, Sec. 24 (12 N., 10 W.) may be taken as showing the average sequence and thickness of the strata over the greater portion of the area mentioned:

1.	Soil and drift clay	13 feet.
2.	Limestone (fossiliferous)	2 feet.
3.	Gray argillaceous shale	12 feet.
4.	Sandstone (massive)	12 feet.
5.	Shaly sandstone merging into blue shale or "soapstone"	42 feet 6 in.
6.	Coal	4 feet 8 in.
7.	Fire clay (not passed through)	6 feet.

The lower two-thirds of stratum No. 5 is the blue shale or soapstone found in the uplands on both sides of the river. That portion of it suitable for vitrified products or dry pressed brick, varies in thickness from 15 to 35 feet, the former being the minimum amount which can be relied upon. Passing upward this shale merges gradually into the sandstone, No. 4. In a few places, as along the roadside in front of Mr. Bennett's house, one-third of a mile east of the Broadhurst mine, a thin stratum of non-fossiliferous, bastard limestone is found, separating the sandstone, No. 4, from the overlying shale, No. 3. The latter, No. 3, is usually more or less impregnated with leachings from the limestone, No. 2, and its quality thereby impaired.

One-half mile west of Macksville, and just north of the point where the Vandalia Railway strikes the upland, on the Walker farm (S. W. ¼ Sec. 19, Tp. 12 N., R. 9 W.), is a very large deposit of shale, No. 5, which can be gotten by easy stripping. Professor Cox, in the Geological Report for 1870, mentions this point and gives the thickness of the shale as 48 feet. A switch 100 yards long, from the Vandalia Railroad, would be ample to reach the very center of the deposit. The quality of the shale is fully equal to that at present used by the Terre Haute Brick and Pipe Company. Coal "L" underlies this deposit and is at present mined 100 yards south of the railroad.

Another large outcrop of shale No. 5 occurs on the Larrimer land in N. W. ¼, Sec. 25 (12 N., 10 W.) It is in a ravine one-eighth of a mile northwest of the coal mines which are worked on the same land. This shale can be secured by easy stripping. Some of the most handsome and durable pressed front brick that have ever come to my notice were made from it for Dr. J. T. Scovell of Terre Haute. This deposit outcrops over quite an area, is underlaid with coal, and can be easily reached by a switch from the Vandalia, one mile distant.

Along the low bluffs of West Little Sugar Creek on the Hickling land, in the north ½ Sec. 15 (12 N., 10 W.), is an extensive outcrop of the same shale which is exposed for a thickness of 20 feet. It is overlain with 7 feet of soil and yellow clay and underlain with bituminous coal. A switch one and one-half miles would be necessary to reach this deposit.

On the "old Casto farm," now owned by H. T. Thorp of Terre Haute, in the S. E. ¼ Sec. 23 (12 N., 10 W.), is another extensive outcrop. This is within one-third of a mile of the Vandalia Railway and by the side of Sugar Creek, in which is found a never-failing supply of water. A vein of coal 5 feet thick is found at a depth of 50 feet and another at 130 feet. The shale is exposed to a depth of 12 feet, beneath 4 feet of overlying soil and clay. It is a soft, light gray, unctuous material, wholly free from grit or pyrites, easily cut with a knife, and very plastic when ground and moistened. Sample paving brick have been made from it which were very tough and almost non-absorbent. The shale, according to analysis by Prof. Noyes, bas the following composition:

Clay base and sand	90.65 per cent.*
Fluxing impurities	9.87 per cent.

Comparing this with the standard average of shales suitable for vitrified products, given on page 54, as follows:

Clay base and sand	84.78 per cent.,
Fluxing impurities	13.22 per cent.,

we find it to be a much purer and more refractory clay than the average, and it will therefore have a tendency to shrink in burning, which can be readily overcome by mixing with it some of the overlying surface clay or a shale containing more silica. This analysis may be taken as fairly representative of the average composition of these soft gray, unctuous shales found in the uplands west of the Wabash River.

The Terre Haute Brick and Pipe Company has recently purchased 200 acres of land 2½ miles northwest of Terre Haute in Sec. 18 (12 N., 9

*For complete analysis see the table at end of chapter.

W.), almost all of which is underlain with shale and coal. Just above the high water mark of the Wabash River, and a few hundred yards south of where the Indianapolis & St. Louis Railway strikes the uplands, this company erected, in 1894, a modern plant for the making of hollow brick and vitrified wares. At this point the shale overlying the coal outcrops, and the latter is secured through a vertical shaft at the depth of 34 feet. The strata exposed are as follows:

1. Surface and drift .... 1 foot 6 in.
2. Gray argillaceous shale, "soapstone" .... 30 feet.
3. Black fissile shale .... 2 feet 6 in.
4. Coal "L" .... 5 feet.
5. Fire clay .... 9 feet.

The shale (No. 2) is the same stratum as No. 5 of the Broadhurst section. It has the general character and composition of that found in the deposits mentioned above. At the pit, where it had been exposed to the depth of 20 feet, it was seen to lie in laminae $1\frac{1}{2}$ to 4 inches in thickness. Two bands of iron carbonate (siderite) in large concretionary nodules were found in the exposure. They were easily separated and thrown aside by the miners. The shale vitrifies to a handsome dark red color. The body of the hollow brick made from it is exceedingly solid and close textured, and there is no doubt but that it will make vitrified products of a high grade. The fire clay beneath the coal has been used for brick for the walls of kilns, and has fair refractory properties. Mixed with the shale it can all be utilized in the various products made by the company.

Farther north thick beds of the shale overlying coal "L" outcrop at a number of localities. At Durkey's Ferry in the N. W. $\frac{1}{4}$ Sec. 21 (13 N., 9 W.), it is 18 feet thick, and contains many ironstone nodules, some of which when split open disclose very fine impressions of fossil plants.

On the east side of the Wabash River the principal outcrops of commercial shales found at available points are southeast of Terre Haute in Riley and Honey Creek townships. On the land of Hon. J. M. Sankey (N. E. $\frac{1}{4}$ Sec. 17, 11 N., 8 W.) the E. & I. Railway runs by the side of a large deposit of soft, gray argillaceous shale. This is more than 20 feet thick and lies just above coal "M", which at this point is three feet in thickness. The shale will require little stripping and can be used for all kinds of vitrified products. It contains less than an average amount of free silica, and the shrinkage in burning will, on that account, be considerable, but this defect can be readily overcome by mixing with surface clay or some more silicious material. The eastern one-half of section 17 is underlain with this shale, and the coal beneath it. At a depth of 106 feet coal "L" with its overlying blue shale is found, and is mined just west of Riley. The Sankey deposit, having already present the raw material, fuel and railway, is a most promising place for the location of a clay industry.

On the "old Tuller farm" in the N. W. ¼ Sec. 13 (11 N., 9 W.) is a bluff of shale 30 feet in thickness. The point where found is one-half mile north of the E. & I. Railway, to which a level tramway could be readily constructed and the shale hauled to it, or a switch built and a plant erected by the side of the deposit. The shale is of good quality and contains a higher percentage of free silica than that at Sankey's. Coal has not been found here, but borings will undoubtedly show the presence of vein "M" immediately below the shale. Numerous other exposures of shale suitable for manufacturing purposes occur farther south and east, the two mentioned being the closest to railway facilities.

The Terre Haute Pressed Brick Company has been making for two years a good grade of dry-pressed front brick from the sedimentary clays found in the lowlands of the Wabash River. The plant of the company is situated on the border of the eastern river terrace, in the northwestern part of the city of Terre Haute, and the clays used are obtained 200 yards west of and 35 feet below the level of their yard. The clay has been deposited where found by the high waters of the annual overflows. Its thickness has never been determined, but it is known to be more than 20 feet. It is very fine in texture, and for a river-bottom clay remarkably free from pebbles and coarser impurities. The dry-pressed bricks made from it are very hard and smooth.

The one bad feature about this clay is its tendency to burn into different colors. This necessitates much labor in the assorting of the finished product. No less than thirteen different shades are gotten from each kiln. This is doubtless due, in part, to the non-uniformity of chemical composition which such a clay must of necessity, possess, but more largely to the variations of the burning and positions in the kiln. Nevertheless, by careful assortment, the company has been successful in getting a good percentage of first-class brick, and the "seconds" sell readily at fair prices for sidewalks and foundations.

This sedimentary clay is the sole material used in the eight or ten million soft mud brick made annually at Terre Haute. These give good satisfaction, and the clay seems in every way suitable for their production. At Middleport, Ohio, similar sedimentary clays from the lowlands of the Ohio River, are used by two large factories for the making of vitrified brick. They present the cheapest form of clay which can be used for paving material, as they can be dug by steam shovel for a nominal cost, and the labor necessary to prepare them for use is almost nothing. On the other hand the excessive plasticity of the material is against it, as it is difficult to prevent faults of structure in forming the brick.

The analysis of the Terre Haute clay (Noyes, chemist) is here given side by side with that of a similar sedimentary clay from the lowlands of the Ohio River, near Columbia, Ohio, and which, according to Orton, "was worked into vitrified wares of high grade":

	Terre Haute.		Columbia, Ohio.	
Silica (total)	66.11		63.73	
Alumina	13.78		17.17	
Water (combined)	6.34		4.90	
Clay-base and sand		86.23		85.80
Oxide of iron	5.35		5.85	
Lime	1.67		.58	
Magnesia	1.78		.97	
Potash	2.11		2.33	
Soda	1.15		.67	
Fluxes		12.06		10.40

At the mines found in Vigo County along the Vandalia Railway, east of Terre Haute, but little clay or shale suitable for manufacturing purposes was observed. At Seeleyville the section exposed in the shaft of the new "Ray" mine of the Vigo County Coal Company disclosed, instead of the argillaceous shale usually found above the worked seam of coal, 41 feet of arenaceous shale. This contained too high a percentage of silica and mica to be of value. The underclay of the coal is but 18 inches thick. A lack of time prevented my visiting the mines farther north along the I. & St. L. Railway, but from the records of bores furnished me by the Coal Bluff Mining Company I should judge the conditions there to be about the same as at Seeleyville.

The deposits of Vigo County clays mentioned above are all valuable, and a factory located at any one of them will, under normal conditions, prove a paying investment. The city of Terre Haute will doubtless maintain in the future, as it has in the past, a steady, onward growth, and will use clay products for buildings and roadways to the value of many millions of dollars. With large deposits of the raw materials suitable in the highest degree for making these products; with the best of fuel for burning these materials into their proper shapes, and with seven railways stretching in all directions, ready at a moment's notice to carry the surplus to less favored cities, there is no reason why a single dollar should be sent elsewhere for such products.

CLAY COUNTY

has long been noted as the mining center of Indiana. Its beds of non-caking block coal are the most extensive found in the United States, and their development, brought about largely by the energy and acumen of a former State Geologist, Prof. E. T. Cox, has added much to the wealth and prosperity of the county. The beds of bituminous coal underlying the western third of the county are also of great economic value, and their working gives employment to many hundreds of men.

Since 1890, however, another industry based upon the clay resources of the county, has come to the front, and bids fair to, in time, outstrip even that of coal mining in importance. Brazil, the county seat, has become, since that date, the leading clay manufacturing center of the State. Five large companies, each with an invested capital of $40,000 to $100,000, have been formed, and are to-day busily engaged in making from the fire clays and shales of the vicinity many different kinds of clay products. Previous to the date mentioned the clays of Clay County had received little attention. Two potteries, one of which is still in operation, had used the underclay of the vein of coal immediately above the main block seam "I," for making stoneware; and Weaver Bros. had for 21 years made "stone" pumps from the fire clay beneath the latter seam. Other than this no use whatever had been made of a resource which is destined to equal in value that of the seams of coal which it accompanies.

Three or four of the clay manufacturing companies at Brazil conduct their business on a basis at which they can defy competition. Their factories are erected at points where both clay and coal exist, and are readily obtained free from all transportation charges. Railways are used only to ship the finished products. The largest industry whose plant is so situated is that of the Monarch Sewer Pipe Company, whose factory is located one mile northwest of Brazil, in the S. E. ¼ Sec. 25, (13 N., R. 7 W.). This company manufactures sewer pipe, flue linings, etc., from the underclay of the main vein of block coal. The shaft of their coal and clay mine is but a few yards from their main building. A section, to the bottom of the vein of clay used, discloses the presence of the following strata:

1.	Soil and yellow surface clay	12 feet.
2.	Blue drift clay ("hard pan")	7 feet.
3.	Gray argillaceous shale	33 feet.
4.	Coal (top or "rider" vein)	2 feet 3 in.
5.	Fire clay (potter's clay)	3 feet 2 in.
6.	Blue argillaceous shale	19 feet.
7.	Dark fissile shale (bituminous)	1 foot 6 in.
8.	Coal—main block "I"	3 feet 6 in.
9.	Fire clay	5 feet 4 in.

The coal, No. 8, is first mined and then the fire clay is taken up. The latter is a light gray in color, free from sulphur or other impurities, hard when first mined, but weathers after a few weeks' exposure into a fine grained plastic mass. This makes a strong and durable sewer pipe, which with a salt glaze becomes a light reddish brown on the outer surface. Shale, No 6, is a high grade laminated clay, which extends over a wide area between the two veins of coal. A mixture of one-third of it with two-thirds of the fire clay burns to a handsome dark brown color, and makes a sewer pipe of great strength. Shale, No. 3, is also a good product for many wares, especially if mixed with either of the above.

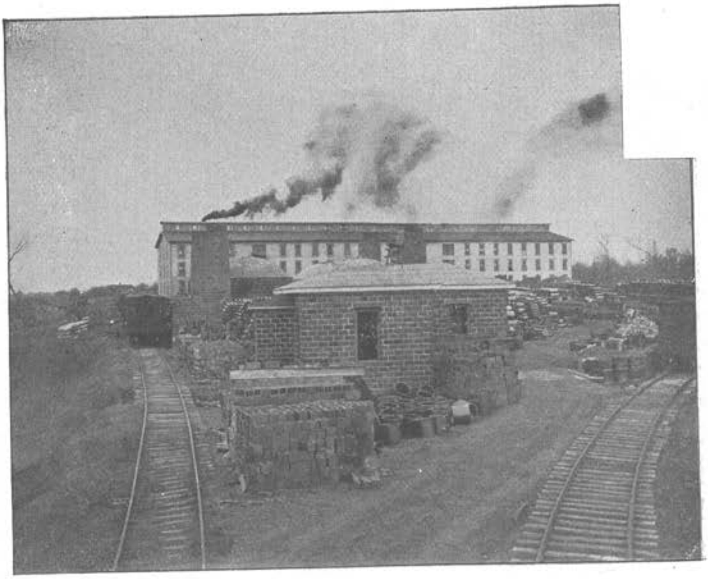
The men in charge of this factory are practical clay-workers of long experience in other States. They state that the block coal found in the vicinity of Brazil can not be excelled for burning clay products. It contains less sulphur than any other fuel and, as a consequence, a better glaze is secured on the surface of all wares. The Monarch Company puts out 1,200 car-loads of products each year, the total value of which is about $90,000.

One-half mile farther north the Brazil Brick and Pipe Company, the pioneer of the new clay industries of central Indiana, has its factory located. Four of the five owners are men whose lives have been spent in clay factories. One of them said: "We tested clays in several different States and those found in the vicinity of Brazil were selected as the best for the business we have in hand. We wanted a clay that would dry quickly without cracking and that would burn safely with a salt glaze. This we have in the underclay of the block coal."

This company mines its coal and clay from a slope shaft, one-eighth of a mile west of their plant, and hauls them to the latter by a tramway. They make of the underclay (No. 9 of the section given above) hollow brick for structural purposes, and vitrified drain tile, to the value of $50,000 annually. By mixing the gray argillaceous shale, overlying the top vein of coal with the fire clay, the company has made both drain tile and hollow brick of a darker and more handsome finish than when made of the clay alone.

The two shales, Nos. 3 and 6, which aggregate 52 feet in vertical thickness at the Monarch Company's shaft, outcrop in many places along the valley of Otter Creek. In a few places No. 3 has merged into a grayish sandrock, beneath which the top vein of coal "K" appears in a vein of varying, but never of workable thickness. The potters clay beneath this coal has been used since 1859 in the pottery at Brazil. When properly washed and tempered it burns into a close textured ware, buff or gray in color according to the intensity of the heat to which it is subjected. This ware is of great strength, and takes a handsome dark glaze with Albany slip-clay. One of the best outcrops of this potter's clay is in the S. E. ¼, Sec. 17 (13 N., 6 W.).

WORKS OF BRAZIL BRICK AND PIPE CO., BRAZIL, IND.



WORKS OF CHICAGO SEWER PIPE CO., BRAZIL, IND.

Since 1891 the Indiana Paving Brick Company, whose plant is located in the western suburbs of Brazil, has used the gray shale (No. 3) from an outcrop near the Otter Creek bridge of the I. & I. C. Railway, two miles north of Brazil. At their pit the bed of shale is 30 feet thick and the underlying coal "K" 2½ feet. The shale is gotten by blasting near the base of the worked ledge, when large quantities of it, sometimes 20 tons, come tumbling down. It is overlain with three feet of shelly sandstone, which must be separated and thrown aside. All the rest, including four feet of yellow surface clay, is loaded onto cars on a near-by railway switch and hauled to the factory.

In the exposed ledge the shale is seen to be in laminae or layers from ½ to 2 inches thick. Some narrow perpendicular cliffs or faults were noticed, down which water, impregnated with oxide of iron, had passed, the water in time evaporating and leaving the mineral in thin sheets in the crevices.

At the plant a mixture composed of two-thirds of this shale, one-sixth of surface clay and one-sixth of the blue shale overlying the main block coal, "I," is used in making the paving brick. Many millions of these bricks have been sold in the cities of eastern Illinois, northern Indiana, and especially in Indianapolis. Everywhere they have given the best of satisfaction.

On a switch of the "Midland" Railway, one and three-fourth miles northeast of Brazil, in the N. W. ¼ Sec. 30, 13 N., 6 W., is the plant of the Excelsior Clay Works, erected during the summer of 1895, for the purpose of making vitrified products and stoneware. The clay used will be the underclay of coal "I," which is mined 150 yards northwest of the plant, the potter's clay beneath the "rider" vein and the gray shale overlying the latter. All of these are of the same character as found at other points mentioned above. The potter's clay outcrops five feet in thickness in the ravine a few yards north of the plant. Both fuel and clays will be brought direct to the crushing room by means of tramways.

One mile southwest of Brazil is located the plant of the Chicago Sewer Pipe Company. This company began in 1893 to make sewer pipe from the gray shale (No. 3) overlying the "rider" vein of coal, and find it in every way suitable for their purpose. Their pit is situated 100 feet south of their plant, and the shale is hauled up over an inclined tramway and dumped by the side of the dry pan. It is mined by stripping only the soil, the seven feet of "hard pan" underlying this being used in the proportion of one-fourth to three-fourths of the shale. The stratum of the latter is thirty feet thick. Samples of this shale have been tested for roofing tile by the Wabash Roofing Tile Company, of Montezuma, Ind. Mr. John Donaldson, the superintendent of the company, informs me that it makes a stronger tile and warps less in drying and burning than any material he has tried.

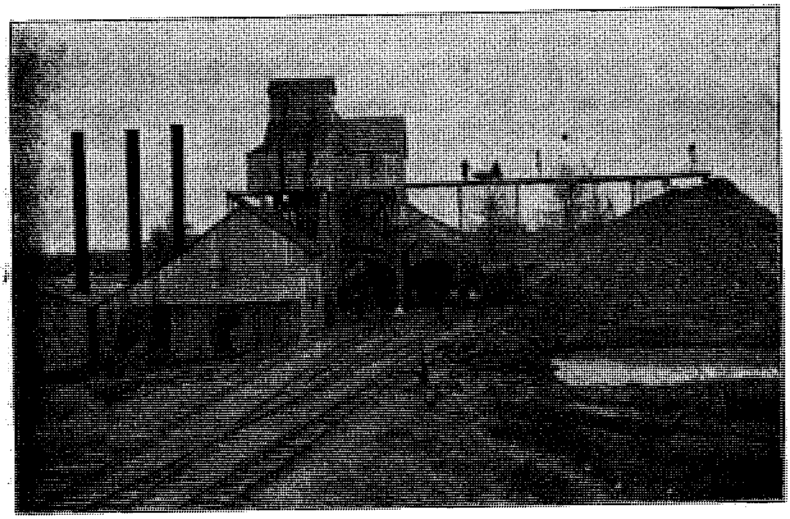
The Chicago Sewer Pipe Company investigated the clays of Iowa, Illinois and Indiana before locating their plant and finally chose the present site as the one where clays of a superior quality for making sewer pipe could be secured at a minimum cost, and where fuel and transportation facilities were of the best. The factory is run to its full capacity, and almost the entire output is shipped to Chicago, the demand being far greater than the present source of supply.

The shale (No. 3) by itself, burns to a dark cherry red; mixed with "hard pan" or surface drift clay, to a brighter red. It has by bores and shafts been proven present on all sides of Brazil to a distance of two miles, except to the southeast, where it seems to be largely replaced by a sandstone. It has an average thickness of thirty feet over the area mentioned, and in most places lies within from twelve to eighteen feet of the surface. The blue shale (No. 6) overlies the middle vein of block coal "I" wherever the latter is found. In some places it contains too large a percentage of pyrites to be of value. The underclay (No. 9) is also co-extensive with the block coal "I," and in the immediate vicinity of Brazil is uniform in character and composition with that used in the factories mentioned above.

On the north fork of Otter Creek, in the northern tier of sections of township 13 N., R. 7 W., are numerous outcrops of a blue argillaceous shale in every way suitable for vitrified products. At the shaft No. 8 of the Brazil Block Coal Co. (N. E. ¼ Sec. 3) it is exposed to a depth of ten feet by the side of the railway switch running past the mine. Two seams of block coal are mined at this place. The upper one is overlain with fourteen feet of blue argillaceous shale and underlain with three and one-half feet of fire clay, both suitable for manufacturing purposes. The underclay of the lower vein of coal contains too much sulphur to be of any value. Having the three essentials, raw material, fuel and transportation present, this is a most inviting site for a paving brick or sewer pipe plant.

In the vicinity of Carbon are also large deposits of commercial clays. Of these the ones on the lands of Benj. Simpson have been worked for some time. Here is found a surface yellow clay of great purity, large quantities of which are used by the Encaustic Tile and Terra Cotta Works, of Indianapolis, as a body for red products, it burning into a very handsome shade of that color.

Both of these companies also secure from the Briar Block Coal Company of Clay City, a fire clay which they use as the main body-clay in the production of their wares. The shaft of this company is located one mile northwest of Clay City, on a switch of the E. & I. Railway. The underclay of the main block coal "I," is the material which is mined and shipped. This coal is here found at a depth of 117 feet and the vein is but 3½ feet in thickness. As a consequence, much of the underclay has to be handled to make height. The proprietors have worked up a good market for it, and during the last year sold over 9,000 tons at 90 cents per ton on board the cars. Besides Indianapolis, it was shipped to



PLANT OF BRIAR BLOCK COAL COMPANY, CLAY CITY, INDIANA.

Chicago and Cincinnati, where it was made into ornamental brick, fire brick and terra cotta. It has essentially the same properties as the under-clay of similar horizon at Brazil. Its refractory qualities are not as high as those of the clays of Montezuma. When ground and wet it becomes a very close plastic material, well suited for the uses to which it has been put. Immediately above the block coal at this mine are 27 feet of blue argillaceous shale, the upper two-thirds of which can be made into vitrified products.

A stoneware pottery was established at Clay City in 1846, and has been operated continuously since. For many years the clay used was obtained from a pit one-third of a mile farther south in N. W. ¼ Sec. 32 (10 N., 6 W.) The clay is obtained by stripping 6 to 8 feet of soil and surface clay, beneath which it lies in a stratum 5 to 7 feet in thickness. Underlying this is a reddish, rotten sandstone of unknown depth. Crystals of gypsum (selenite) occur in some parts of the clay deposit, but not in sufficient numbers to prove deleterious. This clay is very light in color, and has good refractory properties, its one drawback being that the ware has a tendency to air-crack while cooling. It was formerly used in quantities in a pottery in West Indianapolis; several thousand tons having been shipped there. It brought $1 per ton on board the cars at the pit.

On account of the stripping necessary to get at this clay, the present potter, Beryl Griffiths, has gradually abandoned its use, and now secures his supply of clay from the land of Robt. Guthrie, 3 miles southeast of Clay City, and one-fourth of a mile from the E. & I. Railway. At this point a good potters clay is secured with but little labor from beneath a thin seam of coal, where it is found in a stratum 3½ feet in thickness.

One-half a mile north of Clay City is the mine of Burger & Burnham. The underclay of the worked coal is richer in silica and therefore more refractory than that at the Briar Block mine. Mixed with the potters clay from the land of Guthrie in the proportion of one part to two, it improves its quality for stoneware purposes, producing a strong, close textured product which does not air-crack and which stands up well under great heat.

South of Cloverland, three fourths of a mile, in the bed of a creek on the farm of John Williams, is an exposure of good shale 4½ feet thick. Beneath this is a vein of coal 2½ feet in thickness which has been worked by stripping. At one point where the coal had been eroded some fine examples of "cone in cone" were obtained from the underlying fire clay. These appeared as small cone-shaped masses of the fire clay set one within another. They had the appearance of small concretionary or pressure structures, and were probably caused by the slipping of certain of the hardened fire clay layers.

On the land of Henry Stedman, one and one-half mile west of Staunton, the bituminous coal "L" is mined, the vein in several places averaging 7 feet in thickness. A drift bowlder clay rests directly upon the coal with no shale or slate intervening. Much of the coal may have been eroded by the drift before this deposit of clay was made. "Hard pan", where the term is correctly used, applies to the second layer of drift or bowlder clay, which is usually separated from the first layer by a stratum of sand or gravel. It is usually an impervious stratum of hard blue clay and constitutes the most common water horizon throughout the drift covered area of Indiana.

The above mentioned deposits of clay and shale constitute all which I was enabled to examine personally in Clay County. As has been shown they cover a large area of the county and suitable locations for factories for their utilization are abundant. Those already erected have proven the clays fitted in the highest degree for the making of many products. Their orders during the years 1894 and 1895 in many instances exceeded their output, and the trade has been so far worked up only in small areas of the States of Michigan, Illinois and Indiana. The sewer pipe and paving brick industries were scarcely affected by the panic of 1893-'94, as many cities kept their unemployed workmen engaged in street repair, and so the demand for these products was increased rather than diminished. Taking everything into consideration there is no reason why Clay County should not become as noted for her clay industries in the future as she has been for her deposits of block coal in the past.

OWEN COUNTY.

Occupying an area of 398 square miles, south of Putnam and east of Clay, is Owen, a county rich in undeveloped mineral resources. The Coal Measures form the surface rocks of its western third, the Millstone Grit of its middle third, and the Subcarboniferous of the eastern third. Within the last named formations are comprised some highly valuable beds of oölitic limestone which are quarried in the vicinity of Romona and Spencer. Three railroads, the Louisville, New Albany & Chicago, the Indianapolis & Vincennes, and the Evansville & Indianapolis cut across, respectively, the northeastern, the southeastern and the southwestern corners, leaving the center and northern parts wholly without facilities for transportation.

The West Fork of White River flows across the southeastern corner and Eel River across the northwestern, these two streams and their numerous tributaries forming an ample system of drainage.

The more valuable deposits of clays and shales are found in the townships 9 and 10 N., ranges 5 and 6 W. Here are located the principal coal veins, in fact the only ones of value in the county. In the immediate vicinity of Patricksburg the main block coal "I" is found close to the surface in thick veins of great purity. On the land of John Andrews, one-half a mile southeast of Patricksburg in the N. W. ¼ Sec. 15 (10 N., 5 W.) a slope mine has been worked for some years. Here, with the aid of Mr. Andrews, an experienced miner and geologist, the following section was obtained:

1.	Surface and yellow drift clay	5 feet.
2.	Blue gray argillaceous shale	21 feet.
3.	Coal "I"	5 feet 2 in.
4.	Fire-clay	4 feet 3 in.
5.	Sandstone	31 feet.

The deposit of shale above the coal is one of the best I have seen in the State. It is of very fine texture, free from grit and all traces of nodular iron ore. Belonging to the same horizon it is very similar to the seam worked at Brazil into sewer pipe and other products. The fire-clay below the coal is, however, inferior in quality, containing a large percentage of pyrites and other impurities and presenting a shaly or laminated appearance.

A short distance north of Patricksburg, in the S. W. ¼ Sec. 10, are two slope mines where the same shale is exposed to a thickness of 16 to 20 feet. The coal in these mines is fully 5 feet thick, pure non-caking block, equal to the best in this or any other State. Both fuel and clay are here present in almost an inexhaustible quantity. The one thing lacking is a railway switch from one of the three roads touching the county by which these resources can be carried to the points where needed.

The horizon of coal "B," is found from 18 to 25 feet below that of "I," and the vein outcrops in many places north and northeast of Patricksburg. The underclay of this coal is from 3 to 4 feet in thickness, of good quality and suitable for terra cotta, and in some places for potter's wares.

Down the Lick Creek Valley, southwest of Patricksburg, the shale overlying coal "I" comes to the surface in a great many places. A railway switch from Woodside could be easily constructed up this valley to Patricksburg, and so open up the way for developing many of these deposits of shale and underlying coal.

At Woodside, John Andrews has two mines from which the well-known "Lancaster Block" coal is secured. The shale overlying the coal is here about 13 feet thick. The upper eight feet could be utilized but the lower part contains too much bitumen. These mines are located on a switch of the E. & I. Railway. A few years ago Mr. Andrews erected a factory at this point for the purpose of making fire proofing, vitrified drain tile, brick, etc. The machinery with which it was furnished was old-fashioned, and the kilns constructed were patterned after those used in Scotland two centuries ago. As a result it has proven a failure and nothing has been done for a year or more. From $10,000 to $12,000 have been sunk, one-half enough to have fitted it up in good shape with the latest improved machinery. All the essentials of a successful clay industry are present, and a plant constructed and carried on in modern style would doubtless prove remunerative; but Old World methods can not compete successfully with those of the fast striding, onward moving West.

At the air-shaft of an abandoned mine, 100 yards west of the E. & I. Railway at Coal City, and but a short distance from the Clay County line, is an exposure of shale of good quality. The land, N. E. ¼ of S. W. ¼, Sec. 11 (9 N., 6 W.), belongs to Jas. F. Hyatt, who kindly furnished me with the following section:

1.	Surface and yellow clay	7 feet.
2.	Blue argillaceous shale	28 feet.
3.	Coal	4 feet.
4.	Fire clay	3 feet.

On the S. E. of the S. W. ¼ of the same section a bore was put down 94.8 feet through the vein of block coal. Of this distance 47 feet was composed of blue shale and soapstone.

Mr. Hyatt is operating at Coal City one of the largest ordinary brick yards in western Indiana. More than three millions were made in 1895. The clay used is the surface yellow clay, which is here free from lime and other impurities, and makes a strong and lasting brick which find a ready market in many of the towns of the adjoining counties. This clay at the yard lies directly over the shale (No. 2) of the above section. By putting in additional machinery suitable for the making of paving brick, a combination plant could be operated which would doubtless prove a success.

One and three-fourth miles southwest of Freedom, on the land of John McIndoo (N. E. ¼ Sec. 32, Tp. 9 N., R. 4 W.) is a large deposit of pinkish red clay which lies near the surface. The first outcrop visited was by the roadside about one-eighth of a mile north of the I. & V. Railway, where the vein of this clay has been proven by digging to be 6 feet in thickness, and overlain with from 5 to 7 feet of soil and yellow clay. Just across the road, on the land of Israel Light, (S. W. of S. E. of Sec. 29,) the same vein comes to the surface. Further north and west it extends over quite an area, and in places on the lands of A. J. Nelson and Jas. Patterson, it has been stripped and shipped for a number of years to the Encaustic Tile and Terra Cotta Works at Indianapolis, the Encaustic Tile Works at Anderson, Indiana, and to Newark, New Jersey. Probably 800 car loads have been sold, the clay being hauled in wagons 1¼ miles to Farmers Station, where it brought from $1.50 to $2.00 per ton on board the cars.

This is one of the high-grade commercial clays of Indiana, being very fine grained and in most cases free from grit and gravel, tough and exceedingly plastic. Streaks of a whiter color occasionally run through it, which when present in any quantity deteriorate its value for the uses to which it is at present put. That found on the McIndoo land, above noted, contains fewer impurities than at any other exposure visited, and it is more accessible to a railway.

On the land of J. R. Payne, near the center of Sec. 29 (9 N., 4 W.), the same clay outcrops in a ravine. In a well a few rods east of this outcrop the following section was exposed:

1.	Surface and yellow clay	10 feet.
2.	Blue argillaceous shale	14 feet.
3.	Pinkish red plastic clay	? ?

This would tend to prove that the pinkish clay is a decomposed shale, and not a surface deposit, as has been formerly believed. This clay is used by the Encaustic Tile Company to mix with a less refractory clay from Carbon, Ind., in the making of red floor tiling. It is too pure and refractory to use alone, twisting and shrinking out of shape under the influence of great heat. When it becomes more generally known it will probably be put to far more extensive use than at present.

Among the jars of clays in the State Museum, collected by S. S. Gorby, is one filled with very fine white kaolin, and having on the label the name of J. H. Ward, Spencer, Ind. No other data accompanied it, and no such person is known in the vicinity of Spencer. That deposits of kaolin similar in quality to that of Huron, Lawrence County, occur in Owen County, has long been known, yet but little has been done towards developing them.

An outcrop occurs five miles southeast of Spencer, Sec. 12 (9 N., 3 W.), on the land of Mrs. Hopewell, a resident of Bloomington, Ind. A slope shaft was put in a short distance a few years ago, and excellent samples obtained. A visit to the place showed that the opening had been closed by the soil washing down over it. A quantity of the kaolin, stained by iron oxide, was lying, near, but no specimens of the better grade were secured. In the Geological Report for 1875, p. 359, Professor Collett mentioned a similar outcrop as occurring in the N. E. ¼ Sec. 7 (9 N., 3 W.), four miles west of the one mentioned above. The kaolin probably underlies the greater portion of township 9 N., R. 3 W., but the thickness and quality of the stratum can only be determined by a more extensive investigation of the known outcrops.

In the vicinity of Gosport are many deposits of the better grades of surface clays. In a ravine on the land of D. W. Buskirk, in the northern limits of the town (N. E. ¼ Sec. 31, Tp. 11 N., R. 3 W.), is an outcrop of yellow clay which by excavation has been shown to be 8 feet in thickness. It is much lighter colored and finer grained than the ordinary surface clays of the surrounding hills, and judging from appearance will make a good dry-pressed front brick. To the west it becomes more silicious and approaches in character a fire clay. The surface clays overlying the outcropping Knobstone shales are suitable for ordinary soft mud brick, and the mouth of the ravine, between the deposit of yellow clay mentioned above and the two railways, presents an attractive location for a combination plant, capable of making both dry-pressed and ordinary brick.

The Knobstone shale, which forms the lowest surface rock visible in Owen County, is exposed in a bold bluff for nearly half a mile just south of the junction of the "Monon" and I. & V. Railways. This exposure is on the lands of Dr. Jno. W. Smith and Maj. A. H. Wampler, in the N. E. ¼ Sec. 31 and the N. W. ¼ Sec. 32 (11 N., 2 W.). This shale is grayish blue in color, free from lime and iron impurities, and with the proper manipulation makes a good article of buff, pressed front brick. Sample brick from a similar material at Martinsville, Ind., made by Boyd, White & Co., of Chicago, are unexcelled in general appearance. The railway facilities at Gosport are excellent, and cheap fuel can be obtained from the mines of Greene and western Owen counties.

GREENE COUNTY

comprises an area of 540 square miles south of the counties of Owen and Clay. It lies in the form of a parallelogram and is divided into almost equal halves by the West Fork of White River, which flows in a southwesterly direction through the county. This stream is joined at Worthington by Eel River from the northwest, and below Bloomfield by Richland Creek from the northeast. Three railroads pass entirely through the county and furnish excellent facilities of transportation for its resources.

The Conglomerate Sandstone, the western border of which is a most unerring landmark of the eastern horizon of the coal measures proper, forms the surface rock in fully three-fourths of the county. For this reason the best beds of shale and clay, as well as of coal, are found west of the main line of the I. & V. Railway, which follows approximately the western border of the conglomerate. In the eastern half of the county the sub-conglomerate coal "A" outcrops and is mined in a number of localities, but can nowhere be relied upon to supply more than a local demand. Beds of shale suitable for commercial purposes are rarely found above coal "A," but the fire-clay beneath it is oftentimes of excellent quality.

On a hillside just west of Owensboro, and a short distance north of the Bedford & Bloomfield Railway, in the N. E. ¼ Sec. 28, Tp. 6 N., R. 3 W., is an outcrop of fire-clay of excellent quality for the making of stoneware. It was long used for this purpose at the Reynolds pottery, which was located three miles southwest of the deposit. The clay stratum is between 3 and 4 feet in thickness and can be reached by easy stripping.

A bed of similar potter's clay is located on the land of L. J. Faucett (N. E. ¼ of S. E. ¼ Sec. 31, Tp. 7 N., R. 4 W.), one-half mile northwest of Mineral City and but one-eighth of a mile from a switch of the B. & B. Railway. It is exposed by the side of a small stream, is 5 feet in thickness and covered with a layer of soil 4 feet in depth. This clay is grayish-white in color, and contains free silica in sufficient quantities to prevent air cracking while cooling. It has been tested in the pottery at Worthington and found in every way suitable for the making of the better grades of stoneware.

One-half mile south occurs an outcrop of shale in the side of a bluff of Plummer's Creek. The strata exposed at this point are as follows:

1.	Soil and yellow clay	10 feet.
2.	Gray arenaceous shale	8 feet.
3.	Sandstone	6 feet.
4.	Soft blue argillaceous shale	8 feet.

The two shales are suitable either for pressed front brick or vitrified products.

The above clay deposits were all that my limited time allowed me to visit east of White River. Kaolin, similar to that found in Lawrence and Martin counties, is reported by Mr. E. F. Cox, the County Surveyor, to outcrop on the land of Jas. Sullivan in Beech Creek Township (S. E. ¼ of N. E. ¼, Sec. 10, Tp. 7 N., R. 3 W.), and on that of W. R. Arthur, near Newark. The extent and thickness of these beds have not, as yet, been investigated.

At Switz City, the junction of the I. & V. and B. & B. railways, there is found, about three feet below the surface, a thick stratum of tough, blue drift clay, which makes a most excellent drain tile. A factory for their production has been in operation for 5 years and the annual output is constantly increasing.

One-half mile northwest of the town, on land owned by J. B. Spencer (Sec. 15, Tp. 7 N., R. 6 W.), a vein of "fire clay" 4½ feet in thickness underlies a thin stratum of coal. The clay is free from visible impurities, and while not of high refractory grade, it will make excellent sewer pipe or terra cotta.

Linton, situated near the western border of Greene County, is one of the more important mining centers of Indiana. The coal veins found near there range from 4 to 6 feet in workable thickness, and the output ranks in quality among the best bituminous. As good deposits doubtless occur farther north in Wright and Smith townships, but a lack of means of transportation has, up to the present, prevented their development. The shales overlying the coal seams in the vicinity of Linton are, for the most part, too far beneath the surface to allow them to be obtained by stripping. As a consequence no use has heretofore been made of them.

The following connected section was obtained at the shaft of the South Linton Coal Company (S. W. ¼ Sec. 23, Tp. 7 N., R. 7 W.) and at shaft No. 2 of the Island Coal Company, one-half mile farther west. It may be taken as representing the average sequence of the strata through the worked seams of coal in the region about Linton.

1.	Soil and yellow drift clay	10 feet.
2.	Grayish, arenaceous shale	12 feet.
3.	Dark bituminous shale (black slate)	9 feet.
4.	Coal (top vein)	6 in. to 1 ft. 4 in.
5.	Fire clay	3 feet 4 in.
6.	Sandstone, gray, compact	18 feet.
7.	Light gray argillaceous shale	7 to 10 feet.
8.	Dark blue argillaceous shale	17 to 20 feet.
9.	Coal	5 to 6 feet.
10.	Hard fire clay, soon merging into sandstone.	? ?

Of these No. 2 is too silicious for use. Fire clay, No. 5, is of good quality, but the seam of coal above is too thin for working in connection with it. The clay will probably, therefore, never be utilized.

The shales (Nos. 7 and 8) comprise 24 to 30 feet of material, in every way suitable for manufacturing purposes. No. 7 is a soft and unctuous fine grained deposit resembling many of the under-clays in general appearance. It is free from sulphur and iron concretions and is the more valuable of the two. Having above it a good sandstone roof, and below it a bottom of shale, it could be readily and easily mined if occasion should arise to take it out by itself.

No. 8 is darker, harder, and more compact. It forms the roof of the worked seam of coal and, where exposed to air in the entries, it has, like all shales, a tendency to crumble and fall. Much of it, therefore, must, in the older mines, be handled, and either stored in worked out areas or raised and thrown on the dump. This being the case, and the fuel and railway facilities both being present, a factory at Linton for making these shales into vitrified products would, without doubt, prove a paying investment. An analysis of a specimen of No. 8 shale, taken from the dump at the shaft No. 1 of the Island Coal Company, showed the following composition:

Clay base and sand	86.40 per cent.*
Fluxes	13.11 per cent.

This shows a close approximation to the standard average composition of shales used for vitrified products and proves the *chemical fitness* of this shale for such products.

The fire clay (No. 10) below the worked seam of coal is, in most places, very thin, and soon merges into a hard and compact sandrock. At the South Linton Mine the coal lies directly upon the sandstone which is so hard that the miners have much difficulty in sinking their sumps, and the holes for the placing of the roof props.

West and northwest of Worthington are many outcrops of shales and underclays. A pottery has been operated on a small scale in that town for more than 25 years. The clay has been mostly obtained from the land of Mark Hays, three miles west of Worthington. The stratum lies beneath an outcrop of coal "B," is but 2½ feet in thickness and requires much washing to remove the impurities. A better quality of potter's clay has recently been tested and will be hereafter used. It is from the land of H. S. Shouse, (Sec. 12, Tp. 8 N., R. 6 W.) where it occurs in quantity.

Northwest of Worthington a vein of coal from 2 to 2½ feet in thickness has been passed through in digging many wells. Below this is a vein of fire clay 3 to 4½ feet in thickness and suitable for terra cotta and

* Lyons, chemist. For complete analysis see table at end of chapter.

kindred uses. In most places this merges into a fine grained shaly sandstone. Such a deposit of fire clay was found on the land of Chas. Dayhoff (S. E. ¼ Sec. 15,) and on that of Mr. Darnell (S. W. ¼ Sec. 10,) both in Tp. 8 N., R. 6 W.

At the time of my visit a seam of coal on the land of Mrs. S. J. Fuller, (S. W. ¼ of N. W. ¼ Sec. 12, Tp. 7 N., R. 6 W.,) was being mined by stripping. The following section had been exposed:

1.	Soil and surface clay	4 feet.
2.	Drab, argillaceous shale	4 feet.
3.	Coal	2 feet, 2 in.
4.	Fire clay	? ?

Nos. 2 and 4 are both free from grit and above the average in quality. The location, however, is too distant from transportation to allow them to be of present value.

Among the clays collected by the former Geologist, S. S. Gorby, is one bearing the label of Sol. Davis, Worthington, Indiana. No notes accompany it, and letters written to the address on the label have received no response. It is a gray underclay of good quality, as evinced by the following record of its analysis made by Dr. J. N. Hurty and given on the label:

Silica (total)	63.25	
Alumina	24.81	
Clay base and sand		88.06
Magnesia	1.01	
Lime	.48	
Ferric oxide	3.04	
Fluxes		4.53
*Moisture and volatile		7.33

This proves its fitness for either terra cotta or sewer pipe.

The above comprise the principal clays of note in those parts of Greene County which I was enabled to visit. That many others occur, especially in the northwestern part of the county, there is no doubt. These will in time be investigated and brought to public attention. Meanwhile, those mentioned are sufficient in quantity and quality to merit the investment of capital for their development; and where fuel is easy of access and railway facilities at hand, no fears may be felt as to the success of such investment.

*This probably includes some potash and soda.

SULLIVAN COUNTY.

On the western border of the State, just south of Vigo and west of Clay and Greene counties, is Sullivan, a county whose mining interests are rapidly becoming of great importance.

It comprises 443 square miles, all of which are underlain with the Coal Measure rocks. The Wabash River forms the western boundary of the county and receives from the east Turman's, Turtle and Busseron creeks, which branch and ramify into all portions of its area. The eastern part of the county is broken, and the soil, except the low ground near streams, is comparatively poor. The western two-thirds is for the most part level prairie, or river terrace, and possesses a much richer soil.

Two coal seams of workable thickness are mined at many points in the eastern half of the county. The main line of the Evansville & Terre Haute Railway passes north and south through the county, and marks, approximately, the western limit of mining operations, as west of that railway the thicker veins of coal are found at too great a depth to allow of profitable working. The principal exposures of carboniferous shales and fire clays are, therefore, east and northeast of Sullivan, the county seat, which is located in almost the geographical center of the county.

Near the foot of the bluff bordering the bottoms of Busseron Creek on the land of Lewis Eaton (N. ½ of S. E. ¼ Sec. 36, Tp. 8 N., R. 9 W.), a shaft has been recently put down through the top vein of coal, which at this point is about 25 feet below the surface. The mine was not being worked at the time of my visit, but the following section was secured of the strata exposed in the shaft:

1.	Soil and drift clay	6 feet.
2.	Blue, argillaceous shale	17 feet.
3.	Dark, bituminous shale	2 feet.
4.	Coal	3 feet 2 in.
5.	Fire clay	....? ....

Shale No. 2 is a hard, compact, fine grained material which weathers freely on the dump into a plastic mass, valuable for many products. No samples of the fire clay underlying the coal were obtainable, but it is doubtless similiar to that underlying the same coal farther east. This mine is one-fourth of a mile south of the I. & I. S. Railway and one and one-half mile east of the E. & T. H. Railroad.

The mine of Watson, Little & Co. is the third one operated east of Sullivan and is located by the side of the main line of the I. & I. S. Railway. Both veins of coal have here been worked, but the upper one has been recently abandoned, as the output from it, when allowed to stand any length of time, air slacks too rapidly to be of value. If used immediately after being mined, it is, however, an excellent fuel. The upper vein is 49 feet below the surface and the lower one 93. An air shaft was being sunk at the time of my visit and the material from it gave excellent opportunities for examining the character of the strata above the first vein. Of them the following section was obtained:

1.	Surface soil and clay	8 feet.
2.	Gray argillaceous shale	23 feet.
3.	Blue argillaceous shale containing remains of fossil plants	16 feet.
4.	Bituminous shale, fissile	2 feet.
5.	Coal	4 feet.
6.	Fire clay—dark plastic	6 feet.

Of these, all of shale No. 2 and the upper half of No. 3, comprising 31 feet in vertical thickness, are suitable in the highest degree for vitrified brick and similar wares. The fire clay will make a good grade of terra cotta, and may be mixed with the overlying shales for vitrified products, but it evidently contains too high a percentage of the fluxes for refractory purposes. The three things necessary for the production of clay products, viz.: raw material, fuel and transportation, are here present in one spot. Where so combined the finished products may be made at prices that will defy competition. Moreover, if a plant should be located here, the top vein of coal would supply an excellent fuel, as it could be mined only as needed, thus preventing the air-slacking for which it is now condemned.

At Farnsworth, one-half mile east (N. W. ¼ of N. E. ¼ Sec. 32, Tp. 8 N., R 8 W), is located the large mine of Hancock and Conklin. This mine was opened in 1880, the energetic proprietors digging the shaft with their own hands. The first year or two only the top vein of coal was worked, but here, as elsewhere, its quality is inferior to that of the lower vein, and only the latter is now mined. The shaft is located on the I. & I. S. R. R., and a section through it to the bottom of coal "L" is as follows:

1.	Soil and drift clay	12 feet.
2.	Gray arenaceous shale	17 feet.
3.	Blue argillaceous shale	8 feet.
4.	Coal	3 feet 4 in.
5.	Fire clay	8 feet.
6.	Bastard grayish limestone	2 feet 6 in.
7.	Blue argillaceous shale with occasional nodules of iron carbonate	18 feet.
8.	Bituminous shale, fissile	3 feet.
9.	Coal	5 feet 6 in.
10.	Fire clay soon merging into gray, sandy shale	??

The top shale, No. 2, contains more silica than that at Watson, Little & Co.'s mine, and its quality for making vitrified material is, therefore, somewhat impaired. On the other hand shale No. 7 is of better quality than there, being a fine grained, gritless material. All of fire clay No. 5 and 15 feet of No. 7 shale can be utilized for paving brick or sewer pipe.

Two miles farther east, on the land of Robert Pigg (N. E. ¼ of N. E. ¼ Sec. 34, Tp. 8 N., R. 8 W.), a mine has recently been opened to supply the local trade with coal. The shaft, sunk only through the upper vein, disclosed the following strata:

1.	Soil and yellow clay	4 feet.
2.	Shaley "pepper and salt" sandstone	8 feet.
3.	Blue argillaceous shale	16 feet.
4.	Coal	3 feet 4 in.
5.	Fire clay	??

Samples of the shale and fire clay show them to be in every way suitable for vitrified products. This mine is seven miles east of Sullivan and three-fourths of a mile north of the I. & I. S. R. R.

The "Jumbo" mine of the Jackson Hill Coal Company is located in the S. ½ Sec. 10, Tp. 8 N., R. 8 W. It is probably the largest mine operated in the county. The lower seam of coal is worked, the upper one not being present where the shaft was sunk. The only commercial clay at the mine is an unctuous blue shale, remarkably free from grit and fine in texture, which overlies the coal for a thickness of 14 feet. Above it is 8 feet of sandstone and 5 feet of surface soil

The coal, here 5½ feet thick, rests upon a blue shale, instead of a fire clay. The same conditions exist at the "Star City" mine, two miles northwest of the "Jumbo."

In general it may be stated of this region that wherever the upper seam of coal exists it is overtopped with 15 or more feet of shale and underlain with from 6 to 9 feet of fire clay, both of which are suitable for vitrified products. Between the two veins of coal, and overlying the dark bituminous shale which forms the roof of the lower vein, is also from 15 to 25 feet of an excellent argillaceous shale.

For a number of years a mine was worked at Sullivan, the shaft being located about 200 yards north of the E. & T. H. station. Owing to litigation it was abandoned about 1891, and no one could be found who was able to give information concerning the strata passed through above the coal. The vein worked was about 250 feet below the surface. From the clay underlying it a Mr. Pollock made, for a time, vitrified drain tile and paving blocks for sidewalks. His plant was located near the coal shaft, and was abandoned soon after work ceased at the mine. The machinery, engine, pug mill, etc., as well as one down-draft kiln and 200 feet of shed room, still remain in position.

A short distance north of Carlisle, by the side of the E. T. H. Railway, Mr. J. P. Walls is at the present time manufacturing, on a small scale, fire and ornamental brick from the vein of fire-clay 8 feet thick which underlies the top vein of coal. He informs me that this clay withstands great heat with but little shrinkage, and the products do not crack in drying or burning. The top coal at that point is 3 feet thick and gives good satisfaction as a fuel in burning ordinary brick, of which he makes large numbers.

But one deposit of potters clay is known to occur in Sullivan County, though many of the more plastic underclays could probably be used for that purpose. The one mentioned is found in the S. W. ¼ Sec. 9, Tp. 6 N., R. 8 W. It is a light gray clay of great purity, and was for a long time used at Pleasantville in making a better grade of stoneware. The stratum of clay has an average thickness of about 3 feet and is readily accessible.

From a lack of time I was not enabled to visit the northeastern townships of Sullivan County, where it is very probable that outcrops of shales and underclays of even greater value than those mentioned occur. I can only hope that what I have written will call the attention of the owners of coal lands and the citizens of the county generally to these hitherto wholly neglected resources in their midst, and that steps will soon be taken which will eventually lead to the erection of factories for their utilization.

KNOX COUNTY

comprises one of the most fertile sections of southwestern Indiana. The Wabash River forms its western boundary and White River its eastern and southern. The broad valleys of these streams form a large portion of the surface of the county and greatly increase the average richness of its soils. Five hundred and forty square miles are comprised within its bounds. The upper or barren coal measures form the surface rocks of the greater part of this area. The lower or productive measures underlie the whole county, but at such a depth as to prevent the remunerative mining of coal, except at a few points along the eastern border, where the principal veins of these measures outcrop in the bluffs of White River.

The upper or barren measures are made up for the most part of alternating strata of sandstone and shales. At intervals are thin beds of "rash" coals of no economic value. The total thickness of these deposits is more than 300 feet, and above them lie, in most parts of the county, from 50 to 75 feet of drift, alluvium or loess, which hide the more compact rock strata from view. For example, at Vincennes, the county seat, the first sandstone found in a test bore put down in the City Park was at a depth of 71 feet, and the first vein of coal of workable thickness at a depth of 383 feet.

With so great a covering of surface deposits it is difficult to locate the underlying shales and fire-clays. At Vincennes two shafts have been sunk and the coal mined. One of these has been recently abandoned. The other, the Prospect Hill Mine, is being worked for the local trade. The shaft was sunk in a comparatively low place near the Sugar Loaf Mound, one and one-half miles southeast of the City Hall. The worked vein of coal, probably "M," is found here at a depth of 355 feet. It is 4 feet thick and has above it a stratum of fine grained, gray arenaceous shale, 42 feet in thickness. This forms an excellent roof, being massive instead of in laminæ, and when blasted breaking with a conchoidal fracture. An analysis of this shale by Prof. Noyes shows its composition to be as follows:*

Clay base and sand	84.84
Fluxes	12.94

Comparing this with the standard composition of clays suitable for vitrified products (see p. 54), we find it varying but slightly, and that towards a greater purity. Future tests in the kiln will most probably prove what the chemical composition intimates, and show conclusively the fitness of this shale for paving brick and kindred products.

The under clay beneath the coal at the Prospect Hill Mine has been pierced to a depth of ten feet without reaching the bottom. It is a dark gray plastic material, of exceeding fine texture, and with an occasional trace of stigmaria. An analysis of a sample of clay from the same stratum taken from the mine of the Vincennes Coal Co., one-half mile northeast, was made a few years ago by Dr. J. N. Hurty. Mr. Frank Clarke, the present operator of the Prospect Hill Mine, has kindly procured me a copy of this analysis as follows:

Silica (total)	65.315	
Alumina	28.473	
Clay base and sand		93.788
Lime	.179	
Magnesia	2.741	
Ferric oxide	3.120	
Fluxes		6.040
Moisture		.170

"This clay burns a yellowish white and will make excellent fire brick."

J. N. Hurty,

Analyst.

It can also be made into terra cotta, sewer pipe, and fire-proofing for walls and chimneys. Two feet of the clay has to be blasted out in all the entries for height. Most of this is stored in worked out areas, but

* For complete analysis, see table at end of chapter.

hundreds of tons of it and the shale above the coal are raised to the dump, where they soon weather into a fine plastic mass.

In the vicinity of Edwardsport, in the northeastern part of Knox County, three seams of workable coal outcrop. These were designated as "K," "L" and "M," by Prof. John Collett, who studied them in 1873. One and one-fourth miles north of Edwardsport (N. E. ¼, Sec. 36, Tp. 5 N., R. 8 W.), a slope shaft was put into a hill in 1895. This is known as the Hoffman Mine. Test bores put down in the side of the hill above the shaft show the presence of the following strata:

1.	Soil and drift clay	12 feet
2.	Blue arenaceous shale	10 feet
3.	Coal "L"	3 feet 2 in.
4.	Fire clay	3 feet 4 in.
5.	Blue argillaceous shale	39 feet
6.	Dark bituminous shale (black slate)	3 feet
7.	Coal "K"	5 feet 3 in.
8.	Fire clay	2 feet

The fire clay No. 4 is very similar in appearance to that found at Vincennes, and can be used for the same purposes. The blue shale No. 5 has the fine texture and unctuous feel characteristic of the better grades of materials suitable for hollow brick, pre sed front and paving brick, and kindred products.

Nearer town, in the S. E. ¼ Sec. 35, the fire clay at the level of coal "L," was found to be 9 feet thick. Just south of the I. & V. Railway station an exposure of shale suitable for pressed front brick lies alongside the railroad track. It is 6 to 8 feet in thickness and overlies coal "L," which is here exposed to a depth of about 3 feet.

At the Keith mine, three-fourths of a mile south of Edwardsport (N. E. ¼ Sec. 4, Tp. 4 N., R. 8 W.), the fire clay beneath coal "K," which is here worked, is about 4 feet thick, but is much inferior in quality to that found below "L," higher up. It is more silicious than the latter, and contains some pyrites, and many stigmaria and other plant remains. A short distance below this (S. E. ¼ Sec. 4) coal "K" outcrops at low water mark in the bed of White River. At this point it is overlain with a black calcareous shale, above which is a dark-colored limestone; the two together aggregating about 8 feet in thickness and containing numerous fossils, among which are sections of some very large crinoid stems and spines.

In general, it may be stated of the area in the vicinity of both Edwardsport and Bicknell, that the fire clay beneath the top vein of coal ("L,") and the blue shale overlying the bottom vein ("K,") are both of excellent grade for manufacturing. At Bicknell the top vein lies 42 feet below the surface, and the lower vein 92. Both are worked, and the fire clay and shale above mentioned aggregate about 14 feet in vertical thickness.

The location of a large clay industry at either the Prospect Hi Mine near Vincennes, or the Hoffman Mine north of Edwardsport, can not but prove a paying procedure. At both places raw material in abundance and of excellent quality for many products, is found. At both, fuel for burning this material is plentiful. The Hoffman Mine has a railway switch already completed. One can easily be constructed to the Vincennes mine, and the latter being placed in connection with the four railways entering that city, will then have the better transportation facilities. As I have before stated, where raw material, fuel and transportation are found in one spot, clay products can be produced at prices that will defy competition.

DAVIESS COUNTY.

Lying south of Greene and west of Martin County is Daviess, one of the better agricultural counties of southwestern Indiana. It comprises an area of 424 square miles, the larger part of which is covered with the rocks of the coal measures. The West Fork of White River forms the western boundary of the county and the East Fork the southern boundary, the two uniting at the southwestern corner. The northeastern part of the county is quite broken with the characteristic hills and ridges of the conglomerate sandstone which here forms the surface rock. The western and southern parts are more level, with better farming lands especially suited to the raising of wheat which is the staple crop.

Washington, the county seat, secured in 1891 the shops of the Baltimore & Ohio Southwestern Railway. Since that date it has almost doubled in size, possessing at the present a population of about 8,500. Within its immediate vicinity are the principal coal mines of the county, as well as the larger deposits of commercial clays which lie close enough to railways to admit of profitable working. Many shafts have been sunk and bores put down east and south of Washington. These prove the presence of shale and fire clay deposits in abundance, though in but few places do they come so near the surface as to admit being worked by stripping.

One of these is two miles north of the city on the land of Mrs. R. Shepherd (S. E. ¼ Sec. 14, Tp. 3 N., R. 7 W.), where a blue argillaceous shale outcrops along the banks of a small stream. The shale is exposed to a depth of 10 feet, and is overlain with 5 feet of homogeneous yellow clay of excellent quality. The two can be mixed and be made into dry pressed brick, paving brick and many other products.

One-half mile south of the depot of the B. & O. S. W. R. R., at the point where the bridge on the Petersburg road crosses the cut of an old railway switch, is an outcrop of "soapstone," or soft unctuous shale **20** feet thick. The switch could be easily replaced and the deposit utilized. The clay is of the better quality, and suitable for many purposes.

At Cable & Kaufmann's No. 4 mine (S. W. ¼ Sec. 3, Tp. 2 N., R. 7 W.) the seam of coal mined is so thin as to necessitate the removal of several feet of material either above or below, in order to make height for mules and cars. The fire clay beneath the coal is one of the best underclays for terra cotta and similar products that has come to my notice. It is of very fine texture, and free from the impurities that many such clays contain. Thousands of tons of it are raised each year, and up to the present the dump pile has been its landing place. The vein is said to be 7 feet thick, of which the upper 2½ feet is taken out. Above the coal is a soft, gray, argillaceous shale, which can be mixed to good advantage with the fire clay, and the two made into vitrified products.

A few rods south of this mine a bore was recently put down 800 feet in search of coal. At this depth a strong flow of mineral water was obtained which has continued unabated. This water has proven beneficial for many diseases, and at the time of my investigation large quantities were being carried away daily in jugs and kegs by the people of Washington and vicinity. The owners of the well had had an analysis of the water made by Werner & Simonson, of Cincinnati, which showed the presence of the following mineral salts in the quantities given:

	Grains per Gallon.
Calcium sulphate—Gypsum salts ($CaSO_4$)	75.712
Calcium carbonate—Salts of lime ($CaCO_3$)	9.256
Magnesium chloride—Salts of magnesia ($MgCl_2$)	88.480
Magnesium bromide—Salts of magnesia ($MgBr_2$)	.605
Potassium sulphate—Potash salts (K_2SO_4)	7.168
Sodium sulphate—Glauber's salts (Na_2SO_4)	488.088
Sodium chloride—Common salt (NaCl)	1014.336

A record of the bore put down at the well as kept by Cable & Kauffman shows the presence of the following strata above the second vein of coal:

1.	Soil and drift	13 feet.
2.	Gray arenaceous shale	16 feet.
3.	Coal	3 feet 6 in.
4.	Fire clay	7 feet 6 in.
5.	Gray argillaceous shale	12 feet.
6.	Blue argillaceous shale	13 feet.
7.	Gray sandy shale	22 feet.
8.	Blue argillaceous shale	36 feet.
9.	Dark bituminous shale	6 feet.
10.	Coal	1 foot 6 in.
11.	Fire clay	11 feet 6 in.

Of these Nos. 4, 5, 6, 8 and 11 are clays suitable for manufacturing purposes. These aggregate 80 feet out of a total of 146—and, taken in connection with the coal and the switch already in place, form a combination hard to excel for a great clay manufacturing site.

At the old Wilson shafts, Nos. 1 and 2, just east of the corporate limits of Washington, coal "L", which has been largely worked out, is underlain with 7 feet of fire-clay. Beneath the latter is a gray sandstone 5 feet in thickness. This overlies a blue argillaceous shale, which, according to bores made by Thomas Wilson, one of the former owners of the mine, is 37 feet thick. Mr. Wilson, who is an experienced observer, states that the shale closely resembles that used at Clinton for the making of vitrified street brick.

Numerous bores have been put down between Washington and the town of Montgomery, six miles east. These all prove the presence of the carboniferous shales in large quantities. At the mine of the Daviess County Coal Company, just west of Montgomery, large quantities of the fire clay underlying the worked seam of coal have to be removed. Although of excellent quality it is not utilized but is relegated with other refuse to the dump pile. The large expense necessary to mine and raise it is thus totally lost.

Three-fourths of a mile southwest of Montgomery (S. E. ¼ Sec. 27, Tp. 3 N., R. 6 W.), near the residence of Mike O'Heffernan, an outcrop of potter's clay 3 feet thick occurs by the roadside. It has been tested and proved of good quality for the making of ordinary stoneware.

Some excitement has been created in the vicinity of Washington by the statement that gold and platinum had been found in paying quantities on the farm of Cross Bros (N. E. ¼ Sec. 17, Tp. 2 N., R. 6 W.). A visit to the place showed that a shaft had been sunk to a depth of 14 feet, disclosing the following strata:

1.	Soil and surface clay	4 feet.
2.	Dove-colored argillaceous shale	6 feet.
3.	Dark bituminous shale	4 feet.

Shale No 2 is a soft "soapstone," divided into thin layers or laminæ, between which is an incrustation of oxide of iron. This was pointed out to me as the gold-bearing material, and the statement was made by Mr. F. M. Cross that it had been assayed and found to contain gold to the amount of $36 to the ton. It is needless to say that such a statement is absurd. The shale will make a fair quality of vitrified brick or sewer pipe, but all the gold or platinum contained in forty acres of it would not pay one-eighth of the amount spent in sinking the shaft.

The yellow surface clay found in the vicinity of Washington is in quality much above the average of the surface drift clays of the counties to the north. It is almost wholly free from lime or other pebbles, is very fine grained, and the deposits, averaging 15 to 18 feet in thickness, are of uniform character throughout. It can be made into a fine, dry-pressed front brick. The ordinary soft mud brick made from it are harder, tougher and of better quality generally than those made of the drift clays to the north. Mixed with fire clay or shale in the ratio of 1 part to 3, this clay will add to their value for making many products.

Within two years more than three millions of vitrified brick and block from Evansville, Ind., and Athens, O., have been shipped to Washington and put down in the streets. These have cost from $10 to $14 per thousand. The raw material for making them and the fuel for burning them was to be found in abundance within two miles or less of the spot where they were laid. The sum sent out of the county in payment for this paving material would have paid for a good plant for manufacturing it, which would have furnished labor for many hands.

The B. & O. S. W. and the E. & I. railways, or their switches, pass through the leading deposits mentioned above, and connect the city of Washington with numerous towns in Illinois and Indiana where paving brick and other clay products will in the future be used in quantity. The people of Washington should see to it that a factory is soon erected for utilizing on a large scale some of the excellent clay materials with which the city is surrounded.

MARTIN COUNTY

comprises an area of 340 square miles of territory lying south of Greene and east of Daviess County. Its surface is very rugged and broken, not more than one-third being capable of cultivation. The East Fork of White River enters the county near the middle of its eastern border, and flows in many meandering curves to near the southwestern corner, where it turns to the west and forms a small portion of the southern boundary. This stream and its main tributaries from the north and south have been the chief agents in carving the surface rocks into fantastic shapes and ploughing those deep gulches and valleys which are so prominent a part of the scenery of the county.

The Coal Measure rocks form but a small portion of the surface, and that only on the tops of the higher and more prominent hills. The formation prevailing over the greater part is the millstone grit, or conglomerate sandstone. This is most commonly an even grained sandstone of a reddish brown color, the lower part, only in a few places, containing the agglutinated quartzose and other pebbles to which the name "conglomerate" rightfully belongs.

The sub-conglomerate coal "A" is mined at a number of places in the county and outcrops at many more. The under-clay accompanying this seam of coal is a light gray plastic material. Its refractory qualities are not of the best, but are sufficient for potters' use, and large quantities of stoneware have in the past been made from it at both Loogootee and Shoals.

At the former place a pottery was started in 1842 by Upton Stuckey, and continued in operation until 1892. The clay used was obtained from beneath coal "A" on land now owned by Mrs. Charlotta Wood, two miles north of Loogootee. The stratum of clay is here three feet thick, and is obtained by easy stripping. The same clay outcrops in one or two other places on the same land, but the stripping necessary to get at it is much more extensive. According to Mr. Stucky it makes a "nice blue stoneware which does not check in drying." Two other potteries have in the past drawn their supplies of clay from this same deposit.

At Shoals a pottery was established about 1870, and continued in operation until 1892, when it was merged into the Indiana Clay and Specialty Works, which manufactures stoneware, vases, etc., on a more extensive scale. The clay used is of two kinds, and is secured at Sampson's Hill, two miles southeast of Shoals, in the W. ½ Sec. 6 (2 N., 3 W.), where the following section was obtained from the top of the hill through the under clay of the coal:

1.	Hard, gray-pinkish sandstone	1 foot 6 in.
2.	Soft dark blue clay	6 feet.
3.	Coal	1 foot.
4.	Light gray potter's clay	4 feet 6 in.

Of these Nos. 2 and 4 are combined in varying proportions according to the kind of wares required. Both are comparatively free from impurities, and contain silica in the proper proportions to prevent air-cracking while drying and cooling.

Kaolin, of the same nature as occurs in Lawrence County, outcrops at a number of places in the eastern half of Martin County, and in a few instances the beds have been worked on a small scale, though not sufficiently to determine their maximum thickness, or to develop the better portions of the deposits. On the south side of White River in the N. W. ¼ Sec. 27 (3 N., 4 W.), two and one-half miles west of Shoals, and one-half mile from the B. & O. S W. Railway, Messrs. Johnson and Chenoworth have put a slope or drift shaft 40 feet into a bed of this clay. The kaolin here is 4½ to 5 feet in thickness, but is not uniform in character, three or four varieties being mixed and inter-stratified in irregular layers. Of these the uppermost is a hard, semi-transparent, milky colored clay; the next lower a soft chalky white to cream colored; the third layer a hard dark amber brown to black, containing much iron oxide, and the fourth or bottom layer a dirty yellowish brown clay of much hardness. The shaft was put in more for prospecting purposes than anything else, and but little of the kaolin has as yet been used. A bore put down on the opposite side of the ridge proved the presence of this kaolin stratum at a depth of 40 feet.

The following are some of the points south of White River in Martin County, at which the kaolin is known to outcrop:

1. Land of Dr. Thomas Ritter, near Willow Valley (N. E. ¼ Sec. 15, 3 N., 3 W.)
2. Land of Dr. Thomas Ritter, near Willow Valley (S. W. ¼ Sec. 14, 3 N., 3 W.)
3. Land of A. W. Stewart, near Pleasant Valley (S. E. of S. E. ¼ Sec. 5, 2 N., 3 W.)
4. Land of ——— ———, near Pleasant Valley (S. W. ¼ Sec. 6, 2 N., 3 W.)

North of White River the kaolin outcrops in a number of places, but two of which I had time to visit. One of these was near the base of the north slope of the hill on which the town of Dover Hill is located. Here on the land of James Yarnell (N. E. ¼, Sec. 1, Tp. 3 N., R. 4 W.), a slope shaft about 50 feet long, and constructed in a crude manner, was put in a few years ago to determine the thickness and quality of the stratum.

Above the kaolin is a soft pinkish sandrock, which crumbles readily when exposed to air. The props supporting this roof had in places decayed away and allowed the crumbling sandstone to fall down and cover the entry to the depth of several feet, so that much difficulty was experienced in getting into the shaft. Once in, the kaolin stratum was found to be between 5 and 6 feet in thickness. This, for the most part, was an amorphous pinkish brown material, made up of small granular masses. The color was evidently due to its being impregnated with the oxide of iron by the leaching of the surface waters through the overlying sandstone. In the upper part of the stratum were many nodular masses three inches in diameter or less, and exteriorly somewhat resembling geodes in appearance. These were easily broken by the hands, the interior being a soft, pearly white, opal-like mass of pure kaolin. When exposed to the air this loses its transparent properties, and hardens in a few weeks into a flint-like body. At intervals in the stratum of kaolin are found large irregular masses of hard gray limestone containing many fragments of crinoid stems and other small fossils. These have been supposed to be pieces of the stratum of limestone which has been dissolved out of the space now occupied by the kaolin. At the base of the stratum of the latter is usually found numerous rough lamellar masses of iron oxide (limonite) averaging about 6 inches in thickness. These rest upon a dark soapstone or shale, the depth of which could not be determined. A careful examination of the surroundings leads me to believe that the stratum of kaolin will thicken somewhat, and become much purer in quality back farther under the hill. The same stratum outcrops again on the south side of the hill or ridge upon which Dover Hill is situated, and undoubtedly underlies the whole ridge at a depth of 125 to 140 feet. The greater part of this tract of land belongs to Dr. A. W. Porter, of Loogootee, who is considering the feasibility of putting in a slope shaft on the northeast side of the ridge, and working the full thickness of the kaolin.

Three-fourths of a mile south of the Indian Springs Hotel, on land belonging to Robt. Kregg, Silverville, Indiana, in the N. W. ¼ Sec. 20 (4 N., 3 W.), is a large deposit of kaolin which was worked for some time, but is now abandoned. A horizontal shaft enters the side of a large hill, and on entering it the same soft, shelly, pinkish sandstone is seen above the deposit as was noticed at Dover Hill, seven miles to the southwest. Several tons of the pinkish brown variety of the clay were beneath a shed to which a tramway from the mine was constructed. Numerous pieces of the accompanying lamellar iron ore were scattered about the mouth of the shaft, but none of the intermingled limestone was noticeable. The same underlying shale was present as at Dover Hill. In the side entries, 100 to 150 feet back from the entrance, the upper half of the vein of kaolin, here 4½ feet thick, was pure white, and almost equal in quality to the best of that found at Huron, Lawrence County. No one was present about the mine, and I could not ascertain what disposition had been made of that taken out, nor why the mine had been abandoned.

This stratum of kaolin probably underlies the greater part of the eastern half of Martin County, at the lower horizon of the conglomerate sandstone; but it will be found to vary much in thickness and quality. Northward it has been found to occur, as already mentioned, at isolated points in Greene and Owen counties.

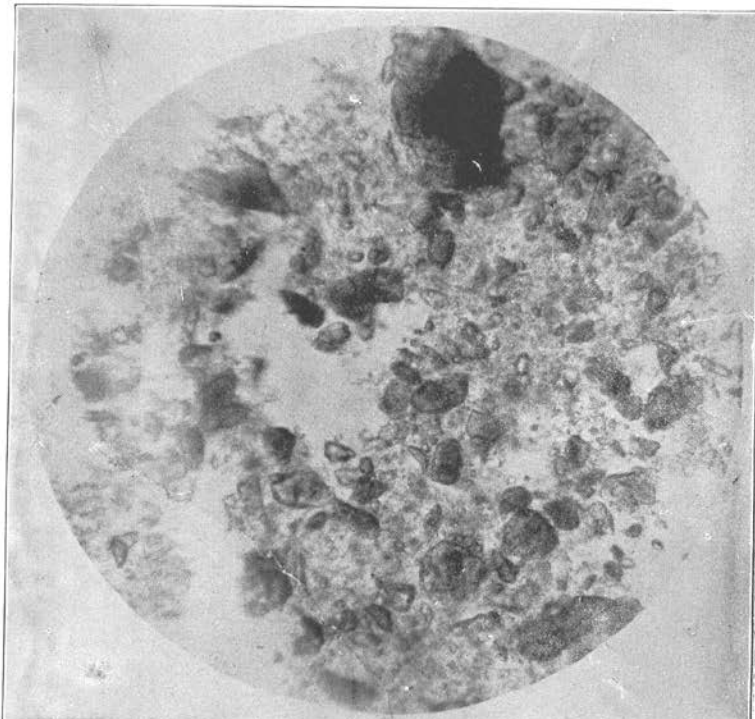
LAWRENCE COUNTY KAOLIN.

This kaolin being the purest form of clay found in Indiana, if not in the United States, an examination was made of the beds of it which have been most extensively worked at Huron, Lawrence County. These are at present owned by Dr. J. Gardner, of Bedford. Although outside of the territory covered by this report, the following facts are here given concerning the Huron deposits, as they will better enable the owners of the kaolin in Martin, Greene and Owen counties to judge of the value of the clay and the uses to which it may be put.

These deposits were first brought to public notice by the State Geologist, E. T. Cox, in the Report for 1874. Locally the outcropping kaolin had been previously known as mineral tallow, and the locality as Anderson's "taller bank." Some workmen in the summer of 1874, while digging out the underlying iron ore for the blast furnace at Shoals, laid bare the full thickness of the stratum of kaolin, and the attention of Mr. Cox was called to it. Dr. Gardner became interested and purchased the land, and extensive tests and analyses were made which proved the great purity and value of the clay. For some years it was mined and sold to Tempest, Brockman & Co., of Cincinnati, who used it as one of the principal constituents in the making of a white porcelain ware of excellent grade. Later the land was sold to the Pennsylvania Salt Co., of Philadelphia. This company for ten years mined annually an average of 2,000 tons of the kaolin. This was shipped to Philadelphia, where each ton was mixed with two tons of dilute sulphuric acid, and formed three tons of "alum cake." This brings from $25 to $35 a ton, and is sold mainly to paper manufacturers as a sizing for the better grades of wall and writing paper. The deposits are four miles from the B. & O. S. W. Railway, necessitating the hauling of the clay that distance over a rough road. The Salt Company finally began to make the alum salt from a deposit of cryolite which could be shipped to their works near Philadelphia in sailing vessels at a much reduced cost, and gradually abandoned the use of the kaolin. The land was then sold back to the former owner, Dr. Gardner, and the deposits have not been worked since 1891.

In the working of the deposit in the past, three slope shafts, each several hundred yards in length, have been put back into the hills in which it is found. The stratum of kaolin has a maximum thickness of 11 feet and a minimum of 4, the average being 5½ to 6 feet in the area worked over. The kaolin lies in a horizontal stratum like a vein of coal, and is mined in much the same manner, though with much less blasting. The overlying sandstone varies much in character. In some places it is a true conglomerate containing many small quartzose and other pebbles, cemented together with a material which, according to Professor Noyes, contains considerable amounts of alumina. In others it is the fine-grained, pinkish brown, shelly sandstone, noted above as forming the roof over similar deposits at Dover Hill. In places there are narrow cracks or crevices, extending a foot or more into the roof, which are filled with the kaolin. Again small, irregular masses of the kaolin are found, as a part of the conglomerate, at a height of six or eight feet above the main stratum.

In many places at the upper portion of the bed of kaolin, and lying immediately in contact with the roof, are masses of the semi-transparent,



MICROSCOPICAL SECTION OF KAOLIN FROM LAWRENCE COUNTY.
Magnified 60 diameters. Natural Light.

light green mineral known as allophane, in which the percentage of alumina and water are the same, and double that of the silica, as follows:

Water	40	per cent.
Alumina	40	"
Silica	20	"

On exposure to the air the water of crystallization shortly passes off and the mineral effloresces into a white powder, made up of particles resembling in a general way those of coarse corn meal.

The upper half of the kaolin stratum is mainly composed of a massive, snow-white clay, which has a smooth, unctuous feel. Associated with this, especially near its top, are occasional concretionary or nodular masses, often a foot or more in diameter, which, when broken, show a light blue lamellar center. Both of these forms disintegrate on exposure to the air into a rather coarse grained white powder. An analysis of an average sample of the massive variety made for this report by Professor Noyes* shows the following results:

Silica	44.75	per cent.
Alumina	38.69	"
Water	15.17	"
Ferric oxide	.95	"
Lime	.37	"
Magnesia	.30	"
Potash	.12	"
Soda	.23	"
Total	100.58	per cent.

The sum total of the impurities is thus seen to be less than two per cent. The quantity of iron is so small as to have no effect upon the color of the burned ware which is, if anything, whiter than the clay itself.

Like many similar kaolins, this is practically non-plastic; but by grinding very fine and then kneading, it can be made to assume a certain degree of plasticity. Maurice Thompson asserted that this kaolin does not contain the microscopic granular crystals which are characteristic of all non-plastic clays.† Prof. Erasmus Haworth, of Lawrence, Kan., a noted expert in the mineralogy of clays, has, however, proven their presence in quantities, as the accompanying photographic representation, kindly sent to this Department by him, will show. Of the kaolin, he

* "The mineral contains no titanium and less than one per cent. of it is insoluble, on treatment with sulphuric acid and sodium carbonate. It is a very nearly pure kaolin, for which the theoretical composition would be, from the formula, $Al_2Si_2O_7+2H_2O$, the composition being as follows:

Silica	46 51 per cent.
Alumina	39.53 per cent.
Water	13.96 per cent."

W. A. Noyes.

† Fifteenth Report Indiana Geological Survey, 1886, 39.

wrote as follows: "I have already studied Indianaite (the name given by Prof. Cox to the Lawrence County kaolin) a little, and find it is completely crystallized throughout, although grouped under *Halloysite* by Dana and given as non-crystalline."

The lower half of the stratum of kaolin in the Huron mines varies in color from a pale buff to a rich, deep brown. This is due to its being stained with the oxides of iron and possibly those of manganese and cobalt. Such a clay, while unfit for porcelain ware, can, however, be used in the making of certain grades of "alum salt", and for this purpose much of it has been utilized in the past.

The refractory properties of this clay are of the highest, as its composition shows. Mixed with a small percentage of a more plastic material as one of the purer underclays of the coal seams, it can be used in the making of the finer grades of retorts, glass-pots, glass-tanks, etc. Ground fine and pressed dry it will make the highest grade of fire-brick.

According to Dr. Gardner this kaolin is somewhat remarkable for the weakness of affinity existing between its silica and alumina. It will give up its alumina to acids or its silica to alkalies with great freedom until after it has been heated to redness and the chemically combined water is driven off, when it acts the same as other clays. On account of this weakness of affinity it is well suited for the making of such chemical compounds as the alum salts.

Thousands of tons of this purest of clays are visible in the mines which have been opened. The stratum thickens as progress is made further back into the hills. 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.

DUBOIS COUNTY,

lying south of Daviess and Martin counties, comprises an area of 432 square miles. The eastern, and especially the northeastern townships, are broken with numerous hills and ridges, the Conglomerate Sandstone forming for the most part the surface rock. The western two-thirds is more level and underlain with the Coal Measure strata, though being deficient in railway facilities, but few mines are worked, and they only to supply the local trade. The county is abundantly supplied with water courses. The East Fork of White River forms the greater part of its northern boundary. Patoka River flows in a westerly direction through the center of the county and its numerous branches ramify through the eastern and southern areas.

The leading clay deposits visited were in the vicinity of Jasper and Huntingburgh. One-half mile north of the former place, Reider Hill rises 140 feet above the level of the Court House yard. Near its top an outcrop of soft, unctuous light-gray shale is exposed for a thickness of 23 feet along the roadside. In this hill are three veins of coal, the middle one averaging three feet in thickness. Two of these veins have been worked in several places by means of slope shafts, and the coal has been proven to be an excellent fuel. Beneath each of these three veins of coal is from 3 to 5 feet of a fine grained, very light colored fire clay, which will prove excellent for pottery or refractory purposes. The shale above noted can be made into either vitrified or pressed front brick of high grade; so that this hill, within one-half mile of the county seat, contains not less than 35 feet of good commercial clay and the fuel necessary for its burning. A railway switch can be readily constructed past the furniture factory in the east side of the town and up the valley to the foot of the hill, where there is an excellent site for a large factory.

Three-fourths of a mile west of Jasper, the "soapstone," or gray shale above mentioned, outcrops in numerous places along the roadside, and underlies the whole of the wooded tract of land known as "Military Park" (N. E. ¼ Sec. 34, Tp. 1 S., R. 5 W.). Several slope shafts have been put in in this vicinity and disclose a good quality of fire clay beneath the coal. Military Park is but three-fourths of a mile from the Jasper and Huntingburgh branch of the "Air Line" Railway, and a switch easily constructed and of sufficient grade to allow cars to run by gravity to the main line, could be built up the valley to the shale and clay. The entire area of Sec. 34 is probably underlain with these deposits. Jasper and vicinity is populated by a frugal, largely German population. The town is well supplied with schools and churches and is rapidly increasing in wealth and enterprise, several large business blocks and a system of water works having been constructed within the past year.

At Huntingburg, an important junction point on the "Air Line" Railway, there exists a large deposit of one of the best potter's clays known to occur in southern Indiana. For a number of years large quantities of it have been shipped by Bockting Bros. to potters at Evansville, New Albany, Louisville and other points along the "Air Line" Railway; and for 18 years it has been used in a pottery at Huntingburg. It is found beneath a thin vein of coal in Beeler's Hill, just north of Huntingburg (N. W. ¼ Sec. 34, Tp. 2 S., R. 5 W.). To secure the clay a slope shaft has been put in by the Bocktings.

Two hundred yards northwest of the opening of this mine is an air shaft put down through the potter's clay by the Huntingburg Pressed Brick Company. From it the following section, disclosing the strata in that part of Beeler's Hill, was obtained:

1.	Surface and yellow clay	14 feet.	
2.	Blue argillaceous shale	16 feet.	
3.	Dark bituminous shale	2 feet.	
4.	Coal		11 to 14 in.
5.	Potter's clay (choice)	5 feet	10 in.
6.	Fire clay impregnated with small grains of iron ore	2 feet.	
7.	Soft gray argillaceous shale (exposed)	7 feet.	

All of these are valuable for manufacturing purposes. Only No. 5 has heretofore been shipped. It brings, on board the cars at mouth of shaft, 85 cents a ton.

The stratum of clay dips to the southwest, and the mine is, therefore, difficult to free from water. Miners are paid $1.50 per day, and furnished powder and tools, and each man gets out 10 to 12 tons of the clay daily. The stoneware made from this clay 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 kiln. The composition of the clay, as shown in an analysis made for Bockting Bros. by Professor Noyes, is as follows:

Silica (total)	69.23	
Titanium oxide	1.50	
Alumina	18.97	
Water (combined)	5.46	
*Clay base and sand		95.16
Ferric oxide	1.57	
Ferrous oxide	.55	
Lime	.12	
Magnesia	.36	
Potash	2.27	
Soda	.33	
Fluxes		5.20

This shows a composition approaching very closely the average standard of stoneware clays (see p. 48), and proves the superiority of this clay for pottery purposes.

The Huntingburg Pressed Brick Company has recently erected a large and well equipped plant a short distance northeast of the shaft worked

*As the titanium oxide does not act as a flux I include it here.

by Bockting Bros. They make from the surface yellow clay a handsome and durable red front brick. This clay closely resembles the surface clay at Washington, Indiana, being like it, free from foreign matter and homogeneous in texture.

From the stratum of potter's clay this company is making a buff front brick, and from a mixture of the potter's clay and the underlying fire clay, containing small grains of iron ore, a speckled or Pompeii front brick which is in large demand. The small grains of iron ore in this lower stratum of fire clay are most probably the ferric or sesquioxide of iron (Fe_2O_3). These are reduced by the influence of the heat and gases of the kiln to ferrous oxide (FeO). When subjected to higher heat a fluxing action begins and causes a chemical union between the ferrous oxide and any free silica in the clay, producing a black ferrous silicate, which is not affected by higher heat. The black specks, ranging in size from a pin head to the cross section of an ordinary lead pencil, found in the Pompeii brick, are composed of this silicate. These brick bring from $25 to $30 per 1,000 at the factory, as against $10 to $12 for the buff, unspeckled brick. From the potter's clay (No. 5) this company makes the fire brick and floor tiling for their kilns. These stand up well under great heat and prove the high refractory grade of the clay as evinced by its chemical composition. Both the upper shale (No. 2) and the lower (No. 7) of the section at Beeler's Hill are suitable for vitrified products. The bottom six feet of No. 2 would probably have to be rejected on account of too high a percentage of bitumen. With these shales present in such large quantities, an addition for the purpose of making vitrified brick would, without doubt, prove a valuable adjunct to the plant already erected.

A short distance west of Bretzville (Sec. 32, Tp. 2 S., R. 4 W.), the "Air Line" Railway passes through a cut in which 20 feet of drab argillaceous shale is exposed. The sub-conglomerate coal "A" outcrops at several places in the same vicinity, and has beneath it a dark plastic underclay suitable for terra cotta.

Southwest of Ferdinand, in the S. ½ Sec. 34, Tp. 3 S., R. 4 W., are found large deposits of clay and decomposed iron ore suitable for the manufacture of mineral paints. The "Anderson Valley Mining Company" erected a mill at Ferdinand and worked these deposits for a number of years. Their products were of excellent quality, and for a time were much used, but a lack of railway facilities caused the abandonment of the enterprise. From a flinty limestone above a seam of coal on the same section a polishing powder called "tripoli" was obtained in quantity and put upon the market. The same material is found at several other points east of Ferdinand, notably in the N. W. ¼ Sec. 26, and the N. E. ¼ Sec. 13, Tp. 3 S., R. 4 W. Should the railroad projected between Rockport, Spencer County, and Mitchell, Lawrence County, be constructed it will pass through this region, and these resources will become of much value.

On the land of J. L. Schiller (S. E. ¼ of S. E. ¼ Sec. 6, Tp. 1 S., R. 3 W.), occurs an outcrop of pale blue fire clay 3½ feet thick. Through the lower part of it are scattered many crystals of selenite ($CaSO_4$), varying in size from 1 inch in length downwards. The owner burns the clay in a kiln, reducing these crystals to a powder, and then uses it as a fertilizer with good results. These crystals of selenite are found in numerous other deposits of fire clay east of Jasper, and have also been noted at other points in the State as at Mecca, Parke County, on the land of S. L. McCune. The crystals are oftentimes acicular, and radiating from a common center, form little rosettes which lie in great numbers on the exposed surface of the clays. With the exception of the one given above, no attempt, as far as known, has been made to utilize the clays containing them.

More than anything else Dubois County needs railways. When these are constructed new mines will be opened up, new deposits of shales and fire clays exposed, and it is to be hoped, put to ready use. Meanwhile those at Jasper and Huntingburg, mentioned above, merit further development. Either of them will furnish material of excellent quality, and in almost unlimited quantity for making vitrified brick, sewer pipe, pressed front brick, stoneware, hollow brick and terra cotta. Where clays suitable for such varied products occur in one bed, capital is bound in time to find them and put them to use. How soon that capital will be invested in their development depends solely upon the energies of the people in the towns near which the deposits lie.

PIKE COUNTY

is rich in undeveloped resources. The thickest veins of coal found in Indiana lie within its bounds. Vast beds of shale and clay cover and underlie these coals, bringing thus in close proximity the materials for fire-proof products and the fuel to manufacture them. Great beds of sandstone outcrop in the southeastern fourth, furnishing, with little labor, excellent material for foundations and walls. The soils of the western and northern parts of the county produce good crops of wheat, oats, corn and grass.

Pike County comprises 338 square miles. Daviess and Knox counties, to the north, are separated from it by the East Fork of White River and by White River proper. Patoka River flows west through the center of its area and furnishes the principal drainage outlet.

In the vicinity of Petersburg, the county seat, numerous mines have been opened, mostly by slope shafts. A few days before my visit an excavation for a reservoir had been made 50 feet south of the E. & I. station in the western part of the town. At the depth of 37 feet a vein of excellent coal was encountered, which will be hereafter mined. Careful measurements resulted in the following section:

1.	Surface soil and blue, mucky clay	16 feet.
2.	Blue argillaceous shale	6 feet 8 in.
3.	Blue limestone (fossiliferous)	10 feet 4 in.
4.	Black shale, with numerous "kidneys" of iron carbonate	3 feet 10 in.
5.	Coal	7 feet 1 in.

One and one-fourth miles northwest of the Court House is a mine operated by Jerome B. Borer. A stratum of under-clay four feet thick is found beneath the worked seam of coal. In the past many tons of this clay have been mined and hauled to Petersburg. There it has been made into strong and durable refractory bricks and flooring for kilns, grates, etc. Some of the brick have been used by the maker in the flue-arches of clamp kilns for twelve years, and others in the sides of a Eureka tile kiln for nine years, yet, to-day, they appear as good as new. The clay was delivered at the brick plant in town for 85 cents a ton. The brick made from it have sold at from $18 to $25 per thousand. But few have been made in the past three years, as the local demand for them has diminished, and no effort has been made to work up an outside market. The lower half of this vein of fire clay contains too many nodules of kidney iron ore to be of value.

At Sand Hill (N. ½ Sec. 22, Tp. 1 N., R. 8 W.), two miles north of Petersburg, the following section is exposed:

1.	Soil and sand	16 feet.
2.	Gray arenaceous shale	7 feet.
3.	Coal	3 feet 4 in.
4.	Fire clay	3 feet 6 in.
5.	Blue argillaceous shale, "soapstone"	8 feet.
6.	Gray arenaceous shale	6 feet 8 in.
7.	Dark limestone, fossiliferous	2 feet 4 in.
8.	Bituminous shale, containing nodules of pyrites	1 foot 8 in.
9.	Coal	2 feet 10 in.
10.	Fire clay	8 feet.

The two fire clays (Nos. 4 and 10) and the blue shale (No. 5) comprise together almost twenty feet of the best of material for manufacturing street brick, terra cotta, and many kinds of refractory products.

East of this, at Blackburn, on the E. & I. R. R., the fire clay beneath the seam of worked coal is hard and dark colored, with too many nodules of iron carbonate to be of use. The shale above is in thin layers and full of mica, rendering it almost worthless. This bed of micaceous shale outcrops along the railway to the southward for one-half mile or more, being overtopped for the greater part of this distance with a massive gray sandstone. It may be laid down as a general rule that when the shale splits, as this does, into layers or laminæ less than one-half an inch thick it is unfit for manufacturing purposes.

At the Smith mine (Sec. 13, Tp. 1 N., R. 8 W.) on land owned by Alexander Killion, Plainville, Daviess County, Indiana, the strata exposed are as follows:

1. Soil and yellow clay .... 8 feet.
2. Sandstone, micaceous, shaly ....10 feet.
3. Blue compact shale.................................14 feet.
4. Coal ....10 feet 2 in.
5. Fire clay...??

The seam of coal at this point is the thickest I have seen in the State. Standing on the lower unworked part of the seam, one foot six inches in hickness, I could just reach with a miner's pick the roof at the top of the worked portion, the clear, unbroken seam of the latter being 8 feet 8 inches thick. If the mouth of the shaft had been made wide enough an ordinary two-horse wagon could have been driven into the mine and loaded directly from the vein. Although the seam of coal ranks among the best bituminous it is at present worked only to supply the local trade, the nearest railway switch being three-fourths of a mile distant. Only the upper part of shale No. 3 of the section given is fit for manufacturing, the lower six feet containing too much bitumen.

Southwest of Petersburg, on the land of Hosea Alexander, a new shaft had just been finished at the time of my visit. It was located one-half mile from the E. & I. Railway, and less than five feet south of the base line, in the N. E. ¼ Sec. 4, Tp. 1 S., R. 8 W. The strata here found were as follows:

1. Soil and surface clay ....10 feet.
2. Shaly sandstone.................................. 6 feet.
3. Blue arenaceous shale .... 4 feet.
4. Coal .... 4 feet 6 in.
5. Fire clay with numerous stigmaria................ 3 feet 4 in.

The fire clay found here is practically the same as that found at the Borer mine above mentioned. It has been tested by Mr. Reed, the brickmaker at Petersburg, and found to make a good grade of refractory brick.

Along the "Air Line" Railway in the southeastern part of Pike County are many outcrops of the sub-carboniferous coal "A." These for the most part occur in ravines running back from the Patoka River and its larger tributaries. The fire-clay beneath this coal is from 4 to 6 eet in thickness, light gray, silicious and suitable for the making of fire-brick and terra cotta. In numerous localities a bed of soft gray shale 12 to 15 feet in thickness separates the coal from the overlying sandstone. This shale is locally known as "soapstone," and combined with the fire-clay beneath the coal will make vitrified street brick of a superior grade. Such deposits of shale are found in the S. E. ¼ of Sec. 16 and the N. E. ¼ Sec. 23, Tp. 2 S., R. 7 W.

GIBSON COUNTY,

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lying south of Knox and west of Pike and Warrick counties, is one of the richer agricultural counties of Southern Indiana. The Wabash River forms its western boundary and receives from the east the White and Patoka rivers. These, with their tributaries, drain the county and furnish a plentiful supply of running water. The soil of the western two-thirds is very fertile and produces some of the largest crops of corn and wheat grown in the State.

The Coal Measure rocks cover the surface of the county, but it is only along its eastern margin that the veins of coal outcrop, and there only in a few localities. The western three-fourths of the county is very similar to that of western Knox, the veins of coal of workable thickness being overlain with from 200 to 400 feet of alternating strata of shales and sandstones. Such formations, containing only a few thin seams of "rash" coals, are known as the Upper or Barren Coal Measures. They form the surface rocks in parts of Sullivan, Knox, Gibson and Vanderburgh counties and in all of Posey County.

At Princeton, the county seat of Gibson County, a number of bores have been recently put down to a depth of 600 to 800 feet, and one to a depth of 1,274 feet. The first vein of coal of workable thickness is found about 270 feet below the surface, and the second about 160 feet lower down.

At the time of my visit a shaft was being sunk in Sec. 1, Tp. 2 S., R. 11 W., one mile northwest of the Court House, to this lower vein. The first rash coal, 10 inches thick, had been found at a depth of 81 feet. Beneath this was seven feet of fire clay, the upper half of which is of excellent quality for terra cotta and similar products. At a depth of 277 feet the first workable vein, 3 feet 7 inches thick, was encountered. Above it was 40 feet of shale, the upper 18 of which was gray arenaceous, and showed a very marked, finely laminated structure, the laminæ being alternately light and dark in color. The lower 22 feet, resting directly upon the coal, was a blue argillaceous shale, very similar to that forming the roof of the worked seam at the Prospect Hill mine, Vincennes. While rather hard and massive in structure, it possesses the characteristics of a good material for vitrified products. Below the vein of coal was three feet of a tough plastic fire clay, which appears to possess high refractory properties, though as yet none of it has been tested. The shaft of this mine is by the side of the E. & T. H. Railway, and less than two hundred yards from the "Air Line." Switches from both roads will be constructed to it.*

The most available deposit of shale found near Princeton is just south of the "Air Line" shops, where an exposure has been made by the roadbed of the main line of that railway. This is in the N. E. ¼ Sec. 18 (2 S., 10 W.), and but one-third of a mile east of the E. & T. H. Railway. A section to the bottom of the exposure is as follows:

1.	Soil	2 feet 6 in.
2.	Yellow surface clay	10 feet.
3.	Sand rock—rotten, shelly	6 feet.
4.	Gray, argillaceous shale	8 feet.

The yellow surface clay (No. 2) is the fine grained silicious material so characteristic of the southern counties of Indiana. Fine pressed front brick are being made of it at Huntingburg, Jasper County. It burns to a handsome shade of red and makes a strong and durable brick. An analysis of a sample taken from the site of the above section was made by Prof. Lyons, of the State University, and its composition found to be as follows:

Silica	71.20	per cent.
Titanium oxide	.88	"
Alumina	18.56	"
Ferric oxide	1.34	"
Ferrous oxide	.15	"
Lime	.14	"
Magnesia	.52	"
Potash	.32	"
Soda	1.26	"
Water	6.30	"

For a surface clay this shows remarkable purity. While the percentage of free silica is high, that of lime, which is the most common and injurious impurity found in such clays, is very low.

*Since the above was written the lower vein of coal was reached at a depth of 440 feet. It is 6 feet 2 inches thick, and of good quality, as shown by the following analysis:

	Per cent.	
Fixed carbon	51.18	
Ash	11.02	
Solid, or coke-producing matter		62.20
Gas	32.71	
Water	5.09	
Volatile		37.80
Sulphur (separately determined)		1.38

The shale No. 4 is a drab or light gray material, showing occasional scales of mica and containing a rather large percentage of free silica. Its composition, as shown by an analysis made by Prof. Lyons, is as follows: *

Clay base and sand	87.33 per cent.
Fluxes	12.64 "

This shows a very close approximation to the standard average (see p. 54) of shales used for making paving bricks, and as far as such analysis and general appearance goes, it is well suited for that purpose The area covered by this shale deposit comprises 30 or more acres, and its situation is most favorable for the location of a combination factory for making both pressed front and paving brick.

In the southwestern part of Princeton, Dr. Wm. Kidd has for a number of years conducted the only brick yard found in that city. He makes ordinary and repressed soft mud brick from the yellow ochery surface clay described above. Beneath this stratum of clay at his yard is a deep red silicious clay, containing in places small geodes and pebbles of quartz and granite showing that a spur of some glacier has in the past extended this far south. From this red clay Dr. Kidd has made, as an experiment, very hard and durable brick which would, in the absence of shale brick, serve well as paving material.

Three miles east of Princeton, on the land of George Eaton (N. E. ¼ Sec. 10, 2 S., 10 W.), along the bottoms of Indian Creek, are outcrops of a vein of coal 14 inches thick, beneath which is an underclay 4 feet in thickness. This was used in making fire brick for the cupola furnace of a foundry at Princeton, and locally for the setting of brick, in grates, etc. It is said to possess high refractory qualities.

Near Bald Hill, north of Princeton one and one-half miles, on the land of Chas. Myers, is the outcrop of another "rash" vein of coal, whose underclay, 4 feet thick, has been used by Dr. Kidd for making fire brick for his kilns. These brick, according to Dr. Kidd, stood the heat as well as those bought at Freeman's Landing, Va., at $17 per thousand.

The only other outcrop of clay noticed during my short stay at Princeton was close to the "Air Line" Railway, by the side of a small stream, in the S. E. ¼ Sec. 1 (2 S., 11 W.), and a few hundred yards west of where the coal shaft, mentioned above, is being sunk. At this point an exposure of a good quality of shale has been made by the erosion of the water. The thickness of this stratum could not be ascertained.

In general it may be stated that wherever in Gibson County the "rash" coals come to the surface they will be found to be underlain with

* For complete analysis see table at end of chapter.

a clay suitable for the making of roofing tile, terre cotta, fire brick and, in some instances, potter's wares.

Southwest of Oakland City, in Sec. 24, Tp. 2 S., R. 9 W., Mr. Fred. Cotterill is operating a mine, the worked vein of coal being 135 feet below the surface. Beneath the coal is a stratum of dark-gray fire clay, 8 feet in thickness. This has been used with good results by Mr. Cotterill for making fire brick for boiler walls and furnaces. A switch of the "Air Line" Railway is completed to the mine.

VANDERBURGH COUNTY

occupies an area of 240 square miles, lying south of Gibson County, and between the counties of Warrick and Posey. Evansville, the county seat, is the second city in size in the State, and is especially noted for the number and magnitude of its manufactories. This is largely due to the excellence of its transportation facilities. Occupying an important site on the Ohio River, below interrupting rapids and ice, and near the outlet of the Wabash, Greene and Tennessee rivers, it has an important water communication with the states to the south and west, which has added much to its enterprise and growth. In addition to this, seven railways enter its bounds and furnish direct connection with the leading cities of the United States. Next to transportation, cheap and abundant fuel is the leading factor tending to promote manufacturing interests. Vanderburgh County lies wholly within the coal measures. A 4-foot seam of strong workable coal underlies nearly the whole area of the county. Numerous shafts have been sunk to it within the corporate limits of Evansville. These, and the mines at Newburgh and Oakland City, can furnish a cheap source of power for factories unlimited.

Three clay industries of large size are located at Evansville. In the next chapter these will be noted in detail. Attention is called to them here because one of them, the Evansville Pressed Brick Company, has been using on a large scale the shales found in the immediate vicinity of the city. This company began in 1890 to make vitrified brick for street paving purposes. For some time fire-clays from Lincoln City, Spencer County, and other points were used. Wishing a cheaper material the company began experimenting with the shales found along the low bluffs of Pigeon Creek, and finding them highly suitable for their purpose purchased a tract of land in the S. E. ¼ of the N. E. ¼ Sec. 24, Tp. 6 S., R. 11 W. The bed from which the shale is at present obtained is on this land, just at the outskirts of the city and one half mile from their plant, necessitating the hauling of the material in wagons for that distance. A section at the pit showed the presence of the following strata:

1.	Surface and yellow clay	5 feet.
2.	Drab argillaceous shale	14 feet.
3.	Blue arenaceous shale	5 feet.
4.	Sandstone	?

At intervals of one foot apart near the middle of the stratum of drab shale (No. 2) are three bands of kidney iron ore, each two inches in thickness. Otherwise this entire stratum is of most excellent material, being that soft, close textured, smooth variety of clay shale locally known as "soapstone." In the making of brick, either dry pressed or vitrified, all of this stratum is used, together with the overlying yellow clay and enough of the blue arenaceous shale to make one-fifth of the bulk. This makes a vitrified brick at once strong, tough and practically non absorbent, and one of which many millions have been sold within the past four years. An analysis of the mixture as it goes into the brick was made by Prof Noyes, and the composition found to be as follows:

*Clay base and sand	86.22
Fluxes	13.50

This proves the mixture well adapted for the uses to which it is put, as the composition is very close to that of the average composition of the Ohio shales used for such purpose. (See page 54.)

This deposit of shale, both drab and blue, covers a large area north and northwest of Evansville, and outcrops in a number of places along Pigeon Creek and its tributaries. An especially large and valuable bed of it is found in the S. E. ¼ of Sec. 8, Tp. 6 S., R. 10 W., about three-fourths of a mile east of Rose Hill cemetery. Along the borders of the stream known as Locust Lick it is especially noticeable. On the farm of Rudolph Fistle in the N. E. ¼ Sec. 14 (6 S. 11 W.) the drab variety is exposed to a thickness of 11 feet; and on the land of Jenner and Nugent, one-half mile farther east (N. E. of S. W. ¼ Sec. 13), is a bold bluff 30 feet in height, which is wholly made up of it. This is equal, if not superior in quality to that worked by the Evansville Pressed Brick Co., as no indications of iron kidneys were seen.

At the Crescent City Park, on the east bank of Pigeon Creek (S. E. ¼ Sec 24, Tp. 6 S., R. 11 W.), a bore was put down a number of years ago which resulted in a strong flow of artesian water. The record of that bore for the first 130 feet was as follows:

1.	Soil and surface clay	7 feet.
2.	"Soapstone"	24 feet.
3.	Gray sandstone	2 feet 6 in
4.	"Soapstone" and shale	37 feet 6 in.
5.	Gray sandstone	1 foot.
6.	Coal	1 foot 6 in.
7.	Fire clay	6 feet.
8.	Gray shale	51 feet.

* For complete analysis see table at end of chapter.

This shows an inexhaustible supply of excellent clay within the city limits, for the "soapstone," of which more than 60 feet were gone through, is the best material known for paving and hollow brick, sewer pipe, pressed front brick and many kindred products.

West of this, near Babytown, is a high piece of ground known as "Law Hill" (N. E. of S. E. of Sec. 23), on the western slope of which Adam Helfrich has one of the largest brick yards in the vicinity of Evansville. The shale outcrops in this yard, and a well 34 feet deep did not reach the bottom of it. He has used it to some extent in making ordinary brick, and states that it is far superior to the surface clay for that purpose, but it requires different machinery and so its use was not continued. Outcrops on the east side of this hill, and on Wheeler's Hill to the northeast, showed that almost the whole of the east half of Sec. 23 is underlaid with this shale. These two hills are less than one-third of a mile from a railway, and the shale at both places can be secured by easy stripping. Indeed, these deposits contain enough of it to furnish paving brick for all southern Indiana for a hundred years.

At the First Avenue Coal Mine, located near Pigeon Creek in the western part of the city, the underclay beneath the worked seam is a very dark plastic material, which can be utilized in the making of terra cotta. It contains some pyrites which can be eliminated to a large extent by exposure to the atmosphere. The shale overlying the coal contains too much bitumen to be of value for vitrified products.

The fire clay found in Vanderburgh County, beneath coal "N," the top vein is of much better quality than that below the worked vein "M," but the upper vein is in most places too thin for profitable mining. If it and the clay were worked together, and the latter put to use, it would undoubtedly prove a paying enterprise.

The yellow surface clay of the county is, like most of that found south of the drift area, suitable in the highest degree for ordinary brick, and will make pressed front brick of a fair quality. Twenty-one brick yards were operated, in 1895, within a radius of two miles of the Court House at Evansville. The most of these were small establishments, where the output was molded by hand. Such competition could but result in very low prices, and the brick were being delivered at $4.50 per thousand at the time of my visit.

A sample of this yellow surface clay from the brickyard of Wm. Schnute in the northeastern part of the city of Evansville, is in a jar among the collections of clay made by Professor Gorby. On the jar is the following record of its analysis by Dr. J. N. Hurty:

Silica (total)	77.930	
Alumina	12.160	
Clay base and sand		90.090
Magnesia	.571	
Lime	.347	
Ferric oxide	4.480	
Fluxes		5.398
Moisture and volatile		4.501

This shows great purity and a composition approaching closely some of the "fire" or under-clays of the coal seams. The low per cent. of iron oxide is surprising, as the color of the clay would denote much more.

WARRICK COUNTY

is situated east of Vanderburgh, and south of Pike and Gibson counties, and the Ohio River forms a part of its southern boundary. The county comprises an area of 388 square miles, and lies wholly within the Coal Measure formation. The land is, for the most part, well adapted to cultivation, large quantities of wheat, corn and hay being annually produced and shipped to markets on the Ohio River. Tobacco is one of the staple products grown, as high as eight million pounds having been raised in the county in a single season. The principal mines are in the vicinity of Boonville, the county seat, and Newburgh, the chief river town.

By the side of the Evansville Division of the "Air Line" Railway, one mile northeast of Boonville, is the mine of Goff & Kellar, in the shaft of which the following section is exposed:

1.	Soil and surface clay	12 feet.
2.	Shelly sandrock, with numerous small iron kidneys	3 feet.
3.	Dark shaly limestone, fossiliferous	13 feet.
4.	Black fissile shale	4 feet.
5.	Coal	6 feet 4 in.
6.	Fire clay,	? ?

No one of these is suitable for manufacturing. The fire clay, the thickness of which I was not able to determine, is of a greenish gray tint, and contains so large a percentage of fluxes as to render it worthless. Brick made from it have been tested by L. Klostermier, of Boonville, in the floor and flue arches of clamp kilns. In a short time they began to swell up, then the surface melted and flowed like slag, and finally the whole body of the brick became black, porous, and lava-like in appearance.

One-half mile farther east is the mine of the Lander, Wooley Co. The strata here are the same as at Goff & Kellar's, except that the shaly limestone is much thinner, and the vein of coal, 8 feet in thickness, is but 17 feet below the surface at the point where the slope shaft begins.

At the brick yards of L. Klostermier, and Henry Felwisch, in the northern part of the town of Boonville (N. ½ Sec. 26, Tp. 5 S., R 8 W.), an exposure of a soft gray unctuous "soapstone" has been made by the removal of the yellow surface clay. This stratum has been proven, by boring, to be from 7 to 12 feet in thickness. On the Felwisch yard the following section is exposed:

1.	Soil	1 foot 3 in.
2.	Yellow clay	6 feet 9 in.
3.	"Soapstone," with layer of iron kidneys in uppper 6 inches	7 feet.
4.	Sandstone	? ?

No use has been made of this soapstone. Mr. Klostermier has ground some of it and attempted to make drain tile, but it clogged the machine too badly. Mixed with a more silicious material as the overlying surface clay, it will undoubtedly prove suitable for vitrified products and hollow brick. Aside from the iron concretions found in its upper part the stratum is remarkably pure and homogeneous throughout.

At the old St. Elmo mine, three miles west of Boonville, on the "Air Line" Railway, a stratum of fire clay of excellent quality underlies the worked seam of coal. It is light gray, silicious, and, judging from appearance, of high refractory grade.

At Newburgh the principal mines are found just above the town along the Ohio River front, in Sec. 2, Tp. 7 S., R. 9 W. The top vein of coal, unworked, is underlain with about 2½ feet of fire clay, and below this is 20 feet of gray argillaceous shale. Both of these, singly or combined, are suitable for vitrified products. The main vein of Newburgh coal is found about 93 feet below the surface. The fire clay underlying it varies in thickness from 3 feet 6 inches to 4 feet 3 inches, and is suitable for terra cotta or sewer pipe.

Although many seams of coal and clay outcrop in the northern half of Warrick County, but few mines have been worked on account of a total lack of railway facilities. Until these are furnished the mineral resources of that section will remain practically undeveloped.

SPENCER COUNTY

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is one of very irregular outline. Lying between Perry and Warrick counties, it is bounded on the north by Dubois County and on the south by the Ohio River. It comprises an area of 498 square miles, the most of which is covered with a soil of great fertility. The leading crops are corn, hay, tobacco and potatoes.

The northern two-thirds of the county is underlain with coal. The southern third has for its surface rock the conglomerate sandstone or millstone grit, which forms the high bluff along the Ohio River, on which Rockport, the county seat, is located. For that reason no clays of importance, other than those used for making ordinary soft mud brick occur in the immediate vicinity of Rockport.

The Eigenmann Contract Company have a large brick yard a short distance from the town, on which the following section was disclosed:

1.	Soil (stripped)	1 foot.
2.	Yellow surface clay	7 feet.
3.	Sand (bottom concealed)	20 feet.

The yellow clay is the characteristic surface clay of the driftless area of Indiana. It makes an excellent stock brick, and, as has been proven at Huntingburg, can also be made into a good grade of red pressed front brick. The sand (No. 3) of the above section is a good moulding material, and large quantities of it are annually shipped for that purpose to various towns on the "Air Line" Railway.

The mine nearest to Rockport, which is worked for coal, is 7 miles north, on the land of James Fisher (N. W. $\frac{1}{4}$ Sec. 16, Tp. 6 S., R. 6 W.). Here the vein of underclay is thin and of poor quality. Three miles nearer the town, on the land of Geo. Shrode (E. $\frac{1}{2}$ Sec. 4, Tp. 7 S., R. 6 W.), is a thin seam of coal beneath which is a vein of much better "fire clay," 4 feet in thickness. It is fine grained, light colored and silicious, and appears in every way suitable for potter's use.

In the vicinity of St. Meinrad, in the northeastern part of the county, a seam of block coal called "I" by Prof. Cox, outcrops in a number of places. It is underlain with a deposit of fire-clay from 3 to 5 feet in thickness, which is suitable for terra cotta and sewer pipe, and in some instances for potter's use. The Cincinnati, Rockport & Southwestern Railway, on which much work was done last season, and which will eventually be constructed, runs through St. Meinrad, and when completed will furnish an outlet for these mineral resources.

One and one-fourth miles southeast of Lincoln City the Cannelton branch of the "Air Line" Railroad runs through a large shale deposit.

A cut 30 feet deep was made for the roadway, which exposes the following section:

1.	Soil and surface clay	4 feet.
2.	Light drab argillaceous shale	10 feet.
3.	Concretions of kidney iron ore	4 in.
4.	Dark gray argillaceous shale	16 feet.

With the exception of the 4-inch band of iron ore this deposit of shale is free from impurities. It is soft, gritless, and weathers, in places, into quadrangular pieces an inch or two in size, indicative of its superior grade. An analysis of a mixture of the two colors of this shale, made by Prof. Noyes, shows the following composition:*

Clay base and sand	84.45 per cent.
Fluxes	14.43 "

This shows but a slight variation from the standard average composition of shales suitable for vitrified products (see p. 54), and proves the chemical fitness of this deposit for that use.

This stratum of shale overlies a large area south of Lincoln City. Exposures from 15 to 30 feet in thickness are made in it by the Rockport branch of the "Air Line" Railroad between Lincoln City and Rockport Junction, and also one-half mile south of the latter point. Other outcrops are found on the Cannelton branch between the big cut above mentioned and Buffaloville, and between the stations of Lamars and Evaston.

An excellent grade of coal is mined by the Henry Shafer Company, one mile south of Lincoln City and one-fourth of a mile north of the "shale cut." The vein of coal lies at a depth of 23 feet. It is 3½ feet thick and overlies a bed of fire-clay which averages about 5 feet in thickness. Much of this has to be removed to make height. One thousand or more cars of it were shipped in 1891 and '92 to Evansville and made into vitrified brick by Lant, Morris & Co. When this firm discovered and began to utilize the shale near Evansville the shipping of the fire-clay was discontinued. It is now raised and thrown on the dump or stored in the worked out areas. It costs 30 cents a ton to handle it and when shipped brought 50 to 65 cents on the cars at the mine. This underclay is a dark gray, fine-grained material containing too large a percentage of fluxes for refractory products, but well suited for the making of vitrified wares or terra cotta. It is co-extensive with the vein of overlying coal, which is worked at a number of points in Clay and Hanover townships.

Lincoln City is a growing town and an important junction point on the "Air Line" Railway. With large deposits of shale, fire-clay and coal in its immediate vicinity, and with good railway facilities, it offers excellent advantages for the location of a great clay industry.

*For complete analysis see table at the end of this chapter.

PERRY COUNTY

lies south of Dubois and Crawford counties, and has a frontage of almost fifty miles on the Ohio River. Anderson Creek forms the greater part of its western boundary, and the numerous tributaries of this stream and the Ohio furnish an excellent system of drainage. The county is a large one, comprising an area of 380 square miles, more than three-fourths of which is covered with the millstone grit or conglomerate sandstone, which is here represented by sandy shale, flags, and a massive sandstone containing quartz pebbles. With the exception of the bottoms along the Ohio River and the larger streams of the interior, the soil is very poor, and the surface of the county exceedingly rough and broken.

The Coal Measures come to the surface in the southwestern fourth and along the Ohio River between Rock Island and the mouth of Anderson Creek, and it is in this region that the clays and shales, herein referred to are found.

Perry County has long been noted for its clay industries. The first pottery of importance in the State of Indiana was located, in 1834, on the banks of the Ohio River, a short distance above the town of Troy. Jas. Clews, a wealthy individual of Liverpool, England, had previously visited the place and made a careful investigation of the clays underlying the seams of coal. From the crude tests which he made he believed them to be fitted for making a light colored grade of porcelain ware. Returning to England he organized a colony of more than 600 persons, many of whom were skilled potters. These he brought to Troy, and, burning ordinary brick for factories and dwellings, and fire brick for kilns, soon had a large industry in operation. To this he gave the name of the "Indiana Pottery Company." Some of the buildings erected were two stories in height and more than 200 feet long.

Unfortunately the clays at Troy proved unfit for the making of white ware; and the company had to ship in lighter clays and mix with them and content itself with manufacturing a yellow or Troy ware, which, in time, came to be much used in southern Indiana. This was, however, unsatisfactory to the leading members, and about 1840 the pottery was abandoned and allowed to go to ruin.

In 1863 a pottery was started on a small scale in one of the old buildings by B. Hincho. Some years later he abandoned this site and erected a new pottery in the town of Troy, where he manufactured from the underclay of the top vein of coal, a mahogany colored Rockingham ware until 1892, when old age caused him to desist. As a practical potter of long experience, Mr. Hincho claims that the clay found in the vicinity of Troy, and used by the Indiana Pottery Company and himself, can not be excelled for the making of terra cotta, ordinary stone ware, or the darker and more expensive Rockingham ware, but by itself burns too dark for the "yellow ware" such as the old company made. In 1865, Samuel Wilson started a pottery in the town of Troy, which he operated until his death in 1891. He made both yellow and Rockingham ware, the former from clay shipped in from Ohio which closely resembles the potter's clay found at Clay City, Indiana.

Near the site of the factories of the old Indiana Pottery Company, one-half mile above Troy, the shaft of the Bergenroth Bros. coal mine is located. One hundred yards east is the clay-pit of the old company. The following connected section was obtained at this point, beginning on the slope of the hillside (N. E. ¼ Sec. 13, Tp. 6 S., R. 4 W.), a few yards west of the section line which runs through the old pit:

1.	Soil and yellow surface clay	17 feet.
2.	Shaley sandstone	10 feet.
3.	Black fissile shale	5 feet.
4.	Coal (top vein)	6 in.
5.	Potter's clay	6 feet 4 in.
6.	Sandstone	33 feet.
7.	Coal	3 feet 2 in.
8.	Fire clay	??

According to Mr. Hincho, the vein of potter's clay No. 5, becomes thicker farther back under the hill, and at the point worked by him, a few hundred yards east of Troy, was fully 12 feet in thickness. It is an exceeding close grained, light colored clay and stands up well under heat sufficient to melt the mixture of lead oxide, manganese and sand used in glazing the Rockingham ware. It is practically the same clay as is used at Cannelton, an analysis of which is given below.

The coal (No. 7) is the vein mined by Bergenroth Bros., and is the same seam as is worked at Cannelton. It is not a cannel coal but a semi-caking bituminous, and ranks high as a fuel. It is mostly sold to steamboatmen on the river, and is used by the engines on the Cannelton Branch of the "Air Line" R. R. This road runs within 20 feet of the shaft, and directly past the outcrops of clay mentioned above, passing over some of the foundations of the old pottery, which are buried beneath the soil washed down from the adjacent hillsides.

In 1862 Clark Bros. established at Cannelton, the present county seat of Perry County, a factory for the manufacture of sewer pipe. This for more than thirty years was the only establishment of its kind in the State. Ten years later Wm. Clark erected by the side of the sewer pipe factory a large stoneware pottery. Both of these are still operated, and the latter is the largest concern of its kind in Indiana. The clay used in both factories is the underclay found so extensively in the vicinity of Cannelton beneath the top coal. That at present used is hauled in wagons from a point one mile northeast of the town, where the vein of clay is from four to five feet in thickness. In many places the coal is absent, and the clay is obtained by stripping the surface soil to a depth of from one to six feet.

The upper half of the vein, a light gray plastic clay of very fine texture, is used mostly for stoneware. Care must be taken in selecting it, however, as in some places it contains particles of pyrites, which, after burning, cause a flaking of small pieces from the surface of the ware, and so render it unsalable. The lower half of the vein is coarse-grained and has more of a reddish-yellow tinge, due to a larger percentage of iron oxide. It is better suited to the making of sewer pipes, as it vitrifies at a lower temperature than the upper, and burns to a darker color. No trouble with the "poppers" (as Mr. Clark calls them), or particles of iron pyrites, is experienced in the making of sewer pipe. This clay resembles shale somewhat in possessing a laminated appearance, but that it is a true fire clay of good refractory grade is shown by the following record of analysis made by Dr. Hurty of a sample from the upper part of the stratum:

Silica (total)	65.830	
Alumina	22.940	
Clay base and sand		88.770
Magnesia	.858	
Lime	.308	
Ferric oxide	2.640	
Fluxes		3.806
Moisture and volatile		7.434*

The surface of the sewer pipes made from the more impure lower portion of the clay stratum are glazed with salt, and become a light reddish brown in color. The pipes are hard, close-grained, very strong, perfect in form, and free from cracks and flaws.

The same stratum of underclay is used by the Cannelton Stoneware Company, which began operations in 1892. This company makes annually 150,000 gallons of stoneware, and finds the upper portion of the vein of clay admirably suited for the purpose.

Neither this company nor Mr. A. D. Clark make any attempts to wash this clay before using, it being simply ground by steam power in a wet pan or "tracer."

Mr. O. C. Lee, the Superintendent of the new company, has made some private tests which go to prove the value of a better system of preparing the clay. He showed me samples of vases and jars made from

*This probably includes 1 or 2 per cent. of potash. Compare the second column of this analysis with the standard average of Ohio stoneware clays given on page 48.

the washed clay, which were superior in design and finish. They were unglazed and when burned were of the peculiar stone-gray color of the raw material. They prove this clay, when properly prepared, to be well suited for the finest of decorative work. If washed before being made into stoneware, a much better quality of the latter could be made, and the increased price which it would readily bring would more than repay the extra expense of preparation.

The American Cannel Coal Company owns several thousand acres of land adjoining Cannelton on the north and east, and for years has carried on the mining of coal and the quarrying of sandstone on an extensive scale. The main vein of coal has been worked at a number of places, mostly by slope or drift shafts. The following connected section, obtained one and one-fourth mile east of Cannelton, on the S. E. ¼ of the N. E. ¼ Sec. 10, Tp. 7 S., R. 3 W., may be taken as representing the average sequence of the strata through the worked seam of coal over a large area of the company's land:

1.	Soil and yellow clay	6 feet.
2.	Gray arenaceous shale	14 feet.
3.	Sandstone	8 feet.
4.	Blue arenaceous shale	11 feet.
5.	Coal (top vein)	1 foot to 18 in.
6.	Potter's clay	4 to 6 feet.
7.	Blue argillaceous shale	34 feet.
8.	Black bituminous shale	1 foot 6 in.
9.	Coal (main vein)	4 feet.
10.	Fire-clay	5 feet.
11.	Sandstone	20 feet.

Large quantities of shale (No. 7) and fire-clay (No. 10) have to be handled each year to make height in the rooms and entries of the mines. Neither of these have heretofore been put to use, though excellent sample, dry-pressed front brick have been made from them for the company. Shale No. 7 is a close-grained material very free from impurities. Its composition, as shown by an analysis made for this report by Prof. Noyes, shows the presence of: *

Clay base and sand	87.08 per cent.
Fluxes	12.34 "

This proves its chemical fitness for making vitrified products of many kinds; as the percentages given are very close to those of the average shale used for such products. (See p. 54.)

The fire clay (No. 10) burns to a handsome buff color and will doubtless make good terra cotta, or can be mixed with the shales to make paving brick. It contains too great a percentage of fluxing impurities to

* For complete analysis see table at end of chapter.

make refractory wares, as the following composition from analysis made by Prof. Noyes will show: *

Clay base and sand	87.15 per cent.
Fluxes	10.30 "

The yellow surface clay, which crowns the hills about Cannelton to a depth of 6 to 8 feet, is a superior article of its kind. The Cannelton Stoneware Company is making from it ordinary soft mud brick, which are but little inferior in appearance to some of the pressed front brick used in our cities. Mr. George Hufnagle, of Cannelton, has had sample, dry-pressed brick made from it which were very handsome in appearance. From deposits of shale and fire-clay on his farm (Sec. 9, Tp. 7 S., R. 3 W.) he has had other samples burned—the shales making a dark maroon brick which can not be excelled in quality, and the fire-clay a fair grade of buff front brick.

All in all, the clays found at available points in Perry County are excellent in quality, and in quantity practically inexhaustible. From them ordinary building brick, sewer pipe, stoneware, vitrified drain tile and Rockingham ware, all of *good quality, have been made in the past,* while paving, pressed front and hollow brick, and terra cotta can undoubtedly be made. Fuel of excellent quality, awaiting only the pick of the miner, underlies these clays. The Ohio River furnishes an ever-ready means of transportation, where not one company, but many, compete for freight, and so keep the rates at a very low figure; while the "Air Line" Railway has a branch line passing within one-half mile of all the chief clay deposits. With these facilities present no better site for the location of large clay factories exists in southern Indiana. The one thing lacking is a railway running northeast from either Cannelton or Tell City via Bloomington, Monroe County, to Indianapolis. Such a road would pass through the main oölitic limestone district of the State, and would open up a vast territory rich in many kinds of undeveloped resources.

* * *

This completes the list of counties comprised in the area covered by this report. As before stated, attention has been called only to the larger and more available deposits of commercial clays found within their bounds. The presence in large quantities of the raw materials suitable for making every kind of clay product used in Indiana, with the exception of some of the finer clays used in the better grades of terra cotta, encaustic tile and china ware, has been shown. The clays for the cheaper and vastly more used products, millions of dollars worth of which are annually imported into the State, are lying undeveloped and

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* For complete analysis see table at end of chapter.

surrounded in most instances with the fuel necessary for their burning. With these resources present why should Indiana be behind the other States in clay manufacturing? Why should she make only 5 per cent. of the total value of clay products made in the United States, when Ohio and Illinois, with no more extensive or better beds of the raw material, make respectively 16 and 13 per cent.?

The people of this State are not awake to the opportunities and advantages in their midst. The majority of the clay industries which have started up at Brazil, Veedersburg, Terre Haute and elsewhere within the past five years are owned by parties outside of Indiana, and the profits accruing, which are large, go mostly without her bounds. As was well said by the superintendent of one of the largest of these factories (himself an Ohio man and the factory owned by Ohio capitalists): "The people of Indiana don't seem to know a good thing when they have it. They wait for outsiders to come in, gain possession of it and make it known to them, and then, too late, they realize its importance." Home factories should be erected, should be protected, should be patronized, for in such a way only can the future wealth and welfare of the State be increased, and plentiful labor be provided for her working-men.

Analyses of Carboniferous Shales.

	1		2		3		4		5		6		7		8		9		10	
	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.
Silica (SiO_2)	56.62	......	59.55	35.98	61.46	33.98	65.87	46.10	65.78	43.25	55.00	22.48	59.77	31.87	59.02	26 13	58.83	29.16	61.05	27.10
Titanium oxide (TiO_2)	......	......	1.00	......	1.20	......	1.10	......	1.00		1.20	......	.80	......	1.10	......	.70	......	1.20	......
Alumina (Al_2O_3)	21.63	......	16.21	.39	16.54	1.72	14.66	2.63	14.79	2.54	20.76	.45	20.60	1.66	20.93	.66	22.34	1.81	21.46	.35
Water (combined)	6.53	......	5.62	......	5.09	......	4.59	......	4.98	......	7.01	......	4.53	......	7.59	......	5.22	......	6.94	......
Clay base and sand	84.78	......	82.38	...	84.29	......	86.22	......	86.55	......	84.06	......	85.70	......	88.64	......	87.09	......	90.65	......
Ferric oxide (Fe_2O_3)	7.08	......	2.18	......	3.77	......	6.23	......	8.03	......	3.00	......	2.22	......	4.45	......	5.13	......	5.57	......
Ferrous oxide (FeO)	......	......	7.13	......	3.71	......	1.37	......	......	......	4.01	......	3.70	......	1.56	......	1.44	......	.71	......
Lime (CaO)	1.11	......	.75	......	.66	......	.39	......	.54	......	1.51	......	.64		.51	......	.49	......	.25	......
Magnesia (MgO)	1.41	......	1.58	......	1.81	......	1 54	......	1.42	......	1.18	......	1.98	......	1.66	......	1.56	......	.70	......
Potash (K_2O)	3.14	......	2.81	.05	3.28	.82	2.66	1.21	2.82	1.13	2.36	......	3.10	.88	2.92	.31	4.18	.14	2.34	.04
Soda (Na_2O)	.48	......	.28	......	1.09	......	1.31	......	.97	......	.34	......	.85	......	.41	......	.63	......	.30	......
Fluxes	13.22	......	14.73	......	14.32	......	13.50	......	13.78	......	12.40	......	12.49	......	11.51	......	13.43	......	9.87	......
Carbon dioxide (CO_2)	......	......	3 15	......	1.45	......	......	......	.26	......	3.04	......	.90	......	......	......	......	......	......	......
Total	98.01	......	100.26	36.42	100.06	36.52	99.72	49.94	100.59	46.92	99.50	22.93	99.09	34.41	100.15	27.10	100.52	31.11	100.52	27.49

Rational Analyses of Above Shales.

	1		2		3		4		5		6		7		8		9		10	
Quartz	......	......	34.61	......	27.94	......	36.87	......	34.34	......	20.90	......	26.04	......	23.82	......	22.81	......	25.87	......
Feldspathic detritus	......	......	1.81	......	8.56	......	13.07	......	12.58	......	2.03	......	8.37	......	3.23	......	8.30	......	1.62	......
Ferrous carbonate	......	......	8.61	......	3.82	......	......	......	......	......	6.46	......	2.37	......	......	......	......	......	......	......
Magnesium carbonate	......	......	......	......	......	......	......	...	.50	......	1.13	......	......	......	......	......	......	......	......	......
Clay substance	......	......	54.97	......	59.68	......	50.06	......	52.58	......	69.48	......	63.22	......	72.90	......	68.89	......	72.51	......

Composition of Clay Substances of Above Shales.

	1		2		3		4		5		6		7		8		9		10	
Silica (SiO_2)	......	......	42.40	......	45.94	......	39.71	......	42.38	......	47.28	......	44.05	......	44.83	......	42.71	......	46.47	......
Titanium oxide (TiO_2)	......	......	1.80	......	2.00	......	2.21	......	1.88	......	1.74	......	1.26	......	1.50	......	1.02	......	1.64	......
Alumina (Al_2O_3)	......	......	28.46	......	24.63	......	24.15	......	23.04	......	29.44	......	29.91	......	27.63	......	29 55	......	28.90	......
Ferric oxide (Fe_2O_3)	......	......	3.92	......	6.30	......	12.50	......	15.10		4.35	......	3.51	......	6.06	......	7.39	......	7.62	......
Ferrous oxide (FeO)	......	......	3.56	......	2.24	......	2.76	......	......	......	......	......	3.74	......	2.13	......	2.08	......	.97	......
Lime (CaO)	......	......	1.35	......	1.10	......	.79	......	1.01	......	2.19	......	1.01	......	.70	......	.71	......	.34	......
Magnesia (Mg O)	......	......	2.84	......	3.03	......	3.10	......	2.22	......	.92	......	3.13	......	2.26	......	2.25	......	.96	......
Potash (K_2O)	......	......	5.06	......	4.44	......	2.92	......	3.18	......	3.42	......	4.90	......	3.98	......	5.86	......	3.20	......
Soda (Na_2O)	......	......	.50	......	1.82	......	2.64	......	1.82	......	.50	......	1.34	......	.58	......	.91	......	.40	......
Water (H_2O)	......	......	10.11	......	8.50	......	9.22	......	9.37	......	10.16	......	7.15	......	10.53	......	7.52	......	9.50	......

Analyses of Carboniferous Shales—Continued.

	11		12		13		14		15		16		17		18		19	
	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.
Silica (SiO_2)	56.68	35.53	53.26	30.17	64.05	....	46.07	26.33	56.32	23.47	55.31	31.67	62.04	43.58	67.82	52.63	68.46	50.63
Titanium oxide (TiO_2)	.90	....	1.05	....	1 00	....	1.19	....	1.07	....	1.15	....	1.30	....	1.10	....	1.49	....
Alumina (Al_2O_3)	20.33	1.62	25.77	.46	16.00	....	24.22	2.97	24.34	2.93	22.46	5.62	18.49	3.70	13.60	3.97	16.08	3.72
Water (combined)	6.54	....	7.00	....	3.79	....	9.76	....	6.33	....	7.48	....	6.50	....	9.72	....	7.04	....
Clay base and sand	84.45	....	87.08	....	84.84	....	81.24	....	88.06	....	86.40	....	87.33	....	92.24	....	93.07	....
Ferric oxide (Fe_2O_3)	4.35	....	3.32	....	.89	....	9.65	....	5.60	....	7.18	....	7.54	....	4.04	....	1.92	....
Ferrous oxide (FeO)	3.69	....	3.82	....	5.85	....	.34	....	.24	....	.23	....	.06	....	.45	....	.06	....
Lime (CaO)	.57	....	.32	....	.42	....	.19	....	.31	....	.66	....	.16	....	.57	....	.99	....
Magnesia (MgO)	2.04	....	1.90	....	2.00	....	1.31	....	.54	....	.93	....	.91	....	.44	....	.05	....
Potash (K_2O)	3.15	.94	2.54	.35	2.59	....	1.66	....	2.85	....	2.05	....	.93	....	1.68	....	1.31	....
Soda (Na_2O)	.63	....	.44	....	1.19	....	2.76	....	2.34	....	2.06	....	2.04	....	1.18	....	2.40	....
Fluxes	14.43	....	12.34	....	12.94	....	15.91	....	11.88	....	13.11	....	12.64	....	8.36	....	6.73	....
Carbon dioxide (CO_2)	.47	....	1.10	....	2.68	....	2.87	....	....	....	1.24	....	....	....	....	....	....	....
Total	99.35	8.09	100.52	30.98	100.46	....	100.02	29.30	99.94	26.40	100.75	37.29	99.97	47.28	100.60	56.60	99.80	54.35

Rational Analyses of Above Shales.

	11		12		13		14		15		16		17		18		19	
Quartz	29.85	....	28.66	....	....	....	15.91	....	13.19	....	11.91	....	30.60	....	38.70	....	37.58	....
Feldspathic detritus	8.24	....	2.32	....	....	....	13.39	....	13.21	....	25.38	....	16.68	....	17.90	....	16.87	....
Ferrous carbonate	1.23	....	2.90	....	....	....	.54	....	....	....	.37	....	....	....	....	....	....	....
Magnesium carbonate	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Clay substance	60.68	....	66.12	....	....	....	70.72	....	73.54	....	63.46	....	52.69	....	44.00	....	45.35	....

Composition of Clay Substances of Above Shales.

	11		12		13		14		15		16		17		18		19	
Silica (SiO_2)	35.83	....	34.54	....	....	....	27.91	....	44.53	....	37.25	....	35.03	....	34.55	....	39.31	....
Titanium oxide (TiO_2)	1.52	....	1.58	....	....	....	1.68	....	1.45	....	1.81	....	2.47	....	2.50	....	3.28	....
Alumina (Al_2O_3)	31.69	....	37.98	....	....	....	30.04	....	29 11	....	26.53	....	28.07	....	21.88	....	27.25	....
Ferric oxide (Fe_2O_3)	7.37	....	4.98	....	....	....	13.64	....	7.61	....	11.31	....	14.31	....	9.18	....	4.23	....
Ferrous oxide (FeO)	3.27	....	3.03	....	....	....	.48	....	.32	....	.36	....	.11	....	1.02	....	.13	....
Lime (CaO)	.97	....	.48	....	....	....	.26	....	.42	....	1.04	....	.30	....	1.29	....	2 18	....
Magnesia (MgO)	3.46	....	2.95	....	....	....	1.85	....	.73	....	1.46	....	1.73	....	1.00	....	.11	....
Potash (K_2O)	3.74	....	3.30	....	....	....	2.34	....	3.87	....	3.23	....	1.77	....	3.82	....	2.83	....
Soda (Na_2O)	1.07	....	.66	....	....	....	3.90	....	3.18	....	3.24	....	3.87	....	2.68	....	5.28	....
Water (H_2O)	11.08	....	10.50	....	....	....	13.80	....	8.60	....	11.78	....	12.34	....	22.09	....	15.52	....

REMARKS ON THE SHALE ANALYSES.

No. 1. Average of ten analyses of shales used in the manufacture of paving brick and sewer pipe in the State of Ohio. Adopted as the standard for this report.

No. 2. Mixture of shales and surface clay as used by Wabash Clay Co., Veedersburg, Fountain County, Indiana, in the making of paving blocks Average sample.

No. 3. Mixture of shales and small amount of surface clay, as used by the Clinton Paving Brick Co., Clinton, Vermillion County, Indiana, for the making of paving brick. Average sample.

No. 4. Mixtures of shales and surface clay as used by the Evansville Pressed Brick Co., Evansville, Vanderburgh County, in the making of paving and dry-pressed brick. Average sample.

No. 5. Mixture of shales Nos. 3 and 4 from the clay pit of the Cayuga Pressed Brick Co., Cayuga, Vermillion County, Indiana. Used for making red dry-pressed brick. Average sample.

No. 6. Bastard shale, No. 5, from the pit of the Cayuga Pressed Brick Co., Cayuga, Vermillion County, Indiana. Used in the making of buff dry-pressed brick. Average sample.

No. 7. Shale No. 2, from the land of S. L. McCune, Mecca, Parke County, Indiana. Average sample.

No. 8. Shale No. 9, from the land of S. L. McCune, Mecca, Parke County, Indiana. Average sample.

No. 9. Shale No. 5, from the land of S. L. McCune, Mecca, Parke County, Indiana. Average sample.

No. 10. Shale from the land of H. T. Thorp, near Terre Haute, Vigo County, Indiana.

No. 11. Mixture of shales from railway cut near Lincoln City, Spencer County, Indiana. Average sample.

No. 12. Shale No. 7, from above the main vein of coal worked by the American Cannel Coal Co., Cannelton, Perry County, Indiana.

No. 13. Shale from above the worked vein of coal, Prospect Hill mine, Vincennes, Knox County, Indiana.

No. 14. Shale No. 6, from the land of Joseph Burns, West Montezuma, Vermillion County, Indiana. Average sample.

No. 15. Shale No. 11, from the land of Joseph Burns, West Montezuma, Vermillion County, Indiana. Average sample.

No. 16. Shale No. 8, from above the worked vein of coal, Shaft No. 1, Island Coal Co., Linton, Greene County, Indiana. Average sample.

No. 17. Shale from near "Air Line" shops, Princeton, Gibson County, Indiana. Average sample.

No. 18. Shale from the land of Frank Landers, near Stone Bluff, Fountain County, Indiana.

No 19. Shale from the land of J. W. Shuster, near Stone Bluff, Fountain County, Indiana.

* * *

Analysis No. 1 is taken from Prof. Edward Orton's (Jr.) report on the "Clay-Working Industries of Ohio" (Vol. VII, Ohio Geol. Surv., 1893, 133). Analyses Nos. 2 to 13, inclusive, were made for the present report by Prof. W. A. Noyes, of the Rose Polytechnic Institute, Terre Haute, Indiana. These analyses were in each case based on the sample dried at 135° C. The parts marked "insoluble" were found to be insoluble in acids and sodium carbonate.

In the "rational analyses" the quartz was determined by subtracting $3\frac{51}{100}$ times the insoluble alumina from the insoluble silica. The remainder of the insoluble portion was counted as "feldspathic detritus" The general method of analysis followed was that given in Wagner's Chemical Technology.

Analyses Nos. 14 to 19, inclusive, were made for this report, after the burning of the Polytechnic laboratory, by Prof. Robert Lyons, chemist at the State University, Bloomington, Indiana, who was assisted by the following students: Messrs. P. A. Yoder, H. A. Bordner, O. W. Brown and H. G. Reddick. The methods followed by Professor Lyons were essentially the same as those used by Professor Noyes.

Analyses of Under-clays of Coal Measures.

	1		2		3		4		5		6	7	8
	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.	Total.	Total.	Total.
Silica (SiO_2)	69.23	41.22	57.57	29.00	54.46	20.28	63.00	27.05	83.44	76.90	68.13	54.53	58.78
Titanium oxide (TiO_2)	1.50		1.10		1.20		1.10		1.29			1.26	.94
Alumina (Al_2O_3)	18.97	.36	21.70	.30	25.71	.17	23.57	.21	10.36	8.71	20.80	27.88	26.47
Water (combined)	5.46		6.78		8.59		6.45		3.15		5.72	8.87	9.96
Clay base and sand	95.16		87.15		89.87		94.12		98.24		94.65	92.54	96.15
Ferric oxide (Fe_2O_3)	1.57		2.26		5.51		1.87		.27		1.20	2.41	1.22
Ferrous oxide (FeO)	.55		4.11		.91		.46		.28				
Lime (CaO)	.12		.32		.24		.44		.36		.42	.42	.59
Magnesia (MgO)	.36		1.12		.83		.89		.14		.37	.68	.32
Potash (K_2O)	2.27	.05	2.16	.24	2.68	.07	2.40	.05	.03		2.28	3.31	.99
Soda (Na_2O)	.33		.33		.33		.29		.71		.27	.12	
Fluxes	5.20		10.30		10.50		6.35		1.79		4.54	6.94	3.12
Carbon dioxide (Co_2)			1.73										
Total	100.36	41.63	99.18	29.54	100.37	20.52	100.47	27.31	100.03	85.61	99.19	99.48	99.27

Rational Analyses of Above Under-clays.

	1 Total.	1 Insoluble.	2 Total.	2 Insoluble.	3 Total.	3 Insoluble.	4 Total.	4 Insoluble.	5 Total.	5 Insoluble.	6 Total.	7 Total.	8 Total.
Quartz	39.36		27.95		19.69		26.31		46.33				
Feldspathic detritus	1.67		1.95		.83		1.00		39.28				
Ferrous carbonate			3.65										
Clay substance	58.37		66.81		79.48		72.69		14.39				

Composition of Clay Substances of Above Under-clays.

	1 Total.	1 Insoluble.	2 Total.	2 Insoluble.	3 Total.	3 Insoluble.	4 Total.	4 Insoluble.	5 Total.	5 Insoluble.	6 Total.	7 Total.	8 Total.
Silica (SiO_2)	47.70		43.29		42.79		49.15		45.44				
Titanium oxide (TiO_2)	2.55		1.67		1.50		1.50		8.96				
Alumina (Al_2O_3)	31.67		32.94		31.95		31.93		11.46				
Ferric oxide (Fe_2O_3)	2.67		3.42		6.89		2.54		1.87				
Ferrous oxide (FeO)	.93		3.32		1.14		.63		1.94				
Lime (CaO)	.21		.48		.30		.61		2.50				
Magnesia (MgO)	.62		1.70		1.04		1.21		.97				
Potash (K_2O)	3.78		2.91		3.35		3.23		.20				
Soda (Na_2O)	.57		.50		.41		.38		4.93				
Water (H_2O)	9.30		10.27		10.63		8,82		21.83				

REMARKS ON THE UNDER-CLAY ANALYSES.

No. 1. Under-clay No. 5, from mine owned by Bockting Bros., Huntingburgh, Dubois County, Indiana. Used for stoneware at Huntingburgh, Evansville, etc.

No. 2. Under-clay from beneath the vein of coal worked by the American Cannel Coal Co., Cannelton, Perry County, Indiana.

No. 3. Under-clay No. 8, from the land of S. L. McCune, Mecca, Parke County, Indiana.

No. 4. Under-clay No. 16, from the land of S. L. McCune, Mecca, Parke County, Indiana.

No. 5. Under-clay No. 10, from the land of Joseph Burns, West Montezuma, Vermillion County, Indiana. Used in the making of fire bricks. Average sample.

No. 6. Average of stoneware clays selected from the ground clays used in several of the large Akron, Ohio, stoneware factories, and then mixed.

No. 7. Under-clay used in large sewer pipe factory at Walker's Station, Columbiana County, Ohio. (Lord, Chemist.)

No. 8. Ballou fire clay, from Muskingum County, Ohio. Used as a bond for flint clays in forming high grade refractory materials. (Lord, Chemist.)

* * *

Analyses Nos. 1 to 4 inclusive were made for this report by Prof. W. A. Noyes. No. 5 was made by Prof. Robert Lyons, Bloomington, Indiana. Nos. 6, 7 and 8 were taken from Professor Orton's report on the "Clay-working Industries of Ohio."

CHAPTER III.

THE CLAY-WORKING INDUSTRIES OF THE COAL-BEARING COUNTIES OF INDIANA.

The clay-working industries of western and southwestern Indiana are yet in their infancy. Previous to 1890 but six clay factories were in existence in the 18 counties covered by this report, the value of whose annual output was more than $5,000. To-day there are 24 in the area mentioned, whose yearly output is more than $10,000 each, and of nine of these it is more than $50,000 each. There is room for five times as many without overcrowding 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.

Eleven years ago the State Geologist of Ohio, foreseeing the coming increase in the use of clay for manufacturing purposes, investigated the clays of that State, and published an extensive paper, calling the attention of capitalists to their value. The result has been a great expansion in the clay-working industries of Ohio, and to-day she ranks easily first among the clay manufacturing States of the Union. With no better or no more abundant clays than Indiana possesses, compare the following statistics of the leading clay-working industries in the two States in 1894:

	Ohio.	Annual Output.	Indiana.	Annual Output.
Paving Brick Factories	44	292,000,000	5	29,000,000
Sewer Pipe Factories	35	....	3	....
Stoneware Factories	37	24,350,000 gals.	11	600,000 gals.
C. C. and White Granite Ware Factories	31	....	1	....
Yellow Ware Factories	10	....	....	....

If Ohio can, as she has been doing, support on a paying basis the number of establishments given above, there is surely room for many more in Indiana.

The rapid growth, since 1890, in the clay industries of southwestern Indiana is due mainly to two causes, viz., the growing use of vitrified brick for street paving purposes, and the discovery of the great value of shale or laminated clay for making many of the grosser forms of clay wares.

Those clay industries already in existence in the coal-bearing counties may be grouped according to the kinds of wares they manufacture into the following classes:

1. The manufacture of paving material.
2. The manufacture of sewer pipe and hollow goods.
3. The manufacture of refractory material.
4. The manufacture of stoneware and pottery.
5. The manufacture of pressed front brick.
6. The manufacture of ordinary building brick and drain tile.

Each of these will be taken up and mention made of the processes involved, and such statistics will also be given in tabular form as could be obtained from the owners of the factories.

THE MANUFACTURE OF PAVING MATERIAL.

CHOICE OF CLAYS.—The two most valuable properties which a paving brick must possess are those of *vitrifaction*, or the power to withstand the absorption of water; and *toughness*, or the ability to withstand abrasion and wear. Parties who are thinking of erecting a plant for the making of pavers must choose a clay, which, when properly burned will possess in a high degree the above properties, else their money will be wasted in a worse than useless project.

Among the clays found in Indiana and mentioned in the previous chapter are many which are undoubtedly suitable for the making of paving material; yet before a plant be located at any deposit, full tests should be made, and the clay found therein proven to be refractory enough to stand up under the heat required to bring about vitrifaction, and yet to contain fluxes sufficient to cause vitrifaction to begin at a temperature considerably below that at which softening and loss of shape takes place. The only fully reliable test which can be made is the taking of a large quantity of the clay to some factory and there making it into brick and burning them under conditions as nearly as possible like those which will be present after the plant is erected. Such a test is far more valuable than the one commonly in vogue of sending a keg or two of the clay to some dealer in brick machinery, and having a dozen or twenty brick made therefrom. Such brick show only the *best products obtainable* from the clay, and are no criterion of what it will do under the normal and average conditions existing in a large plant. *They are made to sell brick machinery*, and all possible precautions are taken to have each one absolutely without flaw.

While the average composition of the best clays for paving brick and other purposes is well known, too much reliance must not be placed upon the chemical analysis of a clay in question, and no plant should be erected with it as the sole existing test. It serves well as a preliminary test to determine the *possible* usefulness of the clay for the purposes wanted, as from it the refractoriness can be readily judged, but it is no criterion of the toughness and other essential properties which the burned product must possess.

The clays found in western and southwestern Indiana which are suitable for making paving brick may be conveniently grouped under the following heads:

1. Carboniferous shales.
2. The more plastic under-clays of the coal seams.
3. Recent sedimentary clays of the river bottoms.

The question naturally arises, which of these is best suited for the purpose in hand? This can best be answered from the experiences of the past, and from the results of a long series of tests made under uniform conditions. When the paving brick industry was first started the larger portion of the bricks were made of the under or so-called "fire-clays" of the coal measures. These have been gradually supplanted by the shales, as actual experience has shown that the brick made from the latter are more lasting, wear more uniformly, and in general give far better satisfaction. Moreover the shales are far more abundant, more easily mined, and, while requiring the expenditure of more power to prepare them for use, are more easily vitrified than the under-clays.

No facilities being at hand for the proper testing of a large number of clays in order to prove the relative value for vitrified brick or the different kinds of materials mentioned above, I have availed myself of the results of a series of tests made by Prof. Edward Orton, Jr., at the State University of Ohio, on clays of the same nature from that State. These results were first published in the seventh volume of the Ohio Geological Survey, and afterwards, in a modified form, in "The Clay Worker" for July, 1895. From the latter publication the following extract is taken:

"The shales, or bricks whose chief component is shale, and whose color is red or dark, were grouped together and were represented by 23 samples. Fifteen varieties of fire-clay bricks, or those in which fire-clay is the largest constituent, and whose color is light, were grouped together. Four varieties of shale and fire-clay mixtures, in about equal proportions, were grouped together, and three varieties, composed of Ohio River sedimentary clays exclusively, constitute the last class. The average results of the tests of these four classes were as follows:

	No. of Samples.	Absorption.	Rattling.	Crushing sq. Inch.	Rank.
Shales	23	1.17	17 61	7,307	1
Fire-clay	15	1.62	17.32	6,876	2
Mixture	4	1.44	18.72	5,788	3
River clay	3	1.36	19.02	4,605	4

"In this table the shales have the advantage over their competitors, showing the first rank in absorption and crushing and a close second in rattling. The fire-clays are indicated as being slightly tougher than the shales, but considerably more porous. Also, the same tendency is again more strikingly illustrated in the table of bricks having the highest average excellence in the test. Taking the ten highest averages, represented by sixteen factories, it is found that thirteen are shale bricks, against three fire-clay bricks, showing that the best material of the State is 80 per cent. of it made of shale clay."

This series of tests, taken in connection with the experience of the past, proves conclusively that the shales are the best suited of the three classes of materials mentioned for the making of high grade paving brick.

LOCATING THE PLANT.—Other conditions besides the quality of the clay must be taken into consideration in choosing the site for the location of a paving brick or other clay factory. Among the most important of these are the quantity of clay, the amount of labor necessary to secure it and its nearness to fuel, railway facilities and markets for the manufactured product.

The quantity of clay used in a large paving brick factory in the course of a single year is much greater than is usually supposed. Taking into consideration the shrinkage in burning, each thousand brick of ordinary size, $2\frac{1}{2}$x4x$8\frac{1}{2}$ inches, will require an average of $2\frac{1}{2}$ cubic yards of clay; and standard paving blocks, 9x3x4 inches, will require one-third as much more. If the clay be 10 feet in thickness and 40,000 brick of ordinary size be made each day, about $1\frac{2}{3}$ acres of the clay will be used each year. If block are made, about $2\frac{1}{3}$ acres will be used. The quantity of clay available must, therefore, be carefully determined before the site of the factory is chosen.

The question of stripping becomes an important one in the securing of large amounts of clay, and its cost must always be considered in choosing a site for a plant. Many deposits of shale and fire-clay, otherwise valuable, are rendered comparatively worthless by the great amount of material overlying them. In some cases much of this material can be mixed with that of the main deposit without injury to the product. This should not be done, however, until numerous tests have proven beyond doubt its suitability for the purpose.

Where the number of factories is large and competition causes the output to be sold at a close margin the cost of fuel becomes an important factor in the making of clay products. This should always be considered, and other things equal, the plant located as near as possible to a cheap and practically inexhaustible fuel supply. In these days of protracted drouths the future water supply is another factor to be considered, for large quantities are used for steam purposes and for moistening the clay in the wet pan or pug mill.

The question of transportation is also a most important one in the choosing of a site for a clay factory. If possible the location should be such that first-class railway facilities can be readily obtained, and side tracks laid into the yard. The finished product can then be loaded directly into the cars without preliminary hauling in wagons. Other conveniences, however, should not be sacrificed to gain such railway facilities. It is much better to locate the plant in close proximity to the supply of clay and then build a single switch to it than to erect it by the main line of a railway a mile or two from the deposit. The latter plan has, unfortunately, been followed by three of the five factories in this State, necessitating much expense in the hauling or shipping of the raw material. Where possible it is better to locate close to the junction point of two or more railways. This eliminates largely the chance of an arbitrary advance in shipping rates, and provides direct communication with a greater number of markets.

Those paving brick factories which are located near cities of sufficient size to use brick for paving purposes have many advantages. If their output is of such a quality as to meet all requirements it can be laid down at a good profit in such a home market at a less cost than any outside competitor can furnish it after paying freight rates. In addition to this saving of transportation there is always a sale in such a city for the second grade brick for use in sidewalks, gutters, foundations, etc. From 10 to 25 per cent. of the total output of the average factory is composed of such "seconds." These are soft brick or those overburnt, cracked or twisted in burning. In the course of a year they amount to several hundred thousands, perhaps millions, and unless sold for some price accumulate until they become a nuisance in the yard. All sums which they bring may be counted as clear gain, and the cost of production of those unsold must be added to the debit side of the year's account.

Preparation of Clays.—But few clays are found in their natural state in such a condition that they can be taken directly from the deposit where they lie to the machine which shapes them into the unburned product. Almost all have to undergo some process of preparation in order that they may be reduced to a fine-grained, homogeneous and plastic mass. While this preparation is more necessary and thorough in the making of the finer grades of clay wares, the manufacturers of paving brick are beginning to realize that on account of the more rigid inspection and close competition of their products, more care must in the future be taken in the preliminary mixing and preparation of their clays. Especially is this true of such clays as contain foreign impurities, such as small nodules of iron carbonate or pebbles of lime. If not present in too great a quantity, these, when ground fine and intimately mixed with the mass of clay do little harm. But if allowed to pass into the body of the brick, or other ware, in coarse granules a large percentage of the finished product will be rendered wholly worthless. Where two or more clays are to be mixed together the mixing must be thoroughly and uniformly accomplished, else the toughness and general structure of the brick will be greatly impaired.

The quality of almost all clays is greatly improved by weathering. While the amount of material used in a paving brick factory is so large that such a procedure, in part, becomes impracticable, yet if the conditions are such that large quantities of the clay can be gotten out in summer and allowed to remain exposed to the winter's rains and frosts a tougher and better grade product will invariably result therefrom.

Although both shales and fire-clays are sedimentary deposits, their natural plasticity has been largely destroyed by the changes which they have undergone subsequent to their deposition. This plasticity can be restored only by grinding and kneading with water. Where large amounts of the clay have to be used, this grinding is almost universally accomplished by means of a machine called a "dry pan." Experience has proven that for the making of paving brick a dry pan nine feet in diameter, supported by an iron frame, and having the rims of the inner wheels or mullers from 10 to 12 inches wide, is the most suitable. With such a machine dry shale sufficient in quantity to make from 30,000 to 35,000 ordinary sized paving brick can be readily ground in ten hours. Where the shale or clay is wet or very plastic, or where the same or a greater number of the larger paving blocks are desired, two dry pans have to be used. These are set side by side, and in the larger and more modern factories in Ohio and Illinois have the clay delivered to them on an inclined chute. Such an arrangement is a great labor saver, as both pans can be tended by one man instead of requiring a half dozen or more, as in the older factories.

A part of the bottom of the dry pan is made of iron plates, with openings varying from $\frac{1}{16}$ to $\frac{1}{8}$ of an inch in diameter. Through these the ground clay passes and is caught and elevated, and then dumped onto screens. Through these screens the particles of clay, of sufficient fineness to enter the substance of the brick, pass to the wet pan or pug-mill, while those too coarse for such a purpose are returned to the dry pan and reground. The kinds of screens used are many. Those known as fixed inclined, or gravity, screens are best suited for use in tall buildings, as they are simple and cheap, and require no power to operate them. For low buildings some style of vibrating screen is the simplest, cheapest and most saving of power. Rotary screens, while capable of performing much work, are wasteful of power and are very liable to get out of order.

The most important preparatory process through which clays are put is the tempering, or mixing with water, in order to develop sufficient plasticity for making them into the product desired. In the manufacture of paving brick the clay is most commonly tempered in pug mills. These are much cheaper and less cumbersome than wet pans, but the latter give far better results, as by them the particles of clay are not only *mixed* with those of the water, but are *ground* into intimate contact with them. The wet pan is also more suitable for mixing clays of different kinds, as a pug mill merely stirs their particles together without bringing them into close contact. However, these advantages are commonly overlooked, and the cheapness and simplicity of the pug mill, coupled with the fact that it requires less attention, leads to its more common use.

If possible, some sort of a storage bin should intervene between the screen and the pug mill, and above the latter. This will secure a more regular flow of clay into the mill, and thereby render its work more uniform and efficient. Difficulty will very likely be experienced, however, in getting the ground clay to run freely from the storage bin, as it will have a strong tendency to bank up and clog the openings. The use of warm water in tempering, especially in winter, will be found to add much to the ease with which the clays may be worked, and will at the same time improve the quality of the finished product.

The processes of preparation thus briefly described are not limited to the paving brick industry, but are practically the same in all factories using indurated clays, whether for vitrified, refractory, or other products.

Making of Brick.—Paving brick are now almost universally made by what is known as the "stiff-mud" process. In this process the ground clay is moistened just enough to render it plastic without becoming soft and pasty. The brick formed from it, on leaving the machine, are firm enough to be handled and piled several courses high without breaking or losing their shape.

Two types of machines are used in making stiff mud brick. These are called, respectively, plunger machines and auger machines. In the former the tempered clay is pushed into a closed space or press chamber and then forced out through the die by means of a piston or plunger, which is operated intermittently by steam pressure. This style of machine is much less used than the auger for several reasons, chief among which are: (a) Numerous defects in the brick caused by bubbles of air which have passed with the clay into the press chamber, and, finding no means of escape, have been forced into the body of the brick and caused therein voids or cavities which weaken its strength; (b) the intermittent nature of the flow of clay which prevents the use of automatic machinery in handling the output; (c) the necessary dividing of the steam power of the engine in order to furnish the pressure necessary to operate the piston; (d) the cost of the plunger machine, which is usually considerably more than that of the auger.

The auger machine consists of a horizontal closed tube or cylinder with a cone shaped front end. The clay is admitted on top of the rear end of this tube, and is pushed forward much in the same manner as the meat in a sausage mill, by a set of blades or knives which are arranged spirally about an inner, revolving, horizontal shaft. These blades both cut and pug the clay, and carry it forward to the auger, or screw, working in the cone shaped portion of the machine. This auger is a solid iron screw with a single or double thread. Gathering up the clay it forces it from the larger to the smaller end of the cone, thereby compressing it greatly and causing it to issue through the die at the front opening in a steady and continuous stream or bar. This may be $4\frac{1}{2}$x9 inches in size, and is then cut off in sections $2\frac{1}{2}$ inches thick into "side-cut" brick; or it may be $2\frac{1}{2}$x$4\frac{1}{2}$ inches in dimensions, when it is cut into sections 9 inches long, producing "end-cut" brick. The cutting of the bar of clay into sections of the proper dimensions is effected by wires attached to a frame, which is operated either by hand or by automatic machinery.

Stiff mud brick, however made, are apt to have certain defects, some of which it is hard to avoid. The most common of these is a laminated condition of the inner portion of the brick. This is, for the most part, due to the outer portions of the bar of clay being retarded by friction against the sides of the die as it is forced through it by either plunger or auger, while the inner portion, exempt from such friction, moves more rapidly onward. These laminations are less frequent in large bars of clay than in small ones, as a smaller proportion of the clay is in contact with the die. Hence the side-cut machines produce fewer of them than the end cut. For this reason more of the former are used, especially in the making of paving brick from soft gritless shales or "soapstones," which have a stronger tendency toward lamination than the harder, more non-plastic clays. All things considered, experience has proven that the side-cut auger machines are the best adapted to the making of paving brick from such raw materials as occur in southwestern Indiana. Three of the five factories now in operation are using such machines. Two of these began with end cut machines but found them unsuitable for working the shales. The latest improved side-cut auger machines, of which there are several patterns on the market, when supplied with automatic off-bearing belts, are capable of making 40,000 brick in 10 hours' time.

In most factories the brick are taken from the cutting table and passed through a repress machine before they are taken to the dryer. The value of this process is as yet a mooted question among paving brick makers. The prevailing opinion at present is that repressing improves the brick in smoothness and general appearance but not in structure The corners are rounded off and the rough sides caused by the passage of the cutting wires through the clay are obliterated. Two represses, each requiring the services of two men, are necessary to take care of the output of a single, side-cut, auger brick machine.

Drying the Brick.—After the brick have been given their shape on the cutting table or the repress, the next process in their manufacture is the driving off of the water which has been added to the clay to secure plasticity. The average daily output of a single modern side-cut machine contains almost 20 tons of this water. How to remove it quickly and cheaply by evaporation has been a question which has sorely puzzled paving brick makers in the past. Many methods have been devised but the one now most used, and which will most probably be connected with such paving brick plants as will be erected in the future, is known as the progressive or tunnel system.

By this system small iron or wooden cars, single or double decked, each holding from 350 to 500 of the undried block or brick, are pushed in at one end of a long, low tunnel or dry house, and by slow progression moved forward to the other end. This tunnel has close fitting doors at each end and three or four sets of double tracks. Beneath these, in the most modern dryers, are many thousand feet of radiating and coiled steam pipes. These are most abundant at the further end of the tunnel, where they are kept full of live steam at boiler pressure.

By the use of either tall wooden chimneys, or fans, currents of air are kept moving from the hot end of the dryer where the steam pipes are mostly located to the other end where the bricks are first entered. "By the time the air currents reach the rear end they have absorbed in passing through the great volumes of brick ahead, about all the vapor they are capable of retaining, consequently, the temperature is low, generally 80° to 100° F., and the air is filled with humidity, almost to the dew point. The new car-load of bricks in an atmosphere like this does not begin to dry at all, but it begins to warm through, till the individual bricks are as hot as the surrounding atmosphere. After a time the cars are shoved down the tunnel to make room for other cars in the rear. The first car now begins to find itself in an atmosphere a little warmer and not quite saturated with moisture. The water now begins to dry on the surface of the bricks, and as they have been previously brought to a warm steamy condition, the surface evaporation is constantly replaced by moisture from the inside. Hence, there is no tendency for the outside of the brick to contract faster than the inside and, therefore, no tendency to cracking or breaking. As the bricks proceed onward they yield up successive portions of their moisture and finally emerge from the hot end of the dryer ready for the kiln." *

In some progressive dryers hot air is used instead of steam, but the latter is the safer, more economical and more efficient drying agent. The daily output of an average factory can be dried ready for setting in the kilns in from 24 to 30 hours by the latest styles of progressive dryers. The cost of drying ranges from 20 to 35 cents per 1,000 bricks; 25 cents being the average cost at the Clinton Paving Brick Company's works.

Burning the Brick.—All other processes of clay manufacturing are subordinate in importance to that of the burning. Especially is this true of the manufacture of paving brick, where, upon the proper management

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* Orton, Edw., Jr., Ohio Geol. Surv., VII, 169.

of the burning, more than upon the quality of the clay or its preparation, depends the degree of vitrifaction and toughness which the finished product will possess. For the most part the burning of vitrified products is carried on in down draft kilns. These are of several patterns, the most common of which is the round down draft from 25 to 28 feet in diameter and holding 28 to 30 thousand standard block, or 40 to 45 thousand ordinary sized brick. On account of the importance of this process, the following full and valuable account of the proper method of conducting it is taken from "The Clay Worker" for April, 1895. It was written by that noted authority on all subjects pertaining to clays, Prof. Edw. Orton, Jr., of Columbus, Ohio.

"The kiln may be supposed to be twenty-five feet in diameter, with ten fire holes of the inclined grate style, and the contents of the kiln are set twenty-five courses high. The fires are lighted at once, when the setters have finished their work and erected a single wicket in each door. The fires at first are very small, not over one-half bushel in cubic contents, and are at the bottom of the grate bars and in the foot of the bag. They are maintained at about this stage for the first twelve hours, when they are doubled in size. The temperature of the waste gases passing off in the stack at the end of twelve hours will be milk warm or a little more During the first three days the draft of the kiln is apt to be too feeble rather than too strong, so under usual conditions the stack has full chance, unobstructed by damper of any kind. The air supply entering the kiln during the first day is very large, as it has nearly the whole area of each fire hole. This space is gradually filled up as the size of the fires increase, so that the temperature of the gases passing into the kiln insensibly increases, hour by hour, as the air passages are diminished and the fires increased. During the first twenty-four hours the wickets, peep-holes and all openings except the fire holes should be finished up and daubed with mud and washed with clay-slip till air tight."

"During the second twenty-four hours the fires are again doubled, the increase being carefully distributed throughout the day. This will about half fill the fire holes, leaving the upper half of the openings free for air. The waste gases in the draft stack will feel much warmer at the end of the second day—probably from 140 degrees to 160 degrees, and they are so laden with water that they appear as clouds of steam if the outside air is cool. During the third day the fires are slightly increased, but not so as to more than two-thirds fill the fire holes. The waste gases rapidly increase in heat during the day, usually getting too hot for the bare hand, and the visible steam becomes less and less, generally disappearing before the end of twenty-four hours."

"The kiln has now passed through what is called in the trade the 'water-smoking' period. The water discharged is largely that which is free and merely left in the bricks from the dryers, though possibly some combined water has been expelled during the third day. The intention of the burner during this period is to subject the bricks to a liberal flow of air and gases, beginning at a low heat, and by the end of the third day attaining a temperature of 300 or 400 degrees. If this is done the last traces of free water will have been drawn out, and the kiln will be ready for raising 'fires.'"

"The fire holes are now filled up so that the air supply is nearly cut off, and what air does draw in over the top of the fire is hardly more than sufficient to consume the inflammable gases from in rear of the fires. Under this condition the fire holes soon become red, and soon after the bags and fire walls are seen to be red as well, and during the second half of the fourth day the bricks will become a dull red, easily seen at night and with difficulty by day. It is at this stage that the combined water is expelled, and the utmost caution and regularity are needed. The heat must be maintained and slightly increased, hour by hour, constantly aiming to cause the redness to travel downwards, course by course, without materially increasing the temperature of the top."

"The draft, if too strong, must be cut down, and the heat regulated by the size of the air inlets over the top of the fires. In cold weather steam will be seen for the second time during this day, but in warm weather the superheated vapor is absorbed into the atmosphere without condensation."

"The kiln should be gauged—that is, the distance from the top of the bricks to the top of the kiln should be carefully measured—during the fourth day, as soon as the bricks are hot enough to distinguish, or before. This figure should be noted down for future reference. During the fifth day the air supply will be nearly cut off, and the fire holes will be at their full heat. The temperature at the beginning of the day should be distinctly red on top and a barely visible red in the middle peep-hole on the twelfth course from the bottom. During the twenty-four hours the heat should be increased to a clear, bright cherry red on top, decreasing to a distinctly visible red on the bottom of the kiln, and on the draft stack. When this color is seen in the stack it is a sign that the necessary heat to expel the combined water from the clay has been attained from top to bottom, and that the bricks are now ready to take the finishing temperatures as fast as they can absorb them. The constant danger will be, during the fifth and subsequent days, that the top courses will become overheated for a few moments. If the burner is not constantly on the *qui vive*, after every firing, especially, the heat will become too great and the quality of the top courses will be damaged or ruined. If the work is skillfully done the top course will be still only a good, hard building brick at the close of the fifth day, while the bottom has arrived at the softest salmon stage."

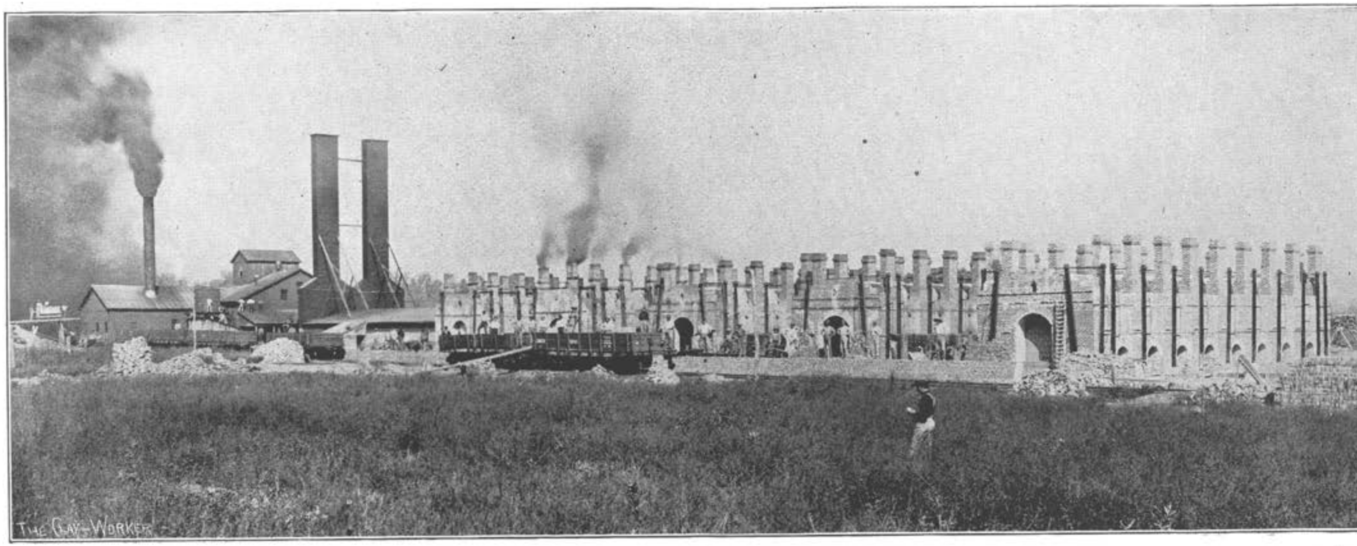
"On the sixth day the finishing process or 'high fire' begins. So far the rise in temperature has been comparatively regular and gradual. But after the gases have been expelled from the clay the danger of sudden changes in the heat is only that the highest limit may be exceeded; variations inside of that limit do no harm. The fires are managed much as before, the air supply being greater or less according to the heat needed for the moment. The top of the kiln becomes heated up to its practical limit of safety a few hours after the finishing process begins, and if the heat is still maintained without cessation the bricks will soon become spongy. If the heat be kept on for a few hours, until the top bricks begin to show signs of distress, and then allowed to cool off somewhat, together with an increase of draft, it is found that the top portions of the kiln will give out heat again, and, while cooling down themselves, they assist in bringing up the heat of the courses below them."

"By working the kiln as described and carrying wave after wave of heat from the top downwards the bottom of the kiln ought to become strongly red by the end of the sixth day, the top being as hard as is desired before this time. The gauge at this stage should show about five or six inches settle from the first figure, with a setting 25 courses high."

"The same method of firing during each succeeding 12 hours ought to show a further settle of two inches. By the end of the seventh day the settle will probably be 9 or 10 inches, and the trials taken from the top, middle and bottom will show the vitrification to be complete on top, fair in the middle and too soft on the bottom. Twelve hours more ought to bring the heat down to the bottom so that the settle shows 11 or 12 inches and the trial a hard building brick or poorly vitrified paver. The burn is ready to conclude at any time the burner sees fit, and he must now weigh in his mind the benefit and danger of each fire before putting it on. The conclusion of a burn under such conditions as have been described should not be later than the middle or end of the eighth day."

"In cooling off the practice varies. Experience has shown that the danger point in cooling vitrified clay ware is at a dark red or black heat. When the ware is very hot it can not be damaged by free admission of air, providing that it all enters through the fire holes and red-hot flues. The proper plan is to allow the kiln to cool down under full draft until it begins to look dark, then shut the dampers and cool as slowly as the kiln capacity will allow. Three to six days are allowed to round kilns."

"The slower the cooling the greater toughness is found in the product. The top course and the bricks immediately next the bags are always likely to be brittle in any case, as they are heated up and cooled down many times in the burn in accumulating the waves of heat by which the bottom courses are reached."



WORKS OF THE CLINTON PAVING BRICK CO., CLINTON, INDIANA.

Cost of Plant.—The cost of a paving brick factory fitted up with modern machinery varies much, according to location, size, etc. In general it may be stated that the cost will be $1,000 for each one thousand daily capacity of output. This does not include the cost of land on which clay is situated, railway switches, nor the capital necessary to carry on the business before the returns begin to come in. Through the kindness of Mr. J. W. Robb, Secretary and Treasurer of the Clinton Paving and Building Brick Co., I have been furnished with the figures showing the exact cost of the plant of that company, which is one of the best and most modern in the State. These figures are as follows:

Five Eudaly kilns, capacity 125,000 each, including royalty of $1,000 for use of same	$14,782
Buildings, yards, etc	8,276
Machinery	7,766
Dryers (two "Ironclad" Progressive, complete)	9,144
Total	$39,938

The daily capacity of this plant if run full 10 hours is 40,000 paving brick, showing a very close approximation to the average cost as mentioned above. Further details concerning the machinery found in this plant are given in the following table of statistics of the paving brick industry in Indiana:

Statistics of Indiana Paving Brick Factories.

NAME OF FIRM.	Location.	Began Oper't'g.	Capital In-vested.	Product.	Kind of Machinery.	System of Drying.	Number and Kind of Kilns.	Total Kiln Capac-ity.	Number Hands Empl'd.	Average Daily Wages.	Annual Output, Millions	Value of Annual Output.
Clinton Paving and Building Brick Co.	Clinton, Vermillion County, Indiana.	1893	$50,000	Clinton pavers ((8½x4x2½ in.) and vitrified sewer brick.	One 9-foot dry pan. One 9-foot pug mill. One auger side-cut, Penfield No. 10 brick machine. Two Columbia re-presses.	Progressive ("Iron Clad"). Two 5-track tunnels.	Five square Eudaly down draft.	625,000 brick.	60	$1.42	8	$70,000
Wabash Clay Co.	Veeders-burgh, Fountain County, Indiana.	1892	$90,000	"Poston" block (9x4x3 in.) and sidewalk brick.	Two 9-foot dry pans. One open-top pug mill. One augus side-cut. Bucyrus "Giant" brick machine. Three Raymond re-presses.	Progressive. One 6-track "Iron Clad" and one 8-track "Poston" tunnel.	Seventeen round, down draft.	510,000 block.	75	$1.35	8½	$110,000
Indiana Paving Brick Co.	Brazil, Clay County, Indiana.	1891	$40,000	Brazil block (9x4x2½ in.)	One 9-foot and one 7-foot dry pan. One open-top pug mill. One Wellsville auger side-cut machine. One Raymond and one Eagle repress.	Three dry floors; one heated by under-flues and two by steam. Total capacity, 240,000.	Eleven round, down draft.	350,000 block.	65	$1.35	6½	$70,000
Evansville Pressed Brick Co.	Evansville, Indiana.	1890	$50,000	Evansville pavers (8½x4x2½ in.)	Two 9-foot dry pans. Two horizontal pug mills. One Chambers auger end-cut machine.	Progressive. Two 4-track tunnels.	Seven square, down draft, of owner's design.	60 ,000 brick.	50	$1.50	5	$50,000
Hoosier Brick Co.	New Albany, Indiana.	1894	$40,000	Hoosier pavers (8½x4⅛x2⅛ in.)		Progressive. Andrews system.	Two square, down draft.	500,000	25	$1.25	1	$10,000

WORKS OF THE WABASH CLAY CO., VEEDERSBURG, INDIANA.

Cost of Making Paving Brick.—This also varies much according to location and size of plant, price of labor, cost of fuel, etc. Where a factory is fitted up with modern machinery, has an output of 35,000 or more daily, and is situated by the side of the clay, fuel and water, so that these necessities can be obtained at a minimum price, the actual cost of making repressed paving brick and putting them on board the cars, is in the immediate neighborhood of $5.00 per thousand; of block, $5.50 per thousand. To this must be added the interest on capital invested, insurance, taxes, office expenses, salaries of salesmen and all other general expenses, which will bring the cost up to near $6.00 per thousand for the brick, and $6.50 for the block. The prices at which they now sell in Indiana are said by the makers to be $10.00 for the brick and $13.00 for the block on board the cars at the factories.

The Testing of Paving Brick.—The question of the proper tests to which samples of the brick destined for paving streets shall be subjected is a most important one. Each city engineer has, up to the present, had his own opinions on this matter and has made his tests according to his own best judgment. As a result there is no recognized standard, nor official tests which can be taken as such. At the ninth (1895) meeting of the National Brick Manufacturers' Association a committee was appointed to report a standard method of making such tests. It is to be hoped that such a report will soon be made and a standard fixed which will become generally adopted by city engineers. This will enable manufacturers to test their own output, and if not up to the standard to devise means and methods of making it so. In the past they have had to trust, as it were, to luck in having their output adopted, as it was impossible to try to make it correspond with the many whimsical standards which were set up by city engineers.

As already stated the two essential qualities of a good paving brick are vitrifaction and toughness. Hence, the most important tests which can be made are those which will go to prove the presence of these qualities in proper degree. These are the absorption test and the abrasion or rattling test. As it may be some years before a set of standard tests is adopted, the following methods of making the absorption and rattling tests are given as ones which have been commended by experts.

For the absorption test, one whole and three half bricks of average hardness, which are free from kiln sand and which have not been subjected to the abrasion test, should be taken. These should be dried carefully over a register or in a radiator for twenty-four hours, at a temperature between 200 and 300 degrees. Each specimen should then be weighed accurately on scales which are graduated to at least $\frac{1}{4}$ of an ounce, and a record kept of their separate and combined weights. They should then be soaked in clear water for 24 hours, after which they should be wiped dry with a cloth and weighed again. The increase in weight denotes the amount of water absorbed. The sum of this should be reduced to a percentage of the dry weight, and this will be the per cent. of absorption. The maximum amount of this which is allowable in a paving brick is, as yet, an unsettled question. Some city engineers make two per cent. the limit. More fix the amount at one and one-half per cent. By far the greatest number of paving brick placed upon the market show a gain of less than one per cent., so that two per cent. is probably not far from the limit which it is best to allow. No brick should be condemned or endorsed on the absorption test alone, as such a test is an index only of the quality of vitrifaction, and gives no proof of the presence of the other qualities which the brick must possess.

For the abrasion test which is made to indicate the toughness of the pavers, a cask-shaped rattler with the staves and heads made of cast iron, or lined with steel or iron plates, should be provided. This should be 28 inches in diameter and 32 in length, and should have no shaft in the center, but be suspended by opposite corners.

The brick to be tested should each receive a special mark with a steel punch, and then be weighed carefully. Enough should be placed in the rattler to fill as nearly as possible 20 per cent. of its volume, and no foundry shot or other iron material should accompany them. If a sufficient number of brick to make out the 20 per cent. of the volume of the rattler are not to be tested, standard paving brick from the most available source should be used as "fillers."

The rattler should then be turned for 40 minutes at the rate of 25 revolutions per minute. The brick are then taken out and weighed individually and collectively, and the percentage of loss by impact or abrasion is thus obtained.

The percentage of loss under the above method will vary much. The extremes will probably be about 5 and 25 per cent., and the average of 20 samples about 15 per cent. It will be found to be a severe test, but it will show with absolute certainty the *toughest* brick in the lot tested.

Other tests of paving brick which should be made are those showing the hardness and the cross-breaking or transverse strength. The former is easily determined by the use of the scale of hardness or scratching test, as the ability to scratch or to be scratched determines the relative hardness of any two substances. This scale is explained in all works on elementary physics, and is the one commonly in vogue with mineralogists. Its numbers run from one to ten, and certain well-known minerals are taken as types of each degree, talc or soapstone being No. 1; calcite No. 3, etc. Nos. 6 and 7, represented respectively by feldspar, a common constituent of granite rocks, and quartz, a very common mineral, are the two degrees of the scale which should be used comparatively in testing paving brick. No brick should be used for street purposes whose hardness is not 6 or above, while none showing a hardness above 7 are made. In making the test the inspector should be provided with pieces of feldspar and quartz, 2 x 4 inches, or larger in size, and also with an ordinary three-cornered file. The file should be drawn with considerable pressure over the narrow face or edge of the brick, and with the same amount of pressure over both the feldspar and the quartz, and observation made as to whether the depth of the cut in the brick is greater, less, or equal to that made in the minerals. If the scratch in the brick is less than that in the feldspar and deeper than that in the quartz the hardness of the brick is between 6 and 7, or the one desired; but if the scratch in the brick is plainer and deeper than that in the feldspar the brick is too soft and should be rejected.*

In making the transverse or cross-breaking test the brick should be placed edgewise on rounded knife edges, set 6 inches apart, and the load applied in the center by a rounded knife edge until the brick is broken. The transverse or tensile strength is then determined by the following formula:

$$f = \frac{3\ W\ l}{2\ b\ h^2}$$

in which

f = tensile strength in pounds per square inch.
W = breaking load in pounds.
l = length between the bearings.
b = breadth of brick.
h = height of brick.

The crushing test for brick was at one time largely used, but of late years has been considered of little value. "The crushing strength of a cube cut from a good paving brick is, say, 8,000 to 10,000 pounds per square inch, and if the pressure is applied on only a portion of the upper surface the strength is about twice as much. The surface of contact between a wheel having a $1\frac{1}{2}$ inch tire, loaded with half a ton, is roughly about one square inch, which gives a pressure on the brick of only 1,000 pounds per square inch. Therefore there is no danger of the brick being crushed."† If made, the brick to be tested should be placed edgewise, and the edges should be previously ground smooth, else the real strength will not be obtained.

After the four tests of absorption, abrasion, hardness and transverse strength have been made it becomes necessary to average them, as in

*If doubt occurs as to the pressure exerted by the file being the same in each instance a piece of the brick can be used on the smooth surfaces of the pieces of the minerals, and *vice versa*. The harder bodies will scratch the softer.

†Baker I. O., Brick Pavements, p. 8.

most cases one sample will show the highest per cent. in one particular, and a second in another particular. The question then arises, what relative value or weight should be given to each test? The qualities of toughness and vitrifaction being most desired it is obvious that the tests of absorption and rattling should be rated higher than the other two in making out the average. Probably the best relative value which can be given each of the four in making out the final average is as follows:

Rattling	40 per cent.
Absorption	30 per cent.
Hardness	15 per cent.
Transverse strength	15 per cent.

The engineer in prescribing his specifications for bids should make known fully the manner in which each test shall be made, and the relative weight which shall be given each in computing the final average.

THE FORMATION OF BRICK PAVEMENTS.—While the making of brick streets is an industry entirely distinct from that of the manufacture of paving brick, the future of the latter industry depends wholly upon the successful wear of such streets and the satisfaction which they give to the general public.

Many brick pavements which have been put down in the past have proven costly investments, but a much larger number have proven entirely satisfactory both in comparative cost and wear. The failure of those unsatisfactory has been due to many causes. One of the most common of these has been the use of poor foundations. It has been long proven by experience that no matter how superior the wearing surface of the street may be, unless such surface is supported upon a firm and enduring foundation its lease of life will be short. Such a foundation is best made from hydraulic cement concrete, and its minimum thickness should be 6 inches. The manner of its proper formation has been well set forth in the specifications of the city engineer of St. Louis, Mo. These specifications are so plain and definite, both as to forming the concrete foundation and the choosing and laying of the brick, that that portion of them pertaining to these objects is here given as follows:

"SPECIFICATIONS FOR CONCRETE FOUNDATION."

"Upon the roadbed thus formed a sub-foundation of hydraulic cement concrete shall be laid to a uniform depth of 6 inches, which shall be prepared and applied as follows: The sand to be used in the mortar shall be clean, sharp, silicious river sand, free from loam or dirt, and before it is used all gravel, sticks and other foreign admixtures shall be removed by screening."

"The cement used shall be hydraulic cement, equal in all respects to the best Utica or Louisville cement. It shall be newly made, fine ground, and capable of withstanding a tensile strain of sixty (60) pounds per square inch of section when mixed pure and made into test bars and exposed thirty (30) minutes in air and twenty-four (24) hours or more in water. Cement in bags or packages not branded with the name of the maker will not be received. Cement in jute sacks will be rejected without test. Samples for testing shall be furnished in such manner and at such times as may be required. On all casks or packages accepted, such inspection marks will be placed as may be required, and the contractor shall carefully preserve these marks and not allow them to be imitated. The cement shall be kept under cover and dry until used, and any cement exposed to the weather after testing shall not be used. Cement may be re inspected at any time when the street commissioner shall so direct, and if not found to be of proper quality it shall be rejected. All rejected cement shall be at once removed from the line of work."

"The mortar shall be prepared from cement and sand, in the proportions of one part of cement to two parts of sand, by measurement. The sand and cement to be thoroughly mixed dry in proper boxes, after which a sufficient quantity of water shall be added to produce a paste of proper consistency, and the whole thoroughly worked with hoes or other tools. The mortar always to be mixed fresh before being applied to the broken stone."

"The concrete shall be made of broken limestone and hydraulic cement mortar, the stone to be broken so as to pass through a two and one-half ($2\frac{1}{2}$) inch ring in its largest dimensions. The stone shall be clean from all dust and dirt, and thoroughly wetted, and then mixed with mortar; the general proportion being one part of cement, two parts of sand, and five parts of stone. It shall be laid quickly and then rammed until the mortar flushes to the surface. No walking or driving over it shall be permitted when it is setting, and it shall be allowed to set for at least twelve (12) hours, and such additional length of time as may be directed by the Street Commissioner or his duly authorized agents, before the pavement is put down. All materials used in the construction of the pavement shall be brought on to the concrete only in barrows, or delivered on the concrete from the sidewalk."

"SPECIFICATIONS FOR WEARING SURFACE."

"Upon the foundation of concrete shall be laid a bed of coarse, sharp sand, free from gravel, loam or vegetable matter, and ...... inches in thickness when compacted to serve as a bed for the bricks. Upon this base of sand a pavement of the best quality of vitrified paving brick shall be laid. The bricks shall not be less than seven and one-half inches nor more than nine inches long, not less than..............................inches nor more than three inches wide, not less than three and one-half inches nor more than four and one fourth inches deep, with rounded edges with a radius of three-eighths ($\frac{3}{8}$) of an inch. Said brick shall be of the kind known as "repressed" brick, and shall be repressed to the extent that the maximum amount of material is forced into them. They shall be free from lime, sand and other material, except pure shale; they shall be as nearly uniform in every respect as possible; they shall be burned so as to secure the maximum hardness, so annealed as to reach the ultimate degree of toughness, and thoroughly vitrified so as to make a homogeneous mass."

"All paving brick must be homogeneous and compact in structure, free from lumps of uncrushed shale or from laminations caused by the process of manufacture, or fire cracks or checks of more than superficial character or extent. The brick to be used shall be made from pure shale of quality equal to that found in Galesburg and Glen Carbon, in the State of Illinois, and Canton, in the State of Ohio. All bricks so distorted in burning or with such prominent kiln marks as to produce an uneven pavement, shall be rejected. All bricks shall be free from lime or magnesia and shall show no signs of cracking or spalling on remaining in water ninety-six hours."

"The bidders shall submit twenty-five samples of the brick they propose using. A portion of those bricks shall be subjected to such physical tests as the Board of Public Improvements shall deem necessary, and the remainder be retained as samples of the material to be furnished and used. Any brick which does not stand the tests satisfactorily will be rejected, and no bid contemplating the use of the rejected brick shall be entertained. Samples may be submitted by manufacturers, in which case the bidder proposing to use brick of such manufacture will not be required to submit samples. The quality of the brick furnished must conform to the samples presented by the manufacturers and kept in the office of the Street Commissioner."

"Such specimen brick shall be submitted to a test for one-half hour in the machine known as a "Rattler" with cast-iron bricks weighing six pounds each, making thirty revolutions per minute, and if the loss of weight by abrasion or impact during such test shall exceed fifteen per cent. of the original weight of the bricks tested, then the brick shall be rejected. The brick shall have a specific gravity of not less than two. They shall not absorb more than one and one-half per cent. of water when dried at 212 degrees Fahrenheit and immersed twenty-four hours in water."

"The Street Commissioner reserves the right to reject any and all brick which in his opinion do not conform to the above specifications."

"All brick may have a proper shrinkage but shall not differ materially in size from the accepted samples of the same make, nor shall they differ greatly in color from the natural color of the well-burned brick of its class and manufacture."

"No bats or broken brick shall be used except at the curbs, where nothing less than a half brick shall be used to break joints. The bricks to be laid in straight lines and all joints broken by a lap of at least two inches, to be set upon the sand in a perfectly upright manner as closely and compactly together as possible, and at right angles with the line of the curb, except at street intersections where they are to be laid as the Street Commissioner may direct."

"The pavement shall be thoroughly rammed two or three times, as may be directed by the Street Commissioner, with a paver's rammer weighing not less than seventy-five pounds, or a road-roller weighing not less than three nor more than six tons; and all the joints in the pavement shall be completely filled with.. and an additional layer of sand not less than one inch in depth shall be spread uniformly over the whole surface of the pavement."

THE PERFECT PAVEMENT.—The requirements which shall constitute a perfect pavement have been well summed up as follows:

First. Reasonableness in first cost.

Second. Low in cost of maintenance and easy to repair.

Third. Durability under traffic and reasonable freedom from noise and dust.

Fourth. Free from decay, waterproof and non-absorptive.

Fifth. Of low tractive resistance and furnishing a good foothold for horses.*

Suffice it to say that such a pavement has never as yet been constructed. The nearest approaches to it are those of vitrified brick, made from just such shales as are found in so great abundance in southwestern Indiana.

In order to gain some idea of the extent to which vitrified brick have been used for street paving purposes in Indiana, their durability and the general satisfaction which they give, a letter was sent to the city engineer of each city in the State where brick pavements are in use, and a blank was enclosed to be filled out and returned. Replies were received from all the engineers except those of the following places: Elkhart, Summitville, Dunkirk and Decatur. From these replies the following table has been compiled:

* Mead, Daniel W. Proc. Ninth Ann. Conv. Nat. Brick Manf's. Ass'n., 1895, 34.

Statistics Concerning the Use of Vitrified Brick for Street Paving in Indiana.

NAME OF CITY.	No. of Miles of Brick Pave-ments in Use.	Kind, and Thickness of Foundations.	Average Cost per Lineal Foot Each Side of Street.	Average Width of Street.	Total Number of Brick Used to Date.	Total No. of Block Used to Date.	Total Cost of Pave-ments.	Places of Manufacture of Brick.
Alexandria.	1,900 feet.	Broken stone; 8 inches.	$5.50	55 feet.	520,000		$22,000	Minerva, Ohio.
Anderson.	4¾ miles.	Gravel; 10 inches.	$4.50	40 feet.	7,000,000		$230,000	Canton, Ohio (6,000,000). Minerva Ohio, (1,000,000).
Elwood.	2½ miles.	Broken stone; 10 inches on 1 mile. Gravel; 10 inches on remainder.	$3.96 for vitrified brick; $2.40 for common brick.	35 feet.	1,050,000 common brick; 2,250,000 vitrified brick.		$105,000	Canton, Ohio (2,100,000 shale brick). Malvern, Ohio (150,000 fire-clay brick). Elwood, Ind. (1,050,000 common brick).
Evansville.	18 miles.	Concrete; 6 inches on 13 miles. Broken rock and two courses of brick, making 8 inches, on 5 miles.	$3.85	38 feet.	13,750,000	4,000,000	$701,000	New Cumberland, W. Va. (3,000,000). Middleport, Ohio (1,000,000). Decatur, Ill. (1,500,000). Ironton, Ohio (1,000,000). Evansville, Ind. (7,250,000).
Frankfort.	11 squares.	Concrete; 8 inches. Sand, 1 inch.	$4.72			1,050,000	$40,000	
Franklin.	¾ miles.	Concrete; 6 inches.	$4.10	28 feet.			$28,700	
Ft. Wayne.	4.57 miles, or 88,788 square yards.	Broken stone; 6 inches on 66,096 square yards. Concrete; 6 inches on 16,782 square yards. Concrete; 8 inches on 5,910 square yards.	$3.15	33 feet.	4,089,000	935,000	$157,838	Bucyrus, Ohio (1,550,904 shale brick). Canton, Ohio (1,830,400 shale brick). Massillon, Ohio (117,646 fire-clay brick). New Cumberland, W. Va. (581 000 fire-clay brick).

Statistics Concerning the Use of Vitrified Brick for Street Paving in Indiana.

Name of City.	Places of Manufacture of Block.	Cost of Brick per 1,000.	Cost of Block per 1,000.	Cost of Brick and Block Made in Indiana.	Cost of Brick and Block Made Outside of Indiana.	Durability of and Satisfaction Given by Brick Pavements.	General Remarks.
Alexandria.		$13.00			$6,760	Not used sufficiently to prove durability; satisfaction good.	Probably 15 squares will be put down next season.
Anderson.		$12.00			$84,000	Pavements constructed in 1892 93 show very little signs of wear; satisfaction good.	Probably 2,000,000 paving brick will be used in 1896.
Elwood.		Vitrified brick, $13.00; common brick, $5.		$5,250	$30,000	Canton brick where foundation has not been disturbed have given entire satisfaction. Fire-clay brick crumble rapidly after hard outer shell has worn through.	Common brick pavements last 5 years without repairs as compared with gravel at almost same price, with constant repairs.
Evansville.	Middleport, Ohio (2,000,000). Ironton, Ohio (2,000,000).	$10.00	$13.50	$72,500	$119,000	All shale brick are wearing well under heavy traffic. West Virginia fire-brick are showing signs of disintegration under same conditions.	Seventy-five to 100 squares of brick pavement will be put down in 1896. Two million vitrified brick have in addition already been used in alleys.
Frankfort.	Veedersburg, Ind.		$13.00	$13,650		Just constructed.	
Franklin.	Veedersburg, Ind.		$14.00			Good as new after two years' wear; satisfaction excellent.	Twelve squares will be put down in 1896.
Ft. Wayne.	New Cumberland, W. Va. 935,000 fire-clay block.	$11.50	$18.00		$62,853	Pavements laid in 1891 in fair condition; satisfaction good.	10,272 square yards of vitrified brick have been laid in alleys to date.

Statistics Concerning the Use of Vitrified Brick for Street Paving in Indiana—Continued.

Name of City.	No. of Miles of Brick Pavements in Use.	Kind, and Thickness of Foundations.	Average Cost per Lineal Foot Each Side of Street.	Average Width of Street.	Total Number of Brick Used to Date.	Total No. of Block Used to Date.	Total Cost of Pavements.	Places of Manufacture of Brick.
Gas City.	4,977 feet. (lineal.)	Crushed stone; 6 inches. Sand; 2 inches.	$6.22	50 feet.		1,326,500	$61,968	
Huntington.	2 miles.	Broken stone; 8 inches.	$3.70	36 feet.		2,000,000	$72,182	
Indianapolis.	14.6 miles.	Concrete; 6 inches.	$3.72½ including curbing.	35 feet.			$744,432	
Jonesborough.	4,550 lineal feet.	Coarse gravel, 10 inches.	$3.75	50 feet.		1,200,000	$33,000	
Kokomo.	$\frac{4}{10}$ miles.	Concrete, 6 inches.	$5.34	36 feet.		388,810	$10,890	
Lafayette.	1$\frac{53}{100}$ miles.	Gravel, 6 inches; sand, 2 inches; hard brick, flat, 2 inches; sand, 1½ inches.	$4.18	39 feet.	1,776,000		$68,996	Veedersburg, Ind.; Clinton, Ind.; Canton, Ohio; Bloomington, Ill.; Galesburg, Ill.
Laporte.	15,393 square yards.	Broken stone, 6 inches; sand, 2 inches.	$5.48	39 feet.	877,500		$22,012	Canton, Ohio.
Logansport.	$\frac{63}{100}$ miles.	Broken stone, 8 inches on 4 squares; concrete, 8 inches on 5 squares.	$3.60 with broken stone foundation; $4.87 with concrete foundation.	50 feet.		753,000	$27,586	

Statistics Concerning the Use of Vitrified Brick for Street Paving in Indiana—Continued.

NAME OF CITY.	Places of Manufacture of Block.	Cost of Brick per 1,000.	Cost of Block per 1,000.	Cost of Brick and Block Made in Indiana.	Cost of Brick and Block Made Outside of Indiana.	Durability of and Satisfaction Given by Brick Pavements.	General Remarks.
Gas City.	Logan, Ohio.		$18.00		$23,877	Satisfaction excellent.	
Huntington.	Hocking Valley, Ohio.		$20.00		$40,000	Good.	Probably 10 squares will be laid with vitrified brick in 1896.
Indianapolis.						Those laid last two years are fairly good; those laid prior are poor.	
Jonesborough.	Canton, Ohio.		$13		$15,600	Constructed in 1895	
Kokomo.	Veedersburg, Ind.		$13	$5,044		Just completed.	Probably 6 squares will be paved with brick in 1896.
Lafayette.		$13.62		$8,000	$16,089	Durability of the brick from Bloomington and Galesburg, only fair; the others, satisfactory.	
Laporte.		$15			$13,175	In use but one year; satisfaction good.	Seven squares will probably be put down in 1896.
Logansport.	Veedersburg, Ind.		$16	$12,048		Good.	Two rows of common red tile are placed under the foundation and connected with sewers. This investment pays better than any other portion of the construction. Concrete foundation is preferable.

Statistics Concerning the Use of Vitrified Brick for Street Paving in Indiana—Continued.

Name of City.	No. of Miles of Brick Pavements in Use.	Kind, and Thickness of Foundations.	Average Cost per Lineal Foot Each Side of Street.	Average Width of Street.	Total Number of Brick Used to Date.	Total No. of Block Used to Date.	Total Cost of Pavements.	Places of Manufacture of Brick.
Marion.	$3\frac{1}{10}$ miles.	Macadam, 8 inches; sand 2 inches.	$3.50	30 feet.	2,283,600	795,000	$115,605	Canton, Ohio.
Michigan City.	3.16 miles.	1 inch pine board, and 5 inches crushed stone.	$1.37	23 feet.	2,147,558	224,000	$62,401	Michigan City (1,352,000 hard brick); Brazil, Ind., 403,980 vitrified brick; Clinton, Ind. (391,220).
Montpelier.	1,972 linear feet.	Concrete; 6 inches.	$2.83	30 feet.		243,000	$11,206	
New Albany.	¼ mile.	Concrete; 6 inches. Sand; 2 inches.	$6.55, including curb and sidewalk.	60 feet.	412,750		$14,385	New Cumberland, W. Va.
Noblesville.	1⅓ miles.	Gravel; 12 inches.	$4	40 feet.		900,000	$45,000	
Peru.	7,700 square yards.	"Paved bowlders"; 6 inches. Sand; 1½ inches.				369,600	$8,131	
Richmond.	$1\frac{1}{10}$ mile.	Broken stone; 6 inches. Sand; 2 inches.	$6	45 feet.	3,000,000	75,000	$75,000	Canton, Ohio (2,500,000). Athens, Ohio (400,000). Trumble, Ohio (100,000).
Seymour.	1,070 linear feet.	Gravel, concrete; 6 inches. Sand; 2 inches.	$4.48, including curbing of oolitic limestone.	54 feet.		320,000	$9,587	

Statistics Concerning the Use of Vitrified Brick for Street Paving in Indiana—Continued.

Name of City.	Places of Manufacture of Block.	Cost of Brick per 1,000.	Cost of Block per 1,000.	Cost of Brick and Block Made in Indiana.	Cost of Brick and Block Made Outside of Indiana.	Durability of and Satisfaction Given by Brick Pavements.	General Remarks.
Marion.	Veedersburg, Ind.	$15.50	$15.00	$11,925	$35,395	The first brick street was built six years ago; has never cost a cent for repairs, and is in good condition at this time. No complaint except as to noise.	Sixteen squares will be put down in 1896.
Michigan City.	Veedersburg, Ind.	$11.00	$16.50	$24,600		General satisfaction given by the *vitrified brick* and block.	
Montpelier.	Canton, Ohio.		$14.00		$3,402	Put down in 1895.	Ten thousand square yards of brick pavement will probably be put down in 1896.
New Albany.		$13.00			$5,365	Excellent.	
Noblesville.	Canton, Ohio (572,000). Zanesville, Ohio (328,000).		$16.50		$14,850	Good.	
Peru.	Veedersburg, Ind.		$13.00	$4,803		Satisfaction good.	
Richmond.	Haydenville, Ohio. (75,000).	$16.00	$18.50		$50,000	General satisfaction, poor. Not the fault of the brick, but the bad manner in which the work was done.	
Seymour.	Athens, Ohio.		$12.50		$4,000	Constructed in 1895.	Seven squares will be put down in 1896.

Statistics Concerning the Use of Vitrified Brick for Street Paving in Indiana—Continued.

NAME OF CITY.	No. of Miles of Brick Pavements in Use.	Kind, and Thickness of Foundations.	Average Cost per Lineal Foot Each Side of Street.	Average Width of Street.	Total Number of Brick Used to Date.	Total No. of Block Used to Date.	Total Cost of Pavements.	Places of Manufacture of Brick.
South Bend.	4 miles.	Gravel; 6 inches; thoroughly rolled.	$2 08	39½ feet.	5,500,000	308,600	$87,904	South Bend (2,750,000). Canton and Malvern, Ohio (2,000,000). Zanesville, Ohio (750,000).
Terre Haute.	3.53 miles.	Broken stone; 8 inches; on 2.28 miles. Concrete; 5 inches; on 1.25 miles.	$5.71 on broken stone.	42 feet.	5,635,380	119,080	$236,284	Canton, Ohio (3,770,000). Clinton, Ind. (690,600). Veedersburg, Ind. (1,274,200).
Tipton.	2.71 miles.	Gravel; 10 inches.	$4.84 for vitrified brick. $2.18 for common brick.	33 feet.	651,000 vitrified brick; 1,430,000 common brick.	519,000	$82,274	Canton, Ohio; vitrified brick. Tipton, Ind.; common brick.
Washington.	2 miles.	Concrete; 6 inches. Sand; 2 inches.	$390 including curbing.	34 fect.	640,000	1,520,800	$87,182	Evansville, Ind.
Total outside of Indianapolis.							$2,416,131	

Statistics Concerning the Use of Vitrified Brick for Street Paving in Indiana—Continued.

NAME OF CITY.	Places of Manufacture of Block.	Cost of Brick per 1,000.	Cost of Block per 1,000.	Cost of Brick and Block Made in Indiana.	Cost of Brick and Block Made Outside of Indiana.	Durability of and Satisfaction Given by Brick Pavements.	General Remarks.
South Bend.	Carrollton, Ohio.	$12	$14	$33,000	$37,000	From indications of pavements in use five years, they are good for twenty years on the streets having the most heavy traffic. South Bend and Canton brick give good satisfaction. The "fire clay" brick do not seem to stand so well.	The South Bend bricks are made from a plastic blue clay (calcareous), which burns buff, or, when thoroughly vitrified, blue. It is entirely free from pebbles and must have been deposited in still water.
Terre Haute.	Veedersburg, Ind.	$15	$20.50	$31,875	$56,550	Good.	
Tipton.	Canton, Ohio.	$10, vitrified brick. $6, common brick.	$13	$8,580	$12,738	Vitrified brick, good. Common brick, all right, if properly burned, but some which were too soft have been used.	Twenty-five squares will probably be paved in 1896.
Washington.	Athens, Ohio.	$10	$13	$6,400	$19,770	The pavements from brick are wearing well. The brick being a little too hard the edges and corners are somewhat rounded by eighteen months' use. The block pavements were constructed in 1895.	Twenty squares will probably be paved with brick in 1896.
Total outside of Indianapolis.				$237,675	$647,022		

When it is remembered that the use of brick pavements did not begin until 1890, it will be seen that they have come into popular favor in our State in a very short time. Those made from shale brick, when the foundation has been properly constructed, have everywhere given good satisfaction; while the durability of those from "fire-clay" brick is generally reported as poor. From the foregoing table it may be seen that in Indiana, outside of Indianapolis,* $2,416,131 have been expended in brick pavements. Of this large sum the brick have cost $884,697. But $237,675 have been spent for material made in Indiana, while $647,022 have gone to Ohio, West Virginia and Illinois for brick, every one of which could have been made in Indiana, and laid down at a fair profit in the cities using them for a less price than they were shipped in from other States.

THE MANUFACTURE OF SEWER PIPE AND HOLLOW GOODS.

Under this head is included the making of sewer pipe, fire-clay chimney tops and flue linings, hollow building brick and vitrified drain tiles. In one or two factories all of these wares are made, but in most places only special lines are produced. All of these products except the chimney tops and flue linings are vitrified in the making; the two exceptions are burned at a lower temperature, and are not salt glazed as are the others.

The clays used are the same as for making paving brick, *i e.*, under-clays or shales, but in this State more of the products are as yet made from the former. Shale is used by the Chicago Sewer Pipe Co., of Brazil, and the Terre Haute Hollow Brick and Pipe Co., and in both places the wares are of superior grade, and there is less loss in drying and burning than in those factories which use an under-clay exclusively.

The preparation of the clays for these goods is made by essentially the same processes as those used in the making of paving brick. The wet pan is most used in tempering, and the latter process is therefore more thorough than can be accomplished in a pug mill.

A machine known as the sewer-pipe press is the one almost universally used in the making of pipe and hollow goods. It is a modification of the "plunger" brick machine previously mentioned, and consists of two cylinders placed upright one above the other, and separated by a heavy cast iron frame, to which the cylinder heads are bolted. The upper or steam cylinder is usually 40 inches in diameter, and the lower or clay cylinder, 18 inches. The piston rod is made either single or triple, and is continuous from the clay piston to the steam piston. The clay piston

*I was unable to secure complete statistics at the office of the City Engineer of Indianapolis.

is a cast iron head which can be replaced easily when worn. Steam pressure is used in operating the machine, and is controlled by a lever from the level of the working platform.

Seven or eight men constitute the "press gang" necessary to operate the machine and remove the pipe as fast as made to the dry floors. The size of the sewer pipe varies from 4 inches in diameter to 36 inches, or even larger, but the sizes most used range from 8 to 16 inches. As fast as made they are cut to the desired length, and each is set upright on a wooden pallet of appropriate size. These pallets are then placed on trucks and taken to the dry floors

The drying of sewer pipe is almost wholly accomplished on what is known as "sewer pipe floors,' by means of steam. These floors vary much in size, according to the output of the factory, and are usually three or four in number, one above another. They are slatted or open and the steam pipes are arranged beneath the lower one or two. The largest pipes are placed on the lower floor. Exhaust steam from the engine and presses is used by day, and direct steam by night. The process is necessarily a slow one else many of the pipe would crack. Those made from shale are much less apt to crack while drying than those from fire-clay.

Sewer pipe are burned, for the most part, in round down-draft kilns, and the process is essentially the same as that described under paving brick, except that much less time is required, owing to the thin sections of clay to be vitrified. For shale pipe three days is usually sufficient, and for those made of fire-clay, three and one-half to four. The pipe are usually glazed by the addition of small quantities of packing-house salt to the fuel during the last stages of burning. This glazing is done to secure smoothness of surface and a dark color. The color makes little or no difference in the quality of the pipe, but they are largely graded according to it. Prof. Orton has well said: "The system of grading sewer pipe is unnecessarily severe. For any ordinary use, the seconds are as good as the firsts; it is not the consumer who profits by the severity of selection; it is the middle men or retailers who buy the seconds at low rates and work them off on the public as first-class goods, which for any matter of service and utility they are."*

The making of hollow building brick or tile is rapidly assuming large proportions in western Indiana. Three large factories have been erected since 1890, in which these brick form the special output, and a fourth has added them to its former productions. These brick are plain sections of a square hollow bar. Their standard size is $8\frac{1}{4}$x$8\frac{1}{4}$x$16\frac{1}{2}$ inches, with the hollow portion cross-webbed to give them additional strength. They can be made by either the auger or plunger brick machines, and

*Ohio Geol. Surv. VII, 214.

dried on dry floors or in progressive tunnel dryers. The advantages claimed for them over ordinary brick or stone for building purposes are as follows:

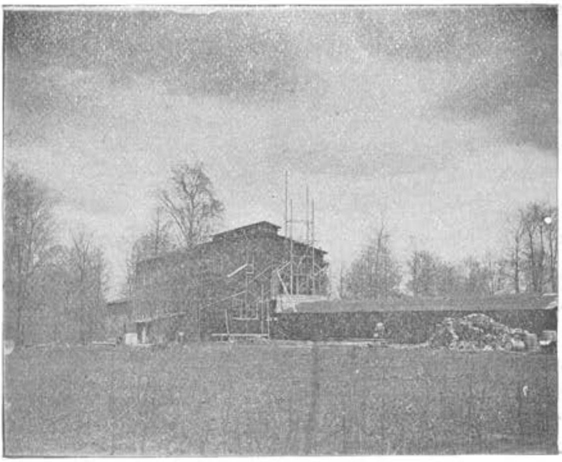
1. Cheapness, costing less than either brick or stone.
2. Being thoroughly vitrified they do not absorb any moisture, and always make a dry wall.
3. Being hollow they are more healthful for dwelling houses—warm in winter and cool in summer.
4. Make a stronger foundation, as each brick will stand a weight of more than 100,000 pounds.
5. As all ware is vitrified the walls will always keep clean, and will not become dingy as cut stone and brick usually do.

A handsome rock-faced tile for foundation work above ground is also made by several of the factories.

The making of pumps from clay has been carried on for 21 years by Weaver Bros., at Brazil, Indiana. The entire pump, except the handle, bolts and suckers, is made of vitrified fire-clay. These "stone" pumps are guaranteed to last for 10 years, and a number about Brazil have been in use for 21 years, and are none the worse for wear. They are fitted up and put in the well for $8 for the first 10 feet, and 25 cents for each additional foot.

The following table comprises the available statistics of the sewer pipe and hollow goods industries of Southwestern Indiana:

WORKS OF WEAVER BROS'. CLAY FACTORY, BRAZIL, IND.



WORKS OF EXCELSIOR CLAY CO., BRAZIL, IND.

Statistics of Sewer Pipe and Hollow Goods Industries of Southwestern Indiana.

Name of Firm.	Location.	Began Operation.	Invested Capital.	Kind of Products.	System of Drying.	Number, and Kind of Kilns.	Kind of Clay Used.	Number of Hands Employed.	Average Daily Wages.	Value of Annual Output.
Goucher, McAdoo & Co.	Brazil.	1894	$75,000	Sewer pipe, culvert pipe, fire proofing, flue linings, chimney tops, etc.	Sewer pipe floors, steam heated.	Twelve, round, down-draft.	Plastic under-clay.	100	$1.50	$90,000
Chicago Sewer Pipe Co.	Brazil.	1893	$50,000	Sewer pipe.	Sewer pipe floors, steam heated.	Eight, round, down-draft.	Shale and surface clay mixed.	40	$1.50	$60,000
Dee Sewer Pipe Co.	Mecca, Parke County.	1895	$50,000	Sewer pipe.	Sewer pipe floors, steam heated.	Four, round, down-draft.	Shale and surface clay.			$40,000
A. D. Clark.	Cannelton, Perry County.	1862	$15,000	Sewer pipe and stoneware.	Sewer pipe floors, steam heated.	Three, round, down-draft.	Plastic under-clay.	20	$1.25	$15,000
Brazil Brick and Pipe Co	Brazil.	1890	$50,000	Hollow building brick, vitrified drain tile and fire brick.	Sewer pipe floors, steam heated.	Seven, round, down-draft.	Plastic under-clay.	35	$1.50	$50,000
Excelsior Clay Works.	Brazil.	1895	$30,000	Hollow brick, vitrified drain tile, flue linings, etc.	Progressive tunnel, steam heated, 4 tracks.	Seven, round, down-draft.	Shale and under-clay.	50	$1.50	$30,000
Weaver Clay and Coal Co.	Brazil.	1872	$10,000	"Stone" pumps, vitrified drain tile, hollow brick, flue linings, door steps, etc.	Sewer pipe floors, steam heated.	Two round, down-draft, and one oven draft.	Plastic under-clay.	10	$1.50	$15,000
Terre Haute Brick and Pipe Co.	Terre Haute.	1895	$40,000	Hollow building brick, vitrified drain tile, and paving brick.	Progressive tunnel, steam heated, 6 tracks.	Six, round, down-draft.	Shale and plastic under-clay.	35	$1.50	$40,000
Total.			$320,000					290		$340,000

THE MANUFACTURE OF REFRACTORY MATERIAL.

The making of refractory material is carried on in but four factories in Indiana, and in two of these only as a side issue. Fire-brick, cupola linings, tiles for the floors of kilns and grate backs constitute the principal products made. Three of these factories derive their clay from the stratum which occupies quite an area in Parke and Vermillion counties, and which is fully described among the clays of the latter county. It is a white, semi-plastic under-clay of the coal measures and contains 98 per cent. of refractory material.

The dry pan is used in grinding the clay and the wet pan, or pug mill, in tempering it. The latter process is done more thoroughly than in the making of paving brick in order to develop as much as possible the property of plasticity.

The bricks are molded either by hand or on soft-mud machinery, the auger and plunger types of machines being wholly unsuited to their making. Those made on the soft mud machines are much rougher than the ones made by hand, and have to undergo the process of repressing. When first made they are too soft to bear handling and must be partially dried before being repressed. This drying is accomplished on a dry floor heated by under-flues. The moulding usually takes place in the afternoon and the repressing and setting in the kilns in the forenoon. By this system the bricks are dried from 12 to 24 hours.

Round down-draft kilns are used in the burning of refractory products, the process occupying about five days. Less care is taken in the burning than with any other kind of clay wares, as on account of the refractory nature of the material there is little or no danger of fluxing or overburning.

Within recent years the manufacture of fire-brick has been attempted by the dry-press process. The Huntingburg Dry Pressed Brick Company, of Huntingburg, Dubois County, is the only company which has thus attempted their making in Indiana, and that only on a small scale; but in Ohio, according to Orton, this process is being used successfully in one or two fire-brick factories. If the attempt proves successful it will revolutionize the making of refractory products, as they can be made more perfect in form and size, denser and stronger, and at a less cost by the dry-press process than by any other known.

The making of glass-pots and linings for glass-tanks, the highest and most technical part of the refractory clay industry, has not as yet been attempted from Indiana clays. Glass pots vary much in size and shape, the larger covered ones weighing as much as 4,500 pounds. Great care must be taken in their structure, as in use they are subject to the most intense heat and at the same time to the action of such powerful fluxes.

as potash, soda and lead oxides, constituents of the batch of molten material which they contain. Their cost is therefore necessarily great, while their days of usefulness are few, as at the best they wear out in a few months. With near 50 large glass factories in active operation in Indiana it seems strange that no attempt has heretofore been made to utilize the clays of the State in making the pots and tank linings. Two clays are found in western and southern Indiana which are undoubtedly of sufficient purity for the purpose. One is the Montezuma fire-clay, which, according to careful analysis, contains but 1.79 per cent. of fluxes, the other, the Lawrence County kaolin, containing 1.97 per cent.* The analyses were made from average samples chosen hurriedly, and if careful selection be made much material of even greater purity will be found in the deposits mentioned.

A plastic refractory clay found in Greene County has been put to a novel use by Mr. P. J. Harrah, of Bloomfield. The clay is mixed with one-half of its bulk of sawdust and then molded into an oval mass a little larger than a hen's egg, and with four grooves running lengthwise. During the process of burning the sawdust is destroyed, leaving a porous mass of fire-clay of great refractoriness. A handle of copper wire is attached to this by an ingenious machine, and a *fire kindler* is complete. This, when dipped into a can of coal oil and allowed to remain over night, absorbs enough oil to burn for 15 or 20 minutes with a flame sufficient to kindle either wood or coal fires. During the two years of 1894–'95 over 300,000 of these kindlers were sold, yielding a handsome profit to the inventor, and showing one of the manifold uses to which a refractory clay can be put.

The following table shows some statistics of the two fire-brick factories of Vermillion County:

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* For complete analyses see pages 130 and 105.

Statistics of Fire-Clay Factories.

NAME OF FIRM.	Location.	Began Operat'n.	Products.	Number and Kind of Kilns.	Kiln Capacity.	Capital Invested.	Hands Empl'd.	Average Daily Wages.	Value of Annual Output.	Amount of Fire-clay Shipped.	Value of.
Montezuma Fire-brick Works.	Montezuma, Ind.	1872.	Fire-bricks, boiler tile, cupola blocks, floor brick and ground fire-clay.	Five round down draft.	200,000 fire-brick.	$32,000	35	$1.10	$25,000	2,000 tons.	$3,000
Hillsdale Fire-brick and Tile Co.	Hillsdale, Ind.	1888.	Same as above.	Four round down draft.	150,000 fire-brick.	$20,000	17	$1.25	*$4,000	1,100 tons.	$1,050

* These figures are for 1895, when the plant was in operation only one-third of the time.

THE MANUFACTURE OF POTTERY.

The making of the cruder forms of pottery, earthenware and stoneware, has long been carried on in the coal-bearing counties of Indiana. The early settlers discovered along the sides of the ravines and hills of those counties many outcrops of the under-clays of the coal seams. These, by long exposure, had been rendered soft, plastic, and in every way suitable for the making of such wares as jugs, crocks, etc. At the present time but 11 potteries making stoneware, and in a few instances earthenware, are found in the area covered by this report. Of these, eight are small concerns supplying only a local demand. The other three are larger and ship their output to distant markets. In addition to these, one factory making white granite or ironstone ware on an extensive scale is located at Evansville.

Of the three kinds of ware made in these factories earthenware is the lowest and crudest. Examples of such ware are flower pots, cuspidors and hanging baskets. These are made from any clay plastic enough to work freely, and sandy enough to dry and burn without cracking. A porous, unglazed, unvitrified body is desired, and hence the burning is not extended nor the temperature high.

Stonewares rank next to earthenwares in the scale of pottery products. They are distinguished from the latter by the fact that they are always glazed and usually vitrified, the glazing and burning being accomplished at the same time; whereas in the higher forms of potter's wares two operations are necessary.

Stoneware, to be of good grade, requires much care in the selection of the clay. This must possess certain essential qualities, which may be enumerated as follows:

1. Excessive plasticity, so that it may be easily spun or molded into any desired shape.
2. It must be refractory enough to stand up under the heat required to melt the glaze, and must contain enough free silica to prevent air-cracking while drying, or in cooling after burning.
3. It must possess fluxes sufficient to cause vitrifaction to partially take place at or below the temperature required for glazing.
4. It must be relatively free from such impurities as particles of lime, iron sulphide, etc., which will cause a flaking or blistering of the surface after burning.

Numerous clays possessing these properties exist in the coal area of Indiana. Among the best are those found in the vicinity of Annapolis, Parke County; Brazil, Clay County; Shoals, Martin County; Huntingburg, Dubois County, and Cannelton, Perry County, detailed mention of each of which is given in the previous chapter.

In the smaller factories the clays are usually weathered for some months before using. They are then ground for some time with the old-fashioned horse power machines. This grinding causes the clay to become very tough and waxy; but does little towards removing the impurities.

In the larger factories a machine run by steam and called a "tracer" is used for grinding. By this the clay previously moistened is ground, kneaded and stirred for an hour or longer until the grains have been reduced to as near a uniform size as possible, and the property of plasticity strongly developed.

The clay prepared by either of these two methods is then removed to the turning room, where a piece is cut off of sufficient size and weight to make the vessel desired. This is cut into two pieces several times by a wire and each time reunited by throwing one mass with much force against the other. By this means, and by kneading, the air bubbles are worked out and the particles of the clay brought into closer contact. The clay is then thrown onto a horizontal disc, or wheel, which can be made to revolve rapidly by a foot lathe, or other power. By moistening the revolving mass and pressing it with the fingers, the experienced potter can cause it to take any desired shape.

The amount of ware turned in a day varies much according to the size and kind. So many gallons usually constitutes a day's work. A practiced potter can make as many as 125 to 150 gallons of crocks or jars; while 70 to 90 gallons of jugs will be a good day's labor.

In the larger factories at Cannelton and Evansville, much of the ware is formed by jollying or moulding. By this process a rapidly revolving mold is filled with soft clay. The mold regulates the outside shape of the vessel, and a "shoe" or inner piece, the inside shape. The mold is then taken into a hot closet when the water of the clay evaporates, and the ware shrinks and loosens in its case. The handles are put on after the ware is removed from the mold. By this process a single mold can be used several times a day, and many more pieces of ware can be made by one man than by the old fashioned mode of turning.

The ware after being shaped on the wheel, or by jollying, is set on board shelves in open racks, or in large airy rooms where it slowly dries. After drying, if the glazing is to be that of a slip clay, it is dipped into a solution of such clay, and then, after allowing this to dry, is removed to the kiln. There, at the proper temperature, the slip melts and forms a smooth and handsome surface, usually of a dark brown color.

If the glaze is to be one of common salt, the ware is removed directly from the drying room to the kiln without being dipped into a glaze bath, and when the contents of the kiln are at a white heat the salt is thrown on the fire. Its vapors pass upward and form a brownish yellow glaze on the outside of the ware.

The most of the stoneware made in Indiana is burned in the old-fashioned updraft kilns, the process occupying about 36 hours. Three days must elapse after the fires are drawn before the kiln be opened, else much ware will be spoilt by air-cracking. An ordinary round downdraft kiln of about 20 feet diameter is used by some potters with excellent results.

The potters of Indiana, as far as possible, use the Brazil block or non-caking coal for burning their wares. This coal contains less sulphur than the ordinary bituminous coal, and they claim that for that reason a much better and smoother glaze can be secured with it.

The Crown Pottery Co., of Evansville, was organized in 1891, for the purpose of making ironstone china and decorated tableware. The materials used are none of them obtained in Indiana, and consist of feldspar, flint, ball-clay and kaolin, the latter from Florida and North Carolina. On account of the removal of the tariff on such goods, the market became flooded with similar wares of English make, and the factory was compelled to close down four months in 1894, and three months in 1895. Of the 160 hands employed, 50 are girls who receive $3.00 to $4.00 a week; 60 are boys at $4.00 per week, and the remainder are men at $2.00 per day. The capital stock of the company is $75,000, and the value of the annual output, when run steadily, is $100,000.

The following table gives the statistics of the stoneware factories located in the coal area of the State, as far as they could be obtained:

Statistics of Stoneware Potteries of Southwestern Indiana.

Names of Present Owners.	Location.	Began Operation.	Products.	No. of Kilns.	Kiln Capacity in Gallons.	Annual Output in Gallons.	Value of Annual Output.	Capital Invested.	No. of Hands Employed.
Atchison & Lee.	Annapolis, Parke County.	1841	Stoneware.	1	2,000	40,000	$2,400	$2,500	6
Dr. J. L. Myers.	Bloomingdale, Parke County.	1890	Stoneware.	1	2,000	10,000	$600	$1,000	3
Jas. H. Baker & Son.	Rockville.	1872	Stoneware and Earthenware.	1	2,300	25,000	$1,500	$1,500	3
Torbett & Baker.	Brazil.	1859	Stoneware and Earthenware.	1	2,000	20,000	$1,200	$1,500	3
Beryl Griffith.	Clay City, Clay County.	1846	Stoneware and Earthenware.	1	1,500	40,000	$2,500	$2,000	3
George Baker.	Worthington, Greene County.	1875	Stoneware.	1	1,500	10,000	$600	$1,500	2
Indiana Clay and Specialty Works.	Shoals, Martin County.	1870	Stoneware and Earthenware.	1				$15,000	
V. Walz.	Huntingburg, Dubois County.	1877	Stoneware, Earthenware, Stone Pumps and Drain Tile.	1	2,500	35,000	$2,000	$5,000	4
A. D. Clark.	Cannelton.	1872	Stoneware.	2	2,500	125,000	$5,000	$7,500	10
Cannelton Stoneware Company.	Cannelton	1892	Stoneware and Earthenware.	2	5,000	175,000	$7,500	$5,000	12
Indiana Pottery Company.	Evansville.	1891	Stoneware.	2	8,000	125,000	$5,000	$15,000	
Woods Bros.	Spencer.	1890	Earthenware.	1			$800		3
Total.					29,300	605,000	$29,100	$57,500	49

THE MANUFACTURE OF DRY PRESSED BRICK.

The manufacture of dry pressed brick for the fronts of buildings has become a prominent industry in recent years. Architects and builders are constantly inventing new designs in which these bricks can be used to advantage, and the manufacturers, fully alive to every opportunity for increasing their business, are competing with one another in improving the quality and variety of their output. Five large factories have started up in the coal counties since 1890, and all of them are enjoying a prosperous business.

Clays of various kinds are used in the making of dry pressed brick. Surface clays, where free from particles of lime and iron ore, make a handsome red brick; but oftentimes one which is too tender or brittle, the edges being easily broken or rubbed in shipping. Recent sedimentary clays make a tougher brick, but the color can not always be relied upon.

The toughest and most uniform colored pressed brick are undoubtedly those made of shale. Some shales, as those of the "Knobstone" formation at Gosport, and a few of the more refractory deposits of the Carboniferous, can be made into a handsome and durable buff shade of brick, which is rapidly coming into popular favor. The under-clays of the coal seams are also utilized in making buff brick, and by mixing them and the shales or surface clays in varying proportions many different shades can be produced at will.

The only preparation necessary for the clays is grinding and screening. The surface and sedimentary clays are usually ground in a pulverizer; the shales and fire-clays in a dry pan. The grinding should be prolonged enough to render the particles of clay as near a uniform size as possible. From the screens the clay passes down to a receiver or hopper above the brick press. The latter is a powerful machine, which takes the ground and screened clay, and by the exertion of great pressure forms it into a dense, compact brick. As this is made without the aid of moisture it is but little more than an aggregation of particles of clay, held together by the force of adhesion. Such brick are therefore acted upon and worn away readily by friction, and require careful handling, both before and after burning.

The brick are usually removed from the machine direct to the kiln, though in some places, as at Evansville, an intermediate drying takes place by the progressive or tunnel system. The burning is accomplished in down-draft kilns, either round or rectangular in form; the Eudaly being a favorite kiln for the purpose. The process occupies 16 to 18 days, half of which is devoted to "water smoking." Wood is generally used for fuel in this preliminary process, and coal for the later stages of burning. Where the brick are tunnel dried a shorter time is required for the burning.

After cooling, the contents of the kiln require careful assorting, as several, sometimes a dozen, different shades of one color are present, owing to the variations in burning and the position occupied by the different courses of brick in the kiln.

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Although a distinct industry the manufacture of roofing tiles from clay will be briefly treated in this connection. But one factory, operated by the Wabash Roofing Tile Co., of Montezuma, Parke Co., is represented in the State. This company began operations in 1889, but suffered losses by fire and business complications so that only in the past two years has the business been conducted on a paying basis.

The tiles are quadrangular, flat and grooved, with overlapping edges, and are $6\frac{1}{2} \times 10\frac{1}{4}$ inches in size. They are made from the soft drab shale found so abundantly in the vicinity of Montezuma. This shale is ground and tempered in a wet pan, and passes from that to a stiff-mud machine which forms it into a large block and cuts this into thin sections of the desired size. These sections, or "slabs," are then pressed on Raymond represses into the requisite shape. From the represses the tile are taken to the racks in the drying rooms where they are subjected to steam heat for 72 hours. They are then placed in saggar blocks and taken to the kilns where they are burned for five days and nights. During the burning they are heated as nearly as possible to the point of vitrifaction, but are not allowed to become fully vitrified, as the thin clay sections are apt to be warped and twisted by extreme heat.

When properly burned the tile are a bright and handsome shade of red, and possess strength and toughness sufficient to bear all necessary transportation and handling. They weigh 600 pounds to the square, and form a roof strong enough to readily support the weight of an average-sized man while walking over it. The capital invested by the company at the present time is but $12,000. Twenty men are employed, and the daily output at full capacity is 20 squares, which bring $6.50 each on board the cars.

The tile find a ready sale in Chicago, Terre Haute and other points, and the business of the company is steadily increasing year by year. No more handsome or durable material than these tile can be used for roofing purposes; and in artistic effects they can not be surpassed, especially on roofs which are designed for their use.

The following table of statistical information was gathered concerning the pressed brick factories found in the area covered by this report:

Statistics of Dry Pressed Brick Factories, etc.

NAME OF FIRM.	Location.	Began Operation.	Number and Kind of Kilns.	Total Kiln Capacity.	Kind of Machinery.	Capital Invested.	Annual Output.	Value of Annual Output.	Number of H'nds Empl'd.	Average Daily Wages.
Cayuga Pressed Brick Co.	Cayuga, Vermillion County, Indiana.	1892	Four Boyd and one Eudaly, squ re, down-draft. One round, down-draft	445,000	Two 9-foot dry pans; two Boyd & White brick machines.	$100,000	5,000,000	$50,000	40	$1.25
Hillsboro Pressed Brick Co.	Hillsboro, Fountain County, Indiana.	1895	Two Eudaly, square, down-draft.	280,000	One 7-foot dry pan; one "Penfield" brick machine.	$30,000		$25,000	20	$1.35
Terre Haute Pressed Brick Co.	Terre Haute, Indiana.	1894	One Eudaly, square, down-draft. One round, down-draft.	185,000	One "Williams" pulverizer; one "Simpson" brick machine.	$30,000	2,000.000	$25,000	20	$2.00
Huntingburg Pressed Brick Co.	Huntingburg, Dubois County, Indiana.	1893	Three Eudaly, square, down-draft.	375,000	One clay pulverizer; one "U. S." brick machine.	$30,000	2,500,000	$20,000	18	$1.50
Evansville Pressed Brick Co.	Evansville, Indiana.	1892	Four square, down-draft.	400,000	Two 8-foot dry pans; one "Simpson" brick machine.	$25,000	2,000,000	$20,000	25	$1.50
Wabash Roofing Tile Co.	Montezuma, Parke County, Indiana.	1889	Three square, down-draft.	50,000 Roofing Tile.	One 9-foot wet pan; one stiff mud machine; four Raymond "Perfection" repress machines.	$12,000	3,000 Squares of Roofing Tile	$19,500	20	$1.20
Total.						$227,000		$160,000	143	

THE MAKING OF ORDINARY BRICK AND DRAIN TILE.

Ordinary brick and drain tile are the crudest forms of clay wares made in the State, and their manufacture requires but little, if any, technical skill. They form, however, a large proportion of the commercial output of such wares, and the aggregate sum invested in the business of their making is a large one.

The clays used in their structure are either plastic drift or sedimentary clays, both of which are comparatively common in all parts of the State. The only preparation which these clays usually receive is the tempering in crude pug mills. The bricks are made by either hand moulding or by soft-mud brick machines; the tile on a form of the auger machines especially adapted for the purpose. The drying of the bricks is accomplished by the air and sunshine, in open yards, or in racks and pallets protected by sheds. The tile are dried in the latter manner.

The burning of tile usually takes place in round, down-draft kilns, of small dimensions. The bricks are burned either in permanent, clamp up-draft kilns protected by sheds; or, in the smaller yards, in the old-fashioned temporary casing or scoving kilns, each of which is but a nine-inch wall put up around a green kiln and taken down after each burning. The clamp kilns are far superior, and in the long run more economical; as the labor of rebuilding the kiln at each burning is saved, and a much larger percentage of the bricks burned are first-class.

The stiff-mud process of making ordinary brick has not gained much headway in Indiana. Such a process is best suited to a plastic unctuous clay, but the brick are always more or less imperfect, and adapted only for inside work. The soft-mud machine makes a brick of better structure, but each brick has one rough side where the mold is struck off. Brick made by hand are freer from structural faults than by either of the machine processes, but the possible daily output is much smaller.

An attempt was made to gather full statistics relative to the manufacture of ordinary building brick and drain tile in the counties covered by this report. Blanks were sent to each manufacturer, and many of the yards were visited personally. The following table, while not complete, owing to the failure of a small number of the makers to return the blanks, gives the more important facts concerning the industry. The figures are for 1895, and according to statements of the brick and tile-makers, represent only about two-thirds of the average annual business. The continuous drouths of recent years have greatly diminished the demand for drain tile, and the general business depression that for ordinary building brick.

Statistics of Ordinary Building Brick and Drain Tile.

Name of Maker.	Location.	Capital Invested.	How Moulded.	How Dried.	Annual Output in 1895.	Value of.	No. Hands Employed.	Average Daily Wages.	No. of Months Worked.
Bracken & Elliott.	Rockville.	$1,500	"Hoosier and Eagle" Machines.	Open yard.	400,000	$2,200	6	$1.25	6
J. G. L. Myers.	Bloomingdale.	$1,500		Sheds and pallets.			6	$1.00	6
W. H. Prather.	Covington.	$1,200	Hand.	Open yard.	200,000	$1,200	8	$1.35	3
J. M. Booe & Son.	Steam Corner.	$2,500	"Ohio" Brick and Tile Machine.	Sheds and pallets.	50,000 and 90,000 tile.	$1,850	4	$1.00	5
Daniel Carpenter.	Mellott.	$4,000	"Hoosier" Machine.	Sheds and pallets.	25,000 and 110,000 tile.	$1,650	5	$1.25	6
Geo. F. Holder.	Attica.	$2,000	Hand.	Open yard.	300,000	$1,650	10	$1.50	6
Jas. A. Furr.	Steam Corner.	$2,000	E. M. Freese Auger Tile Machine	Sheds and pallets.	100,000 tile.	$2,000	6	$1.15	5
Geo. W. Campbell.	Toronto.	$3,000	Terre Haute Tile and Brick Machine.	Sheds and pallets.	40,000 and 72,000 tile.	$1,500	4	$1.25	5
Omara Bros.	Terre Haute.	$6,000	Hand.	Open yard.	1,100,000	$6,000	16	$2.00	6
Wm. Baker.	Terre Haute.	$2,000	Hand.	Open yard.	800,000	$4,400	7	$2.00	6
W. Bergmann.	Terre Haute.	$5,000	Hand.	Open yard.	1,000,000	$5,500	14	$2.00	6

Statistics of Ordinary Building Brick and Drain Tile—Continued.

Name of Maker.	Location.	Capital Invested.	How Moulded.	How Dried.	Annual Output in 1895.	Value of.	No. Hands Employed.	Average Daily Wages.	No. of Months Worked.
Chas. Hoff.	Terre Haute.	$10,000	Hand.	Open yard.	3,500,000	$18,000	40	$2.00	7
J. Bennett & Sons.	Terre Haute.	$3,000	Hand.	Open yard.	1,700,000	$9,350	14	$2.00	6
Emil Teitge.	Terre Haute.	$4,000	Hand.	Open yard.	500,000	$2,500	15	$2.00	6
Henry Offen.	Terre Haute.	$1,500	Hand.	Open yard.	350,000	$1,750	8	$2.00	6
Terre Haute Pressed Brick Company.	Terre Haute.	$10,000	"Henry Martin" Machine.	Sheds and pallets.	3,500,000	$20,000	30	$2.00	7
L. O. Sheets.	Riley.	$1,500	"Hoosier" Machine.	Open yard.	400,000	$2,000	11	$1.25	5
Carter Clay Works.	Coal Bluff.	$2,000	Terre Haute Brick and Tile Machine.	Sheds and pallets.	425,000	$2,250	7	$1.20	7
David McGrew.	Lewis.	$600	Hand.	Open yard.	135,000	$900	6	$1.50	2
C. H. Morgan.	Prairie Creek.	$3,000	Hand, and Tile Machine.	Open yard and sheds and pallets.	250,000 and 150,000 tile.	$3,500	6	$1.25	4
Jas. W. Watts.	Sandford.	$1,000	"Richmond" Tile Machine.	Sheds and pallets.	120,000 tile.	$2,000	6	$1.00	2
Clay City Brick Company.	Clay City.	$5,000	"New Anderson" Machine.	Open yard.	800,000	$3,600	18	$1 30	6

Chas. O. Reutschler.	Centre Point.	$1,000	"Old Reliable" Machine.	Open yard.	350,000	$1,925	4	$1 40	2
F. M. Tapy.	Poland.	$1,100	"Tiffany Centennial" Machine.	Sheds and pallets.	90,000 tile.	$1,200	5	$1 00	7
Woods Bros.	Spencer.	$4,000	"Brewer" and "New Departure" Machines.	Sheds and pallets.	200,000 and 2 kilns of tile.	$2,000	9	$1 15	6
Geo. G. Kaiser.	Patricksburg.	$650	"Old Reliable" Machine.	Open yard.	75,000	$375	1	$1 25	4
Jas. F. Hyatt.	Coal City.	$15,000	One "Potts" Soft Mud and One "Plymouth" Stiff Mud Machine.	Sheds and pallets.	2,500,000	$11,000	30	$1 25	6
Taber & Moore.	Quincy.	$400	Hand.	Sheds and pallets.	6 kilns tile.	$720	4	$0 75	3
Wm. E. Routt.	Cunot.		Hand.	Open yard.	75,000	$500	7		2
J. B. Mullane.	Sullivan.	$2,500	Hand.	Sheds and pallets.	850,000	$4,250	12	$1 25	7
Chrisman Bros.	Sullivan.	$1,500	Hand.	Open yard.	675,000	$3,375	11	$1 50	7
Jas. Nichols.	Sullivan.	$1,500	Hand.	Open yard.	400,000	$2,000	6	$1 50	7
J. P. Walls	Carlisle.	$6,000	"Anderson Chief" Machine.	Sheds and pallets.	600,000 and 45,000 tile.	$3,900	6	$1 10	7
W. C. Bennett.	Farmersburg.	$2,000	Hand.	Open yard.	360,000	$3,000	4	$1 65	5
Lyontown Brick Company.	Cass.	$1,000	"Anderson Chief" Machine.	Sheds and pallets.	380,000	$1,900	9	$1 10	4
Jos. O'Neal & Sons.	Shelburn.	$1,000	Hand.	Open yard.	118,000	$590	4	$1.25	2

Statistics of Ordinary Building Brick and Drain Tile—Continued.

NAME OF MAKER.	Location.	Capital Invested.	How Moulded.	How Dried.	Annual Output in 1895.	Value of.	No. Hands Employed.	Average Daily Wages.	No. of Months Worked.
Vincennes Brick & Tile Co.	Vincennes.	$15,000	"Henry Martin" Machine.	Sheds and pallets.	2,000,000	$10,000	20	$1.50	7
F. G. Lutes & Son.	Montgomery.	$3,000	E. M. Greer's Stiff Mud Machine.	Sheds and pallets.			10	$1.25	6
E. N. Dougherty.	Odon.	$3,000	"Quaker" Machine.	Sheds and pallets.	900,000	$4,900	12	$1.10	4
H. Smiley & Son.	Odon.	$4,000	Kells & Sons "Auger" Machine.	Sheds and pallets.	420,000 and 100,000 tile.	$4,300	8	$1.00	6
Brown Bros.	Washington.	$10,000	"Quaker" Machine.	Sheds and pallets.	1,500,000	$7,500	25	$1.25	7
Riester Bros.	Washington.	$4,000	"Quaker" Machine.	Sheds and pallets.	800,000	$4,000	7	$1.25	7
Philip Kretz.	Washington.	$7,000	"Quaker" Machine.	Sheds and pallets.	1,000,000	$5,000	14	$1.25	6
Andrew M. Keck.	Bramble.	$1,000	Hand.	Open yard.	185,000	$925	8	$1.00	2
M. Moran & Sons.	Loogootee.	$500	Hand.	Open yard.	230,000	$1,150	5	$0.80	3
Wm. Lawhead.	Loogootee.		Hand.	Open yard.	200,000	$1,000	4	$1.00	3
Nicholas Melchior.	Jasper.	$800	Hand.	Open yard.	400,000	$1,900	6	$1.35	4

Michael Hochegsang.	Jasper.	$3,000	"Quaker" Machine.	Open yard.	650,000	$3,000	11	$1.35	6
Bockting Bros.	Huntingburgh.	$2,000	Hand.	Open yard.	400,000	$2,000	6	$1.25	6
Wm. H. Stormout.	Princeton.	$3,500	"Little Wonder" Machine.	Sheds and pallets.	100,000 and 60,000 tile.	$1,900	5	$1.00	7
W. G. Kidd	Princeton.	$5,000	"Eagle" Machine.	Sheds and pallets.	1,500,000	$9,750	25	$1.60	6
Potter & Kimball.	Owensville.	$2,000	Hand.	Sheds and pallets.	300,000	$2,000	7	$1.25	7
Johnson Bros.	Oakland City.	$2,000	"Quaker" Machine.	Sheds and pallets.	400,000	$2,700	11	$1.25	6
Thomas Reed.	Petersburg.	$10,000	Potts' Machine, and Kell's Tile Machine.	Sheds and pallets.	750,000, and 8 kilns of tile.	$4,700	18	$1.25	7
Wm. C. Schnute & Co.	Evansville.	$4,000	Hand.	Open yard.	1,000,000	$4,500	8	$1.50	7
Louise Griese.	Evansville.	$2,500	Hand.	Open yard.	500,000	$2,250	8	$1.50	7
Buente & Hoge.	Evansville.	$3,000	Hand.	Open yard.	700,000	$3,150	6	$1.50	6
Wm. Schnute.	Evansville.	$5,000	Hand.	Open yard.	1,200,000	$5,400	12	$1.60	7
First Avenue Brick Co.	Evansville.	$15,000	"Creager" Machine.	Sheds and pallets.	3,000,000, and 7 kilns of tile.	$14,500	30	$1.50	7
Henry Alexander.	Evansville.	$2,000	Hand.	Open yard.	400,000	$1,800	8	$1.50	6
Samuel Wagler.	Evansville.	$2,000	Hand.	Sheds and pallets.	500,000	$2,200	8	$1.50	6

Statistics of Ordinary Building Brick and Drain Tile—Continued.

NAME OF MAKER.	Location.	Capital Invested.	How Moulded.	How Dried.	Annual Output in 1895.	Value of.	No. Hands Employed.	Average Daily Wages.	No. of Months Worked.
Suhrheinrich Bros.	Evansville.	$10,000	"Creager" Machine.	Sheds and pallets.	2,500,000	$11,250	20	$1.40	7
Adam Helfrich.	Evansville.	$15,000	"Henry Martin" Machine.	Sheds and pallets.	2,000,000	$9,000	25	$1.50	7
William Meinert.	Evansville.	$3,000	Hand.	Sheds and pallets.	1,000,000	$4,500	10	$1.50	7
Rudolph Buente.	Evansville.	$2,500	Hand.	Sheds and pallets.	600,000	$2,700	7	$1.50	7
Klamer Bros.	Evansville	$3,000	Hand.	Open yard.	650,000	$2,800	6	$1.50	6
William Hertung.	Evansville.	$3,000	Hand.	Sheds and pallets.	500,000	$2,250	8	$1.50	6
Louis Klostermier.	Boonville.	$8,000	Morena Brick and Tile Machine.	Open yard.	600,000	$3,000	12	$1.00	7
Lowell Bros.	Boonville.	$3,000		Sheds and pallets.	15 kilns of tile.	$3,000	6	$1.10	8
Henry Felwisch.	Boonville.	$12,000	"Grand Automatic" Machine.	Sheds and pallets.	1,000,000	$5,000	10	$1.00	7
Cook Bros.	Newburgh.	$2,500	"Penfield" Brick and Tile Machine.	Sheds and pallets.	150,000, and 8,000 rods tile.	$1,200			5
Henry Weihe.	Newburgh.		Hand.	Open yard.	500,000	$2,500	8	$1.50	5

Jarvis & Thene.	Elberfield.	$4,000	Hand.	Sheds and pallets.	500,000	$2,750	6	$1.25	4
Eigenmann Contract Co.	Rockport.	$4,500	Hand.	Open yard.	1,200,000	$6,000	16	$1.25	7
Philip Feigel.	Rockport.	$1,000	Hand.	Open yard.	350,000	$1,750	4	$1.25	5
Anton Dickman.	Tell City.	$1,500	Hand.	Open yard.	500,000	$2,750	7	$1.25	7
Wm. Hampschafer & Son.	Tell City.	$3,000	Hand.	Open yard.	200,000	$1,000	8	$1.25	3
Total.		$295,250			53,343,000 brick and 1,250,000 tile.	$291,510	792		