REPORT OF THE DEPARTMENT OF GEOLOGY AND NATURAL RESOURCES

(Forty-Third Annual Report)

EDWARD BARRETT, State Geologist.

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FOREWORD

Early last spring a request was made by the U. S. Bureau of Mines for co-operative work in raw materials that would conduce to the winning of the war. Acting on the suggestion of the above Bureau I selected three raw materials for the work of the field season:

1. A survey of the pyrite of the coal fields.
2. A survey of flints or cherts.
3. A survey of molding sands.

The pyrite is used in the manufacture of sulphuric acid, which is necessary in making high explosives. The flints or cherts are used as abrasives, and the molding sands are used in our steel and iron industries.

The field work was done under my direction, ably assisted by the men whose names appear at the head of the several surveys.

INTRODUCTION

BY EDWARD BARRETT, STATE GEOLOGIST

The U. S. Geological Survey has divided the coal areas of the country into six large units or provinces, viz., the Eastern, the Interior, the Gulf, the Northern Great Plain, the Rocky Mountain, and the Pacific Coast provinces.

The Interior province includes all the bituminous coal fields of the Mississippi valley and the coal fields of Texas and Michigan. The Interior province is again divided into the Eastern, Western, Southwestern, and Northern regions. The Western region embraces the coal fields of Iowa, Missouri, Kansas, Arkansas, and Oklahoma. The Eastern region embraces the coal fields of Illinois, western Kentucky, and Indiana. Thus it is seen that the Indiana coal fields belong to the Eastern region of the great Interior or Mid-Continent coal province, and it may be added that the coal fields of Indiana lie on the very eastern margin of the great Interior province. To be more specific and to confine the discussion within the limits of the State of Indiana, we would say that the following sixteen counties are underlain with coal: Vermillion, Parke, Vigo, Clay, Sullivan, Greene, Knox. Daviess, Martin, Gibson, Pike, Dubois, Posey, Vanderburgh, Warrick, and Spencer. In addition to these the following nine counties are partially underlain with coal: Warren, Fountain, Montgomery, Putnam, Owen, Lawrence, Crawford, Orange, and Perry. The sixteen counties above comprise about 7,000 square miles, and this may be taken as a conservative estimate of the number of square miles of workable coal lands in Indiana.

The coal regions of the great Interior province have a total thickness of about 2,000 feet in southeastern Illinois. The portion of the basin included in the Indiana field has a thickness of about 1,300 feet. Coal seams of various thicknesses to the number of thirty-four occur, and two-thirds of this number are fairly persistent over the entire coal area. The thickness of the seams varies from a few inches to 12 or 14 feet. All of the coals of Indiana are of the bituminous class, and may be divided into Bituminous, Block, and Cannel coals. The principal workable seams of coal are numbered from the bottom upward, by using Roman numerals, from Coals I. to IX. Between any two seams of coal there are alternate layers of shale, sandstone, or limestone.

The pyrite investigations made during the past summer under the direction of the writer and ably assisted by Mr. L. P. Dove, of Northwestern University at Evanston, Illinois, show that the best and most extensive pyrite-bearing seams are Coals III, V, and VI, and of these three seams, perhaps 80 per cent of the pyrite occurs in Coal V. The discussion of the origin, occurrence, and concentration of pyrite in our coal seams is found in another part of this report. And in addition to the above phases of the investigation, Messrs. Holbrook and Dove discuss the chemical and physical composition, and appearance of pyrites, as well as its uses and methods of recovery. The matter of the preparation of pyrite for the market and the question of a modern washery plant are also outlined by them.

PRELIMINARY REPORT ON THE MOLDING SANDS OF INDIANA

(By Allen D. Hole, Assistant, and Edward Barrett, State Geologist.)

PREFACE

In planning for the investigation of the molding sands of Indiana, it was thought desirable that information on the following points should be sought, namely:

1. Data as to the amount, kinds, and value of molding sand used by foundries in Indiana the past year, together with information as to the present sources from which the molding sands used are secured.

2. Data concerning deposits of sand within the State which are being used by foundries for molding sands, together with an examination of the various grades which occur.

3. The mode of occurrence of these deposits, for the purpose of determining conditions under which they were formed.

4. The location of undeveloped deposits which give especial promise for the production of sands of a desired quality under conditions which would make their exploitation economically possible.

The work outlined above has been only partially completed, since the amount of time available for the work has been limited to a portion of the summer of 1918, but the results so far reached seem to be of sufficient importance to warrant the issuing of this preliminary report, since it has been found that there is a great demand for information in regard to the molding sands of the State both on the part of the owners of foundries and also on the part of the men who own land upon which deposits of sand are found which are thought to be suitable for use as foundry sands. The conditions which make this demand for information particularly urgent are, briefly, the great increase in the iron industry in the State of Indiana in the past few years, together with the fact that the opening up of new deposits of molding sand has not kept pace with the increased demand in the State. To these two conditions there are to be added two others, namely, the increased difficulty which foundrymen have experienced within the past year of securing cars for the transportation of molding sand as rapidly as it was needed, and the increased freight charges for the transportation of the sand, even after the cars needed were secured. The effect of these conditions working together has of course been to stimulate the search for suitable molding sands located as near as possible to the foundries in order that the cost of transportation might be reduced and that an ample supply when needed might be more sure. On the part of those owning deposits of sand suitable for use in the foundry there has also come the increased inducement of a higher price which the foundries can readily afford to pay in consideration of finding the sand nearer, so that even though a higher price per ton is paid for the sand desired the total cost when delivered to the foundry may be less because of the elimination of a considerable part of the increased freight charges.

It is for the purpose therefore of assisting both the foundrymen and the owners of deposits of molding sand that this partial report is issued at this time. It is hoped that the investigations outlined above may soon be carried to completion and that a final report representing in an adequate way the molding sand industry in the State of Indiana may be given to the public.

INTRODUCTION

The term molding sand as here used is intended to include those natural mineral deposits, largely siliceous, which are suitable for making molds or cores for use in casting metals, especially iron, steel, brass, aluminum and bronze. The materials suitable for such a purpose vary through a relatively wide range from a very coarse sand, or even fine gravel on the one hand to a heavy loam containing a considerable amount of clay, on the other. There is also a very considerable range in the kind of material needed, depending upon the character of the casting to be made, and the methods to be employed in the work. For example: If the size of the casting to be made is small, that is, weighing from a few ounces up to a few pounds, the material desired is usually a fine to a very fine sand and if an especially smooth surface be desired in the finished casting, a considerable amount of clay in the sand is not only permissible but may be necessary; on the other hand, if the casting is large, weighing from a few hundred pounds up to forty or fifty tons, the sand required is usually coarse with a high degree of porosity or openness, with the amount of clay permissible relatively small. Again, the quality of the sand required for making the mold, that is the form into which the molten metal is poured, is in general different from the quality of material needed in making the cores, that is, those parts which are introduced into the mold representing holes or open spaces in the finished casting. Furthermore, a different quality of sand is required for what is termed "green-sand molding," as contrasted with dry or baked sand. The term "green-sand molding" here applies to the use of moist sand without any special preparation before the molten metal is poured into the mold while in the case of the dried or baked sands the mold is subjected to a greater or less degree of heat to remove most of the moisture before the molten metal comes in contact with its surface. Although these and other conditions which might be named make possible the use of sands of a rather wide range as to composition and properties, nevertheless for any one kind of work the quality of sand used should be nearly uniform in order that uniformly good work may be turned out. It is therefore necessary that the owners of deposits of sand suitable for use in the foundry should be careful in taking out the sand, either to keep the different grades which may be present separate or to mix the different grades in a fixed proportion so that the quality of a given grade when shipped shall be as nearly uniform as possible. If a producer of sand becomes known among foundrymen as one who sends out sand practically uniform for each grade offered he will be able not only to retain his old customers but will be able to increase his business to an extent which would be impossible if he is less careful in sending out sands practically uniform for each grade which he is able to supply.

As yet, no well established method of testing the qualities of molding sand has been found, although there is an increasing disposition to place some reliance upon physical analysis as furnishing a means of comparing the quality of sands derived from different sources or from the same pit at different times. The main reliance, however, is upon the results which are secured by the use of the sand in the foundries, and it is therefore absolutely necessary in the development of any deposits that the advice of a man accustomed to judging the quality of molding sand should be sought before any great expense is incurred. Men of the kind of experience required are to be found among the foremen of foundries and also among geologists who have given special attention to this phase of the subject.

PROPERTIES OF MOLDING SAND

The value of a sand for use in foundry work is determined by certain properties, chief among which are the following:

Color. The first property here mentioned, namely, color, is, strictly speaking, not an essential characteristic of molding sand providing the other characteristics named below are present, but in view of the fact that the color of the sand is one of its most noticeable characteristics and in view of the farther fact that in prospecting for molding sand it is very helpful to have in mind the color which is most commonly found associated with the really essential properties, it is worth while mentioning the property of color, first.

The color of molding sand as used on the floors of foundries is very dark to black. This black color is, however, due to the fact that a considerable proportion of the sand has been used one or more times before in the making of molds and there has become incorporated in the sand a certain amount of graphite and minute particles of iron, together with dust containing a small amount of soot, which gives the very dark or black color to the sand after it has been in the foundry and the process of making castings has been going on. The color of the sand as found in the pits from which it has been taken and as shown in the bins in the foundries from which the sand is drawn to replenish the floors is most commonly yellow or yellowish-brown. In some cases, especially in the case of the coarser sands used for large castings, the color is decidedly red. In the case of sand used for the making of cores, the color is usually white or light gray, since the kind of sand used in largest quantities for the making of cores is lake sand or sand taken from valleys or hills near streams, which has been deposited by water. In prospecting for molding sand, therefore, it is well to have in mind the fact that a sand suitable for making molds is likely to be yellowish-brown to reddish in color and that sand suitable for use in making cores may be a clean white or light gray sand.

Bond or Cohesiveness. One of the essential properties of a good molding sand is the ability of the grains to adhere to each other when slightly moistened. A rough test of the amount of bond which the sand contains can be made by squeezing in the hand some of the slightly moistened sand and observing the amount of resistance to an effort to pull the mass apart after it has been pressed together. It has been found that the bonding power of a sand depends chiefly upon the fineness of grain, the presence of moisture, and the presence of clay particles. A good molding sand should have enough cohesiveness to enable the sand to retain the shape given to it in molding after the pattern has been withdrawn and also sufficient cohesiveness to withstand the action of the molten metal as it is poured into the mold; that is, sufficient cohesiveness so that the particles of sand on the face of the mold will not fall away as the metal is being poured in. If the amount of clay or very fine sand particles is too great the value of the sand is impaired because the next-named essential property is to too great a degree destroyed.

Openness or Permeability. Another essential property of molding sand is its openness or permeability. This means the degree of readiness with which the sand will permit gases under a slight pressure to pass through it. In "green-sand molding" a certain amount of moisture is present in the sand when the molten metal is poured into the mold. This moisture is in part converted quickly into steam and must find a way of escape without separating the sand grains from each other, if the casting is to come from the mold uninjured. In the case of molds which are dried or baked, there is present in the spaces between the sand grains, air, which upon being heated by the molten metal expands and, like the steam, must find a way of escape without forcing the grains apart if the casting is to come from the mold in perfect condition. In the "green-sand molding" also, there is the action of the air as well as the action of the moisture. In all cases there is in addition a certain amount of gases of various kinds which are given off from the molten metal itself in the process of cooling, and this adds itself also to the steam and to the heated air, and unless the mold is sufficiently open blow holes will be formed and the perfection of the casting will be marred.

The openness or the permeability depends upon the size of the pores or open spaces between the grains of sand. Other things being equal, the coarser the sand the greater the permeability. A fine sand may have as large a volume of pore space, that is, as great porosity, but be much less open than a coarse sand, just because the pores in the fine sand are all small and therefore obstruct to a greater degree the passage of the gases which at the time of casting must find a way of escape. If the amount of clay particles or fine sand particles is too great the openings between the sand grains are filled up and therefore the presence of too high a percentage of the materials which give bonding power destroys to too great a degree the necessary openness of the sand.

Refractoriness. By refractoriness is meant the property by virtue of which the sand resists the effect of the heat of the molten metal. In order that a molding sand shall be suitable for use in making castings it must of course be able to retain its form without melting even though molten metal comes in contact with it and remains in contact until it cools. It is because common sand in general is composed chiefly of quartz which will not melt at the temperature of molten iron that it has been found suitable for use in the making of molds for use in foundries.

Composition. Closely connected with the property just named, refractoriness, is that of composition, since the ability of sand to resist heat depends upon the kinds of minerals present. As already stated the mineral which should be present in largest quantity is quartz. In order that there shall be sufficient bonding power a small percentage of clay is permissible, but if there be present more than a fraction of a per cent of iron, or if there should be present lime or magnesia in considerable amounts, these substances will act as a flux and cause the melting of a greater or less amount of the sand next to the molten metal. This will introduce defects into the casting; and especially in castings where a very high degree of heat is necessary, such as steel castings or malleable iron castings, the melting of the sand when fluxing elements are present is likely to be sufficient to injure the casting to such a degree as to make it unfit for the purpose for which it was intended.

Texture. The texture of the sand is closely related to the property of openness, which has already been discussed. Texture relates to the size of particles and therefore coarseness of texture necessarily accompanies high permeability. It cannot, however, be stated that the texture determines the permeability entirely, since molding sands are made up of a mixture of sand grains of different sizes and the relation between the percentage of each of the sizes is also a factor in determining the openness or permeability of the sand. It is in giving information in regard to this property of the sand that physical analyses have one of their chief values.

Life of the Sand. Another property which is important is expressed by the term life of the sand. This means the number of times which a given portion of sand can be used before it loses some one of its essential qualities. The quality which is soonest destroyed is that of bonding power. Some good molding sands can be used but once, as the cohesiveness seems to be destroyed by one contact with the molten metal. Others may be used again and again. It is, of course, true that in a given mold the sand next to the molten metal loses its cohesiveness first, and in the case of all sands a certain amount of fresh material must be added each day to the supply on the floor, but there is a very wide range of difference in the amount which must be added each day when sands from different sources of supply are used. From experiments which have been made it seems that the loss of life or loss of bonding power is due chiefly to the chemical changes produced in the clay in the presence of the heat of the molten metal. Some other elements enter, perhaps, also.

MOLDING SANDS USED BY INDIANA FOUNDRIES IN 1918

Data in regard to the grades of molding sand used by Indiana foundries, sources of supply, amount, and cost, have been secured from about 90 per cent of the foundries in the State. The statistics collected are in most cases accurate, being furnished by officers of the various firms interviewed, from records on file in their respective offices. In a few cases the amounts reported are estimates only. The total results given in the table below are listed as "approximate" partly because some of the data collected are known to be estimates, but chiefly because the prices charged per ton have not been uniform throughout the year, and also because the cost of transportation has likewise been changing. Both of these changes have, however, been in the direction of increase, so that the totals for the calendar year, 1918, are probably somewhat in excess of the amounts tabulated below which have been made up from the figures reported by the various foundries.

APPROXIMATE AMOUNT AND VALUE OF MOLDING SAND USED IN INDIANA IN 1918

(Values given include freight charges from pits to foundries.)

	Molding Sands.		Core Sands.	
	Tons.	Value.	Tons.	Value.
From deposits in Indiana	23,568	$35,804	31,548	$36,522
From deposits outside of Indiana	100,485	227,442	5,250	10,710
Total	124,053	$263,246	36,798	$47,232

Total molding sands and core sands, 160,851 tons.

Total cost delivered at foundries, $310,478.00.

Of the above total, 55,116 tons, costing $72,326.00, were derived from deposits within the State of Indiana, while 105,735 tons, costing $238,-152.00, were secured from sources of supply outside of Indiana.

DEPOSITS OF SAND IN INDIANA

The examination of localities in Indiana where deposits of molding sand are known or where it is probable that they exist has not been completed. The investigations so far made have shown that molding sand of excellent quality for certain classes of work is found in not less than twenty-five counties of the State. The localities where it has been ascertained that deposits of sands occur which are suitable for use in foundries are listed below by counties. In some cases it is evident that the supply is limited and perhaps would not warrant the expenditure of a sufficient amount of money in development to place the sand on the market outside of supplying the needs of local foundries. In other cases the supply is very large and has already been developed to such an extent as to warrant the laying of a switch to the nearest railroad and the shipment of sand amounting to hundreds of carloads from a single point per year. Foundries desiring to secure sand from any of the points named below may secure further information by writing to the companies or individuals named.

Allen County. Molding sand has been found near New Haven on a farm belonging to Sturm Brothers and is delivered by them to foundries in Ft. Wayne by wagon.

In the northern part of the city of Ft. Wayne, along the river, deposits are found containing some sand suitable for use as molding and core sands. Southwest of Ft. Wayne about three miles, near the greenhouses on the Bluffton road, molding sand is found on farms belonging to Charles Stuck and William Stuck (postoffice R. R. Ft. Wayne, Indiana,) which is delivered by wagon to foundries in the city.

Bartholomew County. Sand suitable for use in foundry work is found about three miles east of Columbus. Supplied to foundries in the city by Fred Dahn, Jr.

The southern part of Bartholomew County no doubt contains good molding sand at a number of points but it is so far not developed.

Cass County. Sand used chiefly for core sand is supplied from Lake Cicott, by the Lake Cicott Sand and Gravel Company.

Clark County. Low hills and terraces on the east side of Silver

Creek, about one and one-half miles east of New Albany, afford a supply of molding sand of good quality which is being taken out for the use of foundries in New Albany. The pits already opened are on the farms of Mr. Martin Durking, and Messrs. Taylor, Emery, and McCullough.

Clay County. A deposit of molding sand on the property of the Crawford and McCrimmond Company's foundry supplies the needs of that foundry for molding sand.

Elkhart County. Deposits in the northeastern part of Goshen, the property of local foundries, are used to supply their needs in part.

Grant County. Deposits of molding sand on the north side of the Mississinnewa river at Marion have been used to a limited extent by foundries in the city to supply their local needs. These deposits are not, however, being used at the present time except to a very limited extent.

Henry County. A small amount of good sand is found in the northwestern portion of Newcastle which is drawn upon by a local foundry to supply a part of its needs. The covering of soil and glacial till overlying the molding sand is, in the only place so far examined, too great to make an extensive digging of the sand at this point profitable.

Jackson County. One and one-half miles southwest of Brownstown on the farm of Phillip Gossman a deposit of sand has been worked for about twenty years and is reached by a switch from the B. & O. S. W. railroad. The sand is here chiefly somewhat coarse in quality and very suitable for use in making heavy castings. The output is at present controlled by the Newport Sand Bank Company, Newport, Kentucky.

About three miles south of Seymour, on a farm belonging to John Kilgas (R. R. 5), Seymour, Indiana, molding sand of good quality is found similar in general to the deposit near Brownstown. Molding sand has been shipped from this pit from time to time for several years.

Jefferson County. Fine molding sand, and sharp sand suitable for use in making cores, are found at various points in and near Madison in amounts sufficient to supply the needs of the local foundries.

Knox County. Foundries in Vincennes are supplied chiefly from local deposits for both molding and core sands. The pit supplying most of the sand used at present is on land owned by Theodore Wagner, located just west of Lakewood Park.

Lagrange County. Extensive deposits of sand and gravel one mile northeast of Wolcottville are being developed by the Northern Indiana Sand and Gravel Company. The sand and gravel, washed and graded, is shipped to contractors chiefly for construction purposes, but carload shipments of their "No. 2" sand are constantly in demand for use by foundries as a core sand.

Lake County. From various points in the county, especially at and near East Gary and Hammond, sand is hauled or shipped to foundries for use in making cores.

Laporte County. Sand dunes near Michigan City supply most of the sand used by Indiana foundries for core-making. So far as reports received show, the firms having offices in the county that ship the largest amount of "lake sand" are the Hoosier Slide Sand Company, the

Pinkston Sand Company, and the Silica Sand Company, all of Michigan City, Indiana.

Marion County. Molding sand of good quality has been supplied for some years by James A. Hagerty, 1667 Union street, Indianapolis, Indiana. The pits from which the sand has been secured are located in or near the city of Indianapolis.

Morgan County. Molding sands and core sands of practically all grades needed by foundries are shipped by Bradford Bros., of Centerton. This deposit, located about one and one-half miles southwest of Centerton, has been a source of supply for about thirty years.

Investigations made in the progress of the work during the past summer indicate that other deposits of molding sand of good quality occur directly across White river east of Bradford Bros., and on Indian creek, two miles east of Martinsville, on the farm of J. E. Robinson. Also on the north bluff of White river four miles southwest of Martinsville near Hindsdale.

Porter County. For some years shipments of molding sand have been made from pits about five miles east of Valparaiso, one mile or more from Nickel. These pits are operated by the Garden City Sand Company, of Chicago, Illinois.

Shipments are also made from pits near McCool, in the northwestern part of the county by Mr. J. S. Robbins.

St. Joseph County. Foundries in South Bend and Mishawaka are for the most part supplied with various grades of molding sand from sources sufficiently near to permit delivery by wagon from pit to foundry. Some foundries purchase the sand in place, and haul with their own teams. In other cases the owners of the land deliver upon order.

A complete list of owners of land where good molding sand is found could not be obtained in the time available for the investigation, but the following includes those who have recently supplied the largest amounts, viz.:

G. W. Wiggins, Mishawaka, Indiana; and Charles Smith, Harvey R. King, David Whiteman, Albert Powell, William Konzen, and Edwin L. Perkins, all in or near South Bend.

Spencer County. Extensive deposits of good molding sand of medium to fine grade are found at Rockport and at other points near by, notably at Richland Junction. Shipments in quantity are being made by various companies, but chiefly by Hougland & Hardy, with office in Evansville as well as Rockport, and by the Southern Indiana Molding Sand Company.

Starke County. Sand used chiefly in making cores is shipped from pits about one mile southeast of North Judson. The business is under the management of Mr. C. W. Weninger, of North Judson.

Steuben County. Washed sand "No. 2," and in smaller amounts "No. 1," are grades supplied by Lennane Bros. from their sand and gravel separating plant at Pleasant Lake. These grades are supplied to foundries for use as core sands.

Tippecanoe County. "Bank sand," derived from stratified deposits in hills in the southwestern part of Lafayette, and other "sharp" sand from other localities in the city supply, in part, the needs of local foundries for core sands.

Vanderburgh County. Foundries in Evansville are in large part supplied with molding sand from deposits in or near the city of which the following are the principal localities reported, viz.:

(1) Just west of Oak Park Cemetery, operated by J. C. Hawkins.

(2) On the Newberg Pike, beyond the city limits (an extension of Lincoln avenue road).

(3) At Kentucky avenue and Division street, property of the Vulcan Plow Works.

Vermillion County. Sand suitable for core sand and molding sand is known to occur at and near Hillsdale, though shipments for these purposes are not at present being made.

Vigo County. One foundry in Terre Haute is supplied with molding sand, including coarse and medium coarse grades, from pits owned and operated by Harry Lynn (post office address, Terre Haute, Indiana, Route E.). These pits are between Terre Haute and Seeleyville, about five miles east of the former place. Other deposits occur near by which are not yet opened up.

GEOLOGICAL RELATIONS OF MOLDING SAND DEPOSITS

So far as now known the deposits of molding sand in Indiana lie either within the area which was covered with glacial ice in Pleistocene time, or near to streams flowing from the glaciated area. The materials appear, therefore, to be glacial in origin, though a part of the deposits, as for example those near Rockport, were laid down at considerable distances beyond the farthest limit of ice movement. In age the deposits are either Pleistocene or Recent. No residual deposits of molding sand, as distinguished from transported deposits, have been observed.

The agents involved in the formation of the deposits observed include the following as chief, viz.:

1. Water.
2. Wind.
3. Temperature changes and gravity, aided by organic agencies.

The frequent occurrence of molding sand in hills or terraces near to well developed drainage lines, but yet not directly adjacent to the alluvial flood plains which are almost invariably found in the bottom of such channels, seems to indicate that conditions favorable to the deposition of sand with small quantities of silt or clay were found in bay-like bodies of water extending away from streams swollen with water from rains and from melting ice, forming thus relatively quiet backwater areas in which most of the sand and a small portion of the clay held in suspension could come to rest. Examples of deposits which were probably formed under these general conditions are found in Morgan County, near Centerton; in Clark County east of Silver Creek, about one and one-half miles east of New Albany; in the eastern part of Vincennes, just west of Lakewood Park; and five miles east of Terre Haute along the valley of Lost Creek.

The work of wind is clearly the predominant proximate agent in the case of the sands used for cores derived from the dunes in the northwestern counties of the State; and while possibly not predominant, yet probably an important factor in such deposits as those at and near Rockport, where the loess seems to form an important part of the finer particles, constituting in some places the major part of the deposit, in other places mingling with true sand of various degrees of coarseness, becoming thus an important factor in giving to the product the necessary bonding power.

In certain other parts of the State as, for example, in St. Joseph County north of Mishawaka and again in parts of southern Bartholomew and northern Jackson counties, the history of the molding sand deposits seems to have been, in general, about as follows:

1. Deposition of sand, coarse, medium and fine in a broad sheet with a slightly undulating surface, sometimes by water, sometimes by wind, sometimes by the co-operation of both these agencies.
2. After the surface had become established permanently above the water level, or above the level of water for the greater part of the year, the wind added silt and clay particles from adjacent till areas, forming finally in co-operation with the growth of vegetation a soil, which while still sandy, was nevertheless much richer in fine mineral particles than the dune areas.
3. A gradual downward movement of a certain per cent of the silt and clay into the sand below, due to the co-operation of freezing and thawing, the slow downward filtration of water tending to move the finer particles into the larger openings, the growth and decay of roots of plants, the burrowing and carrying done by ants, worms, and other forms of animal life.

No doubt other agencies co-operated in the work, but it is conceived that the above-named agents and processes as the principal ones co-operated with other minor agencies to produce the kind of formation observed, namely, a layer of sandy soil, eight inches to two feet in thickness, underlain by fifteen inches to four or five feet of sand, silt and clay mingled together in proportions suitable for use as molding sand, grading downward gradually into a bed of clean sharp sand which can be used in the foundry only for cores.

SUGGESTIONS

1. The production of molding sand in the State could no doubt be greatly increased if a careful examination were made to ascertain the location of other deposits in addition to those now known, and in some cases to develop more fully deposits which are being worked for only a part of the time.
2. Detailed instructions concerning prospecting for new deposits can hardly be given; but in general it may be said that the most promising localities are, first, among the low hills a few rods to a mile or two away from a well developed valley—hills situated usually near to a tributary of the main stream, affording in this way a close connection with the larger valley; and, second, beneath gently undulating

surfaces which are covered with a distinctly sandy soil. When once a deposit of sand is found which appears to have the general qualities listed in the early part of this report as essential properties of molding sand, the assistance of some one who has had experience in judging such sands should be sought.

3. The kinds of sand purchased in largest amounts by foundries within the State from sources outside the State, are refractory sands suitable for use in making steel castings. While an increase in the production of molding sands of other kinds can perhaps be brought about most easily, it should be remembered that the production of refractory sands offers the largest field, and a consideration of this somewhat more difficult line of development of the molding sand industry should not be overlooked.

ACKNOWLEDGEMENT

The authors of this report hereby record their obligations to owners of foundries, superintendents, foremen, and other officers, for the uniform courtesy shown when an interview was sought on the questions involved in the investigation upon which report is here made. Without this hearty co-operation, involving in some cases hours of time unhesitatingly given by busy men, one part of this report could not have been written. In a precisely similar way owners and operators of pits from which the various grades of sand are produced, have given invaluable aid in another part of the work. To all those who have given such generous assistance acknowledgement is hereby gratefully expressed.

REPORT OF THE STATE SUPERVISOR OF NATURAL GAS

FLOYD E. WRIGHT, State Supervisor.

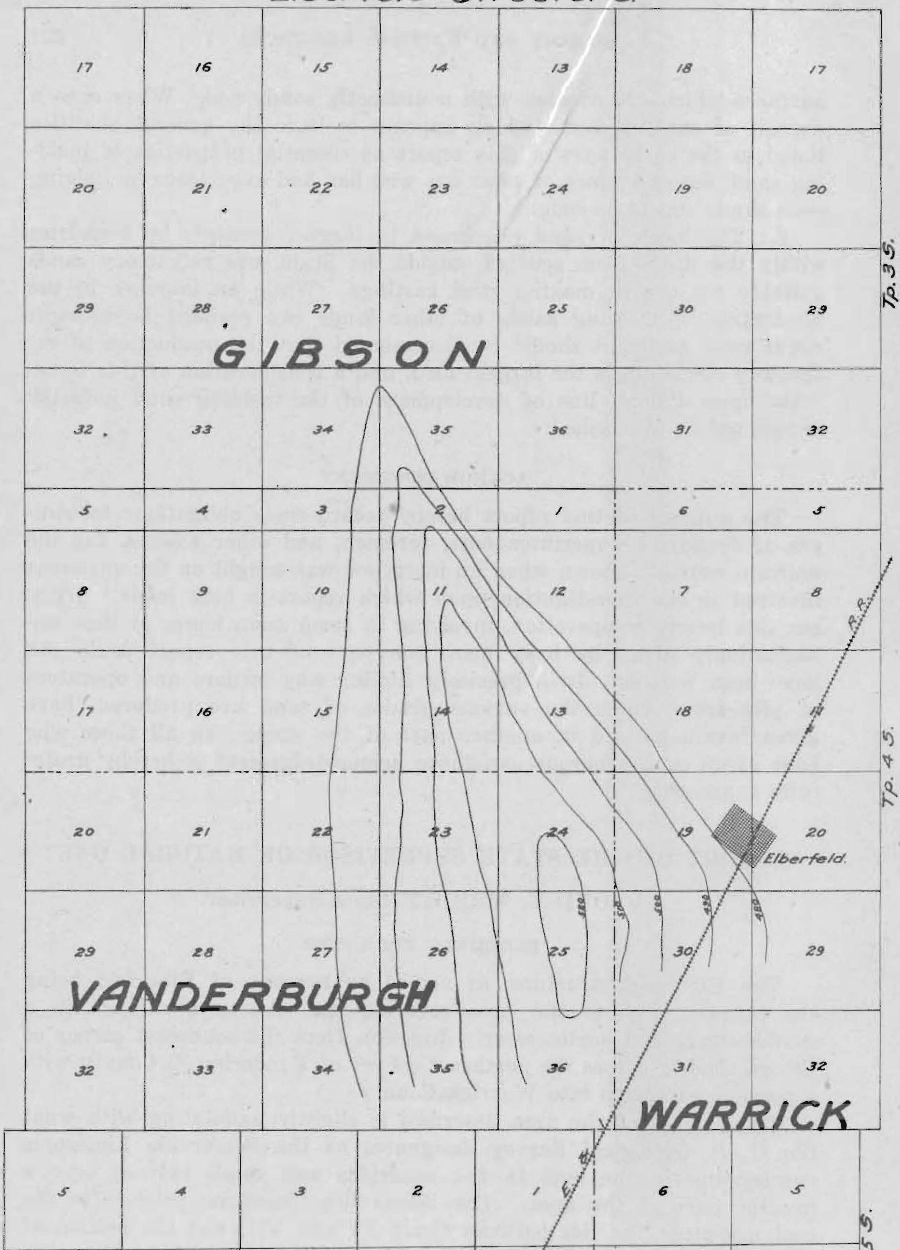
ELBERFELD STRUCTURE

The Elberfeld structure, so named on account of Elberfeld being the nearest town to the area covering the structure, extends in a southeasterly and northwesterly direction from the southeast corner of Gibson County across the northeast corner of Vanderburgh County with a possible extension into Warrick County.

The surface of the area described is slightly undulating with what the U. S. Geological Survey designates as the Somerville Limestone outcropping in the cuts in the roadsides and small ravines over a greater part of the area. The Somerville Limestone belongs to the coal measures and lies between Coals VI and VII, and the bottom of the limestone is 230 feet above the top of Coal V, which is 90 to 125 feet below the surface in this vicinity. The limestone in the eastern part of the area has been eroded away until only the bottom few feet remain, so that the levels taken and shown later indicate the bottom of the limestone, but farther west it shows a thickness of 35 to 40 feet.

The formations in general in this part of the State dip to the southwest, but in this area the formations have the necessary reverse dip

Elberfeld Structure.



to the east to form a well defined anticline. The formations from a point near the north end of the line between Sections 34 and 35, Tp. 3 S., R. 10 W., in Gibson County, following a line in a southeasterly direction (22° east of south) running through the middle of Section 25, Tp. 4 S., R. 10 W., in Vanderburgh County, dip to the northeast. The axis of the anticline rises to the southeast at the rate of 8 feet to the mile to a point in the south edge of Section 24, Tp. 4 S., R. 10 W., where it then dips to the southeast as far as it could be traced, since beyond this point the lack of outcroppings in the valley of Pigeon Creek made accurate work impossible. The Somerville limestone from the above mentioned point in Section 24 dips to the east for a distance of two miles, with a total reverse dip of 70 feet.

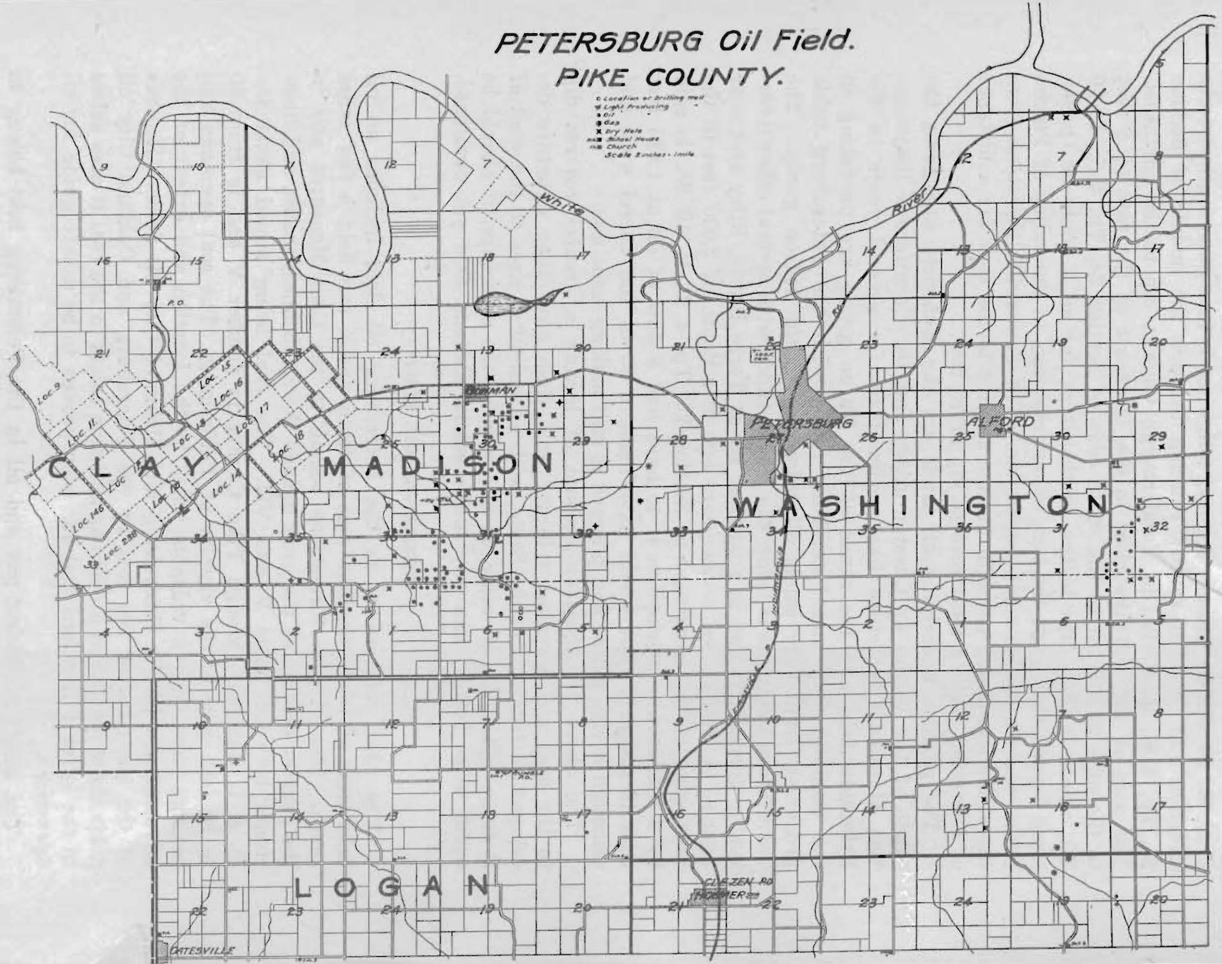
The possible underlying oil sands are the Mansfield sandstone, the sands of the Huron or Chester group and the Corniferous limestone. The Mansfield sandstone has produced oil for several years in the Princeton field and the sands of the Huron group are producing in the Oakland City and Petersburg fields, with the Petersburg fields producing from four sands all belonging to the Huron group. The Corniferous limestone is below the Huron sands with several other intervening formations and is producing oil at Terre Haute, Riley and near Lyons. A well drilled seven years ago to a depth of 2,000 feet in the west edge of this structure in Section 23, Tp. 4 S., R. 10 W., is said by a driller who worked on it to have had a flow of oil at 1,825 feet that if properly shot would have made a 60 to 100 barrel well, and although it was pulled and plugged is still making some gas.

The above structure on account of having a greater reverse dip to the east and covering a larger area than any other structure developed in that part of the State, with an unlimited area to the west of it from which the oil could be collected by the structure, it should be equal to or better than any southwestern Indiana field yet developed.

PETERSBURG OIL FIELD

The area referred to as the Petersburg oil field includes an oil field west of town, another east of town and a gas field a few miles south. The surface formations belong to the Coal Measures and in the greater portion of the area include the sandstones, shales, and limestones between Coals V and VII. The coal being mined along the E. & I. Railroad through Pike County is number V and is from 60 to 90 feet deep in the vicinity of Petersburg. The coal openings and borings have been a valuable index to the location and extent of the oil structure in the Petersburg and Oakland City oil fields. Records of the elevation of the coal in the Petersburg and Oakland City oil fields show that when a dome or anticline exists in the coal it also exists in the lower formations and has been proven to be a safe guide for oil operations.

The sands producing gas and oil in the Petersburg field belong to the Huron group of sandstones and shales, the two lower sands being the same as those producing in the Oakland City field, while the two upper sands, locally known as the Rumble and Gladdish, belong to the same group but do not produce oil in the Oakland City field. A dry



PETERSBURG Oil Field.
PIKE COUNTY.
Location or Drilling well
Light Producing
Oil
Gas
Dry Hole
School House
Church
White River
CLAY
MADISON
WASHINGTON
LOGAN
PETERSBURG
ALFORD
DORMAN
OATESVILLE
P.O.
Loc. 9
Loc. 11
Loc. 13
Loc. 14
Loc. 15
Loc. 16
Loc. 17
Loc. 18
Loc. 19
Loc. 146
Loc. 238

hole drilled on the Rumble farm (near the west end of the N. ½ of the S. E. ¼ of Section 36, Tp. 1 N., R. 9 W.) to a depth of 1,375 feet penetrated all the sands producing in the field at the following depths: Rumble, 904; Gladdish, 1,082; Oakland City, 1,272; and the Brown at 1,315.

The gas wells belonging to A. B. Bement located south of Petersburg are finished in the Rumble sand. The four wells have a volume of 6,000,000 cubic feet each per 24 hours with a pressure of 400 pounds. The strong flow and the high pressure of the wells indicate that they are located in a well-defined structure which will no doubt in the future produce some oil. A well drilled recently a short distance southeast of the gas wells is producing some oil. Future operations will doubtless develop an oil field southwest of the gas since the area southwest is on the slope of the anticline following the general dip of the country, which in most cases is the slope that is most productive in oil.

Developments west of Petersburg show that in the central part of the field the Rumble and Gladdish sands dip rapidly to the west and quit producing, while the Oakland City and Brown sands rise rapidly to the west and produce farther west than the other sands.

The production from the various oil fields in Indiana for the year ending September 30, 1918, is as follows:

Field.	Wells.	Bbls.
Petersburg	120	208,126
Princeton and Oakland City	220	76,624
Sullivan	488	209,345
Hazelton	33	115,200
Trenton Rock	1,449	192,627
Total	2,310	801,922

The gas laws of Indiana were enacted several years ago when the developments were confined to the Trenton Rock field, where the water conditions were very simple and easily taken care of in the event of abandonment of the wells. It was discovered that by allowing the fresh water from the upper strata to flow, either from pulling the casing or by reason of leaks in the casing, that the water damaged the oil or gas and would finally drown it out. Since there was no salt water in the formations above Trenton Rock, and the true reason for the damage caused by the fresh water was not discovered, the law only required that all fresh water be cased off from the oil or gas bearing rock, and in the event the pipe was pulled from the well it was required to be plugged in the manner described in the law, all of which was very satisfactory and effective for the Trenton Rock field. The real damage done by water leaks from the upper strata in a gas or oil well is not on account of the character or kind of water, but for the reason that it comes from a point near the surface and flows to the bottom of the well and creates a pressure at the bottom of the hole too great to be overcome by the upward pressure of the water in the oil or gas bearing rock, and consequently causes an inflow of water into the oil or gas bearing rock which floods the rock and drives away the oil or gas. The law should require all water in the upper strata to be cased off from the oil bearing rock, as in many cases in the southwest part of the State salt water is reached at a shallow depth.

In the oil fields of the southwest part of the State, where in one small field there are three or four oil producing sands and the intervening shales which furnish the only place to properly set the plugs are thin and irregular, it is sometimes impossible to follow the method described by law and properly plug the wells.

All the southwestern oil fields are located in the coal area of the State and every well drilled penetrates all the workable coal in the area and leaves the coal exposed to the water above it and the gas below, which in the future will cause great inconvenience and danger in operating the coal.

The gas laws should be revised so as to protect the oil sands in the event of there being more than one sand and should compel operators to record a log and exact location of each well for the benefit of future coal operations, and should require the coals to be plugged so as to be protected against gas and water.

THE FLINTS AND CHERTS OF INDIANA

By L. F. Bennett, Assistant, and Edward Barrett, State Geologist

The Department of Geology of the State of Indiana was requested by the United States Bureau of Mines to investigate the mineral products which occur within the State and which can be used directly or indirectly as war materials.

Flints and cherts were two of the rocks the Bureau requested the State to investigate.

Because of the shortness of the time allotted to the task not much more than a reconnoissance was possible. A large number of limestone quarries were carefully examined and many miles of roads and fields were traveled over on the lookout for outcrops and for chert as it appears in the soil.

Definition. Flint is an almost lusterless variety of quartz. Under the microscope it appears to consist of very fine crystals mixed with a variable amount of amorphous silica. It has a compact texture, breaks with a conchoidal fracture and with sharp edges. It contains traces of lime, alumina, iron, and carbonaceous matter. The color varies from white to black; various shades of gray are the most common. It often shows a banded structure.

"Chert is an impure flint." "It is an amorphous mineral substance composed of a mixture of hydrated and anhydrous silica." A flint which contains a high percentage of lime is called a chert by some writers. It is coarser and less homogeneous than flint.

Occurrence and origin. Both flint and chert are most commonly associated with limestones. It collects along the bedding planes and never along joint planes. The silica may be due, partly to a mechanical deposition, partly to a chemical precipitate derived from solutions moving through the still unconsolidated calcareous deposits, and in part to concentrations subsequent to the formation of the limestone. The silica was primarily the tests of plants, as diatoms, and of animals, as radiolarian skeletons or the spicules of sponges.

Thin layers of a siliceous limestone may be entirely silicified and all parts of the structure of the limestone may be retained. These weathered layers form the "nigger heads" of the soil of many localities and also form much of the chert of these areas.

Most of the so-called flint of Indiana is technically a chert, and occurs disseminated through the limestones in small masses and grades gradually into the limestones. These cherty masses are left in the soil upon the decomposition of the limestone, and when of large size they form a distinct hindrance in the cultivation of the soil. If the fragments are small they form a gravelly mass. These are washed in great quantities into the stream beds and are used as gravel on the roads of these same localities.

In this paper the deposits will be called flint when present in layers in the limestones and will be called chert when found in irregular masses grading into the surrounding limestones and when found in the soil.

The presence of chert in the soil indicates that the limestone from which the soil was derived was cherty, and it also suggests that the remaining limestones of that level have the same general composition as those decomposed.

The purer flint is present in lens like masses in the limestone and in what may be termed pseudo-layers. These so-called layers vary from an inch to six or eight inches in thickness and are very irregular in horizontal and vertical distribution. On the weathered surfaces of the limestone the flint forms slight projections and weathers in small and nearly rectangular pieces.

Itinerary. Most of the places visited will be mentioned. The character of the deposits and local uses, if any, will be discussed for each locality. No attempt was made to trace carefully the different formations of the various periods in order to determine the exact geological locations of the deposits.

Laurel, Franklin County. Two or three layers of flint were found south and southwest of Laurel. The two localities visited are at least a mile apart. Whether the flint in the two places belongs to the same layers was not determined. The layers are from two to six inches thick and very brittle at the outcrop and at no place was it possible to trace them any considerable distance. There is very little chert in the soil. The limestones containing the flint belong to the lower part of the Silurian.

Laughery Creek. The creek was traversed from Versailles in Ripley County to its mouth two miles south of Aurora. This whole distance the creek flows through Ordovician limestones. Only now and then a small fragment of chert was seen. The hillsides have but few rock exposures and these show no flint.

Very little chert is present in the soil about Aurora and not any was seen in the limestones of this locality.

Madison and Vicinity, Jefferson County. All of the rocks except those close to the Ohio River are Silurian. Chert was found in the soil in small quantities in several places, but no traces of it were seen in the nearby limestones. At Cragmont, the home of the Southeastern Hospital for the Insane, chert is present near the highest part of the bluff in Niagara limestone, 400 feet above the Ohio River. Large pieces six or eight inches in diameter were found in one place.

Hanover. Near this place several small patches of chert are to be found, but nowhere in large quantities; and at a lower level along the Madison-Hanover road just above a small limestone quarry there is a small outcrop. The chert here, as in most places, has no economic importance and is considered a nuisance in the fields in which it is found.

Northwest of North Madison in East Fork of Clifty Creek several thin layers of flint are present. Five layers in five feet of limestone were seen in one place, and in another ten layers, none much over an inch in thickness, were counted in four and a half feet of limestone. Much thicker pieces of chert in the soil nearby shows that the flint was thicker in the overlying limestone. The flint of the layers is almost white and nearly pure.

Vernon, North Vernon, and Vicinity, Jennings County. The rocks here are Devonian limestone and shales. There is a very great deal of chert in the soil to the northeast, and east, and west of North Vernon. Along the Pennsylvania Railroad much chert is present above the limestone just as if it has weathered from the shales.

In a limestone quarry just north of North Vernon there are several thin layers of flint with an occasional rounded mass six inches in diameter; in another quarry to the northeast flint is also present, but much less than in the first named quarry. None of this has any economic importance; it would be better to say that it is a hindrance in the quarrying of the limestone.

One-half mile south of Brewersville and five and one-half miles north of North Vernon on the south bank of Sand Creek there are ten layers of flint in a nine-foot exposure of limestone. The ten layers together are about eighteen inches thick. Nowhere else was there so much flint found in so small an exposure of limestone. Four miles southeast of this exposure, in a creek bed, more flint was seen, and the soil in the immediate vicinity contains much chert. It is a great hindrance to cultivation. Along the North Fork of the Muscatatuck River five miles east of Brewersville a limestone exposure of seventy-five feet in Silurian limestone shows no flint, but the soil above contains considerable chert.

In the quarry of the Muncie Stone and Lime Company, one mile south of Vernon, there is no flint, but in a nearby old quarry and at a higher level two irregular layers of flint are present; two layers are also to be seen in a limestone exposure in the south part of the town of Vernon.

Three miles south of Charleston, Clark County, on the Ohio River bluff near the mouth of Fourteen-mile Creek, ten or more layers of flint were found in Devonian limestone. They are like, and may belong to the same horizon as those found near Brewersville. Much fine broken up chert is present in the soil near the bluff, but very little to be seen near Charlestown.

The remainder of the places visited are all in the Mississippian rock areas and for the most part in limestone regions.

Corydon, Harrison County. Several kinds of limestone are found here. All belong to the Mitchell formation. Much is nearly a lithographic limestone and breaks with a conchoidal fracture. It is called by many of the people of the region "flinty," but a careful examination shows very little silica in it. Some of the limestone is coarse grained, and a very little is almost oolitic. Occasionally a cherty piece is seen in the limestone, and in one exposure cherty concretions have weathered out like warts. Some of these contain fossils. In places the soil is full of chert. The pieces vary from the size of small gravel to six inches or more in thickness and a foot or more square. These larger pieces are built into fences and are thrown into holes, or otherwise used as riprap. On the surface these pieces are rough and slightly porous, within they are compact and flinty. No attempt has ever been made to use them, so far as I could learn, except in the ways mentioned above.

At Corydon Junction, eight miles north of Corydon, a little flint was found in, and only in one place. There is but little chert in the soil.

Milltown, Crawford County. The observations were made in the quarries of J. B. Speed & Co. All of the limestone belongs to the Mitchell formation. The largest quantity has an exposure of 125 feet. It contains several grades of limestone. One layer which averages six feet in thickness and is midway between the top and the bottom is about one-sixth quartzitic or cherty. The cherty part is plainly visible and is intimately mixed with the limestone. It would be practically impossible to separate it from the limestone. The quarrymen crush this impure stone for road material. It gives excellent satisfaction. The cherty part wears well and the calcareous part acts as a good binder. The cherty layer is present in the three working quarries and is on the floor of a large abandoned quarry. It also outcrops in the country a short distance from the town. There is a comparatively small amount of chert in the soil.

The following analysis shows the siliceous matter is really a chert:

Loss on ignition	14.90%
Silica (SiO_2)	61.28%
Alumina (Al_2O_3)	0.32%
Ferric Oxide (Fe_2O_3)	3.06%
Calcium Oxide (CaO)	20.36%
Magnesium Oxide (MgO)	0.10%
	100.02%

Marengo, Crawford County. There is very little flint in this vicinity and but a small amount of chert. A large quarry in the town has an exposure of 75 feet and contains several differently textured Mitchell limestones, but no flint is present.

English, Crawford County. No chert here of any consequence and not any flint is found. All of the rocks belong to the Huron and Mitchell formations, except in the bed of the creek which flows through the town. Three layers of limestone interstratified with sandstone and shale are present in the hills but none of these appear cherty.

French Lick, Orange County.—Mitchell limestone is found in the base of the hills and Huron sandstone and shale above. The three layers of limestone present in the vicinity of English are present here. The Mitchell limestone varies in texture from the nearly lithographic to the coarse-grained kind. But one large piece of chert was seen in the soil of this vicinity. There is very little chert of any size.

Paoli, Orange County. Several quarries were examined. The limestones are characteristic of the Mitchell formation; some compact, some coarse grained, and some with considerable clay. No flint was seen in the limestone and very little chert in the soil of the vicinity.

Salem, Washington County. Harrodsburg, Salem (Bedford) and Mitchell limestones are represented here. Several quarries, none very large, were visited and flint was found in but one of them. This quarry is in Salem, just north of the Monon Railroad. It contains but one layer and this is very irregular. The largest single piece is eight feet long and one to eight inches thick. Very little chert is present in the soil in the immediate vicinity, but much is found in places some distance from the city. Many miles of roads here are made largely from a gravel taken from the creek beds and consists of small chert fragments, small geodes, and clay and sand.

On the side of the road, one and a half miles east of Salem, layers of nearly pure silica one to three inches thick are found. The fossiliferous character of the stone from which the chert was derived is nearly perfectly preserved.

Mitchell, Lawrence County. Mitchell limestone is only found in the immediate vicinity. The larger quarries are owned by the Lehigh Portland Cement Company. In a small quarry of this company five or six layers of flint are present. Some of the flint shows a banded structure, parts are nearly white and other parts are black. At no place was the flint over six inches in thickness and all of the deposits were somewhat lens-shaped.

The following analysis shows that the flint here is of a high grade:

Loss on ignition	1.15%
Silica (SiO_2)	93.64%
Alumina (Al_2O_3)	0.76%
Ferric Oxide (Fe_2O_3)	4.08%
Calcium Oxide (CaO)	0.68%
Magnesium Oxide (MgO)	Trace
	100.31%

No flint is present in the largest quarry, and there is very little chert in this locality. In a Baltimore and Ohio railroad cut near the town there are many large rectangular blocks of chert, most all highly fossiliferous and nearly pure silica. Some of the pieces will weigh several hundred pounds. No large sized pieces were seen in the fields nearby.

Bedford, Lawrence County. A long description could be given concerning the limestones of this region. Flint is not found anywhere and chert is present in very small quantities. What little siliceous matter there is has been washed into the stream beds from either the Upper Harrodsburg, the Salem, or the Lower Mitchell limestones, all of which are found here. Small geodes and chert fragments have been taken from the creek beds and used as gravel on the roads.

Harrodsburg, Monroe County. The most noticeable siliceous deposits are the geodes, which are very abundant in the Harrodsburg limestone. These are of all sizes up to a diameter of sixteen inches or more and may be seen in stream beds, fields, and in the outcropping limestone. They are nearly pure silica. No general use other than as museum specimens and for private curio collections has been found for them. Chert is present in small quantities.

Bloomington, Monroe County. This vicinity has very little flint and only a small amount of chert. Geodes weather out from the Harrodsburg limestone to the east and chert from the Salem and Mitchell to the west. The chert is very irregular in distribution. Most of the fragments are small.

Ellettsville and Stinesville, Monroe County. Both Salem and Mitchell limestones are found in the quarries. Not any flint is present and there is very small amount of chert. The same conditions prevail here as found farther south in Monroe County. The Mitchell limestone of this region shows no evidence of any highly siliceous limestone such as represented by the large chert masses of Salem and Mitchell.

Gosport, Owen County. All of the limestone belongs to the Harrodsburg formation. One typical exposure is in a cut made by the Pennsylvania railroad. The limestone is very hard, some is coarse grained and some fine, and parts are highly fossiliferous. There are many geodes, most of which are small. The soil contains very little chert.

Spencer, Owen County. Only Mitchell limestone is present. There is but one large quarry near Spencer. In this the limestone is thin bedded and shows the general characteristics of the Mitchell stone. Near the top of the quarry there are three layers of flint within a vertical space of two feet. These are not continuous. There is almost as much space between the flint concretions as their horizontal extent. Some of the particles are nearly round on the face of the exposure and others are thin and flattened. The thickest particle is nine inches in diameter. The flint is almost pure. There is a little chert in the soil; perhaps this small amount is partly due to the fact that sandstone is on the hills and it contains very little chert.

Cloverdale, Putnam County. Only a few good limestone exposures are found here. There are several small quarries in the vicinity of the town, from which stone is taken mostly for road making and for fertilizer. All of the quarries were visited. Flint is found in one place only and this in a quarry one mile southeast of Cloverdale. A lens four feet long and four inches thick is present. This flint is typical of all found in other places in the Mitchell limestone. There is a very small amount of chert.

Putnamville, Putnam County. Nearly all of the observations were made in quarries on or near the State Penal Farm. A thin layer of nearly pure flint is found in a quarry just east of the Farm and two thin layers in the Monon railroad cut about three-fourths mile north of Putnamville. A very impure flint, better called a chert, is found in a quarry on the east part of the Penal Farm. There are ten to fifteen imperfect layers within a vertical space of ten feet and less. In a horizontal exposure of at least 300 feet these layers are found throughout the whole length, but there are breaks in all of them. Now and then a nodule of nearly pure flint is found, but much of the cherty material is not cleanly separated from the enclosing limestone. An application of acid shows the chert to contain considerable calcium carbonate. The cherty layers are dark colored and can be distinguished from the limestone at a distance of a hundred feet or more. The limestone containing the chert is good for road material but not for any other purpose.

From a large quarry near the center of the Farm, limestone is obtained for roads, fertilizer, and for lime. It contains no flint and is a high grade of Mitchell limestone. The soil is nearly free from chert.

Greencastle, Putnam County. Two quarries were visited. There are no extensive outcrops on account of the covering of glacial clays. The Ohio and Indiana or "O & I" quarry is two miles southwest. It is large, fully 50 feet high in the highest part and nearly one-fourth mile long. In the lower part there are several layers of cherty material similar to those found in the quarry at the State Penal Farm. The limestone containing the chert is thin layered, and the chert itself in places is very thin. Such layers as these when separated from a limestone by a decomposition of the stone are undoubtedly the origin of the thick masses of chert found in the soil in many places.

The "A & C" quarry just east of Greencastle also contains the typical Mitchell limestone. The exposure is about 50 feet in height. There are several layers of cherty material similar to that found in "O & I" quarry. The layers have a vertical distribution of about 9 feet. Above and below these layers there are several feet of nearly pure limestone. Near the upper part of the quarry there is a layer of flinty nodules, but it is not continuous the whole extent of the quarry. The following is an analysis of the chert:

Loss on ignition	11.71%
Silica (SiO_2)	69.08%
Alumina (Al_2O_3)	0.40%
Ferric Oxide (Fe_2O_3)	2.90%
Calcium Oxide (CaO)	16.22%
Magnesium Oxide (MgO)	Trace
	100.31%

A few observations were made in the sandstone of the Knobstone formation. There were no indications either of flint or chert.

Uses. "Flint in the early history of mankind was as important relatively to the general condition of life as iron is at the present day."

Flint at present has but few important uses: It is used in the manufacture of pottery. It helps to diminish shrinkage. For this purpose it is calcined, thrown into cold water, then finely powered. It must contain less than one-half per cent of iron bearing minerals. It is used as a lining for tube mills. Most of the flint for this purpose was imported from Belgium before the war. Now other hard siliceous rocks are being substituted which can be secured in the United States. Pebbles for grinding: Well rounded pebbles from about one and one-half to four inches are preferred. "These are used for grinding minerals, ores, cement clinker, etc., and those employed in the United States have been chiefly flint pebbles obtained from the chalk formations of Denmark and France, but not a few have been imported from other foreign countries. The value of the flint pebbles lies in their hardness and uniform character, moreover they contain little else than silica, and hence there is little danger of the material worn off contaminating the ground product, as for example in grinding feldspar, which must be free from iron oxide.

"The decrease in the foreign supply due to the present European war has stimulated search for domestic sources of supply with some results. Pebbles of granite and quartzite have been imported into the United States from New Foundland and Ontario for some time, and similar ones can be found here. Stream pebbles of quartz have been tried in California gold mills, dense silicified rhyolite has given satisfactory results in some of the metallurgical mills of Nevada, and basalt has been tried in Oregon."—Economic Geology. Fourth Edition, Ries, John Wiley and Sons.

Chert as chert is not listed as having any economic importance except for road material. It is crushed with the limestone with which it occurs, and it is taken from stream beds and put upon the roads as gravel.

There is very little flint in Indiana that could be used in the ways mentioned above. It is not uniform in texture and composition, and it occurs in too small quantities to pay for separation from the enclosing limestones.

The cherts are too soft except the large pieces, which may have a hard core or may be hard throughout. It would be an expensive process to gather and prepare even these for the market.

Much of the flint imported from European countries has been brought into the United States as ballast. This has made it possible to bring it here and sell it at a much lower price than it can be produced in Indiana.

Other States have flint and chert in much larger quantities than Indiana, and it may be they will become important competitors with other countries.

Under present conditions it may be said that the flint and chert of Indiana do not represent a very important asset. In many places the flint is considered a positive harm in the quarrying of limestone, and the chert in the soil a serious hindrance to its cultivation.

Workable Coal Seams of Indiana. By Edward Barrett

Pyrite in the Coals of Indiana. By Leonard P. Dove

The Concentration of Pyrite from the Coals of Indiana. By E. A. Holbrook

Co-operative Agreement Between Indiana Department of Geology and United State Bureau of Mines

INTRODUCTION

Early in the present year 1918, it became necessary to greatly curtail imports of bulky ores that could be produced in this country, in order to release shipping for more important immediate needs. Pyrite, which had hitherto been brought from Canada[1] and Spain,[2] was included in the list. Importations at once dropped so that added to the expansion in the use of sulphur[3] for making acid a heavy demand for sulphur for other industrial purposes put a severe strain on the sulphur industry. So strong was this demand that it was a question whether sulphur could be produced in sufficient quantities to satisfy the needs. It seemed necessary for domestic supplies of pyrites to be opened to avoid a crisis. Accordingly the United States Geological Survey, the United States Bureau of Mines, and the State Geological Surveys became active in locating adequate supplies of pyrite available to the bulk of the acid plants, located east of the Mississippi River.

Pyrites are found in association with bituminous coals in the form of lenses, bands, nodules and replacements. For some years a limited tonnage of "coal brasses," as coal pyrites are commonly known to the trade, has been utilized in the manufacture of sulpuric acid. The developments of the past year and a half have demontsrated that pyrite can be recovered profitably from coal. The problems involved are not insurmountable. Among notable contributions to the literature of the industry may be mentioned "The Utilization of the Pyrite Occurring in Illinois Bituminous Coal," by E. A. Holbrook; Circular No. 5 of the Engineering Experiment Station of the University of Illinois, Urbana, Illinois, and "A Description of the Pyrite Washery near Danville, Illinois," by C. M. Young, in Coal Age, Vol. XI, No. 1, p. 7, January 6, 1917. Since then other plants have been built until it may be said the industry is in a fair way of becoming established.

On April 22, 1918, a conference of State Geologists from nine of the Central States was held at Urbana, Illinois, the States represented being: Iowa, Missouri, Illinois, Michigan, Indiana, Kentucky, Tennessee, Ohio and Pennsylvania, together with H. A. Buehler in charge of the pyrite investigation, and E. A. Holbrook representing the U. S. Bureau of Mines. It was decided to make a co-operative examination of the coal mines of the various States for pyrites and make available the data of these resources.

Under this co-operative agreement, the investigation of the coal mines of Indiana was undertaken by the writer. The period between June 4, and August 23, 1918, was occupied in collecting field data.

Numbering of the Coal Seams. The numbering of the coal seams adopted by the Indiana Geological Survey is used throughout this report. This is described more in detail on page 196.

Plan and Scope of Investigation. As the total number of mines in Indiana employing over ten men is two hundred and two,[4] and as usually but one mine could be visited in one day, it was necessary to select mines typical of a district (which were examined with the detail time allowed), and depend upon data from these mines to estimate the quantity of

[1] Total 210,615 tons in 1917. Smith, Phillip S., Min. Resources of the U. S., Pt. II, P. 27.

[2] 747,830 in 1917. Ibid.

[3] Over 210,000 long tons in 1917 over 1916. Smith, Phillip, S. Min. Resources of the U. S., 1917, Pt. II, p. 61.

[4] Report of Industrial Board of Indiana, 1917, p. 15.

pyrite in adjoining properties working the same seam. Two or more widely separated portions of a mine were usually visited.

The method followed was to examine working faces, gob piles in the mine and on the surface, noting the amount of "sulphur" in each instance and reducing the estimated amount to a percentage of tonnage mined.

Wherever possible many vertical sections of the coal, exactly ten feet apart, including the coal, bone, rock and "sulphur," were measured and noted. Where bands and lenses were abundant, ten to twenty sections in various portions of the mine made accurate estimates of available tonnages possible. Pyrite was regarded as having three times the weight of an equal bulk of coal, hence if an average section shows sixty inches of coal and one inch of pyrite, the percentage by weight of pyrite would equal 1 (inches of pyrite) x 3 (times the weight of an equal bulk of coal) x 100 (to reduce to percentage), divided by 60 (inches of coal), or 5 per cent.

Suitable deductions were made for clay bands, bone, rock, etc., that do not appear in the tonnages of coal marketed. Wherever possible, the estimates were checked by estimating the amount of pyrite in gob piles, and where all pyrite had been sold, the ratio between pyrite and coal marketed was easily reduced to a percentage.

In most cases where the amount of pyrite was less than two or three per cent of the coal mined, gob piles in rooms and on the surface were relied upon for an estimate of quantity.

A constant effort was made to make estimates as accurate as possible. In most cases the estimates of tonnage of pyrite are conservative.

This report should be considered a reconnoissance rather than a detailed estimate of the quantity of pyrite available. As such it is hoped it may call attention to a resource that if utilized might add a substantial income each year to the coal industry of the State and serve the Nation in supplying a necessary mineral.

Acknowledgements. The writer is under obligation to E. A. Holbrook, Superintendent of the U. S. Bureau of Mines, Experiment Station, Urbana, Illinois, for suggesting methods of field work and for much data. Edward Barrett, State Geologist of Indiana, contributed of his wide knowledge of the geography and geology of the State. Complete freedom was granted of all facilities at his disposal for making the investigation. Wendell Barrett assisted for a few days in collecting data. W. M. Blanchard, Head of the Department of Chemistry, De Pauw University, Greencastle, Indiana, contributed analyses and identifications. H. F. Yancy, Chemist, U. S. Bureau of Mines, Urbana Station, made analyses of several samples. Courtesy was extended by mine operators at every mine visited. Miners and other citizens extended uniform assistance. The Grasselli Chemical Company, of Cleveland, Ohio, and E. Rauh & Sons Fertilizer Company, of Indianapolis, Indiana, submitted valuable opinions and analyses.

MINERALOGY AND CHEMISTRY OF PYRITE

Pyrites, "fools' gold," "sulphur," "sulphur balls," "kidney sulphur," "cat faces," "coal brasses" are a few local and common names by which pyrite is known. It is found as an accessory mineral in fresh exposures of essentially all ages and kinds of rock. Chemically it is iron di-sulphide, and when pure contains 46.6 per cent of iron and 53.4 per cent of sulphur. Its chemical symbol is $Fe\ S_2$.

The crystal habit of pyrite is usually some form of cube, pyritohedron, octohedron or combinations. When pure and clean it varies from silvery to bronze or brassy yellow in color. In crystals it will scratch glass but is fairly brittle and gives off brilliant sparks when struck with a hammer or pick; also the odor of burning sulphur may be detected due to the heat generated by the blow setting fire to particles.

Another mineral identical in composition with pyrite is marcasite. There is no quick and sure method of telling one from the other except by well defined crystals of either which are rare, and by the color when perfectly fresh. In general, marcasite favors the tabular form of crystalline aggregate belonging to the orthorhombic system and is lighter in color. It has been generally assumed, and probably rightly, that marcasite oxidizes more rapidly than pyrite. But, as pointed out by Stokes[1], other conditions such as fineness of division and exposure to oxidizing agents are seldom identical, to identify iron di-sulphid as marcasite simply because it oxidizes rapidly, is not a safe method. In the following discussion all iron di-sulphid will be called pyrite as considerable laboratory work would be necessary to determine with any accuracy just what proportion of each mineral is present in the coals, and if determined would be more of academic than of commercial importance.

COAL PYRITE AND ITS ALTERATION

When freshly broken the pyrite masses from the coals of Indiana vary in color from steel gray to bronze yellow, or rarely brassy yellow. They vary from coarse to fine granular, the size of granules from one-thousandth to one-fourth inch in diameter. Well defined crystals are rare. A few good specimens of cubes and pyritohedrons were collected from cracks in the balls or niggerheads in Seam No. 5, and a few tabular crystals suggestive of orthorhombic shapes from the shales above the same seam. Well shaped crystals are locally known as "coal diamonds." Other than noted above, the masses of pyrite are largely structureless except as may be pointed out in more detail in the pages following.

When exposed to the air and moisture a tarnish develops rapidly and the whole pyrite mass is soon coated with white iron sulphate or copperas, which is soluble in water. Free sulphuric acid also forms along with copperas. These give an acrid, bitter taste to the altered pyrite.

Not uncommonly a black sulphur zone, an intimate mixture of carbonaceous material and finely divided pyrite, is found as a transition from a pure portion of a pyrite mass to the including coal. This alters very quickly. Specimens collected and left about for only three weeks had altered so badly that the outer portions shelled off, destroying surface features for which they were collected. It is probably to this finely divided pyrite that rapid heating and spontaneous combustion of coals is due. In general as the surface (mass) factor increases, the rapidity of

[1] Stokes, H. N., Bulletin 186, U. S. G. S., p. 13.

alteration increases in proportion. This is a well known law of oxidation.

Gob piles both in the mine and on the surface contribute evidence of the changes that take place in pyrite on exposure to air and moisture. If the mine is relatively dry a coating of white copperas (iron sulphate) forms on the faces of the coal, especially where pyrite in any form is abundant. So common is this that use was made of it in locating lenses and bands in older faces of coal along roadways and in rooms. Often when these white spots were struck with the hammer the hard lens or band was revealed beneath. This may accumulate from zones of but slight pyrite content. Aggregates of delicate white to yellow needle-like crystals are common. Occasionally where moisture is more abundant they are tinted a delicate blue green. Fibrous melanterite in silky masses was found in several gob piles.

Where water is more abundant, the iron sulphate and sulphuric acid formed by the oxidation of the pyrites is carried away in the mine waters, attacking pipes, rails and tools so rapidly that they are rendered unfit for use in a short time. Waters from the mines in No. III seam in the region of Seeleyville, Indiana, and Staunton, Indiana, are especially acid. Under suitable conditions after forming, the copperas and free acid attacks and breaks down the aluminum silicates in the clays, forming complex salts of varying composition.

When much lime is present the copperas reacts with it to form gypsum and iron carbonate. A portion of the iron is altered to the basic condition, giving a yellow or rusty coating in ditches carrying mine waters away. The removal of pyrite from mines is generally desirable, for in gob piles with a high percentage of coal and pyrite both on top and below ground fires are not uncommon. In some mines the heating is so marked that the temperature of the mine air is not uncommonly increased. Various gases freed by the spontaneous heating of pyrite and coal vitiate the air. It is a common occurrence to have to seal off these fires. Gob fires, where combustion is slow, often distill free sulphur from the pyrite, forming miniature fumeroles about which delicate needles of yellow monoclinic sulphur collect.

In such cases oxidation of the iron is often complete and rounded masses of pure hematite ($F_2 O_3$) may be found as the residue of a lens or "sulphur ball." The red color of burned gob piles is an evidence of the complete oxidation of the iron.

OTHER COMBINATIONS OF SULPHUR IN COAL

Not all sulphur occurs in coal as pyrite. Coal is undoubtedly of organic origin, mostly vegetable. It is well known that vegetable matter contains sulphur combined organically and best detected by chemical analysis. It seems quite probable that some sulphur in coal is so combined. A white thin scale is often noted in vertical joint cracks in coal. This is often largely gypsum—$CaSO_4 2\ H_2O$. Sulphates of magnesium, aluminum and other metallic elements are often present in small amounts. The above forms usually represent but a small fraction of one per cent of the coal. They have no commercial significance.

In general it may be said that coal pyrite oxidizes rapidly, forming soluble salts of iron and other metals and is carried away eventually in the waters to be redeposited in some more insoluble and stable form in a locality possibly at some distance from the mines.

OCCURRENCE OF PYRITE ASSOCIATED WITH THE COALS OF INDIANA

The following classification of pyrite aggregates in the coal seams of Indiana is based on physical resemblance. The order is based on their probable commercial importance.

1. *Bands and Lenses.* Pyrite bodies of recoverable size in coal are usually lens shaped as are most ore bodies. When a lens is very long for its thickness it is usually called a band. There is no evidence that most lenses and bands differ in composition and origin. They lie flatwise or parallel to the bedding planes of the coal. Most bands thicken and thin much as a series of lenses joined edge to edge. Where lenses and bands lie between shale and coal, the shale side is often knobby while the coal side is relatively smooth. In places in the coal, pyrite bands may be continuous for 15 to 20 feet, and in the aggregate weigh several hundred pounds. As broken by mining the average size is from one to three inches in thickness and weighs from five to twenty-five pounds with an average of about ten pounds exclusive of the coal that adheres as broken by mining.

Their color is usually a dull stone gray to bronze, and fine grained. Smaller bands of from a knife edge to one-fourth inch in thickness are often lustrous, shiny and coarsely granular. They usually break up badly on shooting the coal and little is recoverable.

Bands are best developed in Seam No. III in the region of Clinton, Indiana, and Rosedale, Indiana. Here they are usually sharply defined from the coal or clay, sometimes with a zone varying in thickness from 1/16 inch to ¼ inch of shiny pyrite between the coal and the dull stony portion of the band. Minute veins of shiny pyrite often cut them transversely, suggesting a secondary enlargement and filling at a later stage. Seam No. III is divided at about the middle with a parting of impurities that varies in composition from gray clay or shale to blackjack, sandstone, sandstone cemented with pyrite to pure pyrite bands and varying in thickness from 2 to 12 inches. In some localities two or more partings were noted, but this one midway is most persistent.

Pyrite lenses and bands are often present just under this dirty band. They are often found between the roof and coal especially where the roof is shale.

Two other persistent zones of lenses and bands are common in Seam No. III. The upper from 10 inches to 12 inches below the roof and the lower 6 inches to 10 inches above the bottom. Scattered lenses, in general more abundant in the lower half of the coal, make up about half of the recoverable pyrite from this seam.

Bands are also found in Seam No. VI and form a considerable portion of the recoverable pyrite from the mines east and southeast of Shelbourne, Indiana. In this area two shale partings are quite persistent, the upper 24-26 inches, the second 30-34 inches below the top of the coal. The pyrite bands may be above but are more commonly below the second shale parting. Occasionally the shale gives place to a pyrite band only, for distances of several feet, then again the position of the parting may be indicated only by impure dull black coal from one-quarter to one inch in thickness.

The bands are uniformly high grade pyrite. The fragments as broken by mining are commonly from one to one and one-half inches thick and twenty to one hundred inches square in lateral area. They are finely granular and silvery to stone gray in color.

Occasionally bands, instead of being set off sharply from the coal, show a transition through a black zone of coaly matter and finely divided pyrite to the dull stony portion of the lens or band.

2. *Flattened lenses without definite structure.* Throughout seams Nos. III, V and VI are scattered lenses of pyrite varying in size from a few ounces to 100 pounds or more. They are commonly stone gray and lusterless on fresh fracture, to steel gray or bronze colored. They may or may not show transition zones of interseamed coal and pyrite or fine grains of coal and pyrite, and are seemingly distributed promiscuously. In a few cases they are definitely associated with shale bands, but so rarely as to give no clue to the law controlling their occurrence. In seams Nos. V and VI they are probably more abundant in the lower half of the coal. Being uniformly present in all seams examined and whenever tested showing a high sulphur content—42 per cent to 46 per cent—as roughly cleaned by hand—they may be considered as an important source of pyrite.

3. *Nigger-heads, boulders, balls or kidneys.* Seam No. V contains masses of more or less pure pyrite in the form of nigger-heads, boulders, balls or kidneys, which seem to be names applied in different localities to the same occurrence. As the names suggest, they are either nearly spherical or spheroidal rather than lense shaped, although all gradations between may be found.

They may be found in any position in the coal, but probably are more abundant near the bottom. They are found in this seam wherever examined. They range in size from 1 to 4,000 pounds or more, a typical one being shown in Plate —. Many of these pyritized boulders show open cracks on breaking, the cracks being more or less lined or filled with crystalline pyrite. This often gives a porous or spongy appearance to the mass. Some good specimens of pyrite crystals with pyritohedron faces were collected from these.

In general the smaller sizes, from 1 to 15 pounds in weight, are a good grade of pyrite, and not uncommonly those weighing upwards of 100 pounds may be found that are nearly pure pyrite. Although very large ones (150-4,000 pounds) are usually more or less pure calcium carbonate with the outer portions replaced by pyrite and with dendrites of shiny pyrite extending inward. Occasionally they may contain rather high percentages of iron as carbonate or hydrated oxide. The following typical partial analysis shows the most important constituents:

Sulphur	11.51%
Iron Oxide	15. %
Calcium Oxide	39.54%
Carbon Dioxide	32.12%

(Analysis by W. M. Blanchard.)

This sample was taken from a large boulder weighing about two hundred pounds that came from about the middle of the No. V seam in the American Mine No. 1 at Bicknell, Indiana. It is an average sample of the outer three to four inches of the boulder and probably shows a higher percentage of sulphur than an average of the whole boulder.

The large size of the boulders in one portion of the American Mine is notable. In a sag or depression in the coal seam 250-300 feet in diameter were several dozen boulders, including individual boulders that would weigh upward of 4,000 pounds. This locality was the only one where they were found in such abundance or so large.

In the region north and west of Terre Haute, Seam No. V could contribute a considerable quantity of these balls or boulders of a good grade of pyrite. An analysis of one of the more doubtful quality from the Sugar Valley Mine at West Terre Haute, showed 32.9 per cent sulphur. When broken, this boulder, weighing about 40 pounds, showed bronze colored pyrite with streaks of brown carbonate in the nature of flat slab-like masses, resembling the flattened stems of plants, 1/16-¼ inch thick and 2 to 4 inches long. The mass exhibited a tendency to cleave along these slabs.

In general the small and purer boulders or balls will yield a pyrite product containing upward of 40 per cent sulphur if some care and experience is used in selection. From the outside a casual examination will not reveal their nature. As breaking entails a considerable amount of work it would seem best to make a careful examination of many of them for each mine to find the limit of size that would best be included as recoverable. Since most of the pyrite impurity is calcium carbonate, the pyrite could probably be freed from the lime by washing machinery if adapted to the purpose. In that case all sizes of boulders from the coal seam might be considered as a potential supply of pyrite.

The nature of these boulders suggests that they probably formed in part as calcium carbonate concretions in the swamp while the peaty material, which later became coal, was accumulating. Perhaps coarse masses of stems and other vegetable matter may have served to start the segregation of lime. Later, these lime concretions were replaced wholly or partly by iron disulphide. Many of the smaller balls probably are true concretions of iron disulphid and not replacements.

4. *Nodules in coal and associated clay.* While many or most structureless lenses and bands mentioned on page 220 are probably nodular in nature as the term is usually used, true and unmistakable nodules are found in the lower 18 inches of roof shale above No. VI coal, especially in Sullivan and Knox counties.

In shape they are oval to arborescent and often knobby, occasionally thick lens shaped nearly circular in outline. When broken they vary from coarsely to fine granular and seldom if ever show concentric structure. In size they vary from a few ounces up to several hundred pounds in weight.

In composition they show a uniform high percentage of sulphur, (46.05% at Bicknell, Indiana), and rarely carry a minute percentage of zinc, probably as sphalerite (ZnS).

Besides nodules, much finely divided pyrite was noted, especially in the lower six inches of the roof shale. The rapidity with which this weathers accounts for much of the shelling-off falls that are so troublesome in many mines working this coal, especially where considerable moisture is present.

It is not uncommon to find these nodules surrounded by a film or layer of clay that causes them when damp to break easily from the containing coal or clay. Their ease of separation together with their high sulphur content make them a hopeful source of pyrite.

5. *Petrifactions of trunk and stem fragments.* Coal seams Nos. III and VI contributed specimens in abundance that show petrifactions of casts of tree trunk and stem fragments. Some of these show them to have been first petrified with calcium carbonate and later in part or totally pyritized. Fragments in all stages from pure calcium carbonate to pure pyrite were noted with the leaf scar arrangement of the lepidodendron and striations of the calamites. It is likely that many were directly replaced with pyrite. They furnish a considerable percentage of recoverable pyrite, especially in Coal No. III and VI, in Sullivan, Vigo and Clay Counties. When these fragments lie about exposed to the weathering and the adhering coal and other matter separates they resemble nothing more than weathered fragments of wood often carrying the illusion to the grain and splinters. They are often about the size and shape of a man's forearm to flattened chip-like, weighing from 3 to 15 pounds. They are of uniform high grade with exception where replacement of calcium carbonate is incomplete, which is rather rare, examples of which were noted in Coal No. III in the region of Seeleyville, Indiana, and Staunton, Indiana.

6. *Roof boulders above Coal Seam No. V.* Allied to the boulders found in Coal No. V, just described, are the oval concretionary boulders that form a conspicuous feature of the roof above Coal No. V. They are embedded in a block fossiliferous, fissile shale and often jut downward into the coal, occasionally making removal necessary, especially in roadways and entries. Sometimes they fall, leaving an inverted smooth pot-like depression in the roof. They vary in weight from a few pounds to three or four tons. Commonly their shape is spherical or spheroidal although they may be elongated until their length is several times their width. Often two or more are grown together, giving a knobby or branching effect. In general they exhibit all the forms of true lime or iron-stone concretions found commonly in shales elsewhere but on a very enlarged scale. Not uncommonly they show a depression in top or bottom. They invariably lie with the flattened portion parallel to the bedding of the shale. Many of them are somewhat conical on the lower side with adhering shale or clay, the sides of the flat cone showing slickensides as though developed by thrusting the boulder downward into the shale or clay. They often carry mollusc and molluscoidia fossil remains, but in general are structureless. Occasionally they are broken and recemented by calcite, silica, gypsum or pyrite resembling septaria.

Those that jut downward into the coal are commonly partially replaced by pyrite either frequently as a skin or shell or at the center. It is common to find an irregular mass or bleb of pyrite on the lower part of the boulder weighing several pounds, but not easily separated from the boulder. This pyrite merges with the replacement shell that extends upward and around the lower half. In general the further these jut downward into the coal the more completely they are replaced with pyrite. Fossil remains are often gilded or replaced on the interior of the boulder while the mass shows little or no replacement. Plate —— shows one of these shells or skins, and Fig. 2 a typical boulder unbroken.

These boulders probably formed as true calcium concretions on the bottom of a muddy lagoon or estuary deep enough or protected to escape agitation in the general period immediately following the deposition of the coal. A stratum of from 0-8 inches of comminuted shells and coaly matter with clay just above the coal suggests that the swamp in which the coal formed was submerged rather rapidly and conditions favorable for the accumulation of plant remains gave place to a more or less open sea rich in calcium carbonate.

The pyrite associated with these roof boulders probably has little commercial importance, because the pyrite if recovered would either have to be hammered from the boulder in place or the boulder removed. But few of the boulders are removed in mining, except such as fall or are in the way. Again, the amount of pyrite that is associated with the boulder is but a small fraction of the total weight of the boulders.

7. *Pyrite associated with mineral charcoal or mother of coal.* There is a striking relation existing between mineral charcoal and pyrite. Masses of mineral charcoal are frequently impregnated with pyrite, from filling minute pores to complete pyritization. The satiny lustre of this material makes it at once one of the most beautiful occurrences of pyrite. While in general the quantity of pyrite present is small, in a few cases the replacement has been so complete as to make lens like bodies of nearly pure pyrite.

The quantity of this class of pyrite is not large commercially and was noted mostly abundant in Coal No. V in the region of Bruceville, Indiana, Bicknell, Indiana, and Wheatland, Indiana, although found occasionally in Seams III and VI as well.

8. *Minor occurrences.* "Cat faces" or veins formed in vertical joint planes or cracks in the coal are found in all coals of Indiana. They are most abundant in Seam No. III in Park, Vermillion, Vigo, Sullivan, Clay and Greene counties and in Seam No. V from Sullivan County southward, rather increasing in number toward the Ohio River, and to a minor extent in Seam No. VI wherever found.

Many minute branching veins coalesce to form a fairly solid vein for several inches only to branch again and lose themselves in the body of the coal. Most of the pyrite is coarsely granular and seldom attains a thickness of ¼-⅜ inch in the solid vein.

Due to their granular nature and lying as they do along cleavage lines in the coal, they are usually broken into fine fragments by shooting or pick work and are mixed with the fine coal. When large enough to be detected and thrown out they usually form less than 10 per cent by weight of the discarded lump of the coal. For these reasons they are not considered of commercial importance except as coal which is wasted might be recovered with them.

Joint veins are often continuous with zones of fine interleaved pyrite lying parallel with the bedding. Interleaved zones from one inch to several inches in thickness are fairly common in Seams III, V and VI. It is seldom the total pyrite which is in minute leaves and bands reach a total of 25 per cent by weight of the zone. When these zones are large and noticeable, lumps of coal are usually discarded on account of them. A large percentage of coal so discarded from Seam No. V in Knox County and southward is on account of these zones. A typical discarded lump of coal may show in section two to five times as much coal as pyrite impregated zone. The zone itself being often less than 25 per cent by weight pyrite, makes the per cent of pyrite in the lump very low. This with the finely divided condition of the pyrite would make fine crushing necessary to separate the coal and pyrite, a procedure that would entail the loss of the coal. With the coal lost the pyrite recovered would not repay the expense. This occurrence is therefore not considered as commercially important at present.

Thin scales or leaves of pyrite both along cleavage planes and joints, may be noted in all the coal of Indiana. They are unimportant to the present discussion.

OTHER OCCURRENCE OF PYRITE IN INDIANA

Pyrite is a common accessory mineral in sedimentary rocks. The native rocks of Indiana are all sedimentary and contain fully a normal amount of pyrite.

The Knobstone shales contain small nodules of pyrites and limonite as ironstones scattered through the shales—at no known locality in commercial quantity at the present price. Certain shales of Carboniferous age, especially those in association with the coals, contain varying amounts of pyrite either as grains, nodules or replacements.

Upon weathering pyrite is one of the first minerals to lose its identity as explained on page —. Exposures of shales, sandstones and limestones are often stained brown by the iron oxide resulting from its decay.

At no known locality in the State other than that in coal where it is already mined does it offer inducements for its recovery. That such other places may be discovered is entirely probable, especially if prices remain high enough to offer a stimulus for prospecting for it.

DISTRIBUTION AND AMOUNT OF PYRITE RECOVERABLE FROM THE COALS OF INDIANA

There are few if any coals that do not show sulphur upon chemical analysis. It varies in coals of Indiana from .89%[1] for No. IV seam to 5.14%[2] for Seam No. III as mined.

As all impurities that are discarded in mining are not included in analysis the maximum sulphur content may reach as much as 10 per

[1] Lord, N. W., Bul. 22, Pt. I, U. S. B. of Mines, 1913, p. 96.

[2] Ibid., p. 97.

cent if all sulphur bearing minerals were included. Most of the pyrite, either in aggregates that are easily seen or that may be selected by their superior weight, is discarded by the miner in the rooms or thrown out by pickers on the railroad cars or picking belts. It is obvious that this report has most to do with this material so discarded, hence little use could be made of analyses in estimating the quantity of pyrite.

Low sulphur content is to be desired by operators, as any considerable quantity is considered deleterious and in ordinary times makes the coal hard to sell in a competitive market. A chemical analysis does not always reveal much of the nature of the sulphur in coal; it is rather more important to find out in what combinations the sulphur is found. If mostly in fine well disseminated particles or thin leaves of pyrite its combustion is usually complete,[3] generating about one-half as much heat as an equal bulk of coal. If in the form of lenses or aggregates of appreciable size it clinkers badly with corrosive effects on iron grate bars. In either case the fumes corrode the flues of boilers. The iron adds to the weight of ash.

GENERAL NOTES ON THE DISTRIBUTION AND QUALITY OF PYRITE IN THE COALS OF INDIANA

Plate —— shows the areal distribution of recoverable pyrite where data are fairly complete. With few exceptions only mines with railroad connections and employing ten or more men were studied. This will account for the grouping of the areas on railroads. It is probably safe to assume that the undeveloped coal territory not as yet served by railroads contains quantities of pyrite similar to the areas that have been or are being worked, hence a map showing recoverable pyrite would be essentially coincident with a map showing the areal distribution of Seams III, V, and VI. In this connection the chart accompanying the supplementary report on the coal of Indiana, by George N. Ashley may be consulted. The areas shown on Plate —— will, no doubt, be added to as knowledge is extended by the opening up of new coal territory.

COAL SEAM NO III

On an average, Seam No. III in Parke, Vermillion, Vigo, Greene and Clay counties, Indiana, shows the highest percentages of recoverable pyrite.

In the region of Rosedale, Indiana, and Clinton, Indiana, this seam will produce from 6 per cent to 8 per cent of the tonnage mined as bands and lenses of high grade pyrite that separates easily from the associated shale on coal. As mined the fragments of bands and lenses weigh from 5 to 10 pounds commonly, with about an equal weight of adhering coal. The large quantity and pure quality of the pyrite from this area makes further attention to Coal No. III in that vicinity seem worth while if an adequate market could be secured for the pyrite.

Coal No. III is mined in the vicinity of Seeleyville, Indiana, and Staunton, Indiana, and near Burnett, Indiana. At all of these localities the quantity is less than further northwest but still worthy of

[3] Ibid., p. 81.

attention. In the Franklin-Tandy-Lowish mine at Staunton, Indiana, a few masses were found which are probably casts of tree trunks or stem fragments, originally of calcium carbonate and then later replaced by pyrite. The replacement is not always complete and occasionally these masses are impure. Such casts form rather a negligible part of the total pyrite, hence what few contain calcium carbonate would not materially reduce the quality of the whole. An average sample of lenses from the Willow Creek Mine at Seeleyville, Indiana, showed 41.31 per cent sulphur.

At Jasonville, Indiana, and Midland, Indiana, the lenses of purer pyrite from Seam No. III are commonly large and often break from the coal entire. Such large masses may weigh up to 100 pounds or more, with a center of rather pure stone-gray pyrite surrounded with a transition zone of from 2 to 4 inches of black interleaved coaly matter and pyrite or fine grains of pyrite and impure coal. These zones are not easily separated from the pure portion by hammering when fresh, but when allowed to weather either in the mine or at the surface for a few weeks, the outer impure portions shell off leaving the central mass as high grade pyrite. To test the quality of these lenses even when fresh, samples were taken with the following results:

1. Sample from several lenses from Island Valley, No. IV Mine, Jasonville, Indiana. This sample was taken from fresh lenses just mined and represented the quality of pyrite by hand cleaning. To the eye a considerable portion of black transition pyrite was included. Result, 44.96% sulphur.

2. A similar sample from the Tower Hill Mine at Midland, Indiana, from fresh lenses roughly cleaned by hand of adhering impure coal. Result, 42.27% sulphur.

3. Same locality as 2, but sample from purer portions of similar lenses exposed to the weathering for three months. The outer interleaved zone essentially all crumbled off. Result, 46.07% sulphur.

The difference between the sulphur content of 2 and 3 is notable. It seems to show that these black looking masses of pyrite commonly found in the above locality are high grade pyrite and deceptive to the eye. Such lenses if put through a washer as suggested on pages 236-239, following, would concentrate to a high grade product without doubt. The black transition zones would probably appear as jig middlings and would necessitate rather fine crushing to recover most of pyrite contained.

Due to the presence of considerable amounts of clay, shale and rock impurities interbedded with Coal No. III, the gob piles both in the mine and on the surface are relatively large. In the mine the pyrite is thrown back with the other impurities in the rooms and is badly mixed with them. This would make recovery of the pyrite in old works difficult. Immediate sorting while mining would be advisable if the pyrite is to be recovered. Above ground the gob commonly burns except where tipple discards are hauled away and spread out. Where this is done the solid pyrite portions of these lenses have resisted weathering; sometimes for years. Several hundred tons of such material may be found about the surface works of some of the older mines and the newer mines in proportion. These accumulations are often an important index to the quantities of pyrite discarded below ground.

COAL SEAM NO. VI

Seam No. VI wherever mined shows a uniformly high quality of pyrite, and in quantity probably stands second to Seam No. III.

No. VI coal is mined most extensively in Sullivan County. Wherever mined, the seam is subject to falls of shale from the roof, so that all pyrite left in the rooms is buried sooner or later under quantities of roof shale.

An examination of many falls, shows that pyrite in nodules to fine grains interspersed through the roof shale contributes more or less to these falls, especially the sort where instead of a mass of several tons weight falling at once, a shelling off takes place of from one to four inches of shale over an area of several square feet. Such slabs are probably loosened by the disintegration of pyrite from the action of moist air, percolating waters carrying dissolved oxygen and oxidizing agents, together with the softening of the clays along laminæ.

Besides the lenses of high grade pyrite in the coal itself, in a few localities, notably in the Pan Handle Mine at Bicknell, Indiana, large, flat, knobby lenses, or nodules often weighing up to one hundred pounds, occur in the lower six inches of the roof shale. After a short exposure these lenses fall and are easily recovered. The pyrite is often coarsely granular and occasionally carries a small percentage of zinc. Considerable water is encountered in this mine and not uncommonly the lenses of pyrite both in the coal and shale are surrounded with a film to one-eighth of an inch of wet clay-like material that on account of its weakness allows the lens to break free from the containing coal or shale.

The following two analyses from the Pan Handle Mine show the quality of the lenses commonly found in Seam No. VI:

Sample of lenses and bands in coal—46.04% sulphur;

Samples of nodules and lenses from "draw slate" above No. VI coal—46.05% sulphur.

Several hundred tons of discarded pyrite might be recovered about the surface plants of the Kolsem Mine No. 4, the Mildred Mine and the Peerless Mine, all southeast of Shelbourne, Sullivan County, Indiana, and from the Monon No. 15 Mine at Cass, Sullivan County. Most of this pyrite is clean lenses and fragments of bands that have weathered free from adhering coal and may be regarded as material that needs but little preparation other than merely washing off the adhering earth and copperas. It is notable in this connection to observe the concentration of rounded pyrite masses about the margin of high waste dumps from mines. When the car of mixed slabs and shale and rounded pyrite lenses, usually from roadways or entries, is dumped at the top of the pile, the slabs of shale and impure coal slide a short distance and finally come to rest while the more nearly spherical masses roll downward and accumulate at the margins of the dump. Masses containing pyrite are commonly rounded and the quantity of pyrite easily loaded upon a wagon or truck about the edges of dumps is worthy of attention. A periodic cleaning up about these dumps would prevent the pyrite becoming covered by the growth of the pile and the slow creep of the shale and clay.

It would be difficult to recover much pyrite from old workings in mines in this coal due to the roof falls of shale and, like the pyrite in Seam No. III, would best be recovered at the time the coal is removed or shortly afterward.

No dilution of the pyrite masses by calcium carbonate was noted in any mines examined. The ease with which the pyrite separates from the adhering coal and clay is noteworthy. The pyrite is commonly sharply defined from the coal without the transition interleaved zones as noted in No. III coal and may be considered as of uniform high grade.

SEAM NO. V

Coal Seam No. V contributes about 60 per cent of the coal mined in Indiana. The persistence of workable thickness and the uniformly good roof above this seam with the good quality of the coal easily explains its lead in tonnage.

The best grade and largest quantity of recoverable pyrite is found in this seam in Vigo, Vermillion and Sullivan counties. Vigo and Vermillion counties lead in tonnage of coal mined and also in the percentage of recoverable pyrite from No. V coal. The area immediately northwest of Terre Haute is especially notable as a source of pyrite.

Pyrite occurs in the area of the three counties above mentioned as lenses and balls or boulders and to a minor degree as bands in the coal. Since the occurrence of pyrite has been discussed at some length on pages 224-229 details need not be mentioned here aside from calling attention to the calcium carbonate present in some of the large boulders in this coal. The lenses are quite uniformly high grade even though commonly surrounded by transition zones of impure coal and fine grained pyrite, and the balls or boulders, if some care is used in selection, will easily concentrate to a marketable grade of pyrite as shown on page 225.

As was found about mines in No. VI coal, page 232, the dumps about the surface of mines in Coal No. V may be worthy of attention. The concentration of pyrite about the margins of dumps is even more notable than in No. VI, as the balls and boulders often roll to some distance about the edges of the dumps. The roof boulders removed, which are not regarded as recoverable pyrite, exhibit the same tendency, hence the concentrations are not always as high grade as those about dumps from No. VI coal.

But little shale or clay is interbedded with the coal. The gob piles in the rooms are mostly crude pyrite. Where the coal is four feet or less in thickness it is necessary to take up several inches of the bottom clay to make sufficient clearance for the pit cars. This clay is thrown back and usually covers the pyrite discarded during mining. This is necessary at only a few localities as the bulk of the seam where worked is thick enough to allow easy mining.

The mines are quite dry and the roof good, so that much pyrite might be recovered from old workings if the market price were high enough to justify relaying tracks that have been removed.

Knox, Daviess, Gibson, Pike, Vanderburgh and Warrick Counties. Seam No. V in Knox County and southward shows a marked increase in diffused and scattered leaves and grains of pyrite and a similar decrease in lenses and bands of recoverable size, the change becoming more marked as the Ohio River is approached. Chemical analysis of Coal No. V probably would show but little difference in the sulphur that enters into such analyses, between the northern and southern portions of the State.

Balls, lenses and bands are present in this area but much fewer than in the northern area just described.

Zones of interleaved pyrite from one to four inches thick are rather the rule. These zones are continuous and parallel to the bedding. They are rarely accompanied by shiny granular pyrite bands from one-fourth to three-eighths inch thick. As many as four or five zones may be encountered in a working face. If the zones are large and prominent they are discarded, if small they are seldom noticed and probably do no material harm in the marketed coal. Coal discarded on account of these zones in the mine may reach a total of three to four per cent of the total coal mined.

The pyrite content of these zones is low, often not over ten or fifteen per cent of the total coal lump discarded and is commonly less than fifty per cent. The lumps of coal discarded, consequently, have a low pyrite content—from two to ten per cent.

Any method looking to the recovery of the lenses and balls would have to include close sorting of the material discarded unless the recovery of the coal from low grade zoned pyrite should be of more consequence than of the pyrite. Fine grinding would be necessary to free the pyrite from these zones; in that case the coal would probably be rendered useless.

The lenses and balls though present in limited quantities are of good grade. Joint veins or "cat faces" are vertical pyrite veins that occupy the vertical joints common in coals. They seldom attain a thickness or size to be of importance but are present in rather increasing numbers southward in No. V seam as the Ohio River is approached.

Aside from the lenses and balls the bulk of coal discarded on account of pyrite in Knox County and southward may hardly be regarded as a resource. It would be a direct contribution to the conservation of our coal if this waste might be saved.

OTHER SEAMS

Seam No. IV contributes probably less free pyrite than any other coal. Occasionally the seam shows rather high pyrite content, but these localities are so rare as to make it advisable to disregard all coal produced from this seam as a potential supply of pyrite. Where examined a few thin leaves, both parallel to the bedding and in joint cracks, were noted. Other than this it is quite free from this impurity.

The block coals and Minshall seams contain a small percentage of recoverable pyrite in the form of lenses and thin bands.

In the block coals the quantity is greatest near "troubles," clay-filled channels in the coal, and near faults. In the Minshall, the pyrite is found mostly between the coal and roof, or at the bottom of the coal.

The tonnage of coal is small from both of the above seams and hence essentially negligible in considering the pyrite supply.

Seam No. VII is mined in a small way but in two or three localities, one of which was examined. It contains no appreciable amount of recoverable pyrite so far as known.

Seam No. VIII is mined in only one or two localities locally. The recoverable pyrite is negligible.

During the past year considerable interest has been directed toward abandoned mines, especially in coals that on account of the large amount of impurities or difficult physical conditions were not able to complete profitably under pre-war conditions. Several old mines have been reopened. New mines have been developed under the stimulus of unlimited demand for coal, in localities that were considered unfavorable. Stripping, or open pit mining, has increased rapidly until at least nine plants were in operation August 1st, 1918. Only one of these, The Central Indiana Collieries Co., of Dugger, has equipment for the consistent recovery of pyrite, the others picking pyrite from railroad cars as the coal is loaded by steam shovel, or sorting in the pit if loaded by hand.

TONNAGE AVAILABLE

Based on ability to operate two hundred fifty days per year the coal mines of Indiana employing over ten men could produce about 225,000 tons (2,000 lbs.) of pyrite per year. As the mines in the northern portion of the field where recoverable pyrite is most abundant have probably been operating on an average of nearly three hundred days per year, the minimum estimate of pyrite recoverable might be safely placed at about 250,000 tons per year if all were utilized.

As it would seem unwise, at present at least, to try to utilize crude pyrite where fine grinding would be necessary to concentrate the product, or where the recovery of a low grade product would interfere seriously with coal output, this would still leave upward of 150,000 tons per year from mines that would contribute a consistent tonnage of crude pyrite containing 50 per cent or more pyrite.

A considerable amount of pyrite is to be found about the surface of many mines. Much is still recoverable from old works in mines. No definite estimate could be made as time and conditions did not allow. Falls and oxidation has made much pyrite unavailable. Tracks removed could only be relaid at considerable expense and labor. In general it may be safely estimated that from the two sources fully 50,000 tons could be made immediately available. Some experienced operators have regarded this figure as very conservative.

This would make a total of about 200,000 tons from less than ninety mines or considerably less than half of the mines of the State employing over ten men.

Attention should be further called to the fact that the figures above are for pyrite only and if recovered by a pyrite washery utilizing the crude as it comes from the mine, a tonnage of coal that is now left in the mine almost equal to the above would be added to the output of the State.

THE RECOVERY OF PYRITE FROM COAL

A few hundred tons of "coal brasses" have been marketed from the coals of Indiana in the past few years. Most of it has been shipped to nearby acid plants and utilized for the manufacture of fertilizers. No considerable industry has been established, due to the cost of cleaning by hand and the resulting rather low grade of product that did not readily compete with imported clean pyrite. A few small mines utilized idle days to "clean sulphur" or the work was farmed out to superannuated employes. In many cases the owners and operators received nothing for it. But small amounts were recovered from the workings, most of it coming from accumulations from discards at the tipple. Only a few mines are equipped with picking tables or conveyors, or chutes from which pyrite might be loaded. Sporadic attempts have been made to establish the industry, it being reported that a machine for preparing pyrite was once in operation near Clinton.

Most operators have been apathetic toward its recovery, as the price offered was too low to allow a profit by methods then in use. Mines were primarily equipped to handle but one product—coal—and that as cheaply as possible. Anything that appeared to add to the difficulty of recovering coal was not welcomed by the operators. No scale of pay for miners loading out pyrite has been adopted in Indiana.

In all, operators felt they had troubles enough without inviting more by dabbling in the questionable recovery of pyrite.

The developments of the past year and a half have demonstrated that pyrite can be recovered profitably from coal. The problems involved are not insurmountable. The reader is referred to the following publications: "The Utilization of Pyrite Occurring in Illinois Bituminous Coal," by E. A. Holbrook; Circular No. 5 of the Engineering Experiment Station of the University of Illinois, Urbana, Illinois; and a description of the pyrite washery near Danville, Illinois, by C. M. Young, in Coal Age, Vol. XI, No. 1, p. 7, Jan. 6, 1917. Since 1916 other plants have been built, until it may be said the industry is in a fair way of becoming established.

Hand cleaning alone is unprofitable and impracticable, due to labor shortage and a product that is badly contaminated with coal that increases the niter consumption in the chamber process and tends to produce a dark colored acid that is found objectionable for certain purposes, though no objection is made for the manufacture of fertilizer. The market is unsettled and production fitful.

Pyrite washeries or mills to prepare clean marketable pyrite and the accompanying coal cheaply from crude pyrite—masses of pyrite and adhering coal—are being operated successfully. They may be built at a reasonable price, as the machinery necessary is simple and capable of being operated with unskilled labor. A flow sheet for such a plant is shown on page 239. Tests on Indiana coal pyrite in a similar plant are given also on page 241. The successful recovery of coal pyrite has passed the experimental stage.

The advantages in being able to take the crude pyrite with adhering coal as discarded by the miner without further preparation other than throwing it into piles separated from clay and other rock, loading it out in a manner similar to handling coal and then upon cars like mine-run coal, would appeal to both miner and operator.

Most operators would be glad to be rid of it as cheaply as possible, for if left in the mine it heats, developing harmful fumes and causes gob fires. If the mine is wet it adds quantities of free sulphuric acid and copperas to the mine waters that injure steel and iron equipment. Operators generally would regard its removal with satisfaction, especially if it could be removed with a profit.

The general opinion of miners was that it could be removed without excessive labor. It costs powder to mine it and labor to handle it and at present is largely left in rooms. They would generally welcome its disposal at a fair price for their labor.

SUGGESTIONS FOR POSSIBLE FUTURE RECOVERY OF PYRITE

In reply to questions of practicable methods that might be employed looking to the recovery of pyrite where the quantity would justify the attempt, many sensible suggestions were offered and may be summarized here.

As most mines are equipped with screens only below the scales, with no picking tables or belts, and equipped to produce either screened sizes or minerun, if pyrite is to be loaded out whenever the miner finds time or his accumulated crude pyrite gets in his way, auxiliary chutes would have to be built so as to shunt the pyrite into the waiting car. If the mine produced less than a car of pyrite per day, at present this would tie up a railroad car for a time too long when equipment is short. Since the quantity of recoverable pyrite varies somewhat in different portions of the mine and the daily tonnage of coal from the mine fluctuates, the mine might not always fill its car; or again, under favorable conditions, more than a carload would be produced. The excess would have to be either left in the mine or stored in bins at the surface. This general plan is probably not practical, for it places too much responsibility on the pit bosses or room bosses, men whose time now is completely occupied.

An alternative method suggested would be to load only enough out on certain days designated; for example, as "sulphur day," to fill a car, the excess being carried in the mine, possibly different portions of the mine alternating so as to avoid gathering from all parts of the mine. The exclusive business of hauling sulphur might be given to the last trip of the day or first trip in the morning to avoid congestion in entries and on roadways, and not tie up pit cars any longer than necessary.[1]

Where a mine or two mines close together could produce enough pyrite to operate a washery, locating the plant at one mine and hauling

[1] Crude pyrite weighs from one-half more to twice as much as an equal bulk of coal, and account must be taken of this not to overload equipment.

by truck from the other, using auxiliary chutes and bins, loading out sulphur any time would seem to be practical.

At many times a simple rearrangement of tracks on the surface would make it possible to handle "sulphur" much as gob from roadways is handled instead of going to the dump, sending to a loading chute over the railroad car when shipped by rail, or to a cheaply constructed bin if hauled by wagons or trucks.

It would seem impractical to attempt the recovery of pyrite from mines that could produce but a few hundred pounds each day, although idle days here might be utilized a few times a year if found necessary. Experience has shown that the recovery of a by-product can best be undertaken where it settles easiest to a routine, once started. This being true, the mines with the high percentage of recoverable pyrite should offer the most inducement for the experiment.

LOCATION FOR PYRITE WASHERIES

Detailed plans for the location of central washeries would best be left to the discretion of the builders, taking into account the tonnages, quality or kind of crude pyrite, distribution of mines with reference to railroads and truck routes, and outlet for the finished product, with other factors. A mill handling pyrite entirely from Seam No. V might find it advantageous to use special machinery other than necessary for the concentration of raw pyrite from Seams III and VI. These, as well as many other minor problems, suggest themselves to an engineer locating and designing a plant.

In general, adequate water supply should be insured, although by the use of settling dams or tanks water may be used over and over.

Terre Haute, from which several railroads radiate to mines with adequate supplies of pyrite, would seem a logical center for washeries. A railroad haul of less than twenty-five miles would collect nearly 70 per cent of the recoverable pyrite of the State and serve the largest number of mines if it were advantageous to centralize mills. If it were best to distribute smaller units near large producers, some locations on the C. & E. I. R. R. and C. T. H. & S. E. R. R. between Clinton and Terre Haute would bring the mills close to producers. Also smaller units near Shelbourne, Dugger and Jasonville are suggested.

The fields adjacent to Bicknell could probably supply a fair-sized unit, while a small mill could be kept busy at Evansville or Boonville to take care of mines south of Princeton. It might be found more advantageous to locate a plant at Oakland City, as that is a junction point.

It will be understood the above are merely suggestions and not recommendations. Many problems suggested above are to be taken into consideration and too many factors at present are unknown to more than suggest locations. The suggestions are based upon quantity and quality of crude pyrite and not upon market and transportation facilities, which should be gone into in much more detail than time and conditions allowed.

EXPERIMENTS ON THE CONCENTRATION OF PYRITE FROM INDIANA

By E. A. Holbrook*

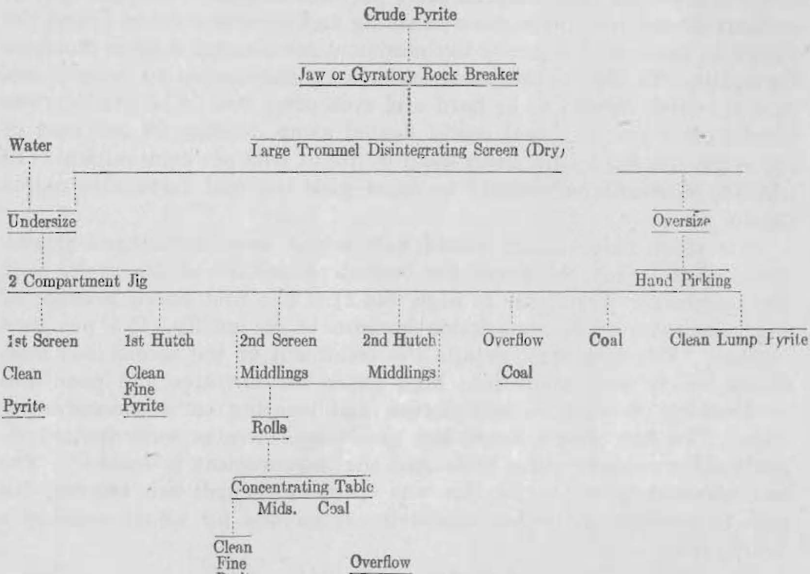
There was some doubt as to whether or not the pyrite in the Indiana mines was really high grade pyrite. For this reason three lots of the crude pyrite, one each from Seams No. IV, V and VI were shipped to the Bureau at Urbana, Illinois. The tests showed that simple crushing and water concentration could produce a pyrite with sulphur content between 42 and 46 per cent, or practically equal to the imported Spanish pyrite of 47 per cent pyrite. The details of the tests follow.

(a) CRUDE PYRITE WITH COAL ATTACHED FROM SEAM NO. VI, INDIANA

Introduction: As received, the material was flat bands and lenses of pyrite with considerable adhering coal. The pyrite was up to 3½ inches in thickness, and the individual lumps, with coal attached, up to 8 or 9 inches in thickness. To the eye there appeared by weight to be about ½ coal and ½ pyrite in the material. The pyrite was dull and stony and in color varied from a bronze to dark gray.

Conclusions: Crude Coal Pyrite from Seam VI, Indiana, offers no difficulty in concentration, and produces high grade pyrite concentrate, even in sizes above one inch. Very few fines are made in crushing and they are easily taken care of in treatment either by saving as a hutch product of the jigs or by treating them on concentrating tables. On account of the large size of the clean pieces of pyrite, it is probable that simple screening after crushing, or screening followed by hand picking, will produce about 1/5 of the total pyrite as a clean lump pyrite.

A flow sheet of a proposed treatment plant follows:



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*From experiments conducted at the U. S. Bureau of Mines Experiment Station, Urbana, Ill., and published by consent of the director.

NOTES: The pyrite tends to break into flat pieces in breaker, while the coal breaks into cubical pieces. Therefore, screening this broken material in a round hole trommel screen allows the coal to fall through the holes with the smaller pyrite, while the coarse pyrite remains on the screen as a nearly pure oversize. This can be cleaned by hand picking from the few remaining pieces of coal.

The coarse screening is done dry. In this way the oversize lump pyrite is prepared for market without wetting.

Details of Test: From the size of the individual lumps of pyrite it seemed that comparatively coarse crushing should free the pyrite from the coal. Accordingly the lumps were crushed in a gyratory rock breaker set at 1½ inches. It should be noted here that the pyrite is so hard that rock crushing rather than coal crushing machinery is necessary for its reduction. Some of the pyrite in the broken mass was of larger size than the coal and was flatter in shape, consequently it seemed that screening the material over a 1-inch round hole screen would produce a coarse oversize that should be pure pyrite. The treatment for the material under 1-inch round hole size was jigging without sizing to obtain pure pyrite and a middling product and recrushing the middling and treating this either on the jig or on a concentrating table.

The complete flow sheet of the test run is given on p. — together with percentages and analyses of products. The crushed material from the rock breaker was screened in a trommel or roller screen equipped with interior ribs for the purpose of breaking adhering coal from the pieces of pyrite. The sizes and analyses given show the definite increased pyrite percentages as the size of the product increased. The product marked over 1-inch round hole, consisted of 14.7 per cent of the original material and analyzed 41.10 per cent sulphur. In other words, without further treatment than crushing and screening about 1/5 of the pyrite in the coal was above the minimum commercial sulphur analysis for pyrite. To the eye this material looked contaminated by many pieces of coal, which seemed to be hard and even often flat. The product was hand jigged and this coal easily floated away, leaving 90 per cent of the original weight as a clean lump pyrite of 44.9 per cent sulphur. In practice it might be cheaper to hand pick the coal from this coarse pyrite.

The sizes under 1-inch round hole screen were united and jigged. The first bed (coarse) saved the largest production of the pyrite, and the percentage of sulphur is high (44.2). The first hutch product of fine conecentrates is remarkable because of its purity, 45.5 per cent sulphur. The flow sheet details the treatment of the second bed middlings which were made into high grade concentrates and poor coal by crushing through ¼-inch screen and treating on a concentrating table. The fine second hutch low grade concentrates were treated directly on a concentrating table and the improvement is marked. The coal screened from the jig run was clean as regards ash content, but high in sulphur. Another compartment on the jig would produce a cleaner coal.

The résumé of the test is given on p. 241.

(b) PYRITE FROM SEAM NO. V, INDIANA

Introduction: Much of the pyrite in Seam No. V in Indiana occurs as round or oval boulders, often of as much as 200 pounds weight. This form of occurrence is illustrated in Fig. 2, p. ——. These boulders generally are at or near the bottom of the seam and must be mined with the coal. In some of the mines worked in this seam large tonnages of these boulders have been thrown back into the gob during regular mining operations. * * * There was doubt as to whether or not these bottom boulders of pyrite were pure enough to be considered commercial pyrite, and as any commercial pyrite cleaning plant erected in Indiana would receive considerable of this material, concentrating tests were carried out with it.

The flow sheet used was the same as for (a) the pyrite from seam No. VI Indiana andd described on p. 239.

Conslusions: The pyrite balls or boulders are a pure form of pyrite and require only crushing, screening and jigging to produce clean pyrite of commercial grade. The percentage of coarse lump pyrite in the material is high.

Carbon Content: It has been stated that a high carbon content in coal pyrite lowers the value in the roasting furnaces. Our statement was made to the writer that clean coal pyrite contained from 8 to 10 per cent of carbon. To determine the real carbon content of the pyrite concentrates, samples from this test were forwarded the Bureau of Mines Laboratory at Pittsburg, Pa., and there analyzed for sulphur and carbon. The results follow:

PYRITE CONCENTRATES FROM RUN (B) SEAM NO. V, INDIANA

Laboratory	Form	Total Sulphur %	Total Carbon %	Organic Carbon %
30542	First Bed Jig	44.77	2.90	2.27
30543	Lump Concentrates	45.88	2.60	1.83
30544	First Hutch	45.03	3.75	2.96
30545	Recleaned Middlings	43.88	6.76	6.61

Since the lump, first bed and first hutch concentrates are in the largest percentage, the average total carbon content of all the pyrite of this run is 2.63 per cent. This may be taken as an average concentrate.

PYRITE FROM SEAM NO. 6, INDIANA

Bands of Pyrite with attached coal. (To the eye, looked about one-half coal and one-half pyrite.)

Crushed in Gyratory Rock Breaker set at 1⅛ inches
1,119 lbs.

105 lb. sample removed. Analysis, 33.8% Sulphur.

Screened in Disintegrating Screen.

¼″—O. R. H.	¼″—½″ R. H.	½″—¾″ R. H.	¾″—1″ R. H.	Over 1″ R. H. Through 2″ R. H.
228.5 lbs.	179.0 lbs.	186.5 lbs.	271.0 lbs.	149 lbs.
22.5%	17.7%	18.4%	26.7%	14.7%
25.8% Sulphur	29.6% Sulphur	35.0% Sulphur	36.6% Sulphur	41.10
				Hand Jigged.

United and 105 lb. sample added.
Total weight 970 lbs.
Jigged.

Pyrite	Coal
134 lbs.	15 lbs.
9 %	10%
44.9% Sulphur.	6.9% Sulphur
	15.1% Ash.

1st Bed Concentrates.	1st Hutch Concentrates	2nd Bed Middlings	2d Hutch	Clean Coal Overflow	Loss
372 lbs.	89 lbs.	72 lbs.	50 lbs.	322 lbs.	65 lbs.
38.4%	9.2%	7.4%	5.1%	33.2%	6.7%
44.2% Sulphur	45.5% Sulphur	35.8% Sulphur	22.7% Sulphur	Ash 14.4%	
				Sulphur 9.6%	
				Table	

R. H.—Round Hole Screen

Crushed through ¼″
Butchart Table

Pyrite	Middlings	Coal	Loss
10 lbs.	6.5 lbs.	28 lbs.	5.5 lbs.
45.5%	33.4% S.	13.2% S.	
		19.0% A	

Concentrates	Middlings	Overflow Coal
48 lbs.	4 lbs.	20 lbs. 2.1%
5.0%	0.3%	35.3% Ash
42.5% S.	36.6% S.	19.8% Sulphur

57.0% Recovery

PYRITE FROM SEAM NO. VI, INDIANA—RESUME

Materia	Concentrate Weight	% of total concentrates	Sulphur analysis of concentrate	Coal Weight	% of total Coal	Coal analysis % Ash	Loss Wt.	% of total Loss	Mids. Wt.	% S. Mids.
Over 1"...........	134	20.4	44.9	15	3.8	15.1	......	......	......	......
1"-0 Size..................	372 89	56.6 13.5	44.2 45.5	322	83.7	14.4	65	92.2	....	....
2nd Bed recrushed Middlings..............	52	8 0	42.0	20	5.2	19.8	....	......	......	......
2nd Hutch Tabled Middlings..............	10	1.5	44.5	28	7.3	19.0	5.5	7.8	6.5	33.4
Total............	657	100 0	44.35	385	100.0	15.3	70.5	100.0	6.5	33.4

Of 1,119 pounds of material treated, 657 pounds or 58.8 per cent was recovered as a pyrite of 44.35 per cent sulphur content; 385 pounds, or 34.4 per cent, was recovered as coal of 15.4 per cent ash. The loss in treatment was 70.5 pounds or 6.3 per cent and the middlings still on hand were 6.5 pounds or .5 per cent.

RESUME OF LABORATORY TEST ON PYRITE FROM SEAM NO. V, INDIANA

Materia.	Concentrate weight lbs.	% of total concentrates	Sulphur analysis of concentrate	Coal Weight	% of Total Coal	Coal analysis % Ash	Loss Wt.	% of Mids. Total Wt. Loss	% S. in Mids.
Over 1".............	174.5	20.4	43.6	....	......	......	......	......	......
1"-0 Size...........	472 1st Screen 102 1st Hutch 114 2nd Bed	53 6 11 6 13.0	42.4 43.5 41.3	.... 112	.... 77.2	.... 21.9	..... 9 5	...... 95	....
2nd Hutch Tabled....	16.5	1.8	42.3	33	22.8	21.0	0.5	5	.....
Mids................	....	......	....	....	......	....	......	......	....
Total..........	879.0	100.0	42.62	145	100.0	....	10	100	.....

Of 1,034 pounds of material treated, 899 pounds or 85 per cent was recovered as pyrite of 42.62 per cent sulphur content; 145 pounds or 14 per cent was recovered as coal of 21.7 per cent ash. The separation was so complete that no middlings were made.

Tests were run on pyrite from seam No. III with equally good results. Pyrite from the coals of Indiana can be mechanically washed in quantity, giving a product that compares well with the imported Spanish product.

THE PYRITE MARKET

Pyrite contains two elements absolutely essential to warfare: sulphur and iron. In a ton of chemically pure pyrite the proportions would be approximately 932 pounds of iron and 1,068 pounds of sulphur. The Spanish pyrite usually contains a small percentage of copper, which is recovered. Coal pyrite of Indiana when thoroughly cleaned by washing usually contains from 40 per cent to 45 per cent of sulphur and a proportionate amount of iron, a little carbon (2.9 per cent to 6.76 per cent, see page 241), rarely a minute quantity of zinc and from 10 per cent to 17 per cent of other impurities. It compares favorably in these respects to the Spanish product. Coal pyrite does not contain arsenic or antimony, impurities that often make otherwise high grade pyrite unsalable. Since the present war, the market for domestic pyrite has been stimulated due to the curtailment of imports and the increased quantity consumed.

Different sizes of pyrite usually have different selling prices, due to the construction of burners and uses made of the iron cinder or residue, so that prices given are subject to modifications. The present (September 15, 1918), price on domestic pyrite ranges from 28 to 32 cents per unit.[1] On a 40 per cent sulphur basis this is $11.20 to $12.80 per ton, a very attractive price compared to the price received for coal at the mine. The belief is general that the price will not be less than 15 cents per unit f. o. b. point of production for some time, possibly two years or more. This of course is a belief based on present conditions which may change before this reaches the reader.

USES AND IMPORTANCE OF SULPHURIC ACID

The tremendous industrial expansion incident to the present war has created a demand for sulphuric acid that has never been entirely satisfied. Acid plants all over the United States have been producing to capacity. Even old plants that stood idle before the war were put into a semblance of condition and set to producing. The demand was stimulated by the needs of acids for the manufacture of explosives as well as the manufacture of dozens of other war necessities.

In order to convey a conception of the importance of sulphuric acid, the following summary is included:

Min. Res. of the U. S., 1917, Pt. II, p. 58. Quoted from Lunge Groye, Manufacture of Sulphuric Acid and Alkali, Vol. I, Pt. 2, pp. 1169-1170.

"1. *In a more or less dilute state (say from 144 Twad. downward).* For making sulphate of soda (salt cake) and hydrochloric acid, and therefore ultimately for soda ash, bleaching powder, soap, glass, and innumerable other products. Further, for superphosphates and other artificial manures. These two applications probably consume nine-tenths of all the sulphuric acid produced. Further applications are for preparing sulphurous, nitric, phosphoric, hydrofluoric, boric, carbonic, chromic, oxalic, tartaric, citric, acetic, and stearic acids; in preparing phosphorus, iodine, bromine, and sulphates of potassium, ammonium, barium (blanc fize), calcium (pearl-hardening); especially also for precipitating baryta or lime as sulphates for chemical processes; sulphates

[1] Pyrites are usually paid for on the basis of their sulphur content, at so much per unit. A unit is one per cent of sulphur as shown by analysis. Thus if the price is 10 cents per unit and the ore shows 43 per cent of sulphur, the price per ton would be ten times 43, or $4.30. The price is neither fixed nor stabilized and is subject to considerable market fluctuation.

of magnesium, aluminum, iron, zinc, copper, mercury (as intermediate stage for calomel and corrosive sublimate); in the metallurgy of copper, cobalt, nickel, platinum, silver; for cleaning (pickling) sheet iron to be tinned or galvanized; for cleaning copper, silver, etc.; for manufacturing potassium bichromate; for working galvanic cells, such as are used in telegraphy, in electro-plating, etc.; for manufacturing ordinary ether and the composite ethers; for making or purifying many organic coloring matters, especially in the oxidizing mixture of potassium bichromate and sulphuric acid; for parchment paper; for purifying many mineral oils, and sometimes coal gas; for manufacturing starch, sirup, and sugar; for the saccharification of corn; for neutralizing the alkaline reaction of fermenting liquors, such as molasses; for effervescent drinks; for preparing tallow previously to melting it; for recovering the fatty acids from soapsuds; for destroying vegetable fibers in mixed fabrics; generally in dyeing, calico printing, tanning; as a chemical reagent in innumerable cases; in medicine against lead poisoning, and in many other cases.

2. *In a concentrated state.* For manufacturing the fatty acids by distillation; purifying colza oil; for purifying benzene, petroleum, paraffin oil, and other mineral oils; for drying air, especially for laboratory purposes, but also for drying gases for manufacturing processes (for this, weaker acid also, of 140° Twad., can be used); for the production of ice by the rapid evaporataion of water in a vacuum; for refining gold and silver, desilvering copper, etc.; for making organo-sulphonic acids; manufacturing indigo; preparing many nitric compounds and nitro ethers, especially in manufacturing nitroglycerin, pyroxylin, nitrobenzene, picric acid, etc.

3. *As Nordhausen fuming oil of vitriol (anhydride).* For manufatcuring certain organo-sulphonic acids (in the manufacture of alizarin, eosin, indigo, etc.); for purifying ozokerite; for making shoe blacking; for bringing ordinary concentrated acid up to the highest strength as required in the manufacture of pyroxylin; and for other purposes."

According to Utley Wedge, of Ardmore, Pa., the amount of 50° Baume sulphuric acid consumed in the United States for various purposes during normal years is as follows:

1.	Fertilizers	2,400,000 tons
2.	Petroleum	300,000 tons
3.	Iron, steel and coke industries	200,000 tons
4.	Explosives (pre-war conditions)	150,000 tons
5.	All other industries	200,000 tons
		3,250,000 tons

Due to the curtailment of the potash supply, complete fertilizers have not been produced in pre-war quantities, hence item (1) will probably not show increase. Consumption in each of the other industries has increased as is shown by the fact that probably not far from 10,000,000 tons of sulphuric acid of all grades will be necessary to supply the demand during the present year. This means an expansion of nearly three times the normal pre-war acid consumption.

Sulphuric acid is manufactured by:

1. Burning brimstone or native sulphur.
2. Burning pyrites, either in lump burners or mechanical furnaces.
3. Roasting sulphide mixtures.
4. Dead roasting zinc blende in kilns; and,
5. Utilizing waste sulphur gases from smelters of low grade copper and other ores.

Adapted from "The Sulphuric Acid Situation in the United States," Lewis B. Skinner. Jan. 1918. Metallurgical and Chemical Engineering, Vol. XVIII, pp. 82-83.

The distribution of ore used in the manufacture of sulphuric acid in 1917, in long tons was as follows:

	Sulphur	Pyrites	Gold and Silver bearing pyrites and galena	Copper bearing Sulphides	Zinc bearing Sulphides
Domestic..............	463,364	376,955	17,380	708,502	584,100
Foreign..	20,463	880,183	....	147,531	152,811
Totals...........	483,827	1,257,138	17,380	856,033	736,911

Mineral Resources of the U. S. 1917, Part II, page 61.

LOCATION OF PYRITE WASHERIES

The most practical method suggested for taking care of the limited output of pyrite from mines is a central washing or concentrating plant of such size as to serve two or more mines. A washery with a capacity of 50 tons per 8-hour day seems to be the smallest practical unit. The capacity of such a plant could easily be tripled by operating in three shifts. Continuous operation of any metallurgical plant is most successful as well as economical. Depreciation is proceeding while machinery is idle, and especially iron and steel in contact with acid waters from pyrite.

In general a 100-ton mill per eight hours could be operated with the addition of only one or two men over a 50-ton unit, thus doubling the capacity with less than double in labor cost. The larger plants would in general be most economical.

Detailed plans for location of central washeries would best be left to the discretion of the builders, taking into account the tonnages, quality or kind of crude pyrite, distribution of mines with reference to railroads and truck routes, and outlet for the finished product, with other factors. A mill handling pyrite entirely from Seam No. V might find it advantageous to use special machinery other than necessary for the concentration of raw pyrite from Seams III and VI. These, as well as many other minor problems, suggest themselves to an engineer locating and designing a plant.

In general, adequate water supply should be assured, although by use of settling dams or tanks water may be used over and over.

Terre Haute, from which several railroads radiate to mines with large supplies of pyrite, would seem a logical center for washeries. A railroad haul of less than twenty-five miles would collect fully 70 per cent of the recoverable pyrite of the coal fields and serve the largest number of mines if it were advantageous to centralize mills. If it were best to distribute smaller units near large producers, some locations on the C. & E. I. R. R. and C. T. H. & S. E. R. R. between Clinton and Terre Haute would bring the mills close to producers. Also smaller units near Shelburn, Dugger and Jasonville are suggested.

The fields adjacent to Bicknell could probably supply a fair-sized unit, while a small mill could be kept busy at Evansville or Boonville to take care of mines south of Princeton. It might be found more advantageous to locate a plant at Oakland City as that is a junction point.

It will be understood the above are merely suggestions and not recommendations. Many problems suggested above are to be taken into consideration and too many factors at present are unknown to more than suggest locations. The suggestions are based upon quantity and quality of crude pyrite and not upon market and transportation facilities, which should be gone into in much more detail than time or conditions allowed.

ORIGIN OF PYRITE

The origin of pyrite in the coal is not well understood. White[1] attributes the "high percentage of sulphur in the sea-overswept coal of the interior basins, to the submergence of the coal form peat deposits by the sea, the immediate occupation of the area by animal life, and the action of sulphur bacteria."

He further regards somewhat richly sulphide rocks in the drainage basins in which the coal forms as a source of the sulphur.

The evidence from the occurrence of the various forms of pyrite in Indiana coals seem to indicate that most lenses and bands formed, at least in part after the peat was buried, perhaps from sulphates reduced by the carbonaceous matter of the seam and before complete consolidation. Some thin bands of pyrite seem to have been fractured at the time of jointing of the coal, and later filled with pyrite of different texture, usually shiny and contrasting sharply with the dull stony portion of the band. Not uncommonly both lenses and bands show enlargement by similar shiny pyrite. Attention has been called on page —— to the "nigger heads" from Seam No. V that show all gradations, from nearly pure calcium carbonate with a little iron in the form of limonite or siderite to essentially pure pyrite, many showing a shrinkage with vugs and cracks partially filled with crystalline pyrite. There seem to be plainly pyrite replacements after calcium carbonate, the shape and size of which were probably determined by the original carbonate boulder. In the coal they are often fossiliferous but with plant remains. The coarse nature of the remains suggests that they were probably more porous than the surrounding material and hence a locus for precipitation.

Lenses and bands of pyrite often show that their position was somewhat controlled by aggregates of coarse fragments of stems, trunks or

[1] White, David, The Origin of Coal, Bull. 38, U. S. Bureau of Mines, 1913, p. 34.

branches, mother of coal, shale bands, or "black jack" that diverted or directed the sulphide bearing waters if not exercising a precipitating effect.

The reducing power of charcoal is well known. The common association of pyrite with mineral charcoal offers a possible explanation for many nuclei, about which it is conceivable lenses and nodules might grow.

The larger amount of massive pyrite bands and lenses in the northeastern portion of the field would seem to indicate that as the direction from which the ferruginous waters came. It seems rather more than a coincidence that all the coals examined showed larger percentages of recoverable pyrite in the northeastern area.

The larger percentage of disseminated pyrite further south would seem to indicate solutions of lower concentration in iron and sulphur, or else meager amounts of similar density.

From the above three stages might be postulated:

1. The neutral or alkaline stage in which the open peat bed had more or less free communication with the sea with consequent precipitation of calcium carbonate, during which nodules or balls (in Seam No. V) and moulds of trunk and stem fragments were formed, especially abundant in Seam No. III, and a second stage after burial and partial consolidation of the coal when ferruginous acid waters replaced many carbonate bodies and formed the bulk of bands, nodules and lenses of pyrite directly. The third after partial unloading and erosion extending to the present, in which some pyrite may have been redissolved and precipitated as filling in fissures in the coal and pyrite.

As pointed out, the above is offered to explain the data available at the present time. New and important facts may later be discovered that would materially alter the conclusions and as such would be a welcome addition to our scant knowledge of the origin of these bodies that are so common and yet have been so long disregarded.

Directory and Tabular Summary of Quantity of Pyrite in Mines Operating in Seams 3, 5 and 6 of Indiana

Abbreviations used: l.—lenses; b.—bands; j.v.—joint veins; lvs.—leaves; nod.—nodules; est.—estimated.

Name of Company	Address	Name of Mine	Location	Seam No.	Railroad	Occurrence	Common Size of Masses in Pounds	Maximum Size in Pounds	Per Cent of Coal mined is Recoverable Pyrite	Possible Daily Production	Per Cent of Pyrite in Crude	Remarks
CLAY COUNTY												
Big Vein Mining Co.	Terre Haute	Lewis	1 mile east of Coalmont	V	C.T.H.& S.E.Ry.							No data
Brazil District Mfg. Co.	Brazil	Hamlin & Heck	½ mile east of Turner	III	Vandalia	e.	1–5	10	.6–.75	1.8–2.5	60–75	
Cleveland Coal Co.	Brazil	West Side No. 2	1 mile southwest of Brazil	III	Vandalia	l.	1–10	15	.75	1	60–75	Est.
Franklin, Tandy & Lowish	Brazil	Lowish	Staunton	III	Vandalia	l.b.j.v.	5–10	25–30	1.52	8–10	50	
Powers Collieries Co.	Staunton	No. 2 Mine	Staunton	III	Vandalia	b.l.v.	1–5	10	.2	2–4	25	Developing
Turner Coal Co.	Brazil	No. 1 Mine	1 mile east of Staunton	III	Vandalia	b.l.	1–5	25–30	1.5	8–10	50	
United 4th Vein C. Co.	Linton	Island Valley No. 4	1 mile north of Jasonville	III	C.T.H.& S.E.Ry.							
Carbon Mining Co.	Carbon	Stripping	Carbon	Upper Block	Big Four	l.	5	150	.2	.5	60	
DAVIESS COUNTY												
Daviess County Coal Co.	Montgomery	Montgomery 4-5	2 miles west of Montgomery	V	B. & O.					2	10–25	Est.
South Washington Coal Co.	Washington	Sunnyside		VI						5		Est.
FOUNTAIN COUNTY												
Indiana Semi Block Coal Co.	Cates	Indio	2 miles north of Cates	III	Cloverleaf				2–3	Idle		Est.
GIBSON COUNTY												
Fluhart McCloud Collieries Co.	Francisco	No. 1 Mine	Francisco	V	Southern						5–1.5	Est.
Fort Branch Coal Mining Co.	Fort Branch	Fort Branch No. 2	½ Mile south Fort Branch	V	C. & E. I.	l.b.j.v.	5–10	25	.15–.3	1–2	20–25	
Princeton Coal Co.	Princeton	Princeton	1 mile west of Princeton	V	Southern	l.b.j.v.	10–15	150	1.5	16–18	50	

GREENE COUNTY

Name of Company	Address	Name of Mine	Location	Seam No.	Railroad	Occurrence	Common Size of Masses in Pounds	Maximum Size in Pounds	Per Cent of Coal mined is Recoverable Pyrite	Possible Daily Production	Per Cent of Pyrite in Crude	Remarks
Ayrdale Coal Co.	Linton	Antioch No. 2	8 miles northwest of Linton	V	C.T.H.& S.E.Ry.	l.b nod.	5	....	.5–.6	5–8	40–50	Est.
Calora Coal Co.	Terre Haute	North West No. 2	¼ mile east of Jasonville	III	C.T.H.& S.E.Ry.	l.b.	5	....	5	4–5	50–60	Est.
Jewell Coal Co.	Linton	No. 1 Mine	2 miles west of Linton	V	Wagon	l. balls	8–10	150	1	2–3	50	Est.
Ohio-Indiana Coal Co.	Terre Haute	Stripping	2½ miles southeast of Jasonville.	V	Monon	....	....	....	1.5–2	....	....	None Recoverable
Queen Coal & Mining Co.	Jasonville	Queen No. 2	½ mile south of Jasonville	V	C.T.H.& S.E.Ry.	l.	2–5	10	.05	.5	50	....
Robertson Bros.	Linton	Robertson	3 miles southwest of Lyons	V	None	l. balls	....	....	1	Developing	....	Est.
Sleepy Eye Mining Co.	Dugger	Sleepy Eye	Vicksburg	V	Monon	l. balls	....	....	1	Developing	....	Est.
Vandalia Coal Co.	Terre Haute	Tower Hill No. 18	1 mile east of Midland	III	C.T.H.& S.E.Ry.	l.	5–10	20	1.5–2	9–12	50	....
Vandalia Coal Co.	Terre Haute	Vandalia No. 20	3 miles west of Linton	V	I. & V.	l. balls	....	....	1	9–10	50	Est.
Vigo Mining Co.	Terre Haute	No. 25 Mine	1 mile south of Midland	III	C.T.H.& S.E.Ry.	l. b.	....	1.5–2	....	3–4	50	Est.

KNOX COUNTY

American Coal Mining Co.	Bicknell	American No. 1	4 miles south of Bicknell	V	I. & V.	l. lvs.	1–5	50	.4–.6	20–30	15–20	
Bicknell Mining Co.	Bicknell	Bicknell	Bicknell	V	I. & V.	l. lvs.	1–5	50	.5	5–8	15–20	
Indian Creek Coal & Mining Co.	Indianapolis	Indian Creek	6 miles south of Bicknell	V	I. & V.	l. lvs.	4–5	50	.5	15–20	15–20	
Indiana Power & Water Co.	Bloomfield	Linn No. 1	Bicknell	VI	I. & V.	1 b. nod.	15–50	100	2–3	6–10	60–80	
Knox Coal & Mining Co.	Bicknell	Knox	½ mile west of Bicknell	V	I. & V.	l. lvs.	1–5	50	.5	6–8	15–25	Est.
Oliphant Johnson Coal Co.	Vincennes	No. 1	Bruceville	V	I. & V.	l. balls	15–25	75	.7	20–22	60	
Tecumseh Mining Co.	Bicknell	Tecumseh No. 1	1 mile southeast of Bicknell	V	I. & V.	l. balls	5–10	50	.5	6–8	40	Est.
Tecumseh Mining Co.	Bicknell	Tecumseh No. 2	1 mile south of Bickmell	V	I. & V.	l. balls	5–10	50	.5	6–8	40	Est.
Wash. Wheatland Coal Co.	Wheatland	Wheatland	¼ mile west of Wheatland	V	I. & V.	l. balls	5–10	100	.2	2–3	30–35	
Pan Handle Coal Co.	Bicknell	Panhandle No. 5	1 mile east of Bicknell	VI	Vandalia	l.b.nod.	15	100	2–3	Developing	80–90	1-2% of tota associated with roof shale. Production estimated from data on adjoining counties and other sources
				V	Vandalia	e. lvs.	5	150	.1–.2	Developing	5–20	

PARKE COUNTY

Parke County Coal Co.	Rosedale	Parke No. 12	2 miles northeast of Rosedale	III	Vandalia	l.b.nod.	5–10	50	6	60	50	

PIKE COUNTY

Ayrshire Coal Co.	Oakland City	Aryshire No. 4	¾ mile southwest of Winslow	V	Southern				.2	1–2		
Aryshire Coal Co.	Oakland City	Ayrshire No. 6	3½ miles west of Winslow	V	Southern				.2	2		
Ayrshire Coal Co.	Oakland City	Ayrshire No. 7	4 miles southwest of Winslow	V	Southern				.2	2.5		
Caledonia Mining Co.	Louisville	Hartwell No. 2	6 miles south of Winslow	V	Southern				.2	.5		
S. W. Little Coal Co.	Evansville	Blackburn No. 2	Blackburn	V	E. & I.				.2	1		
S. W. Little Coal Co.	Evansville	Littles	Littles	V	E. & I.				.2	1		
S. W. Little Coal Co.	Evansville	Gladstone No. 1	4 miles north of Petersburg	V	E. & I.				.2	.08		
Mutual Coal Co.	Oakland City	Peacock No. 2	1¾ miles northeast of Oakland City	VI	E. & I.				1			
Northern Coal & Supply	Winslow	Muran	Muran	V	Southern				.2	.1		
Turkey Knob Mining Co.	Winslow	Hartwell No. 3	6 miles south of Winslow	V	Southern				.2	.6		
Turkey Knob Mining Co.	Winslow	Hartwell No. 4	6 miles south of Winslow	V	Southern				.2			

SULLIVAN COUNTY

Name of Company	Address	Name of Mine	Location	Seam No.	Railroad	Occurrence	Common Size of Masses in Pounds	Maximum Size in Pounds	Per Cent of Coal mined is Recoverable Pyrite	Possible Daily Production	Per Cent of Pyrite in Crude	Remarks
Ajax Coal Co.	Dugger	Stripping	2½ miles south of Dugger	VI	Vandalia	l.nod.	5–10	25	.5	·2	35–40	
Central Indiana Coal Co.	Dugger	Stripping	1 mile south of Dugger	VI	I. C.	l.nod.	5–10	25	.5	5	33–40	
Chicago Carlisle Coal Co.	Chicago	Carlisle	½ mile north of Carlisle	V	C. & E. I.	l.balls	10	50	2	10	40	Est.
Chicago Carlisle Coal Co.	Shelburn	Reliance	2½ miles southwest of Shelburn.	VI	C. & E. I.	l.b.	10–20	75	1.5	7–8	50	Est.
Consolidated Indiana Coal Co.	Chicago	Consolidated No. 28.	2 miles southeast of Shelburn	VI	C.T.H.& S.E.Ry.	l.b.	10–20	75	1.5	3	60	Est.
Consolidated Indiana Coal Co.	Chicago	Peerless No. 7	2½ miles northwest of Sullivan	VI	C. & E. I.	l.nod.	10–15	50	2	18–20	50	
Dugger Mutual Coal Co.	Dugger	Keeley	Dugger	VI	I. C.	l.nod.	10–15	50	2	.5	50	Est.
Indiana Hocking Coal Co.	Shelburn	Kettle Creek	Shelburn	VI	C.T.H.& S.E.Ry.	l.nod.	10–15	50	1.5–2	7–10	50	Est.
Interstate Mining Co.	Terre Haute	Glendora	2 miles northeast of Sullivan	V	C. & E. I.	Developing						
Jackson Hill Coal & Coke Co.	Terre Haute	Jackson Hill No. 2	2½ miles south of Hymera	V	C. & E. I.				.5	4	50	Est.
Jackson Hill Coal & Coke Co.	Terre Haute	Jackson Hill No. 4	2½ miles southeast of Shelburn.	VI	C. & E. I.	l.b.	10–20	75	1.5	15	50	
Rose Hill Coal Co.	Linton	Rose Hill	4 miles southwest of Linton	VI	C. & E. I.	l.nod.	10–20	75	1	8	50	Est.
St. Clair Coal Co.	Shelburn	Consolidated No. 30.	2 miles northeast of Shelburn	VI	C.T.H.& S.E.Ry.	l.nod.	10–20	50	1	2–3	50	Est.
Sunflower Coal Co.	Bloomfield	Sunflower	1 mile northeast of Dugger	VI	I. C.	l.nod.	8–10	150	2	5–6	50	
Sunflower Coal Co.				V	I. & V.	l.balls	5–10	100	1	6–7	50	
Vandalia Coal Co.	Terre Haute	Monon No. 2	Southeast of Farmersburg	VI	C. & E. I.	l.nod.	10–20	50	1	4–5	50	Est.
Vandalia Coal Co.	Terre Haute	Vandalia No. 12	2½ miles west of Dugger	V	Vandalia	l.balls	10	100	.5	1.5–2	50	Developing
Vandalia Coal Co.	Terre Haute	Vandalia No. 17	2½ miles west of Dugger	VI	Vandalia	l.nod.	10–15	50	1.5	7–8	50	
Vandalia Coal Co.	Terre Haute	Monon No. 14	5 miles southwest of Linton	VI	C. I. & L.	l.nod.	10–15	50	1.5	15–20	50	Est.
Vandalia Coal Co.	Terre Haute	Monon No. 15	½ mile west of Cass	VI	I. C.	l.nod.	5–8	50	1.25	15–18	50	
Vandalia Coal Co.	Terre Haute	Vandalia No. 23	9 miles southwest of Linton	VI	I. & V.	l.nod.	5–10	50	1.25–2	7–10	30–50	
Wooley J. Coal Co.	Evansville	No. 8 Mine	1 mile east of Paxton	V	C. & E. I.	l.balls	15–25	150–200	2–2 5	12–15	40	
Wooley J. Coal Co.	Evansville	Mildred No. 13	3½ miles East of Shelburn	VI	C. & E. I.	l.nod.	5–15	50	1.25–1.5	10–12	60	

VANDERBURGH COUNTY

Name of Company	Address	Name of Mine	Location	Seam No.	Railroad	Occurrence	Common Size of Masses in Pounds	Maximum Size in Pounds	Per Cent of Coal mined is Recoverable Pyrite	Possible Daily Production	Per Cent of Pyrite in Crude	Remarks
Crescent Coal Co.	Evansville	Crescent Mine	Evansville	V	L. & N.				.2	1.5–2	10–15	
Diamond Coal Co.	Evansville	Diamond	Evansville	V	Wagon				.2	.5–1	10–15	
Gibson Moore Coal Co.	Evansville	Crescent Mine	Evansville	V	L. & N.				.2	.2–.4	10–15	
Sunnyside Coal Co.	Evansville	Sunnyside	Evansville	V	L. & N.				.2	.8–1.5	10–15	

VERMILLION COUNTY

Bickett & Shirkie Coal Co.	Terre Haute	No. 1 Mine	1 mile northeast of Libertyville	V	C.T.H.& S.E.Ry.	l.balls.			1	8–10	50	Est.
Bickett & Shirkie Coal Co.	Terre Haute	No. 2 Mine	1 mile north of Libertyville	V	C.T.H.& S.E.Ry.				1	4–6	50	Est.
Bogle, W. S. & Co.	Terre Haute	Essanbee No. 1	8 miles northwest of Clinton	V	C.T.H.& S.E.Ry.	l.balls	5–10	75	1.5	18–25	50	
Clinton Coal Co.	Clinton	Crown Hill No. 2	2 miles northwest of Clinton	V	C. & E. I.				1	6–8	50	Est.
Clinton Coal Co.	Clinton	Crown Hill No. 3	1½ miles southwest of Clinton	III	C. & E. I.	l.b.	5–10	25	8	65–70	80	
Clinton Coal Co.	Clinton	Crown Hill No. 5	5 miles northwest of Clinton	V	C.T.H.& S.E.Ry.	l.b.balls	5–25	150	1.5	8–15	80	
Clinton Coal Co.	Clinton	Crown Hill No. 6	4¾ miles northwest of Clinton	V	C.T.H.& S.E.Ry.	l.b.balls	5–25	150	1.5	10–25	80	
Clinton Coal Co.	Clinton	Crown Hill No. 7	3 miles southwest of Clinton	V	C. & E. I.	l.b.balls	5–25	150	1	4–5	80	Est.
Dering, J. K. Coal Co.	Clinton	Dering No. 1	2½ miles southwest of Clinton	III	C. & E. I.	l.b.	5–10	25	5	50–60	80	Est.
Jackson Hill Coal & Coke Co.	Terre Haute	Jackson Hill No. 6	3 miles northwest of Libertyville	V	S. & I.	l.b.balls	5–25	100	1	11–12	50	Est.
T. C. Keller Coal Co.	Clinton	Oak Hill No. 2	3 miles southwest of Clinton	V	C.T.H.& S.E.Ry.	l.balls			1			
T. C. Keller Coal Co.	Clinton	Oak Hill No. 3	3 miles northwest of Clinton	III	C. & E. I.	l.b.	5–10	25	5	20–25	50	Est.
U. S. Fuel Co.	Universal	Universal No. 5	Universal	V	C. & E. I.	l.balls	5–10	100	1	12–15	50	Est.
West Clinton Coal Co.	Terre Haute	West Clinton No. 1	7½ miles northwest of Clinton	V	C.T.H.& S.E.Ry.	l.b.balls	10–25	100	1.5	10–20	50	

VIGO COUNTY

Bogle, W. S. & Co.	Chicago	Bogle No. 3	7 miles northwest of Terre Haute	V	C.T.H.& S.E.Ry.	l.balls	5–10	100	1	8–10	50	Est.
Burnett Coal Mining Co.	Burnette	No. 1 Mine	1 mile south of Burnette	III	C. & E. I.	l	10–15	25	1.5	5–7	75	
Dering, J. K. Coal Co.	Clinton	Dering No. 6	Clinton	V	C. & E. I.	l.b.balls	10	100	1	30	50	Est
Eureka Block Coal Co.	Terre Haute	Dixie Bee	Pimento	V	C. & E. I.	l.balls	10	100	.5	.5–1	50	Est.
Fort Harrison Mining Co.	Terre Haute	Clovally	New Goshen	V	C.T H.& S.E.Ry.	l.b.balls	10–15	50	.5	7–10	50	Est.
Grant Coal & Mining Co.	Terre Haute	Maple Grove	1 mile west of New Goshen	V	C.T.H.& S.E.Ry.	l.b.balls	10	50	.5–1	5–15	50	
Inland Coal & Mining Co.	Brazil	Otter Valley	1½ miles south of Fontanet	III	C. & E. I.	l.b.	10–15	25	1.5	2–3	75	
Lower Vein Coal Co.	Terre Haute	Lower Vein No. 1	2 miles northwest of W. Terre Haute	V	C.C.C.& St.L.	l.balls	10–15	50	1	6–10	50	
Meneely, Albert A. Coal Co.	N. Terre Haute	Meenely Slope	Ehrmandale	III	C. & E. I.				1.5			Est.
Miami Coal Co.	Clinton	Miami No. 6	6 miles south of Clinton	V	C. & E. I.				1	12–15	50	Est.
Miami Coal Co.	Clinton	Miami No. 9	7 miles southwest of Clinton	V	C. & E. I.				1	20	50	Est.
Murphy Coal Co.	Terre Haute	Murphy	8 miles northeast of Terre Haute	VI	C.T.H.& S.E.Ry.	l.b.	5–10	30	1.5	1–2	50	
Sanford Mining Co.	Terre Haute	Pittsburg No. 2	2 miles east of Sanford	V	C.C.C.& St.L.	l.balls	10–25	50	1.25-1.5	5–6	60–70	
Shirkie Coal Co.	Terre Haute	Shirkie No. 1	8 miles northwest of Terre Haute	V	C.T.H.& S.E.Ry.	l.balls	10	50	1	10–11	75	
Sugar Valley Coal Co.	Terre Haute	Sugar Valley	1 mile west of W. Terre Haute	V	Vandalia	l.balls	10–25	150	2	6–10	50	
Sunbeam Coal Co.	Terre Haute	Sunbeam No. 1	2¼ miles northwest of W. Terre Haute	V	Vandalia	l.balls	10–25	100	2	20	50	
Utilities Coal Co.	Chicago	National	1 mile southwest of W. Terre Haute	V	Vandalia	l.balls	10–25	100	2	15–20	50	

Name of Company	Address	Name of Mine	Location	Seam No.	Railroad	Occurrence	Common Size of Masses in Pounds	Maximum Size in Pounds	Per Cent of Coal mined is Recoverable Pyrite	Possible Daily Production	Per Cent of Pyrite in Crude	Remarks
Vandalia Coal Co.	Terre Haute	Vandalia No. 82	Liggett	III & V	Vandalia	l. balls	10–25	100	1	12–20	50	No data on production from each seam. Estimate based on all from V. Probably much too low, if a considerable tonnage comes from III.
Western Indiana Mining Co.	Terre Haute	Riverside	2 miles north of W. Terre Haute	V	C. C. C. & St. L.	l. b.	5–10	55	1.5	10–15	50	Est.
Willow Creek Coal Co.	Seeleyville	Willow Creek No. 1	Seelyville-W. Terre Haute	IV	Vandalia	l. b.	10	200	2.5	25–30	75	....
Willow Creek Coal Co.	Seeleyville	Willow Creek No. 1	Seeleyville	III	Vandalia	l. b.	5–10	25	2.5	10–15	50	....
Wizard Coal Co.	W. Terre Haute	Wizard No. 2	1 mile west of W. Terre Haute	V	Vandalia	l.b.balls	10	200	2.5	25–30	75	....

WARRICK COUNTY

Name of Company	Address	Name of Mine	Location	Seam No.	Railroad	Occurrence	Common Size of Masses in Pounds	Maximum Size in Pounds	Per Cent of Coal mined is Recoverable Pyrite	Possible Daily Production	Per Cent of Pyrite in Crude	Remarks
Archbold, John Coal Co.	Evansville	Red Shaft	½ mile east of Newburgh	V	Electric	l.j.v.	10–15	50	.6–.7	3–5	30–40	....
Big Four Coal Co.	Boonville	Big Four No. 3	2 miles east of Boonville	V	Southern	l.j.v.	5	50	.5	2.5–3	30	Est.
Bryan, Joe A. Coal Co.	Evansville	Chandler	1 mile west of Chandler	V	Southern	l.j.v.	......	......	.3	1–2	30	Est.
Cypress Creek Coal Co.	Boonville	John Bull	3 miles west of Boonville	V	Southern	......	......	......	.3	2–3	30	Est.
Erie Canal Coal Co.	Boonville	Erie Canal	Erie Canal	V	E. M.	......	......	......	.3	1.5–2	30	....
Newburgh Coal Co.	Evansville	Epworth	¼ mile west of Newburgh	V	E.S.M., L.E.C.	l.j.v.	5	25	.3.4	1–2	30–40	....
Possum Ridge Coal Co.	Newburgh	Possum Ridge	3½ miles west of Boonville	V	E.S.M., L.E.C.	......	......	......	.3	.5	30	Est.
Sargeant Coal Co.	Newburgh	Sargeant No. 1	¼ mile north of Newburgh	V	E.S.M., L.E.C.	......	......	......	.3	1–1.5	30	Est.
Sargeant Coal Co.	Newburgh	Sargeant No. 2	½ mile west of Newburgh	V	E.S.M., L.E.C.	......	......	......	.3	.2–.5	30	Est.
Wooley, J. Coal Co.	Evansville	Castle Garden No. 6	2 miles west of Chandler	V	Southern	l.j.v.	5	20	.2	.5–1	30–40	....
C. N. Menden Coal Co.	Boonville	De Forest Mine	3 miles west of Boonville	V	Southern	......	......	......	.3	.5	30	Est.
Sunlight Coal Co.	Boonville	Stripping	2 miles north of Boonville	V	Southern	l.j.v.	2–10	50	.5	4–5	50	....

Notes on Tabular Summary

1. Abbreviations: l=lenses; b=bands; j. v.=joint veins or "cat faces"; lvs.= leaves.

2. The size of pyrite masses refers to fragments of pyrite as found in the gob and does not refer to weight of lump with adhering coal. The lenses tend to break out whole, unless very large, while thinner bands break up into pieces weighing 2 to 10 pounds. Balls come out whole and the maximum size (3) usually refers to these lenses or balls, 3 to 6 inches thick, that are not broken up by shooting.

4. The percent of recoverable pyrite was arrived at by methods stated on page —, (5) the possible daily production of pyrite by multiplying the figures in (4) by the average daily tonnage.

6. Crude pyrite is the pyrite with adhering coal as usually gobbed in the mine or discarded at the tipple. If the per cent is 50, it means that essentially an equal weight of coal is discarded with the pyrite, a large percentage of which might be recovered in a pyrite washery.

7. As stated on page — lack of time made it impossible to make a detailed examination of each mine. Where this was not done the figures given are from data collected in nearby properties, taking the minimum each time rather than the maximum. These are marked Estimated.

SUMMARY

Pyrite is used for making sulphuric acid of which nearly 10,000,000 tons of all grades will be consumed during 1918.

The mining industry of the nation has been called upon to supply a large tonnage of pyrite formerly imported.

Pyrite occurs in recoverable quantity in association with bituminous coals of Indiana. It is being mined and thrown aside as waste in a region close to where it is consumed.

It can be recovered by simple washeries, cheaply constructed and operated by unskilled labor.

A tonnage of coal now left in the mines nearly equal to that of pyrite may be saved to the coal industry at a reasonable cost.

FINANCIAL STATEMENT

Salaries and expenses	$2,205 75
Office supplies	957 43
Transportation and supplies	558 15
Express	12 94
Telephone and telegraphs	64 03
Total	$3,798 30

REPORT OF SUPERVISOR OF OIL INSPECTION

ADAM H. FELKER, Supervisor.

Report of the supervisor of oil inspection as submitted to Edward Barrett, State Geologist, on November 23, 1918, by Adam H. Felker, Supervisor, covering the months of July, August, September and October, 1918:

	Kerosene. No. Bbls.	Gasoline. No. Bbls.	Fees.
Akron	593	983	$97 33
Alexandria	1,104	1,299	149 44
Anderson	4,360	8,794	789 37
Argos	130	512	42 01
Attica	1,150	3,093	250 14
Auburn	1,777	4,779	361 67
Albion	661	1,001	99 91
Bedford	422	834	78 53
Bicknell	1,138	1,254	161 21
Bloomfield	161	130	17 83
Bloomington	735	955	95 85
Bluffton	1,132	3,299	283 38
Bourbon	424	803	77 76
Bremen	130	642	50 46
Berne	725	1,463	138 44
Brook	...	390	25 35
Brimfield	1	...	40
Brookville	1,242	2,232	204 22
Brownsburg	80	207	17 71
Brookston	632	1,443	125 95
Cambridge City	611	1,388	123 67
Colfax	536	1,966	147 86
Churubusco	1,132	1,933	201 15
Cleveland, O.	13	2	4 20
Claypool	332	613	55 65
Columbia City	1,406	3,554	308 05
Cloverdale	701	706	83 12
Connersville	2,357	4,005	381 83
Converse	914	1,508	153 53
Covington	634	1,133	112 16
Crawfordsville	651	2,551	196 16
Crown Point	420	861	79 39
Culver	297	574	53 43
Carlisle	131	543	42 97
Decatur	804	2,264	196 69
Delphi	1,314	4,879	363 18
Dunkirk	1,275	1,807	192 56
Dugger	162	291	27 24
East Chicago	22	2,183	96 79
Elkhart	3,529	10,664	883 81
Elwood	601	1,315	116 63
Evansville	7,899	12,623	1,216 23
Farmland	283	714	61 76
Fairmount	2,129	4,755	407 16
Flora	513	1,274	112 73
Fowler	877	4,957	361 57
Fortville	416	1,123	87 12
Frankfort	2,768	6,536	$555 97
Ft. Wayne	7,115	21,424	1,692 56
Farmersburg	372	498	48 85
Gas City	1,337	864	129 73
Goodland	260	1,099	81 72
Garrett	907	1,090	119 05
Galveston	372	1,018	82 65
Gary	3,082	10,026	747 54
Geneva	803	1,200	128 49
Glenwood	612	1,177	103 22
Goshen	1,036	1,921	179 72
Greenfield	486	1,166	99 61
Greensburg	261	3,256	210 19
Greenwood	...	253	16 69
Hammond	867	4,398	289 87
Hagerstown	620	1,120	102 25
Hartford City	1,961	1,986	241 26
Hazelton	291	450	44 98
Hobart	1,079	2,855	231 77
Haubstadt	674	604	79 29
Hebron	161	161	18 76
Hope	485	812	79 86
Huntington	2,645	5,822	519 53
Hamlet	292	161	27 24
Indianapolis	18,608	68,401	5,102 75
Jeffersonville	1,039	2,981	232 48
Jasonville	404	467	48 58
Kingman	573	1,207	103 45
Kendallville	712	2,926	222 49
Kewanna	584	892	94 33
Knightstown	834	2,100	183 57
Knox	1,044	1,306	147 87
Kokomo	4,505	10,645	922 50
Lacrosse	...	291	17 83
Lafayette	3,002	12,241	916 74
Laurel	291	650	60 08
LaGrange	1,002	3,689	281 27
Lawrenceburg	496	2,318	170 87
LaPorte	337	641	61 19
Lebanon	1,236	4,417	338 87
Liberty	729	2,302	171 77
Ligonier	986	1,865	176 53
Linton	1,973	4,812	412 73
Logansport	2,633	7,422	586 02
Loogootee	799	1,395	100 47
Lowell	411	453	48 67
Lafountaine	842	1,165	123 91