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Vol. IX. Part I.

GEOLOGY

OF THE

Disseminated Lead Deposits

OF

St. Francois and Washington Counties.

BY
ERNEST ROBERTSON BUCKLEY, PH. D.

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JEFFERSON CITY, MO.

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ERRATA

Page VIII, line 5, 1st. word; for "Drawing" read "Drawings."
Page VIII, line 15; for "Ill. So. section of completed" read "Bonne Terre to Riverside, Davis Crossing to Ste. Genevieve, Faulting near Vineland."
Page XIII, line 13, 3rd word; for "St. Joe" read "St. Joseph."
Page XIII, line, 23, 8th. word; for "H" read "T."
Page XIII, line 24., 5th. word; for "F" read "S."
Page XVI, line 11; substitute the following, "—brian formations contain a fairly well preserved fauna, consisting,
Page 2, line 30, 9th. word for "lead" read "ore."
Page 3, line 7; for "1906" read "1907."
line 13 for "Bonne Terre" read "Bonneterre."
Page 9, line 21; for "Cretacious" read "Cretaceous."
Page 11, line 20; for "putrification" read "putrefaction."
Page 40, line 9; for "ltaering" read "altering."
Page 41, line 28, for "id" read "in."
line 29; for "ann" read "and."
Page 57, line 27; for "the" read "tho."
Page 66, line 23, 6th word; for "it" read "they."
8th word; for "contains" read "contain."
Page 66, line 24; for "it was" read "they were."
Page 75, line 34; for "fixed" read "flexed."
Page 76, line 13; for "Plate —" read "Plate XL."
Page 79; after third line insert "the surface a checker-board appearance. The removal of these."
Page 79, line 10; for "only" read "best."
line 27; for "Plate —" read "Plate XV."
Page 79, line 31, substitute the following, "of the other formations, except perhaps in the Davis shale. The."
Page 80, line 32, 3rd word; for "radi" read "radii."
Page 82, line 44; omit the word "valles."
Page 111, line 15; for "38,700" read "78,700."
Page 119, omit line 6.
Page 129, line 16; omit the word "in" before "May."
Page 135, line 7; for "illustrates" read "illustrate."
Page 142, line 18; for "478,100" read "554,500."
Page 143, line 19; for "$21,410,000" read "$29,300,000."
Page 170, line 6; for "Plates" read "Plate."
Page 180, lines 9 and 10; omit "This fault is to fifteen degrees south with an unknown throw."
Page 184, line 6; for "No." read "Nos."
Page 188, line 9; for "was" read "were."
Page 202, line 26; for "worn" read "wavy."
Page 205, line 5; for "Pneumataltic" read "Pneumatolytic."
line 25; for "exception" read "exceptions."
Page 208, line 10; for "—hide" read "—phide."
Page 203, line 21; after tbe word "deposits" insert "in the sandstone."
Page 203, line 29; insert "No." before "2."
Page 245, line 22; for "limit" read "limits."
Page 250, line 5; for "Ph." read "Pb."

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LETTER OF TRANSMITTAL.

Rolla, Mo., Nov. 1, 1908.

To the President, Governor Joseph W. Folk, and the Members of the Board of Managers of the Bureau of Geology and Mines:

Gentlemen: I have the honor and pleasure to transmit to you a report upon the disseminated lead district of Southeastern Missouri, and recommend that it be published as Volume IX, Second Series, of the reports of this Bureau.

This report is the result of several years study and field work by Dr. E. R. Buckley, former director of the bureau. It is the first detailed report to be published upon the district and is a very important contribution to our geological knowledge of these unique deposits.

I consider this one of the most valuable volumes yet published by the Bureau of Geology and Mines.

Respectfully submitted,

H. A. BUEHLER,

State Geologist.

ACKNOWLEDGMENTS.

This report has been made possible only through the generous co-operation of the several mining companies operating in the district. My assistants and myself have been given free access to the mines, while maps and sections have been freely contributed for use in the report.

It is perhaps unnecessary to mention the names of those who have been especially interested in the success of this report. However, I desire to especially acknowledge the courtesies extended by Mr. Arthur Thacher, President of the Central Lead Co., Mr. Charles Schwarz, Superintendent of the St. Louis Smelting and Refining Co., Mr. E. B. Kirby, Manager Federal Lead Co., Mr. T. F. M. FitzGerald, formerly Manager Federal Lead Co., Mr. C. B. Parsons, Superintendent St. Joe Lead Co., Mr. O. M. Bilharz, Assistant Superintendent Doe Run Lead Co., and Mr. Furnam Desloge, Jr., Superintendent Desloge Consolidated Lead Co. Not only to the superintendents and managers am I indebted, but equally so to the mine captains and mine foremen who have contributed much useful information relative to the structures and manner of occurrence of the ore bodies. Our thanks are also due to Dr. C. D. Walcott and Dr. E. O. Ulrich for the identification of fossils and the determination of the age of the formations in which they occur.

I also desire to acknowledge my indebtedness to Mr. H. A. Wheeler, Mr. H. J. Cantwell, Mr. J. H. Monell, Mr. B. J. Hoskins and Mr. R. R. F. Parsons for assistance in various ways.

The maps and drawings are mainly the work of Mr. Frank Gahrtz, draftsman for the Bureau, to whom we are indebted for any merit which their execution may possess. It is my desire to express my indebtedness to Mrs. Lena J. McCaw, stenographer and clerk, for her faithful service in the execution of her duties in the preparation of this and all preceding reports issued by the Bureau during my administration.

E. R. B.

INTRODUCTION.

The preparation of this report was begun in 1903, and the necessary field work was carried on intermittently from that time up to the spring of 1908. Much of the surface of the area included in the report has been mapped twice and most of the mines have been examined in very great detail. In addition to the area included within the Bonne Terre quadrangle, our observations have extended over a wide stretch of country between the Mississippi River on the east, Madison County on the south, Washington County on the west, and Jefferson County on the north.

The topography of the Bonne Terre quadrangle was mapped by the U. S. Geological Survey, while the topography of the special Flat River-Leadwood sheet was mapped by the U. S. Geological Survey in co-operation with the Bureau. In mapping the surface geology, I have been most ably assisted by Mr. G. W. Crane, whose painstaking care in following many of the poorly defined faults, has increased very greatly our knowledge of the structure of the area. In the original mapping of the Bonne Terre quadrangle, I was assisted by Messrs. A. F. Smith and F. B. Van Horn. Mr. A. F. Smith also assisted in the examination of the ore bodies exposed by the mine workings of the St. Joseph Lead Co. at Bonne Terre. The facts relative to these mines, included in this report, are based chiefly upon the notes collected by Mr. Smith.

The author does not claim that the hypothesis offered in explanation of the origin of the ore deposits is in any way original, altho it has been developed without regard to any previously published theory, being based altogether upon the facts as disclosed by our surface and underground investigations.

Attention is especially directed to the geological history of the area in its relation to the ore deposits. The full significance of the ordinary processes of erosion and transportation, both by surface and underground waters, in an explanation of the origin of the ore bodies, became more and more apparent as our knowledge of the ore bodies and the processes now in operation increased.

In taking up the study of the ore deposits of the district, I had in mind three problems, to the solution of which all my efforts have been directed. These problems are, (1) "The original source of the lead"; (2) "The reason for the location of the ore bodies"; and (3) "The reason for the local richness of certain portions of the ore bodies." The contents of the report are therefore so arranged as to best present such explanations.

The formations belong chiefly to the Cambrian and pre-Cambrian, the latter of which offers an excellent field for petrologic studies, to which no attention is given in this report. The Cambrian, the latter of which offers an excellent field for petrographic mainly of brachiopods, trilobites and crinoids. To these very little attention has been directed, only a very fragmentary collection having been made.

The physiography and sedimentation of the district, which are equally as interesting subjects, have been given very little attention.

This report, on the whole, is a study of the ore deposits, and more especially of the so-called disseminated lead ore. An attempt has been made to illustrate the manner of occurrence of the galena through drawings made underground of actual ore faces.

The various structures have been noted and the relation of these to the ore has been faithfully represented in the many drawings inserted herein. The facts from which our conclusions are drawn are well illustrated in this report, but it is impossible to express the effect which repeated observations of these facts has had upon these conclusions. The three important factors involved in the introduction and precipitation of the lead are unquestionably the ground-water, the jointing and faulting, and the composition of the sediments. To these frequent reference is made in the report. In the descriptions of the mines there is probably considerable seemingly unnecessary repetition. However, to the author, it has been the repeated observation of such facts that has led to the conclusions contained herein.

The story has not all been told in these pages, but it is hoped that something may have been added to our knowledge of one of the most important deposits of lead ore in the United States.

ST. LOUIS SMELTING AND REFINING CO., MINE NO. 2.
View of the underground workings.

CHAPTER I.

LOCATION, HISTORY, PRODUCTION AND PHYSIOGRAPHY.

LOCATION.

In the earlier reports of the Missouri Bureau of Geology and Mines, there has been included in the southeastern district, the following counties,—Perry, Ste. Genevieve, St. Francois, Washington, Franklin and Jefferson; the northern portions of Cape Girardeau, Bollinger, Madison, Iron and Reynolds, and the eastern portion of Crawford.* The boundary lines of this district were drawn arbitrarily and were intended simply to include that portion of southeastern Missouri which contains noteworthy deposits of lead and zinc ores. In the report referred to above, this district was divided into sub-districts. "For convenience of description, as well as because of certain differences in the deposits, the following sub-districts were recognized":

"(1) The St. Francois and Madison county sub-district.

(2) The Washington county sub-district.

(3) The Franklin county sub-district."

The present report deals with a portion of what is designated above as the St. Francois and Madison county sub-district. This sub-district was divided, by Winslow into five groups of mines or camps which are as follows: (1) The Mine LaMotte; (2) The Bonne Terre; (3) The Doe Run; (4) The Flat River; and (5) The Avon. Instead of designating these as groups of mines or camps, they will be referred to in this report as areas. In two of these areas, the Doe Run and the Avon, the mines are no longer operated. There have been added, however, two additional areas the Leadwood (also called Owl Creek and Hoffman) and the Fredericktown.

As a basis for this report, a detailed study has been made of an area of about 220 square miles between longitude 90°30′ and 90° 45′ and between latitude 38° and 37° 45′. About four-sevenths

*Lead and Zinc Deposits, Vol. VII, Mo. Geol. Survey, by Arthur Winslow, page 645.

of this area is in St. Francois county and three-sevenths in Washington county. The location is shown on the accompanying general map of southeastern Missouri.

HISTORY AND PRODUCTION.

The first record of mining in St. Francois county is at "Mine a Gebore" where operations were conducted on a small scale between the years 1742 and 1762. "Mine a Layne" was discovered about 1795, "Mine a Manteo" on Big River in 1799, and "Mine a LaPlate" about the same time. Winslow* has estimated that during the 18th Century, St. Francois county produced approximately 1000 tons of lead ore, equal to 500 tons of metal valued at $50,000.

Lead mining began in Washington county at an earlier date. Mine a Renault was discovered about 1725, since which time it has had alternating periods of activity and idleness. What is known as "Old Mines" was discovered about the same time, being actively worked at various periods up to the present time. Mine a Burton was discovered in 1763, producing as high as 1800 tons of ore annually. The Washington county mines produced during the 18th Century about 19,000 tons of lead ore, equal to 9,500 tons of metal, valued at $950,000.

The Washington county mines mentioned above, are outside of the area included within this report. It would require many pages to follow in detail the history of lead mining in St. Francois and Washington counties, and we will pass this subject after reference to two or three epochs in the development of this industry. An excellent summary of the history of lead and zinc mining in Missouri is given by Arthur Winslow in Chapter VII, Volume VI of the earlier reports of this Bureau.

The most important discovery in the Southeastern Missouri district was that of the deposits of disseminated lead which are now being so extensively exploited in the Bonne Terre, Flat River and Leadwood areas. The discovery of disseminated ore was made on the property now owned by the St. Joseph Lead Company, at Bonne Terre, in the year 1864. The most important step in the development of the disseminated lead deposits of this district was the introduction, by the St. Joseph Lead Company, of the diamond drill in 1869. Prior to the year 1869, nearly all of the lead ore obtained in the district was mined from shallow workings, and occurred chiefly in masses or crystal aggregates in crevices, caves

*Lead and Zinc Deposits, Vol. VII, Mo. Geol. Survey, by Arthur Winslow, page 531.

General View of the Flat River area, taken from the hill just west of Flat River.

and caverns in the limestone and chiefly above the level of ground water. The lead ore production of St. Francois county up to 1869, has been estimated by Winslow at 59,526 tons valued at approximately $1,984,900. During the same period in Washington county, the output amounted to 124,930 short tons of ore valued at $5,-082,700. Since 1869, the output of St. Francois has increased enormously. The period from 1869 to 1906, inclusive, shows a production of 1,202,606.9 sh. tons of lead concentrates valued at $59,-869,354.* During this same period, the production in Washington county has decreased.

The enormous increase in the production of St. Francois county is attributable to the extensive development of the bodies of disseminated lead ore which occur in the Bonne Terre formation. Washington county is underlain at the surface, chiefly with the highly siliceous Potosi formation in which disseminated deposits are not known to occur. About 275 to 300 feet below the base of this formation occurs the Bonneterre formation, but its depth, and the difficulties experienced in drilling through the Potosi in order to reach it, have retarded exploration. Such drilling as has been carried on, chiefly in the vicinity of Palmer, Washington county, has given no evidence that the disseminated deposits occur in the Bonneterre formation, where overlain with the Potosi and intervening formations. The production of lead in Washington county has, therefore, been obtained from the shallow mines within the Potosi formation, with the exception of such as was produced at the mine of the Federal Lead Company at Irondale, in which locality the Bonneterre formation outcrops at the surface.

PHYSIOGRAPHY.

Surface Relief.

The lowest elevation in this area is 600 feet, which is along the Big river, where this stream flows off the sheet, near the middle of the north boundary. The most elevated place is the summit of Meade Mountain, which is 1530 feet above sea level. Between the lowest and highest points there is a difference in elevation of 930 feet.

As a whole, the district is rough and hilly, altho the only areas that might be called mountainous are in the southeastern and southwestern parts, in which occur the northern spurs of the

*These figures are as close as can be computed from available data.

granite and rhyolite hills and ridges which have been called the St. Francois mountains. These ridges, spurs and peaks of igneous rocks are presumably the remnants of a lofty range of mountains that occupied this section of the state in pre-Cambrian time. These peaks and ridges are known by various names, such as Simms, Meade, Sulphur, Hughes and Round mountains. They are especially conspicuous features of the landscape, rising, as they do, from 300 to 500 feet above the level of the surrounding country. They are interesting, as being another instance in which the oldest rocks of an area occupy topographically the places of greatest elevation.

These granite and rhyolite hills and ridges are usually steep sided and near their bases occur thick talus slopes concealing the underlying formations. They usually have flat tops which are covered with a thin mantle of soil. Around the margins of these flat tops the igneous rocks outcrop at intervals, exposing smooth surfaces, some of which exhibit a remarkably small amount of decomposition. My examination of the top of Simms mountain did not disclose the presence of any residual material other than that which might have been contributed through the decomposition of the rhyolite.

The remaining portion of the area, consists of hills and valleys, with narrow table-land areas and alluvial plains. Many of the table-land or flat topped divides and isolated hills of sedimentary rocks in this area have an elevation of from 1000 to 1100 feet A. T. These appear to indicate an early period of base-leveling. The condition is illustrated on the accompanying topographic sheet upon which all contours under 960 feet are omitted. This map is very suggestive as showing how nearly this early period of base leveling has been obliterated by subsequent erosion.

Drainage.

This area is drained by the Big and St. Francois rivers and their tributaries. The former is by far the most important, draining approximately 210 out of the 230 square miles of territory in this area. The Big river rises in the northern part of Iron county, outside of this area, flows northeast through the southeastern part of Washington county; then east with many meanders to the center of St. Francois county. Thence north and northwest into Jefferson county, which is again outside of the area embodied in this report. From here it flows in a general northerly direction, emptying into the Meramec river at the northern boundary of Jefferson county.

Altho the meandering course of Big river gives it the appearance of a stream which has reached maturity, yet it flows in a channel which is bounded by a very narrow flood plain, hemmed in on either side by bluffs from which precipitous cliffs often come down to the waters edge. The meandering character of this river is characteristic of most of the streams of the Ozark region, being nicely shown by the Osage, Meramec, Bourbeus, Gasconade and Niangua rivers.

Big river enters this area at an elevation of 800 feet, leaving it again at an elevation of 600 feet A. T., making a total fall of 200 feet in a distance of approximately 46 miles or an average of a little less than five feet to the mile.

The principal streams, tributary to Big river in this area are Flat river, Eaton creek, Hayden creek, Owl creek, Dry creek, Wallen creek, Cedar creek, Terre Bleu creek, Coonville creek, Bee branch and Peters creek, entering from the east and south; and Cadet creek, Mill creek, Three Hill creek, Bear creek and Hopewell creek entering from the west and north.

Flat river, the most important tributary, rises in the hills directly west of Bismark, flows north skirting the crystalline area, and thence northeast, emptying into Big river just outside of the area included in this report.

Dry creek rises in the hills of crystalline rocks just west of Bismark, flows in a northerly and then northwesterly direction through the town of Irondale, emptying into Big river about three-quarters of a mile north of that town.

Wallen creek rises in the hills about three miles a little south of west of Bismark, and flows north and then northwest joining Big river about 3¼ miles southwest of Irondale.

Cedar creek rises in the southwest corner of the sheet, flows nearly due north and joins Big river about 3½ miles from its source.

Eaton creek rises in the hills about four miles west of Elvins, flows a little east of north and joins Big river about two and a half miles from its source.

Hayden creek has its source in the hills about one and a half miles west of the source of Eaton creek, flows in a general northerly direction and empties into Big river about three miles from its source.

Owl creek rises in the hills in Secs. 10, 11, 14 and 15, T. 36N., R. 4E., flows a little east of north, emptying into Big river northeast of Desloge shaft No. 4 in U. S. Survey 3176.

Terre Bleu creek rises in the northeastern part of this area, flows in a general southerly direction, emptying into Big river about two miles northeast of the city of Bonne Terre.

Coonville creek also rises in the northeastern part of the area, flows southwest emptying into Big river about three miles a little east of north of the city of Bonne Terre.

Bee branch rises near the northern boundary of this area, about one and a fourth miles from the northeast corner, flows southwest, emptying into Big river about three miles from its source.

Peter's creek rises in the hills near the northern boundary of this area, flows southwest emptying into Big river about two miles from its source.

Mill creek has its source in the hills south and southwest of Mineral Point. It flows in a general northeast direction for about five miles where it receives a tributary, from the west, known as Keyes branch. It then flows east for a mile and a half making a wide bend to the north and passing off the sheet about five miles south of where it joins Big river. Another small tributary of Mill creek, known as Cadet creek, flows for a distance of about two and a half miles in a northeasterly direction, and empties into Mill creek a short distance north of this sheet.

Three Hill creek rises in the hills about four and a half miles southwest of Mineral Point and flows a little west of north about five and a half miles where it empties into Big river.

Bear creek rises in the hills about a mile and a half a little northeast of the source of Three Hill creek, flows about four miles almost due north and empties into Big river about a half a mile from the mouth of Three Hill creek.

Hopewell creek rises about a mile south of Summit, in the west central part of the sheet, flows about three and a half miles southeast where it empties into Big river.

In addition to those above named there are fourteen or fifteen short branches most of which are southward flowing tributaries of the Big river.

For a distance of six miles the St. Francois river flows in a southwesterly direction across the southeastern corner of this area. A part of its course is between steep bluffs, the remainder being through a narrow flood plain. It receives several small tributaries, the principal one being Doe Run branch. This stream rises in the hills about three miles south of Elvins, flows south a mile and a quarter, emptying into the St. Francois river about a mile and a

Figure I.

Contour Interval 20 Ft

Scale

Miles

— — — — Divides

half west of Loughboro. The St. Francois river empties into the Mississippi river about fifty miles south of Memphis, Tenn.

Intermittent nature of the streams.—Some of the streams, like Davis creek, lose their water through crevices which carry it under ground. Other streams in this region are fed by springs which render them perennial. However, many of the smaller tributaries are maintained entirely by the surface drainage, as a result of which they are intermittent. Likewise many of the springs are intermittent on account of which the volume of water carried by the perennial streams fluctuates very greatly from one season to another. Again some of the streams are perennial through portions of their course and intermittent through the remaining distance. Davis creek, a tributary of Flat river, for example, is fed by springs but the water, during the dry spells, all disappears in a zone of faulting which crosses the channel about a mile from its mouth. Another perennial spring contributes a supply of water to the creek about a half a mile from its mouth, so that both the upper and lower reaches of the stream are perennial while a stretch of about a half a mile near the middle of the course is intermittent.

All of the streams rise very quickly after heavy storms, dry beds frequently becoming raging torrents within a few hours This condition naturally results in the streams scouring their beds down to the rock and along most of the valleys and ravines occur excellent exposures of rock in the stream beds.

There is usually enough water in Big and Flat rivers to supply the mills with all the water required for concentration. Most of them, however, rely almost entirely upon the water pumped from the mines for their supply. These streams are looked upon mainly as a reserve.

DIVIDES.

There are three very well marked divides in this area. The longest and best defined extends in a general westerly direction from a point about a half a mile south of Bonne Terre through Summit on the St. Louis, Iron Mountain and Southern railroad to a point about one and three-fourths miles north of the middle of the west line of the sheet. This divide separates the northward and southward flowing tributaries of Big river as shown on the map. It starts in at the Big river, with an elevation of 640 feet, passing over elevations of 940, 1000, 1040, 980, 1000, 1000, 1000, 1040, 1020, 1060, 1040, 1000, 1080, 1040, and 1200 feet. These figures show an increasing elevation from east to west, which is in a measure proportionate to the distance from the Big river. However, it is thought that the somewhat flat tops of the ridges and hills marking this divide indicate one or more stages of base leveling and that the gentle slope to the east is simply a result of differential erosion. The position of this divide is indicated on the map Figure 1.

The second divide of importance is that which separates the Big river from Flat river its chief tributary in this area. This divide has a general southwesterly course and then a southerly course terminating just south of Bismark where it unites with the divide separating the St. Francois river from Big river and its tributaries. This divide commences at the junction of Big and Flat rivers, at an elevation of 660 feet passing over elevations of 840, 880, 1020, 1020, 1040, 1020, 1040, 1000, 1080, 1060, 1020, 1020, 1080, 1080, and 1020 feet.

The location of this divide is shown on the map, Figure 1.

The third divide separates St. Francois river and its tributaries from Big river and its tributaries. This divide has a general northeast-southwest course through the southeastern part of the sheet, and is very irregular. It commences about one and three-fourths miles northeast of Loughboro, at an elevation of 1040 feet and passes through the following elevations: 1060, 1120, 1140, 1140, 1355, 1400, 1530, 1400, 1020, 1160, 1200 and 1220. The location of this divide is shown on the map, Figure 1.

The third divide shows a much more irregular profile than the two preceding owing to the fact that it passes over several of the peaks of igneous rocks of pre-Cambrian age. This also accounts for its sharp zig-zag course on the map.

The divides, as a rule, are narrow. The flattest and broadest is that portion of the divide separating Flat and Big rivers, lying between the two areas of igneous rocks in the southern part of the sheet. This divide has an elevation of about 1000 feet and the slopes on either side are gentle. This is well shown on the map, Figure 1.

The divide separating the head waters of Flat and St. Francois rivers has an elevation of 1000 feet. At this place it is very narrow and soon one of the streams will be encroaching upon the catchment area of the other.

BASE LEVELS.

The map, Figure 1, shows certain flat topped hills and ridges which may be accounted for by stages of base leveling. At an elevation of 1180 to 1200 feet, there are a few flat topped hills and narrow ridges that may represent an early period of base leveling. The evidence of this base level is very meager and may not be well founded. The map, Figure 1, shows these hills and ridges and from this the reader may draw his own conclusions. Above this peneplain rises the peaks of the St. Francois mountains and occasionally ridges and hills of sedimentary rocks in the southwestern part of the area.

The ridges and hills which mark the divides between the rivers and their tributary streams are usually flat-topped and terminate at an elevation of from 960 to 1040 feet. The chief level is 1000 feet, above which rise mounds and hills of sedimentary rocks from 20 to 200 feet high. The main flat tops of these hills and ridges are evidently the remnants of a late peneplain. This peneplain marks as a rule, the upper level of the gravels of this area, which are thought to be of Tertiary age. For this reason I have been lead to believe that this is a remnant of the Tertiary peneplain. The earlier one may be Cretacious, but of this we have no proof. An inconceivable length of time has elapsed since the rocks of this area were laid down and more ancient peneplains, had they existed, would probably long since have been obliterated.

ALLUVIAL PLAINS.

It is probable that the present meanders of the Big river were formed during Tertiary times, when this entire region was near base level. Since that period the activity of this stream has been little more than sufficient to cut its channel deeper with the gradual elevation of the region. As a result the alluvial plains are narrow, often little more than flood plains during high water. In no place has the stream shortened its channel by cutting across narrow necks of land around all of which it evidently now flows.

In some places the alluvial plain of this river is a fourth of a mile wide, but usually it is very much narrower. The soil of this plain is usually very fertile, although there are frequently areas in which it is chiefly sand and gravel.

SINK HOLES AND CAVES.

Sink holes and caves occur scattered over the entire area, being most abundant where the Bonneterre is the surface formation.

There are very few, if any, sink holes in that portion of the area underlain at the surface with either the Davis or Doerun formations. Some occur in the Potosi formation. Sink holes frequently occur in rows marking underground water channels, or again as isolated funnel shaped depressions.

The sink hole phenomenon is best illustrated on the property of the Federal Lead Company near their No. 1 shaft, in Sec. 8, T. 36N., R. 5E., and in Sec. 26, T. 37N., R. 4E., and south of what was formerly Shaft No. 1 of the Columbia Lead Company.

As explained in other publications of this Bureau, sink holes are formed by underground waters taking into solution and removing the limestone to such an extent that underground caves and caverns are formed. The roofs of these caves, becoming too weak to support the overlying rocks and soil fall in, leaving an irregular conical shaped depression at the surface. Into this the surface water flows carrying soil, clay and debris which sometimes clogs the passage below, holding the water and forming ponds.

In the S. E. ¼ of Sec. 14, T. 36, R. 4E., there is a sink hole which receives the water from a catchment area of nearly a square mile. The water reaching the sink hole flows in a narrow, steep sided channel, which follows well defined joint planes in the dolomite. The water passing into the sink hole finds its way through the base of a rather high hill and issues on the other side in the form of a spring.

There are no very large caves in this area, although small ones abound in the dolomite formations that chance to be near the surface. The largest cave known in this area occurs near the fault in the N. E. ¼ of Sec. 17, T. 36, R. 5E. This cave is reported to extend into the hill for a long distance and to consist of numerous large chambers exhibiting the usual cave formations. Small caves or cavities, two feet or more in diameter, often occur several hundred feet below the surface, as exhibited in the mines. These are usually lined, although frequently filled, with crystals of calcite. In some instances they are partly filled with black or bluish gray mud through which are scattered crystals of galena.

SPRINGS.

Springs are abundant throughout the area, being one of the chief sources of supply for drinking water for the agricultural population. There are two important horizons at which springs occur most abundantly: viz.: between the Davis shale and the Derby limestone and between the Doerun and the Potosi formations. The Davis and Doerun formations are each relatively impervious while above them occur more or less pervious dolomite, which carries water, chiefly along the bedding and jointing planes.

Some of the smaller streams are fed by perennial springs. Murrill spring, for example, supplies a small tributary of Big river, near Bonne Terre, while Shaw spring near Flat river supplies water constantly to Davis creek, a tributary of Flat river.

The number of springs varies with the rainfall and consequently with the seasons. Hundreds of springs which discharge copious amounts of clear, crystal water in the spring become either dry, or stagnant pools during the summer. When flowing and not contaminated from artificial sources, the water is pure and healthful. However, the sources of contamination from barnyards, outbuildings and other sources of putrification are numerous especially in the vicinity of the towns and cities. On this account extreme care should be had in the use of spring water for drinking purposes.

WATER POWER.

There are no water falls or rapids in this area along streams having a sufficient or constant enough supply of water to furnish power. The stream gradients are gentle and no location is known along Big river where power might be obtained to advantage by constructing a dam. At one place a fifty foot fall might be obtained by constructing a tunnel about 2¾ miles long, and a sluice-way of about the same length. A series of dams might be substituted for the sluice-way. Such tunnel would begin where the Hoffman branch of the Mississippi river and Bonne Terre railway crosses the Big river and would extend north two and three-fourths miles opening into the narrow valley of Cabanne creek which empties into Big river about 3½ miles a little west of north of the railroad station at Bonne Terre. Whether the volume of water in Big river or the power derived would warrant the expense of such construction we are unable to say. It is my impression that the quantity of water in the stream fluctuates too much to provide a constant supply.

SOILS AND AGRICULTURE.

The soils, with the exception of the alluvial tracts along the rivers, are mainly residual. Much of the area underlain with the Potosi formation has a heavy, clayey soil, while the surface is often strewn with fragments of chert or flint. In places the flint fragments are so abundant as to render the land almost useless for agriculture. Where the land is underlain with rock belonging to the upper part of the Potosi, it is frequently sandy from the decomposition of sandstone which occurs in the upper part of this formation or above it.

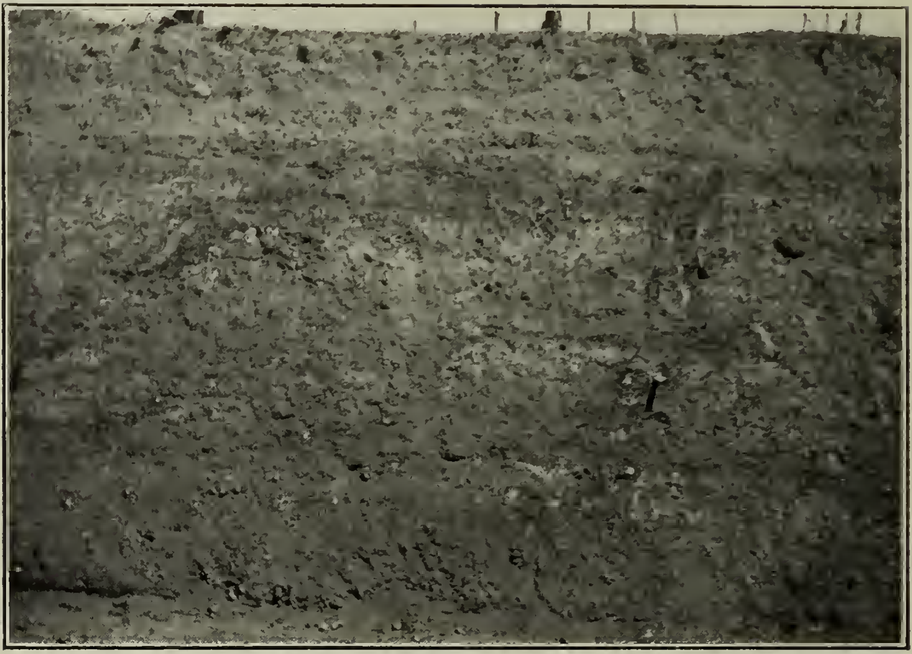
The country which is underlain with the Derby, Doerun and Bonneterre formations usually has a red, clayey surface soil, although there are frequently areas from which the residual material from the Potosi has not yet been removed. The usual soil resulting from the decomposition of the Bonneterre formation is more fertile than that derived from the Potosi. However, it is usually thin and ledges of dolomite frequently outcrop at the surface, even where the ground is comparatively level.

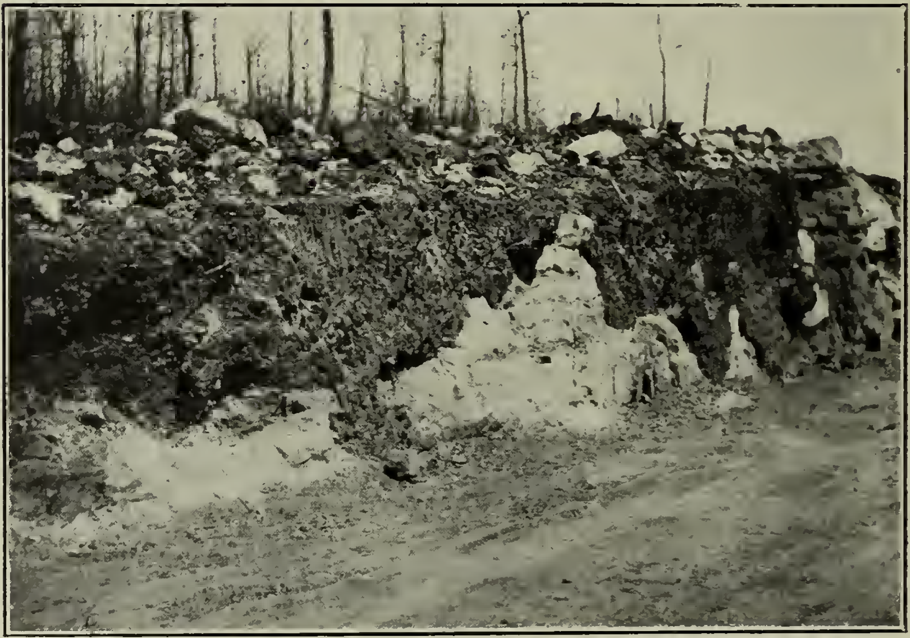
The Davis shale produces a clayey soil often somewhat sandy. The soil resulting from the decomposition of this formation is usually better than that of any of the other formations. Disintegration is more regular and proceeds faster. The residual material is thicker, since less of the formation is removed in solution by the underground waters.

The Lamotte sandstone results in a sandy soil, having very little virtue for agriculture. However, it is often mixed with the residual clay from the higher formations, by which it is tempered to a degree which makes it very excellent.

The igneous areas are chiefly found in the shape of steep sided hills and ridges where there is little chance for soils to accumulate. The soils, wherever they occur are rich and productive. The tops of the granite and rhyolite ridges are narrow and the hillsides are covered with talus.

In Secs. 8, 9, 16, 17, 20, 21 and 22, T. 36 N., R. 5 E., in the southeastern part of the area included in the special map of the Flat River-Leadwood areas, the residual deposits are in places of unusual thickness. Some of the drill holes in this area have passed





The upper view shows a typical outcrop of gravel supposed to be in part Tertiary.

The lower view shows an irregular surface of Doerun dolomite resulting from decomposition.

through over 180 feet of residual clay, some of which contains large and small boulders of flint.

The cuts along the railroad leading to Federal Shaft No. 9 illustrate beautifully the manner in which the Doerun dolomite decomposes beneath a mantle of residual clay and gravel. (See Plate III). The cuts along this line also show the character of the upper 30 feet of the residual material passed through in the drill holes of this area. (See Plate III).

The peculiarities of the weathered surfaces of the various formations are discussed under the heads of the several formations described in the following chapter.

CHAPTER II.

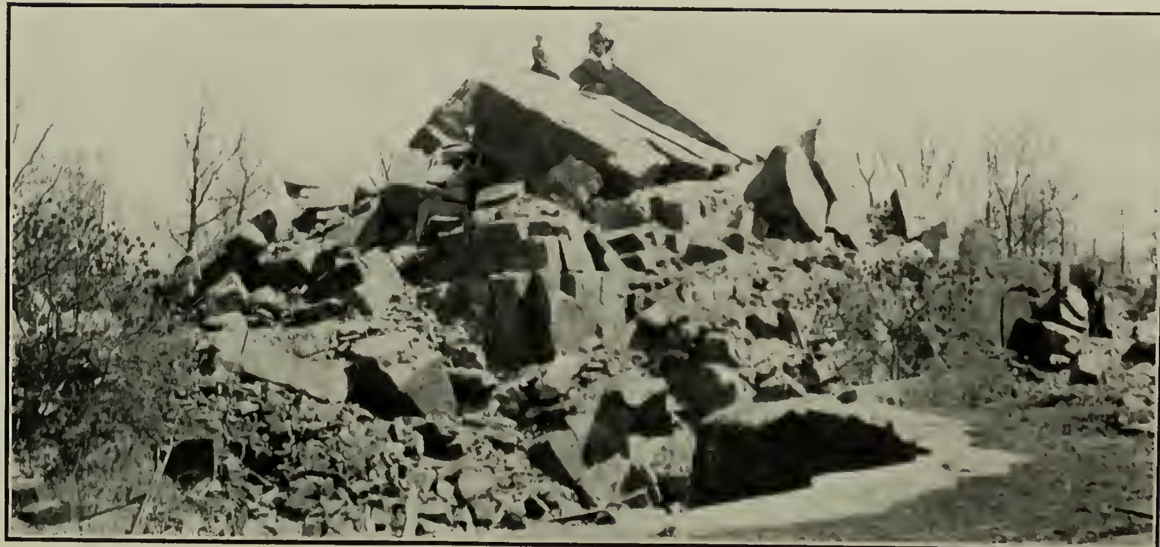
GENERAL GEOLOGICAL HISTORY.

INTRODUCTION.

The Ozark plateau, with which are inseparably associated the enormously rich deposits of lead and zinc of Missouri, Kansas, Oklahoma and Arkansas, consists chiefly of Paleozoic sediments. These were laid down during five or six periods of subsidence and sedimentation which alternated with long periods of elevation and erosion. Most of these series of strata give evidence of having been deposited in shallow water and often one finds evidence of locally unconformable relations within the formations themselves, but these have very little importance in a consideration of the general geology of the region.

For southeastern Missouri, which includes a portion of the Ozark region, the following geological section, based upon the work of the geologists of the State and Federal Surveys has been adopted, provisionally, and will be used as a basis for further investigations.

Quaternary	Alluvium.	
	Iowan Loess.	
Tertiary	Lafayette gravel.	
	Unconformity.	
Pennsylvanian	Des Moines.	
	Unconformity.	
Mississippian	Chester	Birdsville.
		Tribune.
		Cypress.
	St. Louis	Ste. Genevieve.
		St. Louis.
	Spergen.	
	Warsaw.	
	Keokuk.	
	Burlington	Called the Boone in Southwestern Missouri by the U. S. Geol. Sur. geologists.
	Chemung or Kinderhook	Chouteau.
		Hannibal (Vermicular.)
		Louisiana (Lithographic.)
Devonian	Sulphur Springs	Bushberg.
		Glen Park.
		Unnamed shale.
	Grand Tower (Hamilton and Onondaga.)	
	Clear Creek (Oriskany.)	



Outcrop of Granite, near an abandoned quarry north of Bismark.

Silurian	Bailey (Lower Helderberg.)	
	Niagara (Bainbridge)	
	Girardeau (Cape Girardeau)	
	Hudson River (Thebes.)	
Ordovician	Kimmswick (Receptaculites.)	
	Plattin (Trenton, Black River or Birdseye.)	
	Joachim.	
	St. Peters.	
	Unconformity.	
Upper Cambrian (Ozarkian of E. O. Ulrich)	Jefferson City.	
	Roubidoux (Incl. Bolin sandstone.)	
	Gasconade (Incl. Gunter sandstone.)	
	Unconformity (?)	
	Proctor.	
	Eminence.	
	Potosi.	
	Unconformity (?)	
	Doerun	Elvins of Ulrich.
	Derby	
	Davis	
Middle Cambrian (Taconic or Cambrian, restricted, of E. O. Ulrich)	Bonneterre.	
	Lamotte.	
	Unconformity.	
Huronian	Pilot Knob.	
	Unconformity.	
Laurentian	Diabase.	
	Granite.	
	Rhyolite.	

PRE-CAMBRIAN.

The oldest rocks in the State are those of igneous origin occurring in the southeastern part, and making up what is known as the St. Francois mountains. The distribution of these rocks is shown on the accompanying general geological map, see Plate XL.

The igneous rocks are mainly rhyolite (porphyry) and granite but scattered at intervals throughout the whole area occupied by these rocks are narrow ribbon-like outcrops of diabase dikes which are intrusive within the granite and porphyry. Occasionally the diabase covers an oval or oblong area, in which case it is called a boss. The dikes, as a rule, do not average over 2 or 3 feet in width and can seldom be traced more than 50 to 100 yards. Some of the dikes are mere stringers less than an inch wide. The largest boss known in this region covers an area of about 160 acres and is located in Sec. 26, T. 34, R. 8 E. Haworth* says "that invariably the dikes trend northeast and southwest, with the few exceptions lying approximately at right angles to this direction." In addition to the above, mention should be made of the quartz and pegmatite veins of later origin than any of the above mentioned igneous rocks.

About one-fourth of the igneous rocks are granite, of which

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*Missouri Geological Survey, Vol. VIII, p. 138.

Haworth** recognized several varieties. They are more abundant in the eastern part of the area than elsewhere. A class of rocks occur "which, in their structural relations, occupy an intermediate position between the granites and porphyries" (rhyolites).

Haworth recognized two great classes of rhyolites which he called "porphyries proper and porphyrites." These constitute about three-fourths of the igneous rocks outcropping over the region. Such evidence as has been collected tends to substantiate Haworth's conclusion that the granites and rhyolites belong practically to the same general period of eruption, "and that, in many cases, from a particular magma a granite was produced in one portion and a porphyry (rhyolite) in another."

These igneous rocks are of positive pre-Cambrian age. They probably, do not belong to the Archean or Basement Complex series of rocks which are the most ancient of which the geological explorations of this continent afford knowledge. It is thought, however, that they may tentatively be considered as belonging to the granitoid series, sometimes known as the Laurentian. They constitute the oldest rocks of which we have any record in this state.

Between Laurentian and Cambrian times three periods are recognized in geological history, but only one of these, the Huronian, has been recognized in Missouri.

This series is represented by slate and conglomerate, aggregating 200 feet in thickness, according to Haworth. The areas underlain by this series are small, the most important being at the summit of Pilot Knob, at an elevation of 1200 to 1400 feet A. T. These deposits represent the first submergence of this portion of the state beneath the sea; and it is extremely interesting to have evidence that this portion of the continent was not a land area during the long interval which must have elapsed between Laurentian and Cambrian times.

On page 21 of Bulletin 267 of the reports of the U. S. Geological Survey, Dr. Ulrich expresses a belief that the Pilot Knob conglomerate should not be considered "as a formation wholly beneath and older than the LaMotte sandstone." He believes that it is the initial deposit of the invading early Cambrian sea.

From my limited observations, I am forced to conclude that there may be some ground for this conclusion. On the other hand

**The reader is referred to Vol. VII, of the reports of the Missouri Geological Survey, pp. 84-222, published in 1895, for a detailed account of the igneous rocks of this region.

there is so little resemblance between the two formations that I am not surprised that Haworth should conclude that the formation was pre-Cambrian. The age of the conglomerate and slate may be said to be still an open question.

Of the Animikean and Keweenawan periods, which successively followed the Huronian, we have no record in this state. There is an enormous time interval between the Huronian and Cambrian, but for Missouri there are no records remaining, from which the history of those periods can be written.

The Laurentian rocks of this region were undoubtedly one of the main sources of the sediments which make up the succeeding sedimentary formations. It is also believed that through the destruction of these rocks, lead, zinc and other metals were contributed to the surface and ground waters, through which agencies they were later concentrated in the dolomites from which they are being mined today.

The igneous rocks referred to above are the only ones outcropping in Missouri, with the exception of a granitic, pegmatite dike near the boundary line between Camden and Laclede counties, in Sec. 32, T. 37 N., R. 16 W. This dike is thought by Winslow and others, who have examined the region, to be of post-Carboniferous age.

A deep well at the Insane Asylum in St. Louis county showed the igneous rocks to lie 3600 feet below the surface, while in another drill hole near Sullivan, in Franklin county, rhyolite was encountered at a depth of 1200 feet. In the western part of the state the igneous rocks lie at a depth of 2000 feet below the surface, as shown by a drill hole at Carthage. At Raytown, near Kansas City, igneous rock was penetrated at a depth of 2430 feet, while at Forest City, in Holt county, a hole 2500 feet deep stopped in dolomite of Cambrian age.

Thus it is seen that the granite and rhyolite hills of southeastern Missouri, known as the St. Francois mountains, constitute not only the most elevated range of hills in Missouri but also the oldest. Before they were buried beneath the thousands of feet of sedimentary rocks which evidently at one time covered them, they presented an extremely irregular surface, ranges of hills and isolated peaks alternating with deep valleys, the sides of which must have often been steep and precipitous. Since that time the land surface has been alternately depressed and elevated, resulting in faulting and flexuring which has further intensified the irregular surface of the underlying pre-Cambrian base, especially in close proximity to the igneous areas now exposed.

As a result of the mechanical stresses, well defined systems of jointing have been established, the most prominent of which trends N. E.-S. W. according to observations made by Haworth.

It is difficult to estimate the difference in elevation between the deepest valleys and the highest hills of pre-Cambrian times owing to the insufficient knowledge which we have of the extent to which the hills have been denuded as a result of erosion or elevated as a result of faulting. For example, there is a fault along the north side of Simm's mountain, as a result of which the sedimentary series has been lowered approximately six hundred feet. Taking these facts into consideration, it appears altogether probable that the St. Francois mountains are remnants of a range, the peaks of which rose to an elevation of several thousand feet.

The St. Francois mountains appear to have been at least one of the centers about which the sea deposited the successive series of strata which make up the Paleozoic succession. The highest of these peaks is at present about 1500 feet above sea level while forty miles to the northwest, near Sullivan, the pre-Cambrian surface is approximately 250 feet below sea level, and at St. Louis 55 miles northeast, the pre-Cambrian surface is 3200 feet below sea level. During Cambrian time it is scarcely possible that this wide difference in elevation of the Laurentian rocks could have existed. There may have been a gradual and uniform subsidence over the entire region and later a subsidence of the region to the northeast which did not involve the St. Francois mountains. This seems altogether probable in view of the occurrence of at least one well defined fault zone near Valles Mines having a down throw to the northeast of seven or eight hundred feet, as shown in the accompanying sections, Plate XLII.

The trend of this discussion is simply to emphasize our belief that the major irregularities of the pre-Cambrian surface underlying the region usually included within the Ozark plateau are chiefly a result of differential subsidence and elevation subsequent to Laurentian times and not altogether the result of differential pre-Cambrian erosion as some have supposed.

CAMBRIAN.

Such evidence as we have in the way of fossils indicates that this region was a part of the continental area during Lower Cambrian time. The beds of sandstone immediately overlying the igneous rocks carry a fauna belonging to the Middle Cambrian, according to Dr. Charles D. Walcott and Dr. E. O. Ulrich. Dr. Walcott believes that the Lamotte sandstone is well up in the Middle Cambrian. In a personal letter to me he says, "I have not seen any reason to change the view graphically shown on Plate 2 of Bulletin No. 81 of the U. S. Geological Survey in 1891."

The Middle Cambrian is separated from the Upper Cambrian by no well defined stratigraphic or structural break. The line of separation is thought to occur somewhere within the Davis formation, although Dr. Ulrich has suggested that it may be between the Doerun and the overlying Potosi. I am inclined, however, to believe that the separation of the Middle from the Upper Cambrian will be made eventually near the top of the Davis shale. Since writing the above a locality has been discovered, in which there is a limestone bed about fifteen feet above the Central Marble Boulder member of the Davis, carrying an abundance of well-preserved Eoorthis shells which are a very positive indication that the Davis shale above the Central member is Upper Cambrian while that below is Middle Cambrian. Dr. E. O. Ulrich has discussed the stratigraphy of this area, in a very general way, in Bulletin No. 267 of the reports of the U. S. Geological Survey. The data which this bulletin contains were collected very hurriedly and as a result, the thickness and characteristics of the several horizons do not agree with our observations as contained in this volume.

The Cambrian of southeastern Missouri has been made to include, provisionally, all the formations beneath the St. Peters sandstone. In so doing I am following the suggestion of Dr. Ulrich, who has been making a study of the fauna of the formations embraced in the Ozark plateau region. The formations included within the Cambrian are as follows:

Upper Cambrian (Ozarkian of E. O. Ulrich.)	Jefferson City.	
	Roubidoux (Incl. Bolin sandstone.)	
	Gasconade (Incl. Gunter sandstone.)	
	Unconformity (?)	
	Proctor.	
	Eminence.	
	Potosi.	
	Unconformity (?)	
	Doerun.	Elvins of Ulrich.
	Derby.	
	Davis.	
Middle Cambrian, (Taconic or Cambrian, restricted, of E. O. Ulrich.)	Bonneterre.	
	Lamotte.	

LAMOTTE FORMATION.

This is the oldest recognized Cambrian formation in the state. It overlies unconformably the rocks of the Laurentian and Huronian wherever they may occur. However, it is interesting to note that the identified Huronian at Pilot Knob is not overlain with any of the younger formations and that all drill holes which have penetrated the Archean granite or porphyry have failed to show recognizable Huronian strata. This evidence leads one to surmise that the Huronian was either practically all removed prior to the incursion of the Cambrian Sea, or that it never occurred over a greater part of the region. Upon this point we may always be in doubt. There is also some doubt as to whether the conglomerate at Pilot Knob is of sedimentary origin, it being believed by some to be a breccia. The extreme irregularity of the pre-Cambrian floor upon which the Lamotte sandstone rests, although partly attributable to subsequent deformation as pointed out above, is also the result of pre-Cambrian erosion.

The Lamotte formation was spread out over the irregular surface of igneous rocks filling up many of the lesser depressions. This is the only part of the state in which this sandstone is known to outcrop. Here it is the surface formation over an area of approximately 200 square miles, only a small portion of which is in the area included within this report. The boundaries of this sandstone have been mapped with considerable detail over much of the area, for use in the general geological map, Plate XL. From this the reader will see that this sandstone is wrapped about the St. Francois mountains, the greatest area being about the Jonca granite hills.

This formation consists of a conglomerate at the base, above which sandstone and conglomerate alternate for a considerable distance, finally grading into a coarse and then into a medium to a fine grained sandstone. Near the top it consists of alternating beds of sandstone and dolomite passing into the Bonneterre dolomite formation without definite line of contact.

The conglomerate occurs irregularly at and near the base, being present in some places and not in others. It is thirty feet thick in some places and in others it consists of only a thin layer. In the conglomerate horizon beds of coarse arkose alternate with others containing pebbles and boulders of granite and rhyolite. The pebbles and boulders are smooth and well rounded. Beds of conglomerate alternate with arkose near the outcrops of igneous rock while above arkose beds alternate with sandstone, finally passing into a coarse and fine grained sandstone with fairly well defined bedding planes. This condition is well exhibited around the flanks of Simms mountain, especially in Secs. 22 and 27, T. 36, R. 4 E. Along what is known as Dry Fork the conglomerate occurs in isolate patches plastered onto the rhyolite hillsides far up the ravine. On the general geologic map no attempt has been made to locate these patches, the areas being too small to distinguish from the Archean. The beds of gravel and boulders extending some distance from the shore line and interbedded with sandstone are typical intraformational conglomerates, such as have been described as occurring near the base of the Postdam sandstone of the Baraboo Bluffs in Wisconsin.

The thickest exposure of sandstone on the Bonne Terre sheet is in Secs. 22 and 27, T. 36N., R. 4E. Here the sandstone is 150 feet thick. In Secs. 8 and 9, T. 35N., R. 3E., 140 feet of sandstone is exposed. In determining these thicknesses the altitude of the outcrops is taken as a basis. This is not the maximum thickness of the sandstone, which in the deeper parts of the basins must be over 250 feet thick. On the Farmington quadrangle one mile east of Sprott, the Lamotte sandstone occurs between elevations of 1050 feet and 845 feet, which, provided the beds extend horizontally from the crystalline core, will give the formation a thickness of 205 feet.

The transitional zone lying between the Lamotte sandstone and the Bonneterre dolomite is represented by alternating beds of dolomite and sandstone extending in places through a thickness of forty or fifty feet. The beds of sandstone at this horizon are usually chloritic and frequently contain thin laminae of shale.

This alternation of dolomite and sandstone is best exhibited on the Bonne Terre sheet near the old Swallow mines in the S. W. ¼ of Sec. 11, T. 35N., R. 3E. At this place the ore occurs in a 6-8 foot bed of arenaceous dolomite which is overlain with sixteen or more feet of sandstone. This same alternation of limestone and sandstone beds occurs about one mile east of Farmington and also in Sec. 9, T. 35N., R. 7E. The same condition has been found to exist on the Hoffman tract near Leadwood where sandstone beds have been drilled through into lead-bearing dolomite. Drilling on other tracts has shown this to be very generally the condition throughout the district.

Drill holes that have passed through the overlying Bonneterre dolomite into the sand have in some places encountered a very much indurated, quartzitic phase which acts as an almost impervious horizon shutting off the water in the underlying porous sandstone. In the vicinity of Leadwood a thickness of 30 to 40 feet of dark gray sandstone occurs beneath the Bonneterre formation, while in the valley through which Hayden creek flows drilling has revealed the presence of a well defined conglomerate at the base of the sandstone. This conglomerate consists of fragments of granite and rhyolite embedded in a shaly, sandstone matrix.

A hole drilled at the office of the St. Joseph Lead Company at Bonne Terre passed through 239 feet of sandstone into a rhyolite conglomerate and then into rhyolite. Near Flat River the Doe Run Lead Company drilled eighty feet into the sandstone. A hole was drilled 95 feet into the sandstone at Shaft No. 1 of the Federal Lead Company. The following are detailed descriptions of the drill cores obtained from the holes which penetrated the sand on the properties of the St. Joseph Lead Company and the Federal Lead Company:

LOG OF DRILL HOLE LOCATED 70 FEET NORTHEAST OF ST. JOSEPH LEAD COMPANY'S OFFICE AND 120 FEET NORTHWEST OF NO. 1 SHAFT.

From Ft.	From In.	To Ft.	To In.	
0		17	6	Sleeve.
				BONNETERRE FORMATION.
17	6	32		Yellow limestone.
32		87		Light colored limestone, with occasional patches and seams of yellow and buff limestone.
87		97		Gray limestone.
97		99		Dark gray limestone.
99		114	6	Dark gray, porous limestone with about 8 inches of buff colored limestone at 100′.
114	6	123		Buff and light colored limestone.
123		133		Gray limestone.
133		158		Gray, mostly porous limestone.
158		169		Firm, gray limestone.
169		179		Firm, light gray limestone.
179		215		Gray limestone. A thin, diagonal seam of calcite and pyrite at 207′ and 212′ and a thin sheet of pyrite at 214′.
215		217		A light gray brecciated limestone, with waves of dark shale and pyrite.
217		219		Light gray limestone with about 4 inches scattering pyrite.
219		227		Light gray limestone with a vertical seam of calcite and leaves of dark shale at 220′.
227		231		Light colored, becciated limestone.
231		240		Light gray limestone and occasional waves of dark shale, with a small bunch of calcite at 232′.
240		257		Light gray limestone with a vertical seam of calcite. At 248′ and 249′ a thick vertical seam of calcite.
257		267		Light gray limestone with an open, vertical seam at 259′, where water was lost.
267		303		Light gray limestone with occasional waves of dark shale, below 287′ (about 3″ shale at 294′).
303		327		Light gray limestone and thin layers or waves of dark shale, with scattering chlorite from 340′ to 342′.
327		357		Light gray limestone and thin layers or waves of dark shale, with scattering chlorite granules from 340′ to 342′.

From Ft.	From In.	To Ft.	To In.	
357		377		Light gray limestone with occasional layers of shale well mixed with chlorite at 368′, 369′, 371′, 375′ and from 375′ to 377′.
377		387		Mostly chlorite with layers of light gray limestone and some thin layers of shale.
387		392		Chlorite with layers of gray, sandy limestone.

LAMOTTE SANDSTONE.

From Ft.	From In.	To Ft.	To In.	
392		412		Gray, yellow and brown sandstone (at 393′ and 408′ white.)
412		415	6	Gray, very sandy rock, with traces of shale.
415	6	421		Light colored sandstone, (some white and brown at 418′ and at 421′ yellow, with thin layers of shale.)
421		423		Gray sandy rock, with about 3″ limestone and traces of shale.
423		424	3	Light colored limestone.
424	3	426		Light colored, sandy limestone.
426		446		Mostly yellow, white and brown, coarse-grained sandstone. (Cores mostly ground up; probably owing to the extreme softness of the formation.)
446		458		Fine grained, light colored sandstone, with thin layers or waves of dark shale. Coarse-grained, light colored sandstone at 457′ and 458′.
458		462		Fine grained light colored sandstone, with layers or waves of dark shale.
462		472	6	Coarse grained gray sandstone, with layers and waves of dark shale. (Occasionally quite shaly after about 489′.)
472	6	485		Light colored sandstone and then soft, coarse grained gray sandstone to 485′, of which only a few pieces of core were obtained, it apparently being too soft to form cores.
485		502	6	Yellow and buff colored sandstone.
502	6	505	3	Light colored sandstone with shale layers.
505	3	507		White sandstone.
507		531		Light colored sandstone with occasional dark layers. (At 514′ a heavy layer of shale and a little shale inside of core at 524′.)
531		542		Light colored sandstone, with about one inch shale at 533′.
542		544		Mostly shale.
544		581		Light colored sandstone, with a bunch of shale and iron pyrites inside of core at 546′ and 555′; a thin layer of shale at 549′ and 553′; shale at 562′ and 563′ and a thin layer of shale at 567′, 569′, 573′ and 575′; two thin layers of black shale at 576′ and thin layers of shale at 579′ and 580′. (After 558, the sandstone was occasionally of a very coarse, pebbly character.)
581		611		Light colored sandstone with traces of shale at 605′ and 610′ and occasional layers of a very coarse, pebbly nature from 598′ to 605′.
611		623		Light colored sandstone, with a heavy layer of shale at 619′.
623		631		Gray sandstone, with a layer resembling porphyry at 624′.
631		635		A grayish rock, carrying traces of porphyry, shale seams and scattering pyrite.
635		638		Porphyry and shale.
638		652		Porphyry and then changing into red granite.
652		652		Red granite. This granite was too hard to drill, even with a "300 Feed."

SUMMARY.

Depth. From Ft.	In.	To Ft.	In.	Thickness. Ft.	In.	Formation.
0		17	6	17	6	Residual Clay.
17	6	393		374	6	Bonneterre formation.
393		631		239		Lamotte sandstone.
631		652		21		Rhyolite (porphyry)
652		662		10		Granite.

The record of the lead cut in this drill hole has been omitted, the intention being to simply show the thickness of the Bonneterre and Lamotte formations.

LOG OF HOLE DRILLED AT THE BOTTOM OF SHAFT NO. 1, FEDERAL LEAD CO.

From Ft.	To Ft.	
0	40	Dolomite. (Bonneterre formation.)
40	58	Medium grained sandstone. (Lamotte formation.)
58	71	Fine grained, gray sandstone. Some streaks coarser than others.
71	97	Hard, fine grained, gray sandstone. Few irregular shale leaves near base. At about 95' color changes abruptly to yellow and grain becomes coarser.
97	108	Hard but coarse white sandstone.
108	121	One foot of fragments much ground up. White and yellow, coarse grained sandstone.
121	124	Coarse grained, yellow sandstone, hard enough to core well.
124	126	Very coarse grained, dark brown, iron stained sandstone.
126	130	Fine grained to shaly, yellow sandstone. Cores perfectly with diamond bit.
130	135	Very fine grained, hard, white sandstone.

The sandstone has a porosity of about 12 to 15 per cent and as a rule the pores are filled with water which in places is under hydrostatic pressure sufficient to cause it to flow upwards into the overlying limestone, sometimes even to the surface. Prior to the opening of the mines of the Central and Doe Run Lead companies, by which the water level has been lowered, certain holes drilled into the sandstone along Flat River produced flowing wells. North of Bonne Terre and elsewhere in this district the same results have been obtained. In Madison county, where the same relations obtain between the Lamotte sandstone and the overlying formations, flowing wells are sometimes encountered in prospect drill holes. A water pressure of 80 to 95 pounds per square inch is not infrequently met with in underground drill holes that have penetrated the sandstone or channels connected with the sandstone. Such pressures have been recorded in Federal No. 2, Doe Run No. 4, St. Joseph No. 11, and other mines. It is thought that this pressure is not due entirely to the hydrostatic condition of the water within the Lamotte sandstone but that it is in part the result of pressure from water filling channels and branch channels within the Bonneterre dolomite which extend to the sandstone.

However, the prevalent idea that the Lamotte sandstone is an enormous reservoir of water has led the operators of the district to avoid breaking into it, the practice being to leave several feet of limestone above what is supposed to be the top of the sandstone, to act as an impervious cover. It is also the practice to leave several feet of rock between the water channels in the Bonneterre dolomite and the mine workings.

The sandstone, near the top, often contains disseminated galena and has, in a number of instances, been mined with the limestone. This is true at Desloge Mine No. 4, St. Joseph Mines No's. 12 and 14, and at other mines. In places the galena is known to occur thinly disseminated through the Lamotte sandstone to a depth of at least forty feet below the contact with the Bonneterre formation. In Madison county, at the North American mine, some of the richest lead has been obtained from the sandstone immediately underlying the Bonneterre formation. Galena is also known to occur in the conglomerate at the base of the formation. The discovery of workable deposits of ore within the Lamotte sandstone is not at all improbable, in fact galena might be expected to occur especially in the shaly portions of this formation.

The upper surface of the Lamotte sandstone reflects, to a considerable degree, the irregularities of the underlying igneous rocks. It rises and falls, often in gentle undulations, from one place to another. In places it presents abrupt escarpments of from twenty to forty feet, and even more, as shown by the drill records. These abrupt changes in the level of the upper surface of the sandstone are in the main the result of faulting, while the undulations are to be attributed to the uneven floor upon which the sandstone was deposited.

It is interesting to note that in the vicinity of Doe Run and Iron Mountain, which towns are south of this district, records of drill holes show at least two sandstone horizons separated by fairly well defined dolomite beds. A typical drill record shows 209 feet of yellow and gray dolomite, 38 feet of gray and yellow sandstone, 37 feet of dolomite and 36 feet of sandstone and granite conglomerate.* With this condition existing less than ten miles from Flat River, it might be expected that similar dolomite horizons would be encountered beneath what is at present recognized as the upper surface of the Lamotte sandstone. On the other hand the upper sandstone horizon shown by drill holes in the vicinity of Doe Run and Iron Mountain may be the equivalent of some of the lower beds of Bonneterre limestone of the Flat River area. Of this we have no evidence, and the actual succession can only be determined by drilling to the underlying crystallines.

The sea in which the Lamotte sandstone was laid down did not cover the entire surface of the land, as shown by numerous localities in which the overlying Bonneterre limestone rests directly upon the igenous rocks. Its distribution was very general but during the period of its deposition the pre-Cambrian hills still rose above the sea, contributing the detritus of which the sandstone is composed.

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*For additional sections illustrating this condition, reference should be made to the Iron Mountain sheet report contained in Vol. IX, of the reports of this Bureau, published in 1894.

Very little is known of the fauna of the Lamotte sandstone. In some of the transitional beds between the Bonneterre and this formation shells of Lingula and Lingulepis shells have been observed, some of the chloritic beds being rich in these fossils. A number of the phosphatic brachiopod shells were sent to Dr. Charles D. Walcott, who identified them as *Dicellomus* politus, Hall, which has a wide geographic range and occurs in both Middle and Upper Cambrian.

It would have been very interesting to have prepared a map showing the elevation of the top of the Lamotte sandstone throughout the district, but upon investigating the records of drill holes, I discovered that many of them are so unreliable in their location of the sandstone level, that any such map would be of very little service. Hundreds of drill holes reported to have bottomed in Lamotte sandstone only reached the transitional beds.

As a whole, the Lamotte sandstone lies in the form of a pitching trough, hemmed in to the northeast and southwest by masses of igenous rocks; abutting against dolomites and shales which have been lowered by faulting to the northwest; and coming nearly to the surface to the southeast. These conditions are clearly shown in the accompanying map and cross sections, Plates XL. and XLI.

Within this basin there are occasional ridges and other minor elevations of the sandstone, the principal one being known as the Farmington anticline. This ridge practically separates the trough into two forks. In one the mines at Bonne Terre are located and in the other the Flat River Mines. In other words a ridge of sandstone separates the ore horizon of the St. Joseph Lead Company's mines at Bonne Terre from the ore horizon of the mines located south of Big River. This ridge of sandstone is buried beneath the Bonneterre dolomite which gradually diminishes in thickness toward the east and increases in thickness toward the west. The ridge appears to flatten out and disappears about three miles northwest of Desloge.

BONNETERRE FORMATION.

The Lamotte sandstone is overlain with the Bonneterre formation which has a normal thickness of approximately 363 feet of dolomite, arenaceous, chloritic and argillaceous in the lower portion and slightly argillaceous near the top. The Bonneterre for-

*The beds here called dolomite are magnesian limestone in which the percentages of magnesium and calcium are variable. However, they have all the usual characteristics of dolomite and are therefore called by this name in the present report.

Distant and near views of the weathered surface of the Bonneterre dolomite west of Desloge.

mation varies considerably in thickness, since it overlaps the Lamotte sandstone and over-rides its billowy surface. The greatest thickness of which I have a record is for a drill hole near Delassus which passes through 448 feet of dolomite before penetrating the sandstone. Other records in the neighborhood of this hole show thicknesses of 440 and 435 feet. Southwest of Elvins in Sec. 22, T. 36, R. 4E., the thickness varies somewhat, the maximum recorded being 355 feet. In Sec. 12, T. 36, R. 5E., the thickness varies from 396 to 406 feet. West of Irondale a maximum thickness of 310 feet has been recorded. On the land grant, U. S. Survey 3063, north of Farmington Junction there are several holes which indicate a thickness of about 380 feet. In the vicinity of Bonneterre this dolomite is about 400 to 440 feet in thickness as shown by numerous drill holes. West of the city of Bonne Terre on Secs. 2, 10 and 11, T. 37, R. 4E., drill holes show a thickness of Bonneterre dolomite ranging from 372 to 433 feet, the greatest thickness being in Sec. 10. In the Leadwood area this dolomite is 360 to 420 feet in thickness, as near as can be estimated from the available records.

The variations in the thickness of this, as well as the other formations, can best be understood by reference to the accompanying cross sections, which have been drawn to a uniform scale using the records of drill holes, chiefly, as a basis. The variations in the thickness of this formation, as shown in these sections, may be due in part to imperfections in the drill records. The driller does not always recognize the top of the Bonneterre and he also frequently stops drilling in dolomitic or chloritic sandstone, which may lie forty feet or more above the bottom of the Bonneterre. However, they are as nearly correct as can be obtained from the available data.

As stated above, there is no sharp line of contact between the Bonneterre formation and the underlying Lamotte sandstone. The Bonneterre usually contains near the base, beds of sandstone while the Lamotte sandstone contains beds of dolomite. Thus through alternating beds of dolomite and sandstone the Lamotte grades into the overlying Bonneterre. Some of the lower beds of limestone have a very conglomeritic appearance, which combined with the often wavy and irregular bedding suggests the possibility of at least local unconformity. Such irregular bedding is illustrated in the accompanying figures. This is not referred to as being especially unusual, for similar phenomena have been observed in other Cambrian formations of this region, in places where there was no additional evidence of unconformity. It is suggested that these irregularities may be due to movements of the oceanic waters; movements within the formation prior to its consolidation; or the result of settling occasioned by solution and consolidation of the sediments.

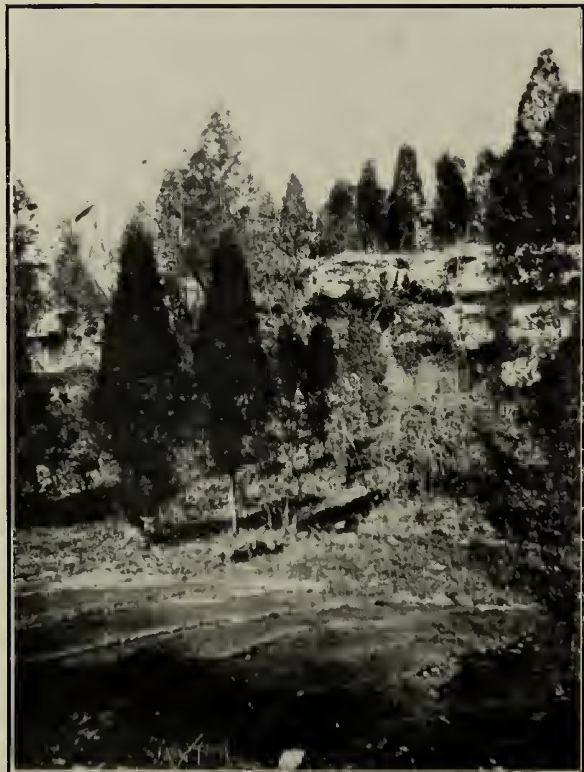
The lower fifty to one hundred feet of the Bonneterre formation is marked by the presence of beds of arenaceous dolomite, thin beds of shale, beds of chloritic dolomite and beds of chloritic, arenaceous dolomite. The dolomite may have a dark gray color from the presence of bituminous matter or it may be light gray or even buff. In some places it has a green color due to an abundance of chlorite, which in some places is reported to be present continuously through a section of a hundred feet. The percentage of chlorite varies, the beds being composed, in some places, almost entirely of this mineral, while in other places the dolomite contains a mere sprinkling of chlorite granules. The arenaceous beds usually have a buff or yellowish color frequently specked with granules of chlorite. The shale is either a green, gray or brownish black and may be soft or hard. The beds are seldom more than eight inches in thickness and usually thin and thicken as they are followed laterally. A single bed frequently splits into two thin beds which may come together at another point. The shale sometimes occurs in thin leaves separating thin beds of limestone.

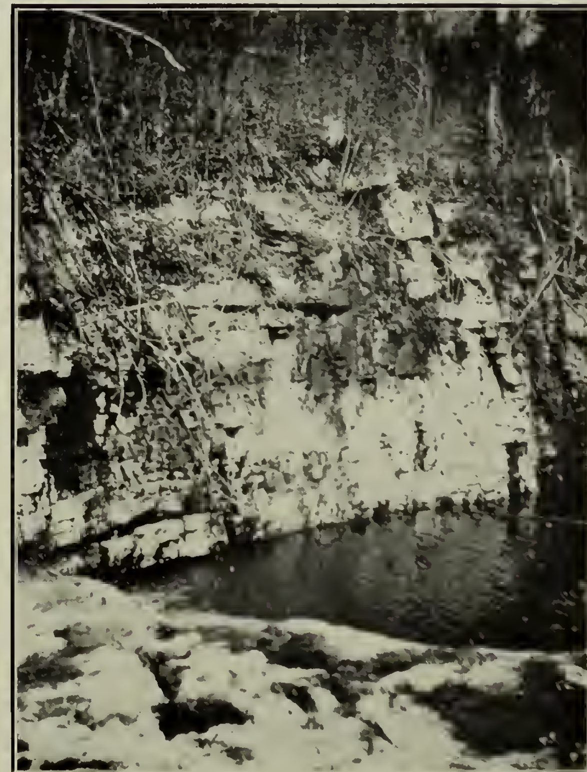
The black shale often has a spotted appearance due to lenticular or irregular inclusions of dolomite. These inclusions are usually small, varying from the size of a grain of sand up to several inches in diameter.

Bluish black, and green clays occur filling irregular cavities in the limestone, sometimes two or more feet in diameter. They occur, likewise, along many of the fault planes and occasionally occupy some of the space between the walls of channels which have formed as a result of weathering. A soft, sticky, red clay also occurs in some of the channels and along adjacent bedding planes. Most of this clay is supposed to have been washed in from near the surface.

In a few places the lower 20 to 30 feet of this formation is mainly shale, with thin interstratified beds of dolomite. As a rule, however, this horizon consists of dolomite interstratified with thin beds of shale and gray dolomitic sandstone.

Although galena occurs throughout the entire thickness of this formation, the principal deposits of disseminated ore occur in the lower portion, as described in a subsequent chapter.





Outcrops of Bonneterre dolomite along Owl creek.

Pyrite, chalcopyrite and calcite are of frequent occurrence throughout the formation.

The lower horizon is fractured, faulted and broken and the bedding planes are well defined. Frequently the beds are sharply inclined and local flexures are of common occurrence. The dolomite is often porous and as a rule, it is thoroughly crystalline. There is evidence that the rock has been completely re-crystallized since being laid down. The rocks at this level are usually saturated with water which rises along joint and fault planes from the underlying sandstone or flows in along channels from the surface.

In general, the lower horizon of the Bonneterre formation is a complex of shale, sandstone and dolomite,—chloritic, pyritiferous and galeniferous,—in places fractured and faulted,—through which there is an abundant circulation of ground water. This horizon passes upwards into dolomite with little or no sandstone and fewer beds of shale. The base of this formation is placed at the top of soft yellowish, reddish, or almost white non-calcareous sandstone. From this it will be understood that the transitional beds between the Lamotte and Bonneterre formations have been included within the latter.

The characteristics of the lower part of the Bonneterre are best exhibited in the mine workings, there being very few exposures of the lower Bonneterre in the region which has been under examination, altho the entire thickness outcrops upon the Bonne Terre and Farmington quadrangles. Wherever this horizon is exposed at the surface, chiefly in close proximity to the St. Francois mountains, the characteristics above enumerated are always in evidence.

Of the upper two hundred and fifty to three hundred feet about one hundred and fifty feet are exposed along Flat river above its confluence with Big river, the remainder being exposed to the east and southeast at various localities. This portion of the Bonneterre formation consists mainly of dark and light gray dolomite the beds of which are occasionally separated with thin laminae of shale. The dolomite is thoroughly crystalline and at many horizons contains large and small cavities, which impart a hackly appearance to the rock. This horizon is broken with numerous sets of joints, some of which are filled with calcite. Large cavities filled with bluish clay and open seams filled with red residual clay are common. The rock adjacent to the open channels is frequently decomposed and has a white, gray or buff color. Near the surface occur caves and openings along the channels, containing crystal aggregates of galena. Hundreds of abandoned shafts mark the localities where shallow mining was carried on during the early part of the 19th Century. Some tracts of land are covered with these abandoned holes, giving the surface a pitted appearance.

As a rule the uppermost bed of the Bonneterre is an argillaceous dolomite having a mottled appearance on the weathered surface due to the irregular laminae of shale which are so interwoven that upon weathering they leave the dolomite in small irregular lenses. Calcite is common in this bed. The mottling is observed mainly on the weathered surface. Some fossils have also been observed. This bed is overlain with several feet of blue shale belonging to the Davis formation. Beneath the mottled bed occur a number of dolomite beds.

The upper beds of the Bonneterre formation are exposed at many places in the Flat River and Bonne Terre areas, but nowhere are they better or more typically exhibited than in the bluff along Davis creek, just west of Shaft No. 4 of the Federal Lead Company.

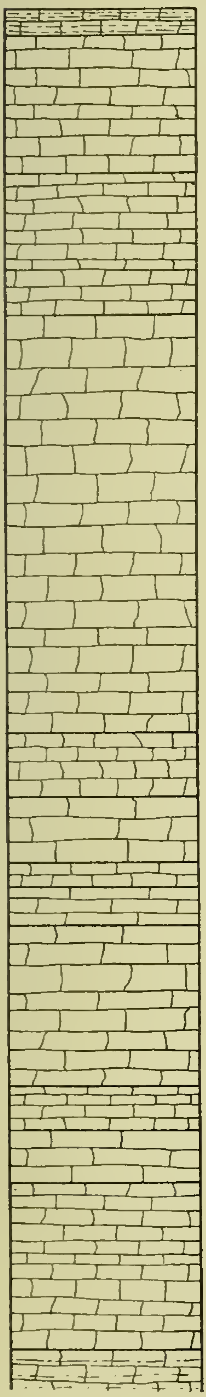
Wherever the upper beds of the Bonneterre are exposed along gentle slopes they usually have a craggy or honey-combed appearance which can be best understood by an examination of the accompanying views, Plates VI. and VII., which show different phases of weathering of these beds. It will be observed that where the Bonneterre occurs in cliffs its appearance is not much different from that of some of the overlying formations. The surface, however, is much more hackly and cavernous.

In several localities flecks of disseminated galena have been observed in the upper beds of the Bonneterre dolomite which outcrop at the surface. Elsewhere in this volume it is pointed out that disseminated ore has been encountered in this formation at a depth of about fifty feet in the mines at Bonne Terre and elsewhere in drill holes. Galena occurs at various horizons from the surface to the base of the formation, altho it has been segregated chiefly in the lower horizon of one hundred feet.

A close examination of the Bonneterre formation shows that the dolomite is, in the main, porous, containing small irregular cavities. These cavities are more or less lined with or enclose calcite which effervesces freely in dilute hydrochloric acid. Altho specimens from nearly all parts of the formation effervesce slightly with dilute hydrochloric acid, the upper half of the formation is distinctly the more calcareous as shown by the following section

Figure No. 2.

BONNETERRE FORMATION



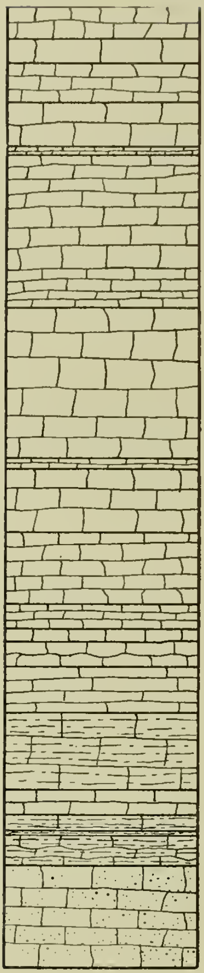
of the Bonneterre formation which is a detailed description of a drill core 1053 feet south and 3600 feet E. of the N. W. corner of Sec. 21, T. 36N., R. 5E.

One experiences considerable difficulty in recognizing horizons at the surface by a comparison with specimens of cores from the same horizon obtained by drilling. The outcrops at the surface are always more or less altered in appearance by weathering and through this process they acquire certain markings which are not recognizable in the drill core specimens. For the purpose of recognizing in the surface outcrops the different beds of a formation like the Bonneterre, a detailed study of drill cores is not altogether satisfactory. A study of the outcrop sections will prove much more helpful. On the other hand if one wishes to recognize the various horizons of this formation as they are displayed in the drill cores, the study of an outcrop section will be equally unsatisfactory.

COLUMNAR SECTION OF THE BONNE TERRE FORMATION FROM TOP TO BOTTOM.

Ft.	In.	
3	4	Mottled, streaked, shaly dolomite. Contains irregular masses of calcite. (Description from surface outcrop.)
22		Light buff to light gray dense hard dolomite. Fine flinty texture. Very slightly calcareous.
22		Brownish gray glistening, finely porous, crystalline dolomite. Slightly calcareous. Chiefly due to calcite crystals in cavities.
65		Very porous, yellowish to light brownish gray dolomite. Crystalline and shows glistening crystal faces. Slightly calcareous due to calcite in minute cavities.
10		Porous (less than last) crystalline, very light gray grading to light buff. Glistening crystal faces. Fine compact texture. Slightly calcareous due to calcite in minute cavities.
10		Dark gray, porous dolomite. About as porous as last. Crystalline and shows glistening faces on fresh surface. Very slightly calcareous due to calcite in minute cavities.
4		Same as last, but somewhat more porous. Smaller crystals are evidently oriented together to give a broad reflection in places. Very slightly calcareous due to calcite in minute cavities.
6		Dark gray limestone, similar to last. Hard, dense and glistening. 3 per cent disseminated galena. Very slightly calcareous due to calcite in minute cavities.
25		Very light brownish gray dolomite. Finely porous. Fine grained. Uniform texture. Slightly calcareous, due to calcite in minute cavities.
7		Brownish gray dolomite. Hard, crystalline, somewhat porous. Drusy calcite faces along fractures.
8		Dark gray dolomite. Hard with ¼″ druses of calcite. Crystalline, glistening surface. Medium fine grained. Very slightly calcareous due to calcite in minute cavities.
26		Light gray or dark. Fine grained and dense. Porous. ¼″ druses of calcite. Fine glistening crystals. Very slightly calcareous, due to calcite in minute cavities.

Figure No. 3.

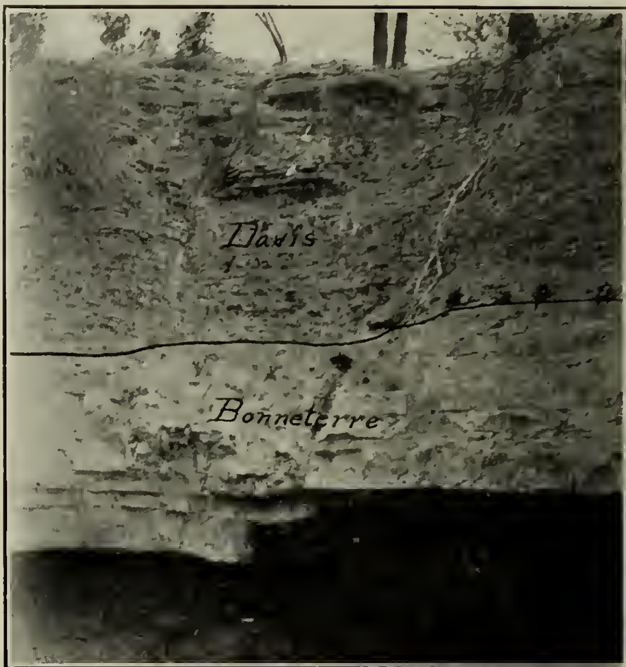


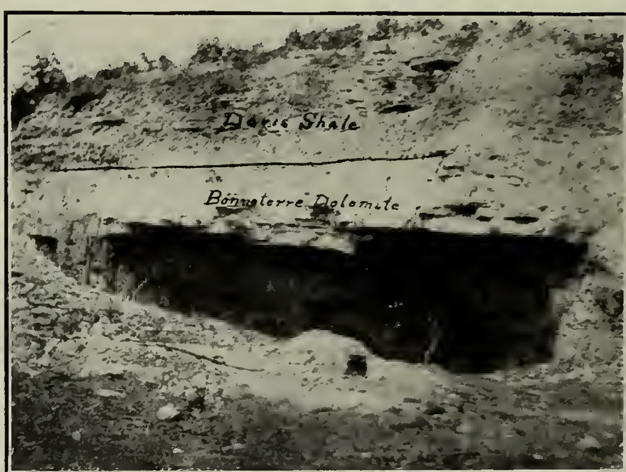
Vertical Scale

0 10 20 30 Feet

Ft.	In.	
7		Light gray dolomite. Few thin shale seams. Dense hard glistening surface porous. 2 per cent disseminated galena and trace of pyrite. Very slightly calcareous, due to calcite in minute cavities.
5		Very porous gray dolomite. 8 per cent galena chiefly in small cavities. 5 per cent pyrite intimately mixed with galena. Very slightly calcareous, due to calcite in minute cavities.
4		Less porous grayish drab dolomite. Glistening surface. Drusy calcite along seams. 1 per cent galena. Trace of iron pyrites. Slightly calcareous.
6		Finely porous, light gray dolomite. Glistening, crystalline and fine grained. Traces of galena.
7		Finely porous, light brownish gray dolomite. Sparkling. Finely crystalline.
1		Dark gray finely porous. Sparkling. Finely crystalline.
24		Light gray dolomite. Finely porous with cavities up to 1″ in diameter. Surface of cavities lined with minute crystals of calcite. Sparkling and crystalline. Some pyrite at 373′. Slightly calcareous.
23	½	Porous light gray. Faint brown tint. Sparkling crystalline. Fine grained. Very slightly calcareous.
1	½	Finely porous dolomite. Dark gray speckled with dark greenish chloritic granules. Sparkling. Medium grained. Crystalline.
10		Light gray, somewhat porous dolomite. Dense, fine grained, crystalline and sparkling.
11		Light gray, hard, dense, porous dolomite. Cavities drusy. Fine grained, crystalline and sparkling.
4		Finely porous, hard, dense, light brownish gray dolomite. Sparkling. Semi-crystalline. A general sugary appearance.
2		Somewhat porous, light gray dolomite. Sparkling. Finely crystalline.
4		Quite porous. Very light brown tinted gray dolomite. Hard, finely crystalline. Slightly chloritic.
7		Porous, light gray, brown tinted dolomite. Somewhat chloritic. Wavy black shale partings. Sparkling. Finely crystalline.
12		Dull gray, slightly crystalline dolomite. Shaly partings. Somewhat porous.
4		Dense dark gray, slightly porous dolomite. Sparkling, finely crystalline, and somewhat shaly along parting planes.
2	½	Soft, dull gray, shaly dolomite. Wavy parting planes. Somewhat crystalline. Matrix appears earthy.
	½	Shale. Earthy texture. Dark green to almost olive green. A chloritic streak.
5		Medium to coarsely crystalline dolomite. Finely porous. Chloritic. Wavy shale parting planes. Dark gray. Sparkling.
16		Medium to coarsely crystalline arenaceous dolomite. Dark gray. Sparkling. Finely porous. Very slightly calcareous.
362 Ft.		

At the close of the Bonneterre the St. Francois mountains still rose about the ocean, as shown by the overlapping of the younger formations and their contact with the igneous rocks. Shallower water conditions prevailed during the succeeding period, the Bonneterre dolomite being covered with the Davis formation consisting of shale, arenaceous dolomite, limestone and conglomerate.





Bonneterre and Davis formations showing contact.

DAVIS FORMATION.

This formation is at least a part of what Dr. E. O. Ulrich describes in Bulletin No. 267 of the reports of the U. S. Geological Survey, as the Elvins formation. The description of the Elvins formation by Ulrich is so very different from that which we offer for the Davis formation that no attempt will be made to compare them. Ulrich includes in his Elvins formation strata belonging to formations overlying the Davis which are known in this report as the Derby and Doerun. Including these formations he gives the thickness of the Elvins as 113.9 feet. The thickness of these three formations measured in the same locality from which Ulrich took his notes gives a thickness of 260 feet, of which 170 feet belong to the Davis formation. These figures have been arrived at by a careful measurement of sections across the outcrop and from a study of drill records from many parts of the district.

Naturally the Davis shale varies in thickness, being especially thin in some places in close proximity to the St. Francois mountains. In some places the relations existing between the different horizons are such as to lead one to suspect that the sedimentation during this period may have been interrupted by short intervals of erosion, in which case there would be a decrease in the thickness of the sediments toward the shore line. The faulting which occurs near the base of the major chain of peaks of the St. Francois mountains in the Bonne Terre area, combined with subsequent erosion, rather obscures in some places the relations existing between the Davis shale and the underlying formations. I am not sure that this formation rests upon any formation other than the Bonneterre and as far as our observations go it lies conformably above this.

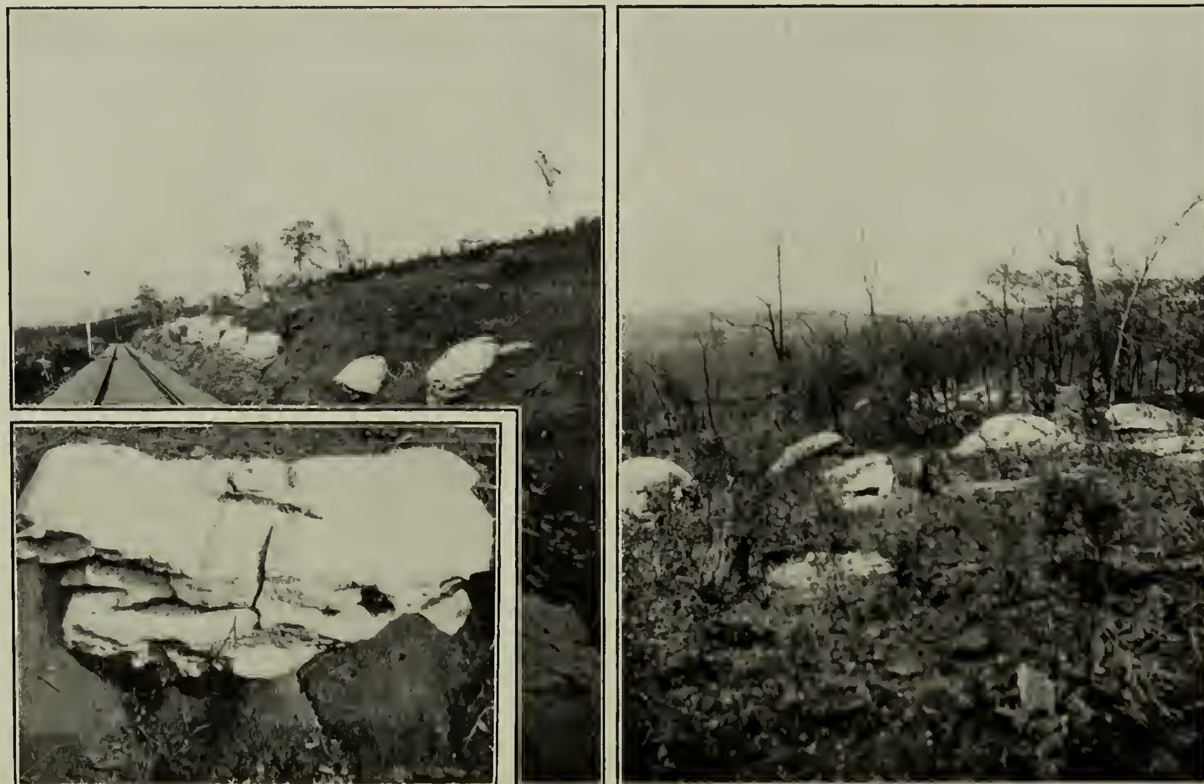
There are many localities in this district where excellent complete sections of the Davis shale are exposed. The most typical occur along the tributaries of Big river, including Flat river and its tributary Davis creek, Owl creek, Hayden creek and Eaton creek; along the Illinois Southern R. R., between Flat River station and Federal No. 2 mine; and along the Mississippi River and Bonne Terre R. R. between Desloge station and Federal Mine No. 2. The sections along most of the streams and along the railroads are broken by faulting and unless one has studied the formation in detail he would be liable to either overestimate or underestimate its thickness.

The thickness of the formation is best determined from the records of drill holes, hundreds of which have been sunk through the entire thickness of the formation in search of ore. These records indicate that the formation has a normal thickness of between 150 and 190 feet, the average being about 170 feet. The section along the Illinois Southern railroad between Flat River station and Federal No. 2 mine, by actual measurement has a thickness of 172 feet 2 inches. This is, perhaps, as typical a section as can be found in the district and for this reason it is given in detail in this report as illustrating the formation as a whole.

Drill hole records in Sec. 8, T. 36 N. R. 4 E., show this formation to be 164 feet, 160 feet, 190 feet, 171 feet, 165 feet and 156 feet thick. Drill hole records in Sec. 2, T. 37, R. 4 E., show this formation to be 194 feet, 150 feet, 160 feet, 147 feet and 190 feet in thickness.

This formation is commonly known by the mining men of the district as the shale horizon, on account of the abundance of shale distributed throughout its thickness. It is not only characterized by the abundance of shale but also by the frequent occurrence of beds of limestone conglomerate. In the section illustrated and described on the following pages fifteen conglomeratic limestone beds were recognized, besides the so-called "Central" marble boulder horizon. In contrast with the other formations of this region many of the beds are limestone or very calcareous dolomite and shale. The boulders of the Central member are almost pure limestone. The first limestone bed occurs about nine feet from the top. The second occurs 48 feet from the top. The upper 52.6 feet, however, is essentially a dolomitic horizon; the middle 79 feet is essentially a calcareous horizon; and the lower 39 feet is essentially a dolomitic horizon, although the conglomerate bed nine feet from the base is a limestone.

About 63 feet below the top of this formation there occurs 4 feet 6 inches of soft blue shale, in which are embedded large and small boulders of crystalline limestone known together as "Central" marble boulder member. This marble occurs frequently in the form of well rounded boulders but usually in masses which have flat bases and smooth roundish upper surfaces. In some places, for example along Davis creek near the southwest line of Land Grant No. 3272, these boulders look very much as though they were a part of a continuous bed. Here they occur in roughly rectangular blocks having smooth roundish upper surfaces, irregular water-worn sides and flat bases. These boulders resist weather-



The Central Marble Boulder horizon in the Davis formation. The view on the left is along the Illinois Southern Ry. south of Elvins.

ing better than the shale in which they occur, on account of which they protrude at the surface. The weathered surface of these boulders is white on account of which they stand out in strong contrast to the dull yellowish or greenish shale background.

There appear to be two somewhat distinct types of this marble, one being very finely crystalline and having a mottled bluish gray color, the other being medium to coarsely crystalline and having a grayish color. The color of the weathered surface of the former is white while that of the latter is yellowish brown. Both are more or less mottled with spots and streaks of green and chocolate brown. The fine grained marble contains a great many fossils and in one place the surface of one of these boulders was thickly strewn with fragmentary trilobite remains. These boulders are usually underlain with a conglomerate about a foot in thickness, with which the boulders frequently coalesce and to which they are frequently attached.

This horizon is especially well exhibited in the Leadwood and Flat River areas, as shown on the special geological map of these areas. This boulder horizon is not well developed around Bonne Terre, but extends southeast beyond the limits of the general sheet covered by this report. Marble, having identically the same composition, color, texture and general appearance, occurs in well defined beds on the Iron Mountain and Mine LaMotte quadrangles which are located south and southeast of this area.

The marble takes a most brilliant and beautiful polish, and although not used it would make a very desirable stone for interior decorations. The appearance of this horizon as it outcrops at the surface is well shown in the accompanying half tone illustrations.

The peculiar and exceptional manner of occurrence of these boulders immediately opens an inquiry as to their origin. In Bulletin No. 267 of the U. S. Geological Survey, Dr. E. O. Ulrich refers to this horizon as "a bed of nearly white, compact, and apparently not highly magnesian limestone about 8 feet above the base of the formation * * * * broken up into a series of large, boulder-like masses that may be of concretionary origin." From this one would be led to infer that he inclined to the belief that they were of concretionary origin. There is, however, no evidence of this either in their manner of occurrence or in their structure. I have examined hundreds of the boulders and find no evidence of a concretionary structure. It is true that some of them are roundish or oval but many of them are also roughly rectangular in shape, having more or less square bases. They contain an abundant fauna and have a uniform, compact, finely crystalline or sub-crystalline texture. Frequently the upper surfaces of these boulders are grooved and the sides hollowed out as tho worn by the action of the waves. Some of these boulders have a peculiar mushroom-like appearance as shown in Plate VIII. That these boulders were all shaped before the overlying shales, limestones and dolomites were deposited is shown by the fact that they lie embedded in shale, the upper surface of which is practically horizontal. The shale has in nearly every instance filled the intervening spaces between the boulders and wrapped itself around them.

If these boulders had been formed through solution by ground water, the upper surface of the enclosing shale bed would have been depressed to correspond with the removed portions of the limestone bed.

That this marble was originally deposited as a continuous bed of limestone there can be very little doubt. Such evidence as I have been able to gather, leads me to believe that it hardened or indurated in spots, and that later it was subjected to erosion by oceanic currents. This scouring action removed the softer portions of the limestone, in some places leaving only roundish or oval boulders and in other places a very much dissected bed of limestone. Perhaps this area may even have been elevated above the ocean for a short period as in the case of the coral reefs of today. In any event this boulder horizon is not a conglomerate in the sense that we use the term, but rather a limestone bed, which has been dissected under somewhat unusual conditions.

This Central marble boulder horizon is so persistent over a large part of the area studied that it serves as an excellent datum plane from which to establish the contacts between the several formations above and below. It actually divides the Davis formation into two parts, an upper and a lower, and in much of the field work it was found convenient to recognize this division. This horizon also serves a most useful purpose in recognizing and locating faults, and in order to determine its exact elevation throughout the area covered by the special Flat River and Leadwood sheet a line of levels were run over its entire course.

As stated above, fifteen different conglomerate beds have been recognized in one continuous section of this formation, of which one occurs above the Central marble boulder bed and fourteen below. Of these fifteen beds eight are typical "edgewise" conglomer-

Typical exposures of the Davis formation.

ates as described by Nason in the Am. Journal of Science, Vol. XII, pp. 358-361, and seven are conglomerates of the ordinary type. The edgewise conglomerate beds all occur beneath the Central marble boulder bed. The conglomerate bed above the Central boulder bed is dolomite, while all the others are limestone except in two instances, where they are magnesian limestone. The conglomerate beds are not all continuous over the area, but appear and disappear at intervals, being replaced with hard, dense, crystalline limestone. A good illustration of this may be observed in one of the Illinois Southern railroad cuts north of Elvins.

The ordinary type of conglomerate, with one exception, consists of roundish disc-like limestone pebbles embedded in a matrix of medium grained crystalline limestone. In the exception referred to dolomite pebbles are embedded in a matrix of dolomite. In the case of edgewise conglomerates, flat lenses of fine grained limestone are embedded in a medium grained, crystalline, limestone matrix, and are arranged with their longer axes normal or inclined to the bedding planes. In some instances these flat lenses are grouped in a radial fashion, a cross section showing a fan-like structure. They appear very much as tho small roundish blocks of thinly bedded limestone were deposited close to the shore and later for a short period subjected to atmospheric disintegration through which the thin layers fell apart. Submergence in a comparatively quiet ocean would soon cause the interstices to be filled with sediments which would support the fragments in the vertical and inclined positions in which we now find them.

The edgewise and other conglomerates are well shown in the accompanying illustrations. (See Plate XI.)

There is an arenaceous, calcareous shale horizon of eleven feet about five feet below the base of the Central marble boulder bed. Two other three-inch arenaceous beds of shale occur 24 feet and 78 feet respectively below the Central boulder bed. These are the only well defined quartzose horizons in this formation.

Two very persistent beds of öolitic limestone occur eleven feet and nineteen feet respectively above the base of the Central boulder bed. These beds are each about one foot in thickness. The öolitic texture is better developed in the lower bed.

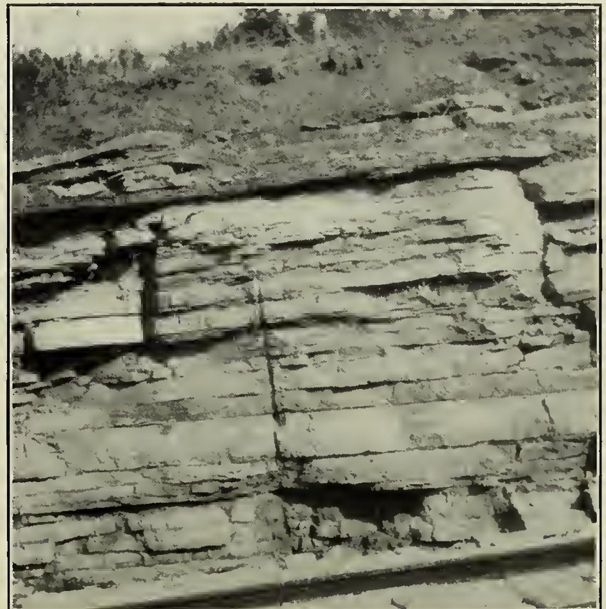
At many places the exposed surfaces of the limestone beds above and below the Central boulder bed show large ripple-marks or perhaps wave-marks. The strike of these sinuous markings was obtained at a number of places as follows: N. 63 W. in S. W. Cor.

of Sec. 7, T. 36 N., R. 5 E.; N. 65 W. in N. W. 1/4 sec. 14, T. 37 N., R. 4 E.; N. 60 W. in Sec. 9, T. 37 N., R. 4 E.; and N. 8 E. in S. E. 1/4 Sec. 17, T. 36 N., R. 5 E. These ripple marks were also noted in S. E. 1/4 Sec. 12, T. 36 N., R. 4 E.; in S. E. 1/4 Sec. 2, T. 38 N., R. 4 E.; near south line of S. W. 1/4 Sec. 14, T. 36 N.. R. 4 E.; and near the west corner of U. S. Survey Land Grant No. 3272. The wave marked surfaces are especially striking and indicate that the general direction of the shore line at that time was south or southwest of the places where the above mentioned ripple-marks occur.

Some of the beds exhibit sun cracks and others are covered with arborescent markings referred to as fucoids. These fucoidal markings are beautifully shown on the surfaces of many of the thin limestone beds.

Some of the beds of limestone and conglomerate contain an especially rich fauna, consisting of the remains of trilobites, brachipods and crinoids. The identification of these fossils will be made by Dr. E. O. Ulrich who has collections from the formations in this region.

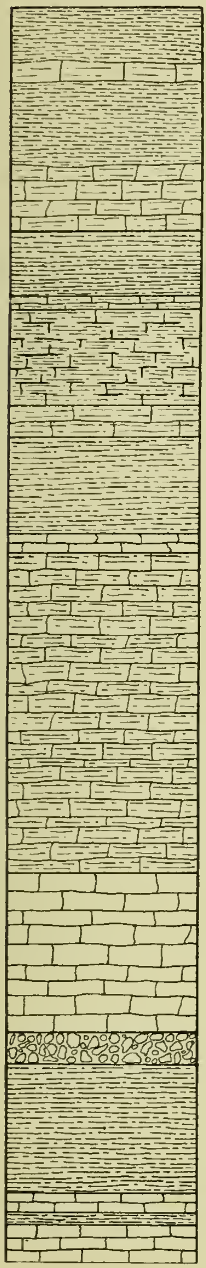
The following is a detailed columnar section of this formation measured and described from the beds outcropping along the Illinois Southern railroad from the Lead Belt Railroad crossing to Shaft No. 2 of the Federal Lead Company. Although this section will apply in general to the area embodied in this report, there are constant variations from place to place, making it applicable only in a broad way. For example, over a considerable part of the southern half of the sheet the upper horizon contains thick beds of dolomite which replace the soft shaly limestone noted in this section. These have been frequently confused with the dolomite beds of the overlying Derby formation, to which they bear a close resemblance. However, these beds are overlain with a soft blue shale which is persistent throughout the area, rendering the separation of the two formations comparatively easy.



Typical outcrops of argillaceous limestone of the Davis formation along the Illinois Southern railroad.

Figure No. 4.

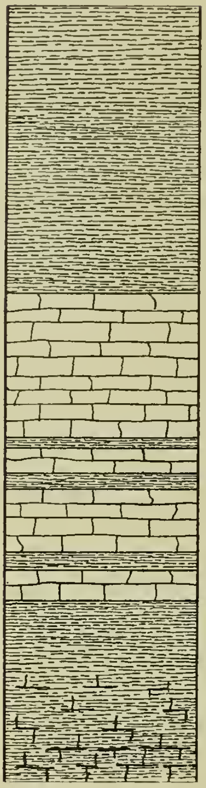
Davis Formation



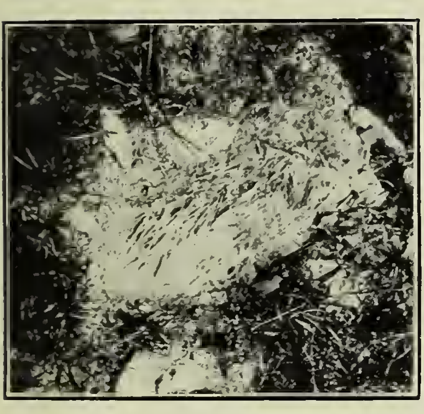
DAVIS FORMATION FROM TOP TO BOTTOM.

Ft.	In.	
7		Soft, thinly bedded and much broken dolomite, with some soft shale seams. Decomposed and not well exposed.
2		Soft, light greenish, calcareous shale.
	4	Soft, shelly limestone. Very much decomposed and not well exposed.
3		Soft, gray shale with many thin disks of hard dense dolomite.
1		Shelly, soft gray and buff dolomite. Finely crystalline. Fossiliferous, small gasterapod.
3		Soft, blue shale. Few thin discs of dense, sugary textured, hard dolomite.
	7	Medium to fine grained, crystalline, hard, dark gray, calcareous dolomite. Calcite in thin seams. Has a brownish cast in places.
10		Shelly, light buff and grayish brown, shaly dolomite. Earthy and finely crystalline texture. Calcite in small druses. In thin beds for most part but in places massive.
4		Medium grained, crystalline, light brownish gray dolomite. Some cavities.
1		Same as last, only more porous. The areas around pores have a reddish brown color.
1		Hard, dense, pinkish to reddish brown conglomeratic dolomite.
	6	Light gray shale weathering to a buff. Platy. Fucoidal markings.
3	6	Soft slate colored shale. Finely plated structure. Very slightly calcareous in places.
	7	Hard, finely crystalline, dense, light brownish gray dolomite. Weathers to a yellowish brown. Slightly calcareous along joints.
	4	Soft, light olive green shale. Fine platy structure.
1	3	Medium grained, crystalline, light pinkish brown dolomite with wavy surface upon which shale was laid.

Figure No. 5.

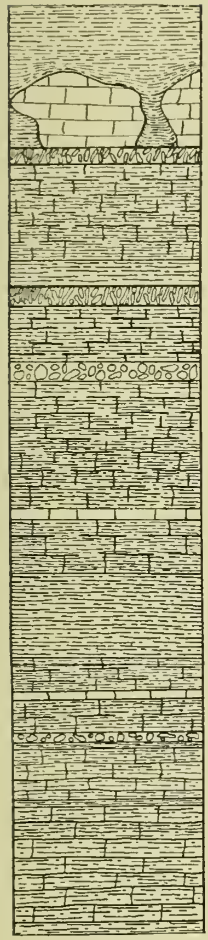


9		Soft, pale whitish gray, very calcareous shale. Fine platy structure.
1		Mottled, brownish gray, finely and coarsely crystalline, fossiliferous limestone resembling "Central boulders." Shows dense fine smooth areas in a coarsely crystalline matrix. Has an öolitic appearance in places on weathered surface. Contains some chlorite granules.
3	6	Mottled grayish brown crystalline dolomite. Some pyrite ltaering to limonite. Hard and uniform, medium grained texture.
	3	Soft, whitish gray, calcareous shale, having a faint greenish tinge.
	10	Coarsely crystalline, very porous, calcareous dolomite. Calcite occurs chiefly in small cavities which have a limonite yellow coating. A pinkish brown color.
	6	Soft, slightly calcareous, gray shale having a greenish cast. Somewhat platy.
2		Coarsely crystalline, porous, pinkish brown, calcareous dolomite.
	6	Soft, gray, calcareous shale. Platy.
1		Hard, gray, fossiliferous, öolitic, crystalline limestone. Oolites embedded in a crystalline matrix.
5	9	Bluish gray, calcareous shale, soft near top but harder near base. Shows glistening calcite grains. Fucoidal markings on bedding. Becomes a gray limestone in streaks.



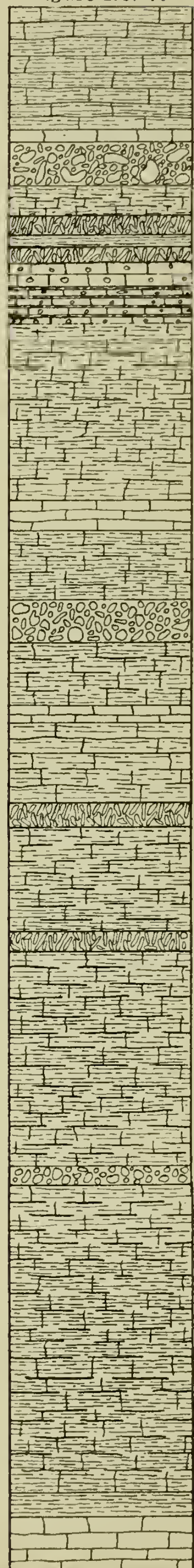
Varieties of conglomerates from the Davis formation.

Figure No. 6.

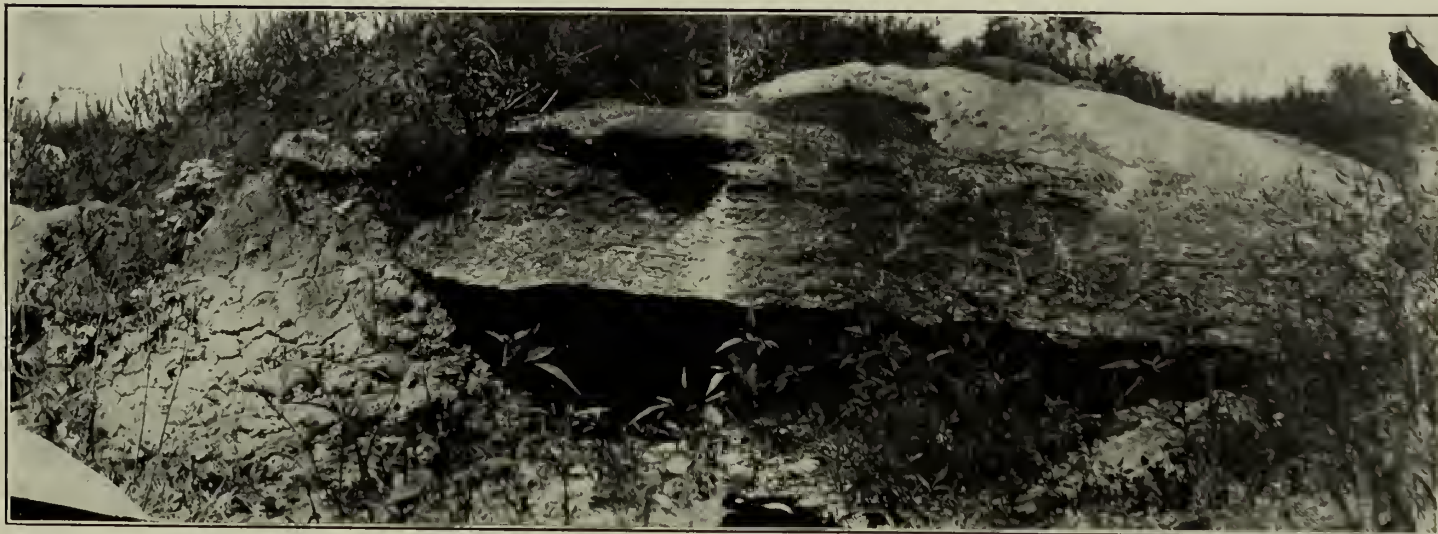


Ft.	In.	
4	6	Soft, blue, calcareous shale. Fine platy structure. Contains white marble boulders known as "Central" marble boulder member. The marble boulders are almost white on weathered surface where texture is fine and dense. Where coarsely crystalline, they are brown when weathered. The two phases occur together. The dense phase has a clear, mottled appearance having a very faint greenish cast with brownish streaks.
	4	Edgewise, limestone conglomerate at base of Marble boulder bed. Dark slate gray, crystalline limestone matrix with smooth, flat, fine grained limestone pebbles. Some chlorite.
3		Dull, slate gray shale with 30-40 thin layers of limestone. Limestone is fine grained and sub-crystalline. Fucoids along bedding planes.
	8	Calcareous, light olive green shale. Few thin plates of limestone. A lingulella shell in the specimen collected.
	10	Hard, dark gray, limestone, edgewise conglomerate. Fine crystalline limestone pebbles in a coarsely crystalline yellowish brown matrix. Exhibits flat plates of fine grained, crystalline, slate gray limestone in a coarsely crystalline yellowish brown matrix. Some large calcite crystals. Fossiliferous.
	8	Arenaceous, calcareous shale. Grayish with a yellowish cast. Wavy bedding with rough platy structure. 12 to 15 thin laminae of limestone.
	8	Streaked slate gray and yellowish colored conglomerate id two 4″ layers. Part limestone, part dolomite ann mixed.
4		Yellowish gray shale with thin plates of limestone. Shale is arenaceous and calcareous. Resembles second horizon above.
	3	Yellowish brown to yellowish gray, finely crystalline limestone. Shows quite distinct stratification planes. Brown color due to distinct spots of iron oxide as seen under lens.
1	10	Pale greenish gray, calcareous shale with thin laminae of limestone. Platy structure. Glistening surface. Fine grained.
2	6	Arenaceous, calcareous, light greenish gray shale. Glistening surface of plates.
1		Calcareous, light yellowish gray shale with thin laminae of gray, limestone weathering to yellowish brown.
	3	Gray, sub-crystalline limestone weathering to brown. Brown due to small spots of iron oxide as seen by lens.
1		Platy, light greenish gray shale separating into thin laminae of finely crystalline limestone. Fucoidal markings abundant.
	3	Limestone conglomerate. Rather dense, fine grained fragments of limestone in a coarsely crystalline limestone matrix. Color is dark gray with irregular yellowish brown spots. Some chlorite. Calcite filling small cavities. Fossils abundant.
	2	Soft, light greenish gray shale. Very thin plates. Very slightly calcareous.
1	8	Hard, dark to yellowish gray limestone in 3″—4″ beds, separated by shale partings. Finely crystalline and magnesian in places.
	2	Very thin, platy shale separating very thin leaves of argillaceous limestone. Fucoidal markings abundant.
3	7	Faint lavender tinted gray, finely crystalline limestone. In thin very irregular laminae separated by shale leaves. In 4″ to 5″ beds. An occasional porphyritic like calcite crystal.
	3	Very thin, platy, arenaceous shale. Dull greenish gray color.

Figure No. 7.

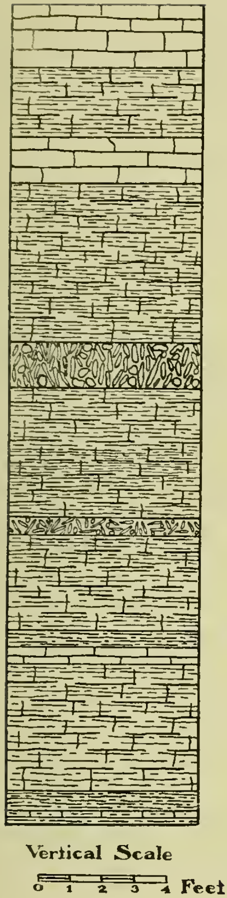


Ft.	In.	
4		Light lavender tinted gray to yellowish brown, finely crystalline, calcareous dolomite. Argillaceous, soft and shelly in places.
	5	Fossiliferous, coarsely crystalline, gray limestone. Contains an occasional small fragment. Chlorite in places.
1	6	Light slate gray, conglomeratic limestone. Medium grained. Crystalline. Shale leaves between beds. Some chlorite.
1		Light bluish gray, shaly limestone. Finely crystalline. 1″ to 3″ beds separated by shale.
	7	Typical "edgewise" conglomerate. Thin flat lenses or plates of finely crystalline limestone standing on edge and at angles inclined to bedding in a more coarsely crystalline matrix. Coarser matrix weathers first to a yellowish brown leaving the edges of the plates protruding. Some chlorite. Lenses from $\frac{1}{8}$″ to $\frac{1}{2}$″ in thickness and several inches in diameter.
	4	Soft, fine, greenish shale. Thin plates.
	6	Edgewise limestone conglomerate, similar to bed described above.
	10	Fossiliferous, gray, coarsely crystalline, conglomeratic limestone in two 5″ beds.
1	2	Gray, fossiliferous, coarsely crystalline, conglomeratic limestone in four 2″ beds with yellowish to bluish gray shale layers between.
6		Thin, irregularly bedded, gray, finely crystalline limestone interlaminated with shale. Weathers to a yellowish brown. Fucoidal markings.
	11	Hard, dark slate gray, medium grained, crystalline limestone in 5″ to 6″ beds.
2	3	Gray, fine grained, sugary textured limestone. Thinly laminated. In 2″ to 3″ beds with shale between. Fucoidal markings.
1	5	Hard, dark slate gray, conglomeratic limestone. Medium grained and crystalline. In two 3″ and one 9″ beds.
2		Light greenish colored shale with 30-40 thin leaves of hard, dense, finely crystalline limestone.
	6	Hard, coarsely crystalline, mottled grayish brown limestone, with calcite crystals along seams.
1		Hard, dense, finely crystalline, pinkish tinted limestone, weathering to a yellowish or buff color. Four 3″ layers separated with laminae of soft shale.
1	8	Lavender tinted limestone in 1″ to 3″ layers with greenish colored shale between. Very finely crystalline texture.
	10	Medium grained, crystalline, dark slate gray, limestone, edgewise conglomerate in 7″ and 3″ beds with shale between. Matrix weathers brown.
3	4	Shale and dense, fine grained, slaty, dark gray limestone.
	8	Edgewise conglomerate. Lenses or plates of finely crystalline, dark gray limestone in a coarser limestone matrix which weathers to a yellow while lenses remain fresh.
7		Hard, finely crystalline, dark gray, thin, irregularly bedded limestone in soft shale.
	4	Conglomeratic limestone. Hard, dense, finely crystalline, gray limestone in a coarser matrix, which weathers to a yellow while fragments remain fresh.
	7	Coarsely crystalline, brownish gray, conglomeratic limestone.
10		Shelly limestone or dolomite and shale. Not well exposed.
	10	Light olive green shale. Fine platy structure.
1	9	Hard, pinkish brown, medium grained, crystalline dolomite in three beds.
	3	Light greenish colored, arenaceous shale. Platy structure well developed.



Conglomerate such as frequently occurs at the base of the Marble Boulders in the Davis shale.

Figure No. 8.



Ft.	In.	
2		Yellowish brown, porous, medium grained, crystalline, calcareous dolomite in beds 3″-9″ thick.
2	2	Thin, irregularly bedded, shelly, fine grained, calcareous dolomite with shale leaves between.
1		Porous, mottled dark and light brown, fine and medium grained, crystalline, dolomite, in two 6″ beds.
	3	Hard, porous, medium grained, crystalline, light brown dolomite, similar to last.
5		Thin, platy, yellowish brown, finely crystalline, dolomite with shale leaves between.
1	6	Medium grained, light brownish gray, conglomeritic dolomite. Edgewise in places. Contains calcite druses. Conglomerate phase not represented in collection.
4		Yellowish gray, finely crystalline dolomite in thin irregular beds with shale between. Calcite along some joints.
	9	Slate gray, medium grained, crystalline, conglomeritic limestone. Edgewise in places. Contains many calcite druses. Calcite smeared along seams. Matrix weathers brown.
3		Thin, irregularly bedded, calcareous dolomite, with shale between. Has a yellowish brown color. Medium grained and crystalline.
	6	Soft, greenish gray, calcareous shale with thin laminae of argillaceous limestone.
	6	Medium grained, crystalline, dark gray, slightly calcareous dolomite. Hard, dense and a few cavities.
4		Shale with many thin plates of argillaceous, slightly calcareous dolomite. A yellowish gray color.
	8	Soft, platy, blue shale.
	2	Coarse grained, soft, chloritic, greenish brown dolomite.
	3	Greenish brown, chloritic, arenaceous shale.

It is very interesting to find such a large number of limestone beds in this formation, while the overlying and underlying formations are essentially dolomites. My attention was called to this by the following analyses which I had made of the marble boulders:

	1	2
Silica (SiO_2)	2.43	5.31
Alumina (Al_2O_3)	0.80	0.69
Iron Oxide (Fe_2O_3)	......	......
Calcium Carbonate ($CaCO_3$)	94.00	93.00
Magnesium Carbonate ($MgCO_3$)	2.94	0.23
Moisture	0.10	0.05
Total	100.27	99.28

In contrast to the above an analysis of the underlying Bonneterre dolomite gave the following constituents:

SiO_2	3.36
Al_2O_3	1.76
Fe_2O_3	.....
$CaCO_3$	55.41
$MgCO_3$	39.54
Moisture	......
Total	99.97

The question naturally arises as to the reason for the change in the composition of the sediments which were laid down in what is supposed to have been an uninterrupted succession. It is my opinion that the magnesium contained in the Bonneterre dolomite was introduced after the sediments were deposited, and that when first laid down they were probably as free from this constituent as the marble boulders. The texture of these sediments, however, were such as to permit a rather free circulation of the ground water, while the thin beds of limestone in the Davis formation were sealed by the layers of shale and thereby practically removed from the ground water circulation. The dolomitization of the Bonneterre limestone may have occurred either while it was beneath the sea or subsequent to its emergence. The evidence furnished by these formations tends to confirm the theory of the secondary origin of the dolomite so common in the Cambrian succession.

DERBY FORMATION.

Above the Davis formation occurs an horizon of about forty feet of dolomite which has been named the Derby formation from its occurrence in close proximity to the Derby mine (now Federal Mine No. 2).

This horizon is characterized by massive beds of hackly dolomite, which, upon weathering, break down into large polygonal blocks often 20 feet in their greatest diameter. Weathering proceeds rapidly along joint planes, of which there are two especially prominent systems, nearly at right angles to each other. In these joints the roots of trees find lodgement and through their growth the blocks are shoved apart.

This horizon has frequently been mistaken for the Bonneterre which it resembles somewhat in general appearance. The Bonneterre dolomite, however, usually weathers into more pinnacle-like forms and has a less cavernous surface. The Derby may also be quickly identified by its position with respect to the underlying Davis formation. It is more liable to be confused with a certain ledge of limestone a short distance below the top of the Davis formation. It may be distinguished from this by the absence of the soft shale which almost invariably occurs above the dolomite of the Davis formation.

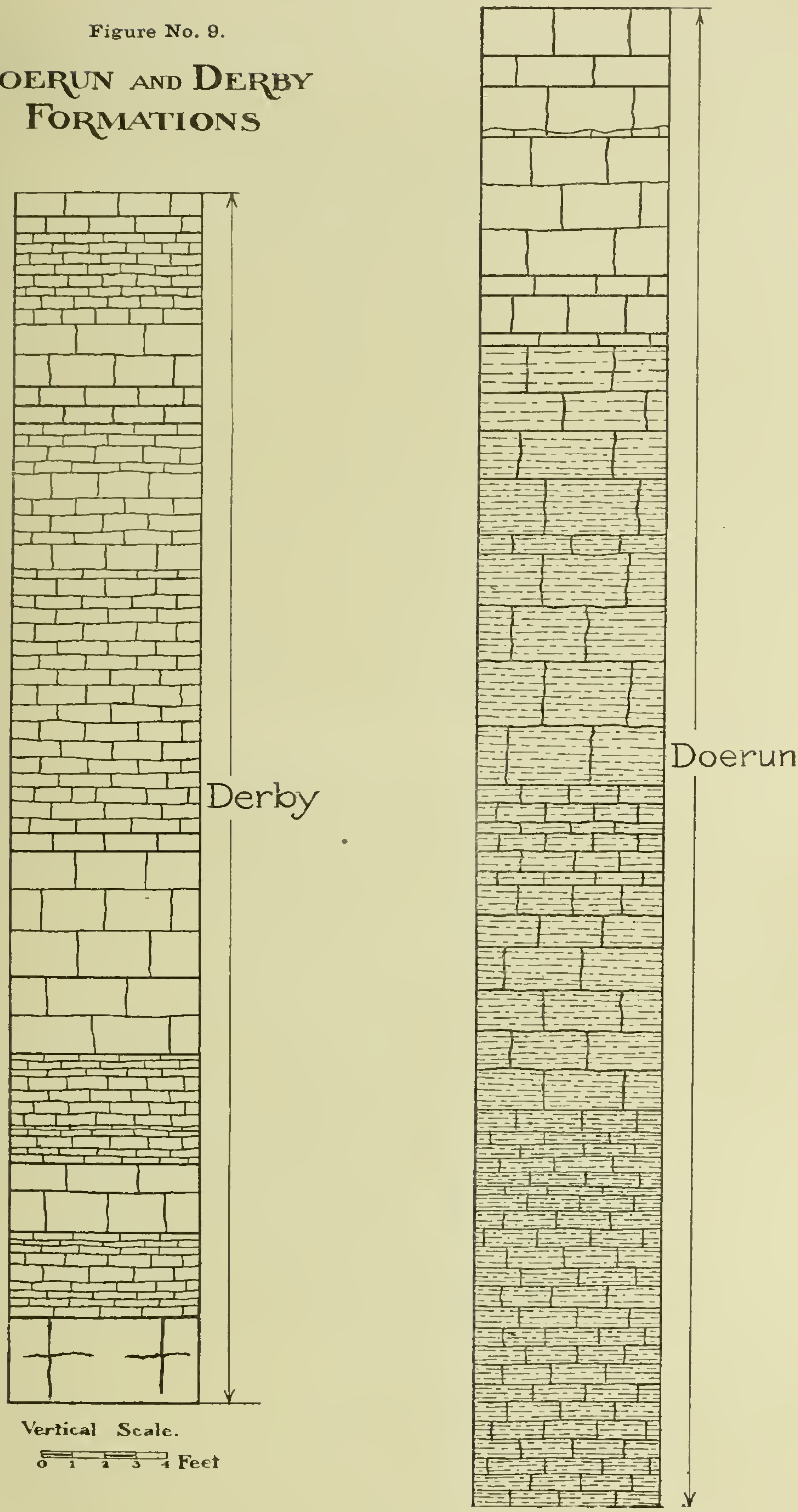
As a whole this formation is a fine grained, crystalline, slightly calcareous dolomite. Soft, porous beds alternate with those that are dense, hard and brittle. In color the dolomite varies from a light gray through yellowish gray to reddish brown. The pitted character of the weathered surface of some of the beds appears to

TYPICAL EXPOSURES OF THE DAVIS FORMATION.

The one on the left is along the M. R. and B. T. Ry. south of Elvins. It shows a small fault. The other is along the Lead Belt Ry., going to No. 9 shaft, Federal Lead Co.

Figure No. 9.

DOERUN AND DERBY FORMATIONS



be due to the solution of the more calcareous areas of the dolomite. At least the more calcareous portions are the partly leached cavities of the dolomite. Seven feet four inches from the top of the formation occurs a thirteen foot horizon which is very calcareous, sufficiently so as to almost pass for a limestone. Calcite occurs in the minute cavities and in the uppermost bed of nine inches it also occurs in seams.

This formation has an average thickness of from 38 to 40 feet and is conformable with the underlying Davis formation and also with the overlying Doerun. It lies between two relatively impervious horizons which it is thought accounts in part for its not being completely dolomitized. The area underlain by this formation is small, although it frequently constitutes the surface rock of small spurs and ridges which finger out from the main divides.

This formation has no economic importance, except that the stone has been used in places for building purposes.

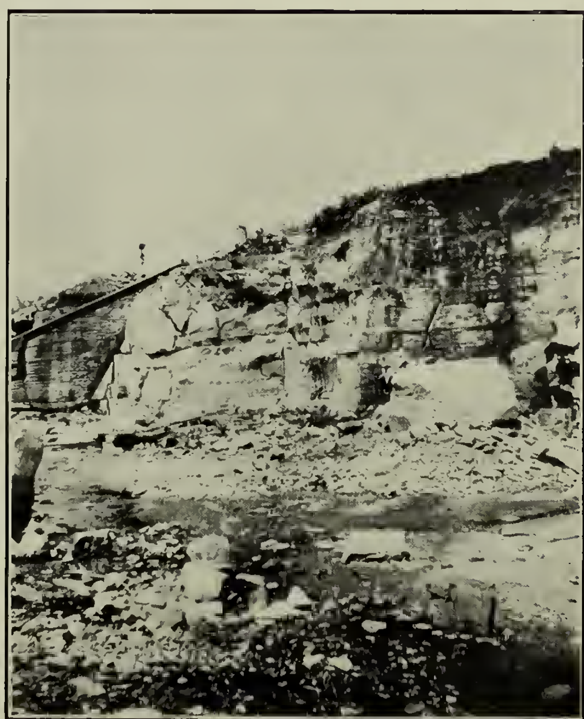
The following is a section of this formation from the type locality on Harris branch near the Derby mine (Federal Mine No. 2):

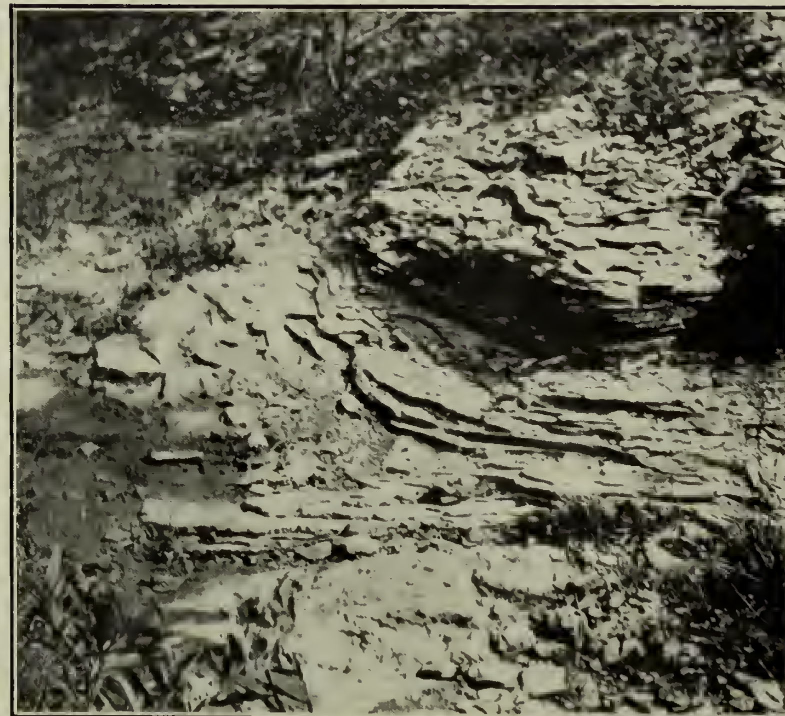
DERBY FORMATION FROM TOP TO BOTTOM.

Ft.	In.	
	9	Porous, medium grained, crystalline, yellowish gray to brownish dolomite containing much calcite in seams, pores and cavities.
	6	Dense, finely crystalline, buff dolomite, shelly in places.
2	10	Finely crystalline, dense, thinly bedded, buff colored dolomite.
2		Finely porous, soft, medium grained, crystalline, reddish brown, very calcareous dolomite.
	7	Single bed of mottled, greenish gray to buff colored, calcareous dolomite. Contains many calcite crystals. Weathers to nodular white surface.
	8	Dense, hard, finely crystalline, light brownish gray, calcareous dolomite.
13		Porous, soft, medium grained, crystalline, reddish brown, very calcareous dolomite. Almost if not quite a limestone.
	5	Dense, hard, finely crystalline, very light brownish gray dolomite containing some calcite in small cavities.
4		Porous, soft, finely crystalline, yellowish gray, slightly calcareous dolomite. Some small cavities.
2	6	Porous, soft, yellowish to buff colored, finely crystalline, calcareous dolomite. The pitted surface appears to be due to solution of the more calcareous areas in the dolomite. These are recognized in fresh specimens where pitting is not apparent.
3	5	Brittle, hard, brownish gray, finely crystalline, slightly calcareous dolomite. Irregular beds 1″-3″ in thickness.
2	3	Hard, finely crystalline, brownish gray dolomite in two beds. Weathers to light dull gray surface.
2	9	Brittle, hard, very finely crystalline, light brownish gray dolomite in beds 1″-3″ in thickness.
2	9	Single bed of very porous medium grained, light brownish gray, calcareous dolomite. The porous portions are the more calcareous.
Ft.	In.	

SEE FIG. 9.

Typical outcrops of Derby dolomite.





Doerun dolomite as it appears in a quarry and in a natural outcrop.

DOERUN FORMATION.

Resting conformably above the Derby formation is an horizon which consists chiefly of argillaceous dolomite. It appears to be a partial return to the oceanic conditions prevailing over this region during the time of the deposition of the sediments of the Davis formation. However, there is no limestone in this formation and the dolomite is not even calcareous. The formation consists of alternating beds of argillaceous dolomite, finely crystalline dense dolomite and soft finely porous dolomite. The name "Doerun" is from the Doe Run Lead Company, which owns the lands upon which the type section occurs.

The thickness of this formation is variable between quite wide limits, owing to an uneven or perhaps unconformable contact with the overlying Potosi formation. The repetition of very similar beds through faulting in certain areas may also have been instrumental in giving to this formation an apparently much greater thickness than it actually possesses. The normal thickness of the Doerun formation is about 50 to 60 feet, but in the west half of Sec. 13, T. 36 N., R. 4 E., it has an apparent thickness of 120 feet. This is an abnormal thickness, which is undoubtedly the result of a zone of faulting through which a repetition of the beds has been brought about. In other places a thickness of from 80 to 90 feet has been observed and in these places faulting may also have resulted in giving the formation a greater apparent thickness than it actually possesses.

The only method we have of separating this from the overlying Potosi formation is the texture of the rock and the presence or absence of the coarse drusy cavities lined with quartz crystals. The contact in this area usually lies well up on hillsides and is therefore seldom exposed, being covered with residual material. Its distribution is shown on the special Flat River-Leadwood and Bonne Terre sheets. On the general Bonne Terre sheet it has been mapped with the Derby as a single horizon.

The most typical and best exposed section of this formation occurs in the S. E. ¼ of S. E. ¼ of Sec. 12, T. 36 N., R. 4 E., and from this locality the accompanying columnar section has been constructed. The bottom of this formation is characterized by a thickness of 12 feet 8 inches of very thinly bedded, argillaceous, light buff colored dolomite. When exposed to the weather it splits into thin plates. About eight feet above this there is another horizon of argillaceous dolomite which, upon weathering, also splits into thin layers. This latter horizon is 12 feet 6 inches thick. These argillaceous dolomites have a bluish gray color when fresh and a light yellowish to buff color when weathered. Wherever this rock has been quarried, there are excellent illustrations of this variation in color as a result of weathering. The buff color is probably due to the oxidation of pyritiferous minerals. The alteration goes on adjacent to both the jointing and bedding planes, leaving a elipsoidal area in the center of the block which retains the original color, where the alteration is incomplete. The upper nine to ten feet of the second thinly bedded horizon contains many small, irregular cavities lined with minute crystals of quartz. (quartz druses). Above this horizon there occurs a buff colored, finely crystalline dolomite having much the appearance of a sandstone. Above these hard, finely crystalline dolomite beds alternate with beds of soft, finely porous dolomite which has a decided pinkish tint near the top.

These beds frequently exhibit cross-bedding, and in one place the upper surface of the bed, directly below the second shelly, argillaceous horizon, exhibits a reef like structure. This bed lies in a serious of rolls having an amplitude of about two feet and a distance from crest to crest of from six to ten feet. This structure was observed near the center of Sec. 25, T. 36 N., R. 4 E.

The upper part of this formation is especially characterized by small quartz druses, in which occasional calcite crystals occur. In several instances, crystals of zinc blende were noted.

At the place where the following section was taken the upper surface of the formation is undulatory and this Dr. Ulrich takes as evidence of an uncomformity. Undulatory surfaces are so common in the bedding of this series that I am not inclined to attach as great importance to them as Dr. Ulrich does to this. However, there is some evidence of uncomformity between this and the overlying Potosi formation in the variable thickness of the Doerun as pointed out above.

Above this horizon the dolomite contains many quartz druses, occupying joint and bedding planes and scattered through the body of the rock.

The thinly laminated dolomite beds are separated by thin leaves of shale and along these, fucoidal markings are abundant and varied. Some of the beds contain abundant remains of crinoids while others are rich in brachiopod fossils. There is scarcely a locality where these beds outcrop that fossils cannot be found. Dr. Charles D. Walcott very kindly identified several of the brachiopod shells as Finkelnburgia osceola, Walcott. of Upper Cambrian age.

The jointing and bedding are especially well developed in this formation. These structural features are nicely shown in the accompanying illustrations. (See Plate —.) A fuller discussion of the jointing will be found in the chapter on "Structures."

The following is a carefully constructed columnar section of this formation as it occurs along the Gumbo branch of the Mississippi River and Bonne Terre Railroad in the southwest quarter of Sec. 12, T. 36 N., R. 4 E.

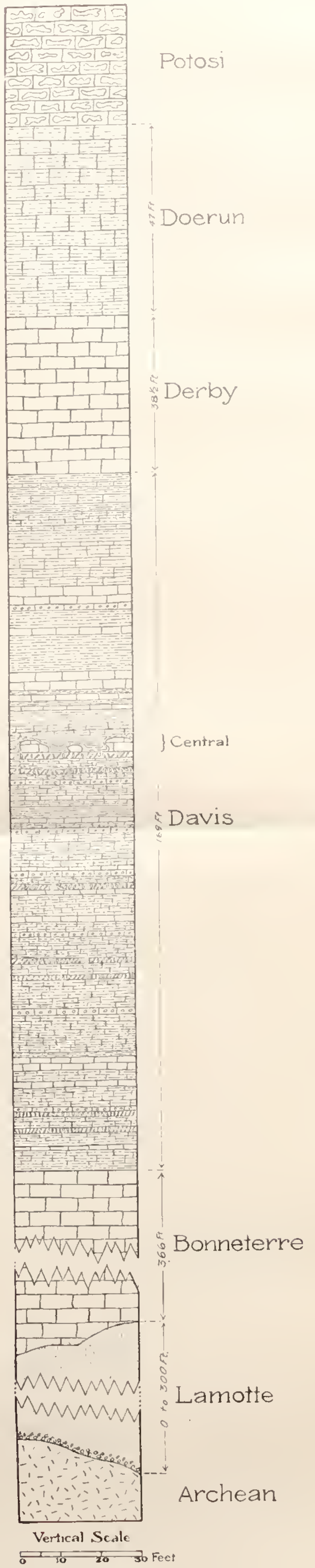
DOERUN FORMATION FROM TOP TO BOTTOM.

Ft.	In.	
1	6	Hard gray dolomite. Dense, finely crystalline. Fracture and jointing planes bearing crystalline calcite and quartz in druses.
1		Rather soft, finely porous dolomite, having a very light buff color, with pink tint in places.
1	4	Like above but more pronounced pink tint.
	2	Very fine grained, dense dolomite. Dendritic. Light gray to light buff color. Much broken and varying in thickness. Resembles chert in appearance.
4	5	Single massive bed of soft, finely porous, buff colored dolomite. Almost identically the same as the second bed above.
	8	Hard, very finely crystalline, somewhat porous, white dolomite, containing many small calcite crystals.
1	2	Hard, white dolomite almost free from calcite or quartz inclusions, and less porous.
	5	Hard, dense, finely crystalline, light gray dolomite. Almost same as the above but no inclusions.
2	8½	Finely crystalline, buff colored dolomite, where weathered. Very few inclusions. These rocks have very much the appearance of fine grained sandstone.
1	7	Same as above. Lighter colored, being less weathered.
9	9½	Bluish gray, finely crystalline, argillaceous dolomite. Weathers to a buff color along bedding planes. Contains many quartz druses. When fresh these beds appear massive. However, they split into rather thin beds upon exposure to the weather. Fucoidal markings abundant.
2	9½	Soft, argillaceous, very finely crystalline dolomite. Has an almost sub-crystalline texture. Occurs in beds from 4″-7″ thick. Dark bluish gray color, weathering to a buff along fracture and bedding planes.
	5	Rather hard, finely crystalline brown dolomite. Occasional small cavities.
1	11	Hard, bluish gray, finely crystalline dolomite. Lower 1′ contains many small quartz and some calcite druses. Weathers to a yellowish brown.
5		Massive bed of argillaceous dolomite. Shelly where exposed to weathering. Has a light buff color. Contains some small cavities with calcite in spots.
12	8	Very shelly, argillaceous, buff colored dolomite. Has an earth like texture. Weathers in thin wavy plates, Fucoidal markings abundant.

SEE FIG. 9.

Figure No. 10.

Generalized Section of Formations.



POTOSI FORMATION.

The name Potosi is taken from a city of that name in Washington county, and although originally applied to a greater thickness of strata, it has been restricted in its present application on account of the adaptation of the term in the mining district to the so-called cherty horizon overlying the above described Doerun formation.

The formation as thus restricted has a thickness of approximately three hundred feet and consists of very siliceous, cherty and drusy dolomite.

In the Bonne Terre area, which is the subject of this report, the upper part is not represented except in the northwestern and northeastern corners. The best and clearest development is to be found in Washington county west of this area, where it is overlain with more recent Cambrian formations. In the Bonne Terre area it is the youngest of the important rock formations, being overlain chiefly by Tertiary gravel, recent alluvium and residual deposits. In the northwestern and northeastern portions of the area it appears to be overlain with a practically non-cherty dolomite (the Proctor) above which occurs what is supposed to be remnants of the Gunter sandstone member of the Gasconade.

Although it appears to be conformable with the underlying Doerun formation, there are some reasons for believing that an unconformity may exist between the two. In no place has this formation been observed in contact with the Archean, although there are reasons for believing that the Potosi sea was more extensive than the preceding. If such were the case, there must have been overlap, as in the case of some of the preceding formations. Evidence of this, however, in the area under discussion has been removed, chiefly through erosion. The Potosi occurs in contact with the Archean along Simm's mountain, but its present position is clearly a result of faulting as shown on the geologic map.

The Tertiary, of course, overlies unconformally this as well as all the other formations in this part of the Ozark region.

The Potosi formation consists chiefly of massive beds of dolomite alternating with relatively thick beds of chert. Some of the beds of dolomite are free from chert but many of them contain extremely irregular masses of honeycombed chert or drusy quartz nodules. The honeycombed chert masses have the appearance of extremely irregular stems of chert coalescing at intervals and giving to the mass a roughly pipe like structure. In other instances the masses consist of roughly intermingled sheet-like forms crossing one another at various angles, imparting a very coarse honeycombed structure. The drusy forms differ from geodes in that the convex side, instead of the concave side is most frequently lined with chalcedony and crystalline quartz. The shapes of these quartz druses are almost infinite and the size of the crystals covering their surfaces range from those of almost microscopic dimensions to those one fourth of an inch in cross section. The chalcedony and crystallized quartz occur frequently in alternating layers. There may be a layer of chalcedony, a layer of crystallized quartz, a layer of chalcedony and another layer of quartz crystals. The first layer of quartz crystals may be one fourth of an inch in diameter. These may have deposited on their surface a layer of chalcedony, which obscures the crystal faces and angles of the quartz. On top of this chalcedony there may be a second layer of very minute quartz crystals. In the early history of mining in this district the drusy quartz was known variously as "radiated" quartz, "mineral blossom" and the frosted variety as "hoary" quartz.

The occurrence of the Potosi is everywhere marked by drusy quartz strewn over the surface. The drusy quartz fragments often extend down the hillside over the surfaces underlain by older formations and the streams frequently transport these hard resistant fragments far beyond the margin of the Potosi formation. These masses of chert and drusy quartz were the "mineral blossom" of the early miners. This was before the disseminated galena of the Bonneterre formation had been discovered, and it was only used in locating the shallow deposits of galena in the Potosi formation. The experience of the miners taught them that the absence of drusy quartz, which meant the absence of the Potosi formation, was evidence that the underlying formation was barren.

That portion of the Potosi formation lying close to the surface is usually intercepted by numerous openings, usually along joints, which are completely or partly filled with a stiff red clay, commonly known as "tallow clay" or "gumbo." The decomposition and disintegration of the Potosi has resulted in the formation of a very characteristic deep red or reddish brown clay in which are embedded the drusy and honeycombed masses of chert. The presence of the Potosi underlying any portion of this district may usually be detected by the occurrence of this residual clay.

The Potosi is the surface formation underlying approximately one-half of the entire area included within the scope of this report, occupying in the main the northwest quarter of the Bonneterre sheet. It was, in the early days prior to the discovery of the disseminated lead deposits, the chief source of galena in this district and from it considerable zinc ore was at one time mined. At the present time it is the principal source of barite in the United States. The mines in this formation are still producing some lead and zinc ore but the quantity is insignificant compared with the production from the Bonneterre formation.

The exploration of this formation with a diamond drill is difficult and consequently costly, on account of the cherty and cavernous character of the formation. For this reason drill prospectors have as a rule avoided areas underlain by this formation.

In the area under discussion occasional holes have been drilled through the lower part of the Potosi but in no case have I been able to secure a record showing the character of the Potosi throughout its entire thickness. The entire thickness of the Potosi occurs between Big river and the tunnel on the Mississippi River and Bonne Terre railroad at Summit, but the exposures are obscure at many places and an accurate, detailed section is scarcely possible. A shaft, a little northwest of the tunnel, which started in the Proctor formation above the Potosi, was sunk 200 feet and at the bottom of this shaft a hole was drilled an additional 200 feet. It is reported that at that depth, 400 feet, the drill was still in the Potosi formation. The core from this hole had been emptied out of the trays before I had an opportunity to examine it.

Another hole, about a mile west of Mineral Point, started in the Potosi formation at an elevation of about 910 feet A. T., and went through 165 feet of the Potosi formation. The hole was sunk to a depth of 603 feet and cored the entire distance. The following is a copy of the log as furnished by the Point Mining and Milling Company. The hole was abandoned September 12, 1903. (The word "limestone" is used for both limestone and dolomite, chiefly dolomite in this section.)

Ft. From surface	Ft. To	Description.
		POTOSI.
0	8	Sleeve pipe.
8	18	Limestone with gravel openings and traces of quartz, druses.
18	38	Limestone with sand openings and quartz druses.
38	50	Limestone.
50	66	Limestone with quartz druses.
66	67	Limestone.
67	69	Flint and quartz druses.
69	78	Limestone.
78	88	Limestone.
88	100	Gray limestone with numerous quartz druses and an opening of 1′ at 96′.
100	102	Quartz druses.
102	106	Gray limestone.
106	120	Limestone.
120	149	Limestone and quartz.
149	165	Pink limestone and quartz druses.
		DERBY AND DOERUN.
165	178	Soft yellow limestone.
178	200	Soft yellow limestone.
200	210	Shaly limestone.
210	225	Limestone and shale.
225	230	Yellow limestone.
230	238	Limestone and shale.
238	253	Limestone with shale.
253	280	Limestone with shale seams.
		DAVIS.
280	312	Limestone with shale seams. Spots of calcite.
312	337	Alternate seams of dolomite and shale.
337	340	Shale.
340	350	Limestone.
350	355	Shale.
355	365	Shale.
365	370	Shale speckled with limestone.
370	375	Shale.
375	392	Shale.
392	404	Shale.
404	416	Shale.
416	420	Speckled limestone and shale.
420	433	Limestone and shale.
433	438	Limestone and shale.
438	445	Limestone and shale.
445	455	Limestone and shale.
455	460	Limestone and shale.
460	465	Limestone and shale.
465	467	Shale.
467	469	Shale, soft and smooth.
469	470	Shale.
470	472	Shale.
472	474	Shale.
474	477	Shale.
		BONNETERRE.
477	480	White limestone.
480	485	Limestone.
485	487	Limestone.
487	492	Limestone.
492	501	Limestone.
501	512	Limestone, loose sand and soft red clay.
512	524	Limestone.
524	534	Limestone.
534	554	Limestone.
554	571	White Limestone.
571	575	Yellow limestone.
575	592	Sandstone.
592	603	Limestone.

During 1906 and 1907 a number of holes were drilled near Palmer, Washington county, on property owned by the Renault Lead Company, through the Potosi and succeeding formations down to the Lamotte sandstone. One of these holes was cored with a diamond drill from top to bottom, the others were begun with a churn drill and completed with a diamond drill. The hole which was cored began in the Potosi at an elevation of about 920 feet A. T., going through about 275 feet of this formation and continuing to a depth of 842 feet. The forty eight feet directly below the Potosi is somewhat drusy but resembles more nearly what has been called the Doerun formation in our section of formations for the Bonne Terre quadrangle. It is interesting to note that in only one of nine holes drilled to the sand was a flowing well developed.

The following is a detailed description of the core obtained from the 842 foot hole above referred to. It illustrates very nicely the character of the Potosi formation and for that reason it is inserted at this place:

Ft. From	Ft. To	Elevation of Sleeve about 922 A. T.
0	100	Light gray to light yellowish gray coarsely to finely crystalline dolomite. Quartz druses throughout at irregular intervals. Small, not over 1" in diameter.
		At 90', and at another horizon not marked, porous chert was observed, finely vesicular. There are some good examples of chert ramifying through the dolomite.
100	179	Medium to finely crystalline dolomite with quartz druses at intervals. Very much like last core. At 121' some solid chert. Dark gray to yellowish gray color.
179	238	Dark gray dolomite. Finely crystalline. Numerous quartz druses. More abundant than in any of the above. Quartz druses along fracture planes. Irregular druses larger than in preceeding. At 226, 234-337 feet the stone is very light buff to white color and less crystalline than the remainder. Small cavities from 220 to 238.
238	286	Light to medium gray dolomite, fine and medium grained, crystalline 262-265. Light colored, fine, somewhat earthy textured dolomite. Drusy. Looks somewhat like cotton rock.
		At 242' one inch of solid pyrite altering to limonite. Stylolites show in places. Druses throughout. Most abundant at 270-274' and 239'-241'. 274' is considered the base of the POTOSI.
		From 276' to 283' the rock has a yellowish (faint) to whitish color. Greenish copper like stains along bed at one place.
		284' -286'. Hard, dense, medium grained, crystalline dolomite. Druses small. Stained yellowish brown.
286	323	From 286' to 294' the rock is a rather hard, gray dolomite with cavities but not much quartz. Hard dense crystalline most of way. Yellówish lining to cavities. 295'-300', rather porous, yellowish dolomite. Coarser crystalline. Some admixture of greenish clay at 289-300.

Ft. From	Ft. To	
		301'-323' is rather fine to medium grained crystalline dolomite. Numerous cavities. Some well defined druses. Light gray to yellowish tinted colors.
323	350	From 323 to 331 feet the rock is soft yellowish dolomite, somewhat porous. From 332'-333' is very porous, soft dolomite. Cavities not lined with crystals. 332' 350' is finely porous, soft, crystalline dolomite, light yellowish to pinkish tint. Looks something like the DOERUN.
350	360	From 350'-354' the rock is a continuation of the above porous dolomite. 355'-360' is shaly horizon. Greenish shale layers grading into and alternating with finely crystalline dolomite. Some irregular wavy laminae of shale. Some small cavities. Several with quartz crystal lining.
360	390	From 360'-374' the rock is dolomite with irregular shale partings and laminae. Core much broken. Porous in places. Some small cavities. The DAVIS formation probably begins at 375'.375'-390', shaly (green) horizon. Alternating plates of shale and dolomite increasingly shaly toward base. Somewhat arenaceous. Small cavities in some thin beds. Some pyrite.
390	422	Platy green shale and dolomite in thin laminae to 409'. At 410' 6" of shale.
		At 420',18" of shale.
		Shale a deep green color. Pyrite at 401' and at other places. Some layers arenaceous.
422	455	422'426'. Nearly solid shale. Some dolomite streaks at top and bottom. At 435'-436', 8" shale. All remaining is alternating bands of green shale and dolomite. The dolomite bands are very arenaceons. 446'-455' is chiefly arenaceous dolomite with interlaminated leaves of shale. Dolomite is chiefly quartzs and.
455	488	Laminae of dolomite and shale breaking into small rings. Arenaceous in places. Porous where shale is absent. Shale shows wavy structure. An occasional cavity in sandy dolomite.
488	518	Same as preceding. Arenaceous dolomite beds somewhat thicker in places.
518	550	518'528'. Same as above.
		529'-539'. Speckled and striped greenish gray dolomite and argillaceous sandstone to 534'. No shale bands from 534'-539'. Some irregular shale bands above.
		540'-542'. Banded sandy dolomite and shale.
		542'-547'. Chiefly shale very fine platy and gray "slate" colored.
		547'-548'. Platy shale and dolomite (hard). Grades below into platy shales.
		548'-550'. Finely platy shale, gray with a green tinge. 3½" core of speckled chloritic dolomite in this horizon. Looks as if core may have been misplaced. No mention of this in original record. Some pyrite.
550	551	Chloritic speckled dolomite 4" of platy shale underneath.
551	554	Alternate layers of platy shale and coarsely crystalline, speckled, chloritic dolomite. This is considered the base of the DAVIS shale.
554	627	Light gray dolomite containing irregular cavities and small pores lined with crystals of calcite and dolomite. At 600' and 623' the dolomite is very porous for about a foot.
		Between 613' and 614' some soft, green, mud-like shale, (may be out of place.)
		A little chlorite at 592'.

Ft. From	Ft. To	
627	675	At 627′ there is some green shale represented by mud in core. From this mud to 629′ there is a very much confused, coarsely crystalline dolomite with green shale irregularly distributed through it, in pockets and seams No regularity. 630′-675′ (inclusive) very finely porous, light gray dolomite. Some large cavities and in places almost honeycombed. Dolomite crystals are small but abundant in openings. From 670′-675′, streaks of greenish wavy partings and hard dense dolomite layers. Also small cavities.
675	723	Porous, honeycombed and cavernous horizon down to 720′. From 720′-723′ much harder and very few cavities. From 688′-690′ the rock has a dark gray color and is very porous.
		Shale between 707′and 708′, thickness not known. From 716′-718′ the rock is argillaceous, almost shaly, with irregular streaks of dolomite along fracture planes. The rock varies in texture but is fine to medium grained and crystalline.
523	533	Stylolites show in places throughout the Bonneterre horizon.
		723′-724′. Medium grained crystalline dolomite with some shale along bedding. Pyrite. Some cavities. 724′-733. Dark gray dolomite, very porous in places. Hard and fine grained at other places. Has a brownish color as the weathered in places.
733	787	Dark gray, crystalline dolomite. Finely porous. At 786′ dolomite contains larger cavities. Some irregular shale partings. Medium grained. Stylolites.
787	810	At 787′ some irregular cavities. Remainder dark to light gray dolomite. Medium grained and crystalline. One speck of lead along a thin shale parting at 803′.
810	842	From 811′-812′, gray, rather dense dolomite with some small cavities and thin dark shale partings.
		From 813′-831′ dark gray dolomite with small irregular cavities and porous. Base of Bonneterre formation. No chloritic rock at base as mentioned.
		832′-842′. White sand. Top of the LAMOTTE formation.

There is some difficulty in defining the upper limit of the Potosi in those parts of the area where the overlying Proctor is supposed to occur. The line of separation is arbitrary and based entirely upon physical grounds, there being no paleontological evidence at hand. The absence of drusy quartz is the criteria which has been chiefly used. The Potosi is distinctly a drusy quartz bearing formation and as such it will probably always be known. Therefore, upon this basis I have felt justified in defining its upper and lower limitations.

CAMBRIAN FORMATIONS YOUNGER THAN THE POTOSI.

In the very much restricted area covered by this report there are no well defined Cambrian formations overlying the Potosi. In a number of localities blocks of sandstone, chert and conglomerate (chert fragments in a sandstone matrix) have been observed lying on the surface and often mingled with boulders of drusy quartz from the Potosi formation. From their texture and position we are led to believe that these are the remains of younger formations of the Cambrian which at one time extended over this area. The fragments of sandstone and massive boulders of chert resemble those that have been observed in the Gasconade and Roubidoux formations in the Ozark region beyond the confines of this area.

It is thought that some of the higher hills and ridges in the northeastern and northwestern parts of the area are underlain with the Proctor formation, but of this there is some uncertainty. The practically non-cherty beds at the tunnel, Summit station, on the Mississippi River and Bonne Terre railroad are thought to belong to this formation. Likewise some of the highest beds of dolomite west of Mineral Point and northwest of Hopewell have the appearance of belonging to the Proctor. Farther to the west and northwest, above these beds, a sandstone appears, which undoubtedly is the basal member of the Gasconade, elsewhere known as the Gunter.

It is not the purpose of this report to enter into a detailed description of the complete succession of formations occurring in the Ozark region or Southeastern Missouri, but for the purpose of a better appreciation of the age of the formations of the Bonneterre area it has been thought advisable to include the following brief descriptions, which are mainly the results of our own observations extending over a period of five years.

EMINENCE FORMATION.

In the southeastern part of the state Dr. E. O. Ulrich has recognized above the Potosi formation a cherty member which he has named the Eminence formation. The writer is unfamiliar with this formation. It does not occur in the southern, western and eastern parts of the Ozark region which have been the special fields of study of the writer.

PROCTOR FORMATION.

The horizon directly overlying the Potosi is thought to be the Proctor, a formation which was first named in Morgan county where these beds are exposed along a creek of that name. This formation has an estimated thickness of about sixty feet and may correspond to the slightly cherty dolomite beds capping the ridge just south of Valles Mines on the Mississippi River and Bonne Terre railroad, as mentioned above.

In the central Ozark region this formation consists of beds of dolomite usually from 2½ to 3 feet thick, but in places ten feet in thickness. The color of the weathered surface is a bluish gray, with occasionally a pinkish, yellowish or greenish tint. It exhibits a rough cavernous surface and has a medium to coarse grained crystalline to granular texture. This dolomite is slightly calcareous. The rock is porous and contains numerous small cavities, some of which are lined with dolomite and white to rose colored calcite crystals. Some of the cavities are also lined with quartz crystals. There are occasional chert nodules distributed indiscriminately through the formation.

GASCONADE FORMATION.

This formation has a wide distribution over the northern and northeastern flanks of the Ozark region, being prominently exposed along the larger streams, including the Meramec, Gasconade and Osage rivers and their tributaries. This formation, including the Gunter sandstone at the base, has a thickness of approximately two hundred and sixty-eight feet in Miller county.

In Miller and Morgan counties, where this formation has been studied in detail, there appears to be a well marked unconformity separating it from the underlying Proctor. Whether or not this unconformity is persistent over the Ozark region is not known. In some places the basal sandstone member appears to be absent with little or no evidence of an unconformity. The weathered surface of the Gasconade dolomite has a uniform whitish or grayish color, except in the upper part where the color is a deep reddish brown. The formation as a whole is composed of beds of cherty and non-cherty dolomite, chert and sandstone. The dolomite is medium to coarse grained, sometimes öolitic. The beds are compact and moderately hard. In several places intraformational limestone conglomerates have been observed.

The chert occurs disseminated through the dolomite, along bedding planes or in beds. It is usually very fine grained, dense and hard, sometimes öolitic. In color it varies from light gray to almost black. The disseminated chert and that which occurs along bedding planes is usually in irregular nodules or concretionary lenses. Small cavities lined with quartz crystals are common. A bed of white, brecciated chert, two to three feet in thickness, occurs in several places about 20 feet above the basal sandstone member. Other beds occur near the top of the formation. The disseminated chert usually occurs in small irregular pieces. The chert beds vary in thickness from place to place and evidently are not persistent over extensive areas.

Thin beds of sandstone occur at several horizons above the basal or Gunter sandstone member. These sandstone beds do not exceed four feet in thickness and do not persist over any considerable area. When followed in any direction they thin out and disappear. The Gunter sandstone is more persistent and in fact it is the best defined sandstone member of this formation in the central Ozark region.

The horizons at which occur lens-like masses or pockets of chert have associated with them galena, blende and barite. Attempts have been made to mine these at many places. Hundreds of prospect holes occur in this formation, and from some of them galena, blende and barite have been obtained in commercial quantities.

ROUBIDOUX FORMATION.

This formation was named the St. Elizabeth in the report on the Geology of Miller county. However, after a conference with the United States Geological Survey committee on nomenclature, it was agreed to substitute the name Roubidoux.

The relation of this formation to the underlying Gasconade is not altogether clear, there being apparent perfect conformity in some places and evident unconformity in other places. An abrupt change in sedimentation is noticeable in most places but the beds are conformable as a rule. This formation grades upward through alternating sandstone, conglomeritic sandstone, shale and argillaceous dolomite into the overlying Jefferson City formation.

The Roubidoux formation is one of the most widely exposed of the Cambrian formations in the Ozark region. It has a thickness of from 70 to 160 feet and occupies the surface of many of the ridges and flat-topped divides throughout the Ozarks.

This formation is a complex consisting of alternating beds of sandstone, chert, quartzite, dolomite and shale, all of variable thickness and areal extent. There is great diversity in the thickness, lithological characteristics and manner of occurrence of the beds of this formation. In some parts of the Ozark region the beds or lenses of sandstone are sufficiently persistent to warrant mapping them as distinct members. This has been done in our reports on Miller and Morgan counties in which the Bolin sandstone, having a maximum thickness of fifty feet, has been mapped as a separate member. In other areas the sandstone beds are not sufficiently persistent to be thus differentiated.

The Roubidoux formation consists of sediments that were laid down in a sea which, although shallow, was constantly fluctuating in depth, as shown by the rather sudden changes from sandstone to shale and from shale to limestone and vice versa. Additional evidence of such a condition is found in the thinness of the beds and the abundance of ripple marks, sun cracks and cross bedding.

Since the sediments were deposited, there have been extensive changes in the formation through solution and deposition by groundwater, as shown by the alteration of dolomitic or calcareous sandstone to chert, the re-crystallization of the dolomite and the transformation of the sandstone in places into quartzite.

JEFFERSON CITY FORMATION.

This formation was named by Winslow from the typical exposures at Jefferson City, Missouri. The areal distribution of this formation is not as great as that of the Roubidoux. However, it occurs pretty generally along the higher ridges of that portion of the Ozark plateau which is directly underlain with formations of Cambrian age. In the area immediately contiguous to the St. Francois mountains this formation, as well as the underlying Roubidoux and Gasconade, has been removed so completely that no trace of it remains in any part of the area included in this report.

The thickness of this formation is variable but probably averages about 150 feet. Some sections measured in the north central part of the Ozark region were 200 feet in thickness, others were less than 100 feet.

In general this formation consists of alternating horizons of very hackly, pitted dolomite and fine grained argillaceous, arenaceous dolomite with intercalated, usually thin, beds of chert and sandstone. Argillaceous dolomite, commonly known as "cotton" rock, usually occurs at the base of the formation. Here it ranges up to 30 feet in thickness but dies out completely in some places. Cotton rock also occurs at the top of the formation and has been observed at two intermediate horizons. Everywhere it has essentially the same characteristics, being a relatively soft, fine grained, dense, earthy textured, argillaceous, siliceous dolomite.

The beds of hackly, pitted dolomite are the most persistent horizons and vary from place to place, chiefly in the amount of chert which they contain. The fresh surface of this dolomite has a mottled or streaked appearance caused by a powdery, siliceous material contained in the cavities and along the bedding planes.

The sandstone beds vary from an inch to five feet in thickness and occur at various horizons. They are seldom persistent over any considerable area and appear chiefly as lenses. The beds are in places öolitic, cherty and ofttimes calcareous. They have a brownish to yellowish color and are medium to coarse grained.

The chert occurs in the form of beds and as nodules, the latter being confined to the cotton rock horizon. The color is black, bluish white and white, and the texture is frequently öolitic. Irregular fragments of chert are of frequent occurrence in the pitted dolomite. The bedded chert is usually thin, being thickest where intercalated with sandstone. The most characteristic chert is the "Cryptozoan minnesotensis" which occurs in large irregularly oval or spherical masses.

This horizon is most easily recognized by the characteristic thick beds of pitted dolomite. Lead and zinc ores and barite occur in crevices and cavities in many parts of the formation. Except at one locality, Fortuna, the production has been small and the results of the prospecting have been unsatisfactory.

ORDOVICIAN.

ST. PETERS FORMATION.

Altho this formation does not occur in the disseminated lead district, it is one of the most distinctive formations of southeastern Missouri. It is a coarse to medium grained white to yellowish brown sandstone, usually soft and poorly cemented. It overlies unconformably the Jefferson City formation and underlies conformably the Joachim. The Joachim, in some places, appears to be unconformably above the St. Peters, but most of those who have studied the areas in which these two formations are exposed, have concluded that they are conformable.

The best exposures of this sandstone occur in Franklin, St. Louis, Jefferson, Ste. Genevieve, Cape Girardeau and Perry Counties. Small, much restricted areas also occur in other counties, but their identification is not easy on account of confusion with the sandstone members of other formations. The surficial distribution of this formation in the area lying between Crystal City and Pacific was carefully mapped by Mr. O. U. Stromme during 1907, the results being shown on the general geological map of southeastern Missouri.

From an economic standpoint the St. Peters sandstone is extremely important, since it is the source of a greater part of the supply of silica used in the plate glass manufactories of the state. It also supplies the sand used for a multitude of other uses.

The thickness of this formation varies greatly, being in places 175 feet. The variable thickness is due mainly to the extremely uneven floor upon which it was laid down, as pointed out by the earlier Missouri geologists.

JOACHIM FORMATION.

This formation has a very limited surficial distribution in Missouri being best developed in the southeastern part of the state in Franklin, St. Louis and Jefferson counties. It has a thickness varying from a few to 150 feet.

The lower part of this formation consists of alternating beds of dolomite, sandstone and sandy dolomite. The dolomite has a yellowish to grayish color, the latter being, as a rule, thinly bedded, compact and brittle. Some of the dolomite beds of this transition zone contain evenly disseminated grains of quartz which are perfectly rounded. This quartzose dolomite has been observed to pass upward into dolomite and downward into sandstone, there being all possible proportions of quartz grains and dolomite.

It is easy to understand how an arenaceous dolomite of this character might be transformed into a quartzitic chert, similar to that which occurs in the Roubidoux formation, through the replacement of the dolomite by silica.

Before the deposition of the succeeding Ordovician formations there was an erosion interval through which this formation was partly removed.

PLATTIN FORMATION (Lower Trenton).

(Also Known as Trenton, Black River and Birdseye.)

This formation has its chief development along the Mississippi river from Cape Girardeau north to the Missouri river. It overlies, unconformably, the Joachim and consists of a fine grained limestone.

This formation was formerly known as the Lower Trenton but has lately been given the name Plattin by Dr. E. O. Ulrich. It is a compact, heavily bedded limestone, often resembling in texture the so-called Lithographic, now known as the Louisiana.

KIMMSWICK (Upper Trenton).

Above the Plattin occurs the well known Receptaculites horizon of the Trenton. This is, perhaps, one of the most easily recognizable horizons of the Ordovician, since it is characterized by abundant remains of the beautiful "Sunflower coral."

This formation consists, as a rule, of a coarsely crystalline, light gray to bluish drab limestone which is typically exposed at Graysboro, Cape Girardeau, Glen Park and Kimmswick in southeastern Missouri. The uppermost two to five feet contain fossils which, according to E. O. Ulrich, are of Richmond age. For this reason these beds are known as the Fernville and are not included in the Kimmswick.

HUDSON RIVER. (Thebes.)

This formation consists of three members, viz: a sandstone in the middle and shale above and beneath. It has a very limited areal distribution in southeastern Missouri, being better developed in the counties along the Mississippi river north of St. Louis. The thickness of this formation in Pike county is 85 feet. Shumard estimated the thickness at 120 feet.

SILURIAN.

CAPE GIRARDEAU (Cape Girardeau).

This is the limestone horizon to which Shumard in 1873 applied the name Cape Girardeau. Keyes describes it as a bluish, very compact, rather thinly bedded limestone, with numerous vertical fractures, and resembling somewhat stone used in lithographing. It has a thickness of about 60 feet.

NIAGARA. (Bainbridge).

This formation embraces, according to Ulrich, all the Silurian limestones beneath the Lower Helderberg, above and below Bainbridge, Missouri, and in the vicinity of Thebes, Illinois. Its distribution is very limited in the southeastern part of the state.

BAILEY (Lower Helderberg).

This is the uppermost member of the Silurian in this region. It consists of argillaceous limestone and shale and is typically exposed at Bailey's landing and Red Rock landing along the Mississippi river in southeastern Missouri.

DEVONIAN.

CLEAR CREEK (Oriskany).

This is a cherty limestone which is typically exposed south of Wittenberg. It is the lowest member of the Devonian recognized by the geologists who have studied this area.

GRAND TOWER (Hamilton and Onondaga).

This is a limestone formation which is supposed to be the local representative of the Hamilton and Onondaga of the east.

SULPHUR SPRINGS.

This formation consists of three members, viz: a yellow friable sandstone, known locally as the Bushberg; a limestone with frequent sand grains, known locally as the Glen Park; and an unnamed shale. Above the Bushberg sandstone, in St. Louis county, there occurs a series of pink or purple, cherty shales and thin limestone beds, known locally as the Fern Glen.

MISSISSIPPIAN.

CHEMUNG OR KINDERHOOK.

This group consists of three formations which are well defined in the counties along the Mississippi river north of St. Louis, altho their identification and limitations have not been fully worked out for the area in southeastern Missouri. They constitute the lowest part of the Mississippian, perhaps a part of the Devonian.

The lower member is known as the Louisiana which is a thinly bedded, dense, fine grained buff to bluish colored limestone resembling the stone used for lithographic purposes. It has been known locally as the "Lithographic" limestone and has a thickness of 60 feet at the typical locality. Such investigations as have been made under the direction of this Bureau indicate that the Louisiana limestone is altogether within the Carboniferous.

The middle member, known as the Hannibal, is a shale-sandstone horizon, seventy feet in thickness at the typical locality. The shale has a bluish to greenish color and is both calcareous and magnesian. The upper portion of this member is a sandstone, known locally as the "Vermicular" on account of the abundance of worm borings which it exhibits. This formation is not clearly defined in the southeastern part of the state, altho its equivalent is probably present. In Pike county it has a thickness of 78 feet.

The upper member, known as the Chouteau, is a fine grained compact limestone having a gray to buff color. It is frequently impure from an admixture of clay. Near Ste. Genevieve it has a thickness of from 75 to 100 feet, while in Pike county it is only 30 feet thick.

BURLINGTON AND KEOKUK.

These two well recognized formations of northeastern Missouri have lately been mapped together in St. Louis county by the geologists of the U. S. Geological Survey under the name Osage. There is evidently some difficulty in separating these formations as they occur south of the Missouri river.

In the southeastern part of the state they consist of a light colored often very cherty limestone. It usually contains abundant remains of crinoids, on account of which, at one time, it was called the "encrinital" limestone.

The limestone is, as a rule, thoroughly crystalline, medium to coarse grained and light colored. In places it is thinly bedded, being separated by layers of chert nodules, but usually the beds are thick. These formations are typically exposed in Ste. Genevieve and St. Louis counties. In St. Louis county they have an aggregate thickness of about 225 feet. In Pike county they have a thickness of 130 feet.

WARSAW.

Overlying the Burlington-Keokuk in St. Louis county is a thickness of about 75 feet of soft bluish to yellowish shales with occasional intercalated beds of limestone. Thirty feet above the base, in St. Louis county, there is a 4 foot bed of limestone carrying abundant spirifers. The lowest ten feet consists of interbedded shale and cherty limestone characterized by numerous bryozoans, among which Archimedes is a conspicuous form. Crinoid stems are also abundant.

SPERGEN.

Above the Warsaw, in St. Louis county, is a limestone horizon, resembling the Bedford limestone of Indiana, having an approximate thickness of 60 feet. It has a granular to öolitic texture, a light gray color and is thick bedded and massive. In some places it is beautifully cross-bedded. About 10 feet from the top there is a five to ten foot shaly horizon and thirty feet from the bottom there occurs a bed which is filled with rynchonella. The basal beds are dense and compact.

ST. LOUIS.

This formation has a maximum thickness of about 325 feet of light colored, fine grained, dense, often cherty limestone. It occurs typically exposed in St. Louis county where it is heavily bedded, sometimes öolitic or granular textured and cross-bedded. In Ste. Genevieve county this formation has a thickness of from 60 to 100 feet, according to Shumard.

STE. GENEVIEVE.

This is a limestone formation which was distinguished by Shumard in 1860, as overlying the St. Louis. It is reported as having a grayish color and as being thinly bedded. It has a thickness of about 50 feet in Ste. Genevieve county.

CYPRESS.

This is the formation which Swallow designated Ferruginous sandstone and is the same as Keyes' Aux Vases sandstone. Shumard gives its thickness as 80 feet altho only 40 feet is exposed. It is a heavily bedded formation consisting in places of coarse sand or even rounded pebbles of quartz. It occurs along the Mississippi river bluffs from the mouth of the Aux Vases to a point about three miles from Ste. Genevieve.

TRIBUNE.

Above the Cypress sandstone occurs a gray, thinly bedded limestone, known in the earlier reports as the Upper Archimedes. Shumard placed the thickness of this formation at 200 feet. It is typically exposed along the Mississippi river bluffs just above St. Marys and near the mouth of the Saline river.

BIRDSVILLE.

Above the Tribune limestone occurs an horizon of shale, sandstone and thinly bedded limestone which is considered to be the top formation of the Mississippian of southeastern Missouri. This with the Tribune and Cypress constitutes what are known as the Chester group.

PENNSYLVANIAN.

Above the Mississippian, in St. Louis county occur shales and sandstones belonging to the Pennsylvanian. These occur in an irregular area, approximately as shown on the accompanying geological map of southeastern Missouri. They have a maximum thickness of about 100 feet as estimated by N. M. Fenniman, of the U. S. Geological Survey.

TERTIARY.

Overlying all the preceding formations occur occasional deposits of gravel, sand and clay which are thought to be of Tertiary age and are denominated Lafayette gravels. They have been observed in many places over the Ozark region especially in St. Louis and Franklin counties and in the area which is the immediate subject of this report.

On the tops of many of the ridges and along the hillsides of St. Francois county, occur great numbers of well rounded chert boulders and pebbles strewn loosely over the surface. They were observed chiefly on the hillsides and flat topped ridges, up to an elevation of 920 feet A. T., along Big river and tributaries to the south. It would have been difficult to have mapped the area covered by this gravel and the work involved would have had very little if any importance in solving the economic problems with which this report primarily deals. The fact that there was during Tertiary time a period of submergence is important, in so much as any change in the elevation of the land effects the level of ground water and consequently the ore deposition.

Typical deposits of this gravel occur in Sec. 11, T. 36 N., R. 5 E., and on the north half of Spanish land grant 3176. These deposits are well shown in the accompanying plates which were taken on the bluffs along Flat river.

QUATERNARY.

The work of N. M. Fenneman during the summer of 1906, verified the observations of J. E. Todd, showing that the Illinoisan and Kansas drift sheets as well as the Iowan loess occur, in St. Louis county. The Illinoisan drift was recognized north of St. Louis and the Kansan drift, as much weathered till, in the same area. The Iowan loess caps the bluffs bordering the Missouri river and the Mississippi river at intervals throughout its entire course along the eastern boundary of the state.

The recent deposits of the area embraced in this report consist chiefly of alluvium occupying the flood planes of the various stream valleys and residuum from the decomposition of the rocks of the varioius outcropping formations. The alluvial deposits consist chiefly of clay, sand and gravel, altho the concentrating mills are now adding to these materials great quantities of finely ground dolomite, which imparts a slate color, to the waters of the streams throughout most of their journeys in St. Francois county.

The residual deposits vary in thickness from nothing up to 200 feet. The locality in which the above thickness was obtained is the southeastern part of the special Flat River-Leadwood sheet near Shafts 9 and 10 of the Federal Lead Company. Several churn drill holes put down in Sections 16 and 21, T. 36 N., R. 5 E., passed through a thickness of from 60 to 200 feet of residuum. Of this, about 75 to 80 feet was mixed flint and clay, while a considerable portion of the remainder was a fine plastic, yellowish red clay called ochre.

These extremely thick deposits of unconsolidated material may be in part Tertiary, but of this we have no direct knowledge. In other parts of this area the residual deposits vary from nothing to thirty feet, usually less than twelve.

GENERAL.

The important stratigraphic relations to be kept in mind are (1) the pre-Cambrian consisting of granite and porphyry (rhyolite) underlying the sedimentary series; (2), that this pre-Cambrian base is extremely irregular, in places protruding hundreds of feet above the present surface of the younger sedimentary rocks and in other places occurring hundreds of feet beneath them; (3) that above the pre-Cambrian there is usually a variable thickness of very porous conglomerate and standstone; (4) that above this there is a dolomite formation, the lower portion of which contains many beds of shale, almost sufficient to constitute an impervious horizon, were it not for the fact that the different seams of shale are usually very limited in areal extent and usually broken by channels and prominent joints; (5) that above this dolomite there is a conglomerate-shale formation constituting an impervious horizon; (6) that above this there is a thin formation of very hackly, heavily bedded dolomite; (7) that above this there is an horizon of argillaceous, arenaceous limestone which is compact and essentially impervious; (8) that above this there is a very cherty dolomite which on account of the cavities which it contains is essentially a porous formation.

In general this area consists of a basement complex of igneous rocks overlain by a succession of sedimentary rocks the highest and lowest in the series being porous with two dolomite formations between, these, in turn, being separated by two essentially impervious formations, one shale and the other argillaceous dolomite.

The question of the age of the sedimentary formations and their equivalents in the Central Ozark series, has continually been a subject of controversy. Their age must necessarily be determined by their fossils content and up to the present time these have not been studied in sufficient detail to warrant making anything but a general statement as to their age. Dr. E. O. Ulrich of the United States Geological Survey has made collections from this area but up to the present time nothing has been published as a result of these studies. Both Dr. Ulrich and Dr. Walcott say that the fauna indicates Middle and Upper Cambrian, the separation being near the top of the Davis shale. The Lower Cambrian is wanting in this region.

There is one statement that can be made with a reasonable degree of certainty—i. e. that these formations are all older than the St. Peters sandstone. We can also go further than this and show their exact position between the St. Peters sandstone above and the pre-Cambrian below. Cross sections have been made west and north from this area, which show the position of these formations with respect to those of the Central Ozark region.

Before making a detailed study of this area I was inclined to the belief that the Bonneterre formation was the equivalent of the Proctor of the central Ozark region. It is now my belief that the entire series from the Potosi down underlies the Proctor. It is possible in going north and west to follow the succession of formations as given in the first part of this chapter, provided one is familiar with the detailed characteristics of each.

CHAPTER III.

STRUCTURES.

All the structures common to little altered sedimentary rocks occur in this area. They are more or less related to one another and a thorough understanding of their position and magnitude is important in a comprehensive study of the ore deposits.

In order to avoid any confusion which may arise from the use of certain terms applied to rock structures, it has been thought advisable to make certain explanations of these terms as each structure is taken up for discussion.

STRATIFICATION AND BEDDING.

The term stratification is applied to the planes along which unmetamorphosed sedimentary rocks have a natural capacity to part, chiefly as a result of the alternation and consolidation of sediments. The more abrupt the change in sediments, the greater will be the capacity to part along these planes. In some cases stratification may be due to a periodic influx of sediments of the same character, which would admit of the settling and partial consolidation of one layer before the next was introduced.

Stratification planes in unaltered rocks usually lie nearly horizontal altho this is not an invariable rule. Occasionally a bed is encountered in which the stratification planes are steeply inclined to the normal position of the stratification planes above and below. Such a structure is known as cross-stratification. Commonly the term cross-bedding is applied to this structure as well as to that which is defined as such below.

In sedimentary rocks the stratification planes are the planes of greatest weakness. It is, therefore, natural to expect that in any re-adjustment of the rocks in response to crustal stresses, there would be movement along these planes. As a result actual parting takes place producing bedding planes. The amount of movement may be very little and evidence of it is usually quickly concealed by solution and deposition from ground water which circulates freely through such openings. The movement between beds may be of sufficient magnitude to come under the head of faulting, or may be so slight as to merely produce a parting where previously only a capacity to part existed.

Bedding planes, as in the case of stratification planes, may be steeply inclined to the usual position of such structure in the formation under consideration, in which case the planes are known as cross-bedding.

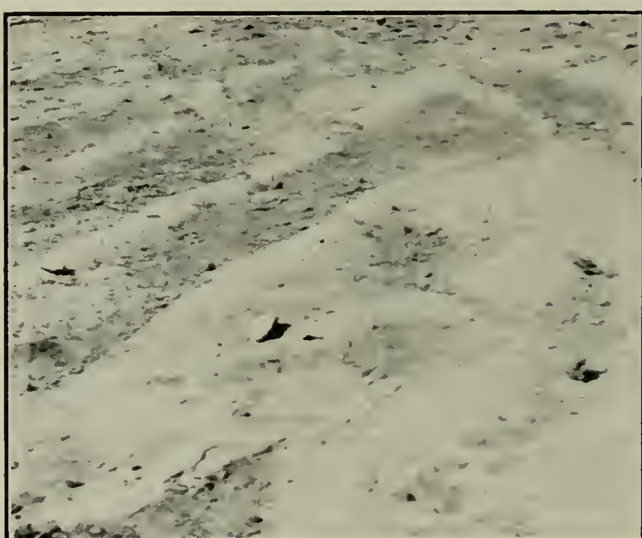
Assuming the correctness of the definition of bedding, a bed would be that portion of a formation which lies between two bedding planes.

In the area included within the present report there occur all the variations in stratification and bedding common to sedimentary formations. The sediments are all near-shore deposits, encircling the St. Francois mountains. There were periods of repeated oscillations in the level of the sea causing frequent alternations of the sediments.

The Lamotte sandstone, which is the lowest sedimentary formation of the series, is at some horizons devoid of both stratification and bedding planes. In place, however, changes in the texture of the rock has caused the development of stratification planes and occasional thin laminae of shale have developed bedding planes. In the outcrops at the surface, bedding planes have also developed at intervals but where there is little evidence of stratification they have very much the appearance of joints. This sandstone also contains occasional thin beds of limestone along which bedding planes have developed. Cross-stratification occurs in this formation.

The overlying Bonneterre formation consists chiefly of dolomite with thin laminae or beds of shale and beds of chloritic, occasionally arenaceous, dolomite. The upper and lower parts of this formation are quite uniformly interstratified with shale while the middle portion contains only occasional thin leaves of shale between the beds. There is very generally an absence of stratification planes but the bedding planes are well defined and reasonably persistent. The position of most of the bedding planes has been determined by thin films of shale and abrupt changes in the texture of the dolomite.

The bedding planes are frequently smooth and level but more often they are rough or wavy. A pitted or pinnacle-like surface is not uncommon. There has evidently been more or less solution and deposition along the bedding, as a result of which some of



Ripple marked surfaces of the Davis formation.

the adjacent beds are attached and others are free. The coalescing of two bedding planes through the feathering out of an intervening bed occurs very frequently in the lower part of the formation. Occasional examples of cross-bedding have been observed in the mines.

The Davis formation, which overlies the Bonne Terre, consisting as it does of shale, limestone, dolomite and conglomerate, exhibits all the irregularities in stratification and bedding which one might anticipate from a formation of this character. The shale exhibits smooth bedding planes, while the bedding planes of the dolomite and limestone are usually rough and uneven. The beds exhibit a great variety of the so-called fucoidal markings, as well as ripple and wave marks. The conglomerate beds, in some places, lie on uneven surfaces suggesting unconformity. Where the laminae of shale are wrapped around the boulders of the Central marble boulder bed, the bedding planes are more or less wavy. Cross bedding occurs occasionally but is not characteristic of this formation.

In the Derby formation the bedding planes are uniformly persistent over wide areas, altho they are rough and as a rule a considerable distance apart. There are no well defined stratification planes.

In the Doe Run formation there are two horizons at which stratification planes are well defined and numerous. Along these the stone splits into thin plates when exposed to the weather. These plates are not absolutely smooth, altho comparatively so. The remainder of the formation exhibits more or less irregular bedding planes separating beds of considerable thickness.

The overlying Potosi formation is poorly exhibited in this area but wherever exposed the bedding planes are rough surfaced and irregular.

RIPPLE AND WAVE MARKINGS.

There may be some question as to the logic of placing these markings among the rock structures, since they are merely forms of stratification and bedding planes resulting from the movements of the water in which the sediments were laid down.

They may be defined as sinuous corrugations of the bedding or stratification planes, due to waves and ripples. When their amplitude is small they are known as ripple-marks; when large, they are known as wave-marks.

The conditions under which the Davis shale was deposited were especially favorable for the production and preservation of such structures as ripple and wave-marks. In the other formations these markings are seldom observed. In the argillaceous limestone beds a short way above and below the Central marble boulder member of the Davis shale beautifully preserved ripple marks are common. In the S. W. 1/4 of Sec. 14, T. 36N., R. 4E.; in the N. W. 1/4 of the S. E. 1/4 of Sec. 12, 2. 36N., R. 4E.; in the West quarter of land grant No. 3273, in Sec. 9, T. 37N., R. 4E. and in the N. W. corner of Sec. 14, T. 37N., R. 4E., very large ripple marked surfaces are common. The ripple marks in these places are of exceptional size, having an amplitude of 6 to 8 inches and a distance from crest to crest of two feet. Similar ripple marked surfaces occur in many other places over the area. Plate XVI. is a photograph of these markings.

Some peculiar wave-like ridges were observed in the Doerun formation in the northern part of Sec. 25, T. 36N., R. 4E. near the line of Sec. 24. These ridges have an amplitude of from two and a half to three feet, and look very much like reefs as defined by Dr. E. O. Ulrich. They consist of rather coarsely crystalline dolomite overlain with thinly bedded shelly argillaceous dolomite. The overlying shelly dolomite apparently follows the sinuosities and rolls of the underlying bed, being conformable with it.

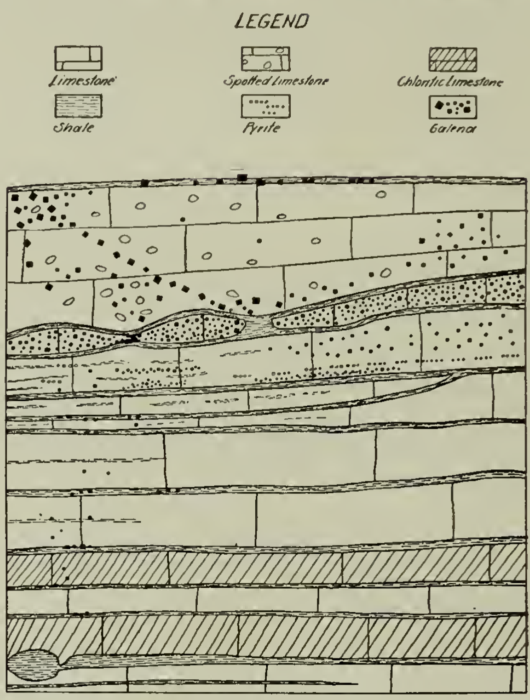
In the Bonneterre formation, near the bottom, the surface of the beds are frequently very uneven, appearing very much as tho they had been eroded or distorted through pressure, as shown in Plate XVII. This condition, however, is, purely a local phenomenon and is best accounted for by ocean scour, through which some of the soft sediments were removed, before the overlying sediments were introduced. This same phenomenon has been noted in other Cambrian formations of the Ozark region, especially the Jefferson City.

SUN CRACKS.

These are irregular polygonal markings exhibited on the surfaces of some beds, either in the form of low ridges or shallow depressions.

Soft clayey sediments shrink and crack when dried. This frequently happens during short periods of emergence of areas along the sea shore. During the succeeding period of submergence these cracks are filled with other sediments thus preserving the structure.

The Davis formation, more than any of the others, exhibits this phenomenon. The markings referable to this cause are not as well defined as one might expect, altho they are abundant in certain parts of the formation. The shale beds are covered with



Eighteen inches of alternating shale, limestone and chloritic limestone. Shale in lower left-hand corner is soft. Mine No. 2, Doe Run Lead Co.

what are commonly called fucoidal markings, there being an almost infinite variety of these.

The shaly horizons of the Doerun formation exhibit a variety of markings which may be due in part to sun cracks. However, many of them are considered to be fucoidal markings.

FOLDING AND FLEXURING.

Flexures or folds in sedimentary rocks may be due either to the conditions under which original deposition has taken place; to settling as a result of solution; or to later compressive stresses. Van Hise* has pointed out that below a depth of 10,000 meters rocks are deformed by flowage. Above this, deformation is by combined fracture and flowage. Flowage may even occur at the surface, under favorable conditions.

In the area under discussion folds due to solution and inequalities in the sea floor upon which the sediments were deposited and flexures due to deformation by fracturing have been recognized.

The flexures resulting from fracturing may be produced in two ways, viz: (1) by thrust, (2) by settling. It has been observed that in little folded limestone and dolomite areas the beds have a very general dip toward the valleys. This is thought to be the result of an increasing amount of solution of the limestone or dolomite from the middle to the slopes of the hills and ridges. Underground solution may also, cause a settling of overlying strata forming synclinal and anticlinal structures. The flexures thus produced are best known as solution flexures. The practical absence of so-called thrust faults in this area argues strongly against the formation of flexures by compressive stresses.

It is often difficult to determine the cause of the gentle flexures occurring in regions similar to the one under discussion. However, we are reasonably certain that the original conditions of sedimentation and solution have been the most important cause of the flexures observed.

Folds such as characterize many mountainous regions do not occur in this area. The beds are fixed in places forming gentle synclinal and anticlinal basins as shown in the accompanying cross sections, but these are, in part, at least, due to solution and the uneven surface upon which the formations were laid down.

The sedimentary formations of this area were laid down in an irregular basin between hills of pre-Cambrian granite and rhyolite. This gave them initially a broadly synclinal structure.

*Principles of North American Pre-Cambrian Geology 16th An. Report U. S. G. S. Pt. I pp. 592-595 C. R. Van Hise.

The uneven floor upon which they were laid down resulted in the beds being more or less gently folded. Due to the uneven floor upon which the sediments were deposited the beds possessed, initially, synclinal, anticlinal and dome structures.

This area is a part of the Ozark uplift and was under the same stresses as the remainder of the plateau region. However, the movements accompanying the elevation of this plateau, apparently had little if any effect either in the production of new folds or in the emphasizing of those already formed. Locally throughout the area there are minor folds having an amplitude of two to ten feet but these are scarcely worthy of consideration.

Referring to the generalized map of Southeastern Missouri (Plate —) and the accompanying sections, we find the basin referred to lying in a general northwest-southeast direction. To the northeast occur the isolated granite peaks known as the Jonca hills while to the southwest occur granite and porphyry (rhyolite) hills making up the main mass of the St. Francois mountains. The area actually constitutes a pitching trough which begins southeast of Farmington and ends rather abruptly at the so-called Big River fault which intercepts it at a distance of about twenty-two miles to the northwest.

About three and three-fourths miles southeast of Farmington the dolomite formations of this basin are only about two and one-fourth miles wide, the underlying Lamotte sandstone forming an almost continuous belt from the Jonca hills to the main area of igneous rocks to the southwest. Both to the southeast and to the northwest occur basins which broaden in these directions. The basin to the northwest includes the area which is the subject of discussion in this report. This basin gradually broadens to the northwest for a distance of 18 miles at which point it is interrupted by a fault striking approximately N. E. and S. W. The basin to the southeast is the one in which the Madison county deposits of disseminated galena occur.

The general structure of the northwest basin is shown by the cross-sections which have been constructed at intervals from the southeast to the northwest. (See Plate XLI.).

The detailed structures of the area included in the Bonne Terre sheet and in the special areas are well shown on the cross-sections accompanying each of these maps. (See Plates XLIV., XLV., XLVII., XLIX., L. and LI.). Small synclinal and anticlinal flexures occur at various places throughout the area. A good illustration of these small flexures occurs east of the site of the old Federal mill at Irondale. Along the Big river

In the following discussion it is especially desired to distinguish normal from inclined joints and those in the upper part of a formation from those in the lower. Those in the upper part of the formation might be called *superficial joints* and those in the lower part *subformational joints.*

In my study of the mines in this district I found it convenient to classify joints according to their importance into (1) channels, (2) prominent joints, (3) and short, discontinuous joints. The first class includes all of those which exhibit marked decomposition along their walls; the second includes all joints of which the wall rock is comparatively fresh; and the third includes all joints which are confined to one or several beds. This classification could probably not be carried out in any other district but it has been found to be especially useful in this locality.

In the study of this area special attention was given to the jointing, as exhibited both in the outcrops and in the mine workings. The joints in the outcrops are frequently open seams or channels altho as a rule they are mere fracture planes. Most of them are vertical or nearly so, inclined joints being the least abundant and of minor importance. There appear to be sets of nearly N.-S. and E.-W. joints which, altho not so numerous, are persistent and marked with broad openings filled with red clay. Not considering these channels, our observations, which were taken chiefly in the neighborhood of the mines, indicate that the most abundant joints strike between N. 54 W. and N. 83. W. The next most abundant strike between N. 16 E. and N. 45 E. Of the latter series those striking N. 37 W. to N. 45 W. will include the greater number. These joints are about the same for both the Davis and Bonneterre formations as shown by about a hundred observations scattered throughout the area covered by the special sheets.

Along some of the joint planes, especially those striking from N. 70 W. to E. and W., lines of caves and sink holes have developed. From some of these galena was mined in the early days, before the deposits of disseminated ore were discovered.

It is evident that only the major channels persist in depth to the underlying Lamotte sandstone. That some of the channels do persist to this depth is shown by observations underground and by the fact that surface water enters the mines soon after a heavy fall of rain. Such channels occur south of Federal Shaft No. 7 along Davis creek, in the vicinity of Columbia No. 1 shaft and near Desloge mine No. 3.

The joints apparently occur in zones. In one place there will

Saw-toothed appearance of weathered edges of Davis shale near Elvins.

be a great number of well-defined joints close together and beyond it the joints will be few and far apart. In some places the beds are broken into large or small blocks with two sets of joints giving blocks frequently causes the edge of the bed to have a saw-tooth appearance as shown in Plate XIX. In some places the jointing is marked by a growth of grass and weeds as shown in Plate XX. In other cases trees have found lodgment in the joints, and the expansion caused by their growth has shoved large blocks of the dolomite apart. These phenomena of joints widened by solution and by the growth of plants are only exhibited in the more massive beds of dolomite, such as make up the Bonneterre and the Derby formations.

The jointing in the upper part of the Bonneterre has, in many places, been such as to cause the formation to weather in a peculiar pinnacle-like fashion, as shown in Plate XXI. In instances, such as illustrated by this plate, the beds appear to have been broken into small flattened rhombs by a major set of close joints and a minor set of cross joints. This structure was not observed in the weathered portion of any of the other formations. In the Derby dolomite, which is somewhat similar to the Bonneterre, the joints are, as a rule, some distance apart and the beds are broken into large rectangular blocks. In the Davis shale the joints are, perhaps, more abundant than in any other of the several formations. In this formation the thin beds of limestone and shale are often broken into small rectangular pieces, several inches or perhaps a foot or two in diameter. The joints in the Doerun are usually regular, sharp and well defined as shown in Plate—. The thinly bedded, argillaceous dolomite, as well as the overlying massive dolomite, is broken into large rhomboidal blocks by vertical joints. Inclined joints are more conspicuous in this than in any usually regular, sharp and well defined as shown in Plate XV. The shale and thinly bedded argillaceous limestone horizons exhibit better defined inclined joints than any of the others.

In the underground workings of the mines there is a series of joint planes which appears to be especially characteristic of this part of the formation. They evidently commence at the base of the formation and after continuing upward a short distance die out. Occasionally one of these joints is open near the bottom as a result of the leaching of the dolomite but such open channels may die out within a space of thirty or forty feet either vertically or horizontally. Such channels are not to be confused with those beginning at the surface and extending downward to the sandstone.

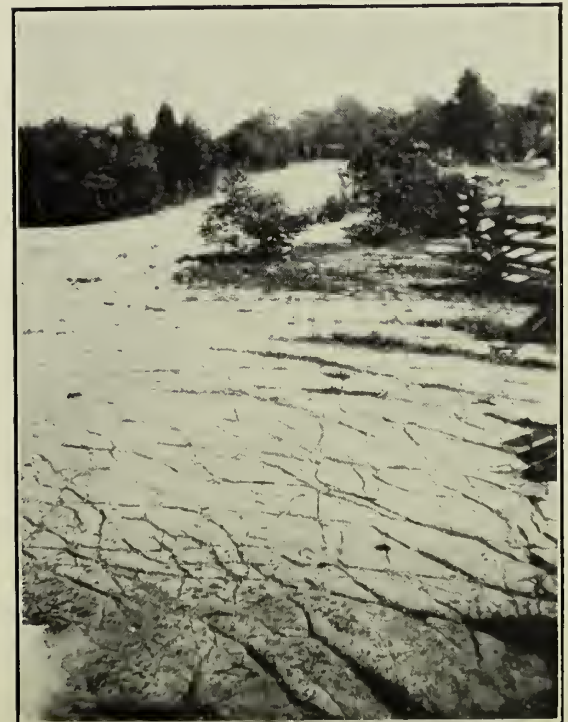
Observations made in nearly all the mines of the district show the joints to be very irregular both in their horizontal and lateral extension. They usually present very rough, irregular walls. They may be open in one place and closed in another, as shown by a channel which was followed by one of the shafts sunk in this district. These openings occur at irregular intervals both horizontally and vertically. In some instances they may be due to movement by which the protuberances have come opposite each other, but as a rule it is thought that they are due to inequalities in the rate of solution due to the character of sediments at different places.

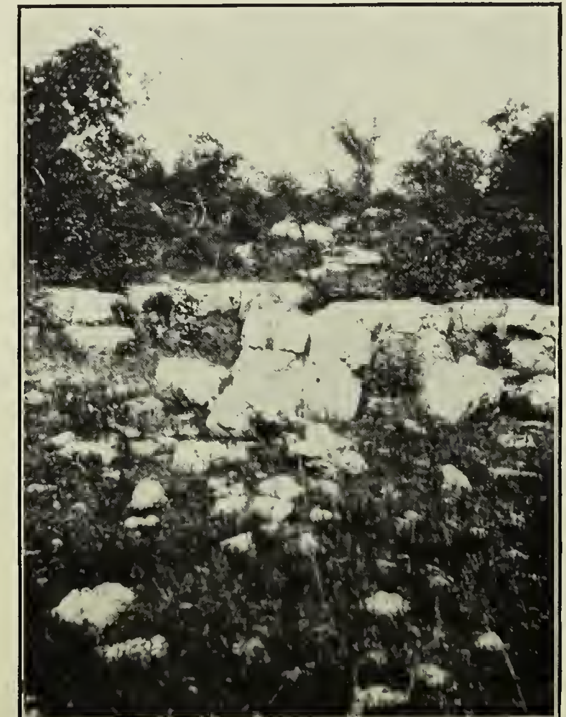
FAULTING.

There appears to be no more useful classification of faults than that which separates them into normal and reverse. These terms, indeed, may not express the precise direction of the movement or the cause of the displacement but as pointed out by Willis they have an important descriptive value. All faults which lie in a plane between the horizontal and vertical and in which there has been a vertical component in the movement may be brought under this classification. Faults in which the upper side has moved downward with respect to the lower side are termed *normal* faults. Those in which the upper side has moved upward with respect to the lower side are termed *reverse* faults. In case a fault plane is vertical, the fault might be called *vertical;* if the fault plane is inclined, the fault might be termed *inclined;* and if the fault plane is horizontal it might with equal propriety be called a *horizontal* fault. These three latter terms do not imply a knowledge of either the cause or the direction of the movement.

The writer recognizes that through a shifting of the fault plane a particle may be carried in a direction represented by any of the radi of a sphere. With respect to a bed on one side of a fault the other side may have a movement in three directions, viz: in two directions laterally and in one direction vertically. The movement may be in only one or two of these directions. These movements are equally important and should receive full consideration where the exploitation of an ore body is under consideration.

It is important to the mining geologist that he know the directions of movement and the distances to which movement in these





Jointing and weathering of the Derby Dolomite.

1 and 3—Typical surface exposures of Bonneterre dolomite.
2—Typical surface exposure of Derby dolomite.

directions has taken place. In the case of faults which are parallel or normal to the ore shoot the movement may be in only one direction and never in more than two. In the case of faults which are inclined to the plane of the ore shoot the movement may be in either two or three directions, never less than two.

In addition to the above, the location of the fault within the formation must be considered. We are accustomed to think of all faults as occurring at the surface and extending downward, dying out with depth. This is undoubtedly true with a majority of faults but there are faults which begin at the base of a formation and extend upward, dying out before reaching the surface. Normal faults may be the result of conditions whereby the displacement will increase, rather than decrease, with depth down to the initial point or focus of disturbance. Such faults may or may not reach the surface. Faults (and joints) of this class cannot be studied at the surface and are only recognized by a careful inspection of the different levels of the underground workings of mines. Faults of this class have been recognized in the Bonneterre dolomite which overlies the Lamotte sandstone.

In case normal faults are the result of the consolidation of sediments they will gradually die out with depth. Such, however, are usually in close proximity to the contact of two dissimilar formations, as, for example, a dolomite and granite formation. If they are due to other causes the amount of displacement may increase with depth until the place of origin is reached.

It is also necessary, in a consideration of faulting to understand that the amount of displacement decreases both laterally and vertically from the point of maximum displacement.

Faults do not continue indefinitely in either a horizontal or vertical direction. If the plane of a fault could be mapped in its entirety one would probably find that it would be roughly semicircular in form.

In areas similar to that under discussion in this report faults usually occur in groups, constituting zones of faulting, here known as *distributive* faults. They seldom follow a direct course for any great distance but take a somewhat zig-zag course across the country. Faults may also branch in which case they are known as *branching* faults.

In our discussion of faults the terms displacement, throw, strike and hade are used in the following sense, viz:—

Displacement—the distance of separation of formerly adjacent particles along the surface of the fault planes.
Throw—the vertical distance through which the beds have been moved at any place.
Hade—the angle which the fault plane makes with the vertical.
Dip—the angle which the fault plane makes with the horizontal.
Strike—the direction of the intersection of the fault plane with the plane of the horizon.

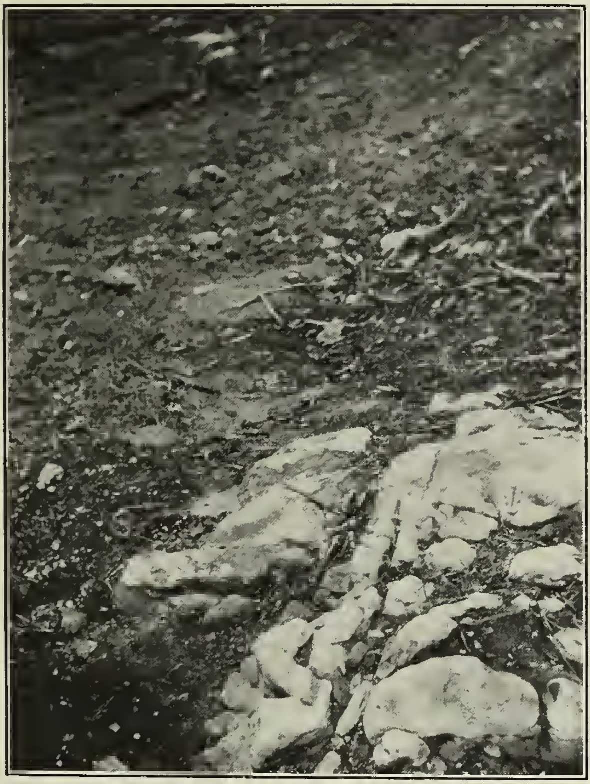
There is probably no area in the state in which faulting has been more conspicuously developed than in that under discussion. The faults are invariably of the normal type and they occur so related to one another as to be characterized as step faults. The displacement does not occur along a single plane but usually along several parallel planes, resulting in a fault zone. These fault zones vary both in width and in the distance that they occur apart from one another.

The fault zones are recognizable both at the surface and in the mines, since those which represent any considerable displacement persist throughout the entire thickness of the Bonneterre formation and into the underlying sandstone. Some of the more prominent faults undoubtedly persist through the Lamotte sandstone and into the underlying igneous rocks. From observations made underground in the mines it is apparent that some of the faults observed in the lower part of the Bonneterre have their origin in the underlying Lamotte sandstone or below and die out before reaching the surface. Such are the basal or sub-formational faults of the formation.

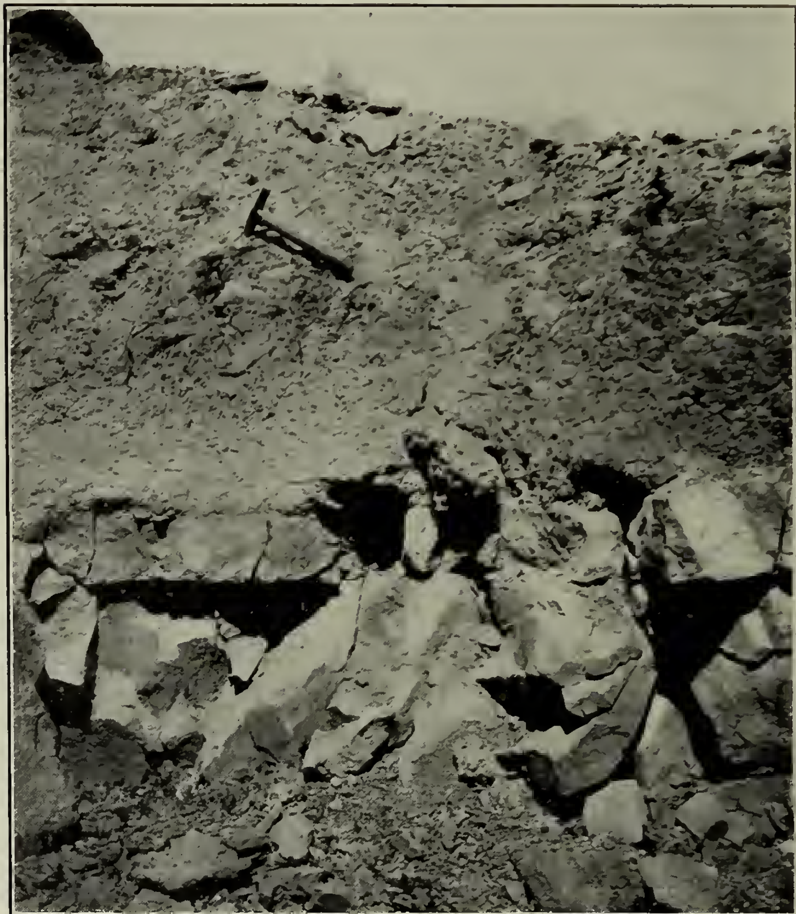
It is extremely difficult to recognize any lateral displacement at the surface, but underground I have been able to recognize it in a number of places. The same may be said of the horizontal movements, abundant evidence of which we have from examinations of the mine workings but none from surface observations.

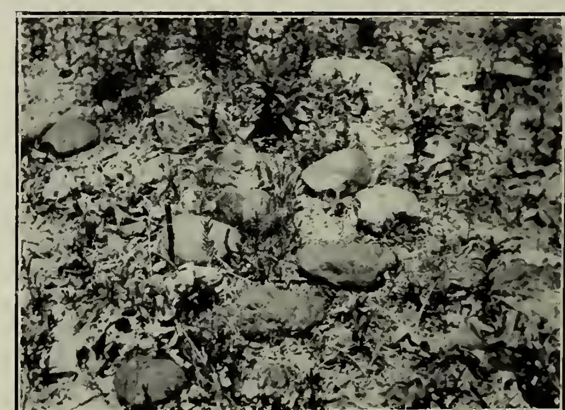
In general it may be said that this area is traversed by two well-defined systems of faulting. One of these has a general northwest-southeast strike while the other has a northeast-southwest strike. In addition to the above there are a number of well defined faults striking nearly east and west and a few which have a north and south strike. All of these faults are shown on the several special maps and accompanying cross sections.

Outside of and to the northeast of the special area included within the scope of this report occurs the Valles Mines fault, which is the most important of any which has been recognized in the southeastern part of the state. The position of this fault is shown on the general map Plate XL., while the detailed structure at Valles



The base of the Potosi formation. The pen points to an open joint filled with drusy quartz. On the Gunbo Branch of the M. R. and B. T. R. R.





The upper view is a cut along the Lead Belt Ry., exposing about four feet of Tertiary gravel overlying the Davis formation. The lower view is of well-rounded Tertiary gravel lying on the surface.

Valles Mines is shown on Plate XLII. This fault is of the normal type and belongs to the distributive class. The downthrow is to the northeast and the amount of throw at Valles Mines is thought to be in the neighborhood of 700 feet. This fault has been traced for a distance of about thirty miles and there is evidence that it extends farther both to the northwest and southeast.

Approximately parallel to this fault and in the southern half of the Bonne Terre sheet occur the Irondale and Cedar Creek faults. These are distributive faults and altho they have a general northwest-southeast course, their strike is in places almost east and west. In both instances the downthrow is to the northeast. The Irondale fault has a throw of about 600 feet, while the throw of Cedar Creek fault is about 400 feet.*

Approximately parallel with the above mentioned faults, twenty smaller ones have been located. West of Irondale there is a group of five faults striking a little north of west. Four of these have a downthrow to the northeast, while the other has a downthrow to the southwest. Northwest of Irondale there are two faults each of which has a downthrow to the northeast. North of Irondale there is a fault having a downthrow to the southwest. Southwest of Elvins there are several faults of which the Bannister fault is most important. This fault has a downthrow to the northeast. Another fault northeast of Elvins has a downthrow to the northeast. Likewise the fault near Federal Mine No. 9 has a downthrow to the northeast. The Cabanne fault northwest of Bonne Terre also has a downthrow to the northeast.

In general there is a series of well defined faults trending in an approximately northwest-southeast direction across this area, most of which have their downthrow side to the northeast.

There is only one zone of faulting of any prominence in this area having a northeast-southwest strike. This distributive fault, here known as the Big River fault, practically separates the Bonne Terre sheet into two parts, a northwestern and a southeastern. The Big River fault has a rather zig-zag course across the area and is in places marked by two somewhat distinct lines of displacement, as shown on the map west of Bonne Terre. The fault appears to be broken just west of Irondale but altogether it is known to have an approximate length of seventeen miles in the area included within this report. It has been located both to the northeast and southwest of this area, but its limits in these directions have not been determined. This fault has a throw of about 120 feet between Big

*The throws of these faults vary from place to place, and the figures given are only round numbers.

river and the Mississippi River and Bonne Terre railroad. This appears to be the point of maximum displacement, the throw decreasing in both directions from this place.

There are very few faults parallel to the Big River fault in this area. Such as were discovered are located on the maps.

The north and south and east and west faults are chiefly local variations in the direction of the northwest-southeast and northeast-southwest faults, altho several apparently independent faults, having throws of twenty to thirty feet, occur near the Irondale fault and northeast of it.

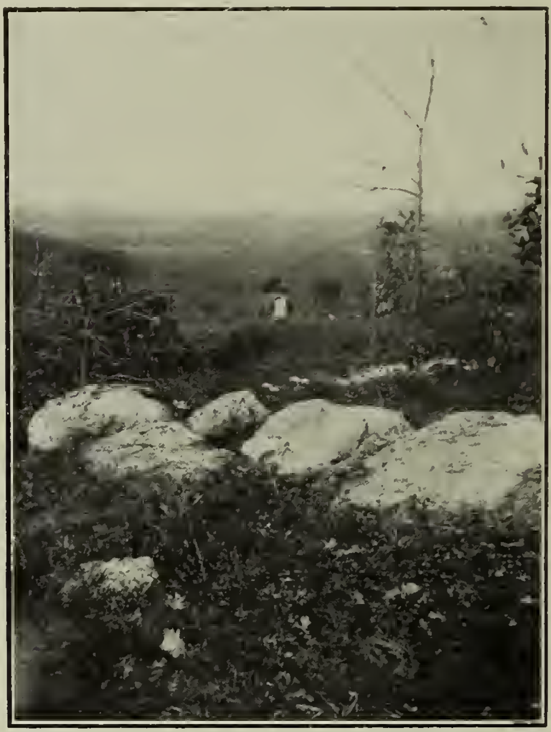
The general effect of these faults has been to lower the Davis shale on the downthrow side of the fault until it is opposite the Bonneterre dolomite. This would result in the ponding of the ground water. In this area the fault zones have also assisted in the formation of channels through which the surface circulation reaches the Lamotte sandstone. The fault zones have not only provided avenues for the movement of the ground water but they have also served to so displace the various formations as to influence the direction of flow.

UNCONFORMITIES.

Van Hise* says that "Unconformity between series implies a difference in number of orogenic movements with intervening erosion." He further says that as guiding phenomena in the discovery of unconformities we have "(1) ordinary discordance of bedding; (2) difference in the number of orogenic movements to which the series have been subjected; (3) discordance of bedding of upper series and foliation of lower; (4) relations with eruptives; (5) difference in degree of crystalization; (6) basal conglomerates; and (7) general field relations."

Where none of these phenomena can be recognized, unconformities have been inferred upon paleontological grounds, altho there has always been some doubt as to the reliability of this criterion. Paleontologists often recognize, in thin beds of conglomerate, uncomformities which can only be inferred from the changes in fauna from one formation to another. Such an unconformity may represent a hiatus in the faunal development, due to the incursion of more highly developed forms, and still have no significance as regards the continuity of sedimentation.

*Principles of North American Pre-Cambrian Geology, 16th An. Report U. S. G. S., Pt. 1 pp. 724, 725.



Residual flint boulders. The remnants of some formation which, with these exceptions, has been completely removed from this area.

The recognition of unconformities in the area under discussion is based altogether upon the phenomena as outlined by Van Hise in the report above referred to.

Laurentian-Lamotte Unconformity.—Reference was made in the preceding chapter to the unconformity existing between the pre-Cambrian and younger formations. In this area there is no evidence that the Huronian ever existed between the Laurentian and the Lamotte, altho in the vicinity of Pilot Knob and Iron Mountain there is some evidence of its former existence. The fossils contained in the upper part of the Lamotte sandstone and the base of the Bonneterre dolomite seem to indicate that the Lower Cambrian is also wanting. If these conclusions are true, there was undoubtedly a very long period of erosion between the time that the Laurentian igneous rocks were formed and the subsequent Lamotte sandstone was laid down.

The rocks underlying the Lamotte are all igneous, consisting mainly of granite, rhyolite (porphyry) and diabase, the latter being intrusive with respect to the other two. All of these are cut by veins of quartz which terminate underneath the Lamotte sandstone. Granite is a rock which is supposed to form under deep seated conditions and its appearance at the surface or immediately underlying the Lamotte sandstone is evidence that the rocks, which occurred above it at the time of its formation, were removed by erosion prior to the deposition of the sandstone. The extremely uneven floor upon which the sandstone rests, the presence of a basal conglomerate and the fact that in places the sandstone is entirely absent between the Bonneterre formation and the pre-Cambrian are additional evidences of an erosion interval.

An inspection of any of the cross-sections accompanying the Bonneterre sheet will be sufficient to convince one of the presence of this unconformity.

Lamotte-Bonneterre Unconformity.—There is very little evidence of an unconformity between the Lamotte and the Bonneterre formations. The Bonneterre apparently marks the inauguration of deeper sea conditions and there is little probability of an intervening period of erosion. The chief evidences are irregular, wavy bedding planes, occasional small lenses of limestone and porphyry conglomerate and considerable variability in the elevation of the upper surface of the sandstone. The irregularities in bedding may all be accounted for through the action of waves or shore currents. The so-called limestone conglomerates may be due to irregularities in sedimentation or perhaps to solution. The variations in the elevation at which the sandstone occurs are probably due in part to the uneven character of the pre-Cambrian floor, as a result of which the sandstone was laid down in irregular undulations. At some places in the area diamond drill cores show, in the uppermost beds of the Lamotte sandstone, small porphyry pebbles, indicating shallower sea conditions and that some of the pre-Cambrian igneous hills probably still rose above sea level.

I have examined the contact between the Lamotte and Bonneterre formations in the surface outcrops, in the mines underground and in many drill holes, without finding satisfactory evidence of an erosion interval between the two.

Bonneterre-Laurentian Unconformity.—During the deposition of the Bonneterre formation, the sea encroached farther upon the land area, and as a result the Bonneterre dolomite extends beyond the limits of the Lamotte sandstone and rests unconformably upon the pre-Cambrian igneous rocks. This condition has been noted both in the surface outcrops and in the drill cores.

Bonneterre-Davis Conformity.—The Bonneterre and Davis formations are conformable, but within the Davis formation itself there are beds of conglomerate and uneven planes of bedding which might in some instances be taken for unconformity. The entire Davis formation was laid down under shallow water conditions and hence one finds alternating shale, limestone and conglomerate with ripple marks and sun cracks.

The Central marble boulder bed occurs within this formation and its extreme irregularity in thickness and distribution offers a suggestion of unconformity. However, if there was an erosion interval at that time it was of short duration. I am inclined to believe that the condition of the Central marble boulder bed is due to the scouring action of tides or currents on unevenly consolidated sediments rather than to land erosion. Undoubtedly there were fluctuations in the sea level sufficient to produce overlap with resultant local unconformities at many places near the shore line. I am doubtful, however, if this formation overlapped the Bonneterre formation at any place in this area, for I know of no instance in which the shale rests directly upon the pre-Cambrian igneous rocks.

Miscellaneous—The Derby and Davis formations are conformable as are also the Derby and Doerun.

There is some evidence of unconformity between the Doerun and overlying Potosi. Dr. Ulrich believes that he has recognized clearly an unconformable contact between the two at the quarry west of Elvins. The most convincing evidence that I have is the wide variation in the thickness of the Doerun, which is fifty feet in some places and in others nearly a hundred feet. Altho I am inclined to believe that such unconformity may exist, I think the evidence thus far obtained is insufficient to warrant an affirmative conclusion.

The Potosi grades upward into the Proctor without any evidence of an erosion interval.

The Tertiary gravel overlies all the older formations, unconformably.

CHAPTER IV.

DESCRIPTIONS OF MINES.

THE FEDERAL LEAD COMPANY.

INTRODUCTION.

The Federal Lead Company began operations in this district in 1902, producing that year, from one shaft, 4320 short tons of concentrates. Since its organization, this company has acquired by purchase, the properties formerly owned by the Irondale Lead Company, the Derby Lead Company, the Central Lead Company, the Missouri Lead Fields Company and other smaller tracts owned by companies and individuals. The company now owns the fee to nearly 16,000 acres of land, all of which is located in St. Francois and Washington Counties. There are now seven producing mines on this property, each of which is reached by a shaft, equipped with modern hoisting appliances. Two additional shafts were nearly completed in 1907, but from these no ore has been hoisted. There are four additional shafts on the property, all of which have been abandoned temporarily, at least. Mines numbers 4 and 5 are connected with Mine No. 1 by means of underground tunnels. The ore from these mines is conveyed by an electric haulage system to shaft No. 1, where it is hoisted in a five-ton skip. Mines Nos. 6 and 7 are connected underground.

Mines Nos. 2, 8, 9 and 10 are separate, not being connected with any of the other mines. They are each equipped with modern hoisting appliances. Mine No. 3, which is on the Derby tract, has not been worked since the Federal Lead Company obtained possession of the land. It was abandoned on account of a heavy flow of water encountered while sinking. The Murrell, the Irondale and the Leadington shafts have not been operated by the present company.

Two mills, having a combined daily capacity of 3,200 tons, are being operated by this company. These mills are equipped with modern machinery and have, perhaps, the highest degree of efficiency of any in the district.

CONCENTRATING PLANT—FEDERAL LEAD CO.

It is not intended, in this volume, to discuss the mining, milling or smelting operations, for which reason no attempt is made to describe the equipment or processes of treating the ore. The following pages are devoted to a discussion of the ore deposits as they occur in the several mines which were being operated when the field work for this report was being done.

There has been produced by the properties now owned by the Federal Lead Company, including the "Central Lead Co.," "The Irondale Lead Co.," "The Derby Lead Co.," and "The Leadington Lead Co.," from 1894 to 1906, 134,570 short tons of lead concentrates of a value, in round numbers, of $5,987,386. Prior to 1894 shallow mining was carried on quite extensively at various places on this property, but it is difficult to make even an approximate estimate of the amount or value of the output.

To obtain the ore included in the above estimate, about 55 acres of ground were mined.

FEDERAL MINE NO. 1.

This mine was equipped ready for operating in 1901, altho the earliest reported production was in 1902. The land upon which it is located was prospected during the two preceding years.

In the early days some shallow, or surface mining was done near the place where this mine is located. The only record that remains of these operations is an occasional cup or saucer like depression, scattered over some portions of the land surface, marking the location of shallow shafts.

The collar of shaft No. 1 is 870.68 feet above sea level. The sea level elevation of the upper level is 518.1 feet and that of the lower level is 448.5 feet. An intermediate level, known as "F 71 Raise," is 526.3 feet above sea level. The upper level is 352.58 feet below the surface and the lower level is 422.18 feet below the surface, measured at the shaft.

The shaft passes through about 40 feet of Davis shale at the surface, and stops in the Bonneterre limestone about forty feet above the Lamotte sandstone. Plate LII. shows the area worked in this mine up to 1908. The cross sections Figs. LIII. show the relation of the different levels to one another, and the position of the ore body with respect to the Lamotte sandstone. Up to the time the mine map was made about 9½ acres had been worked underground.

The ore body represented by the underground workings of this mine has been very irregular. Some portions have been extremely rich while others near by have been correspondingly lean. There is very little black shale in this mine, the main workings being above the usual horizon at which the shale occurs in greatest abundance. There is also very little chloritic rock.

The galena occurs chiefly disseminated in dark brownish colored dolomite and shale; in thin seams filling joints; and in irregular pockets of blackish gray mud. In two instances crystallized galena was observed in open channels, associated with calcite and pyrite. Wherever galena occurs in joints, pockets or similar openings, it is usually associated with calcite and frequently with pyrite. Along tight seams the galena frequently occurs in very thin, flat crystals or leaves. A fresh surface along a joint plane of this character often has the appearance of lead spatters formed by firing shot against an iron plate.

Very little water enters this mine, either from above or below. It is one of the dryest mines operated by this company. In order to obtain an adequate supply for domestic consumption, a hole has been drilled from the bottom of the mine ninety feet into the sand. Nowhere in this mine have I recorded the probable entrance of water into the mine through channels or joints directly from the sand. Water undoubtedly does come into the bottom from the sand, for it is scarcely presumable that when under a pressure of fifty or sixty pounds the water would not find its way into the mine along joint planes. However, the main observable supply of water comes into the mine from channels and joints in the roof. This water may, of course, come from the underlying sandstone by a circuitous route, and, in some instances, this is believed to be its source.

There are a number of recognizable faults of small magnitude in this mine, the greatest having a throw of six feet. This fault has a north and south strike and the downthrow side is to the west. Other faults of lesser magnitude were observed having strikes of N. 73° W., N. 87° W., N. 83° W., N. 45° E. and N. 70° W. The faulting is normal and along planes that are practically vertical. The faults do not have the same strike throughout their course but vary to the right or left making a zig-zag course. Neither have the planes a uniform dip. They may be vertical for a short distance, then dip to the right or left five or ten degrees. In most instances faults do not occur singly but in zones in which there are a number of approximately parallel joint planes along which displacement has occurred.

In case of the faults in this mine, it was impossible to determine whether they had their origin in the underlying sandstone or at the surface. In one instance, at least, the faulting was later than the galena. In this case the galena had been dragged into the fault plane, the pressure being sufficient to transform it from the usual crystallized type into an accicular form known commonly as steel galena.

Two instances were observed in which ore streaks terminated abruptly against what may be fault planes, and were resumed at a higher or lower elevation on the other side. In other instances the abrupt termination of the ore body next to a joint plane could not be attributed to faulting since there was absolute proof that there had been no displacement. In these instances the change in the position of the ore body was evidently due either to the direction given the circulating waters by the jointing or to variations in the composition and texture of the rocks on opposite sides of the joints.

JOINTING.

Observations taken throughout all the levels of this mine show that the jointing is more regular and best developed as the underlying sandstone is approached. The jointing is both vertical and inclined, but chiefly the former. As pointed out above with respect to the faults, a joint may change in dip and strike when followed vertically or horizontally.

The joint planes may be separated, for convenience, into three classes: 1st, Open channels along which the rock shows evidence of leaching and oxidation; 2nd, prominent joints, evidently not communicating directly with the surface and often partly closed with calcite and galena; 3rd, short, discontinuous joints, frequently filled with vein matter or perhaps lined with a frosty incrustation of calcite.

The open channels are the most persistent and in some instances can be traced throughout the length or breadth of the mine. They strike nearly east and west, varying from ten to twenty degrees, and are accompanied with parallel joints which together make up a zone of jointing. In several instances along the channels crystal aggregates of galena, some calcite and bunches of iron sulphide were observed. These channels are, however, especially characterized by the red clay which they contain and the weathering or leaching to a white or yellowish color of the wall rock. The two most prominent channels strike about N. 30° W. and N. 73° W. and can be traced from one end of the mine workings to the other.

The second class of joints are more numerous than the first. These occur in all parts of the mine being especially abundant at the lowest level. They are both vertical and inclined but chiefly the former. In these joints the galena and calcite may occur as extremely thin sheets or in small patches scattered through the openings between the walls. They may be open a half an inch or there may be practically no opening at all. In some parts of the mine they are very abundant and in other parts they are few in number or absent. Some of these seams contain iron sulphide, as well as calcite and galena. These seams are not as persistent as the channels but they are sufficiently well defined as to be traceable for a considerable distance. These seams strike in various directions but are chiefly parallel, or approximately parallel, to the open channels.

The third class of seams, which are spoken of as being short and discontinuous, are more abundant than either of the former. They strike in the main parallel to the others altho there are many which are almost at right angles, N. 10° to 30° E. being common. These joints are also frequently inclined. The dips are seldom very great, being usually 5° to 15° from the vertical. A dip of 45° was recorded in the case of two joints having an approximately E. and W. strike. It is interesting to note that in crossing these joints the continuation of the ore was found, in several instances, to be above or below the horizon at which it had been mined on the other side. In these cases no faulting was noticeable and it is thought that the joint planes simply served to direct the flow of the lead bearing solutions.

BRECCIATION.

Brecciation of the dolomite was observed in this mine only in association with the channels and caverns. At two places limestone fragments were observed along channels, in which cases the fragments were cemented with calcite. At one place a cavern five feet in diameter was filled with fragments of dolomite, cemented with calcite. The dolomite around the periphery of this cavern was also more or less broken. Other instances similar to this were observed and in all cases they appear to have been the result of solution and subsequent settling.

FOLDING.

Throughout the mine there are gentle dips and rolls in the roof which have the appearance of folds. In many places the beds were observed to dip from 5 to 10 degrees, but in every instance these dips die out within a short distance, the beds becoming horizontal or nearly so. In some places these rolls are plainly canoe-shape, usually inverted. In other cases they have a monoclinal aspect. The dips as a rule do not exceed ten degrees, and the amplitude of the folds varies from one to three feet. They usually do not have a length of more than 40 feet or a breadth of more than 10 feet. The axes of these folds strike in various directions, N. W. and N. and S. being the most common. The folds are more abundant in the lower level. The appearance of these rolls is shown in the accompanying illustrations.

These rolls are due in some cases to the thinning and thickening of the strata and in other cases to settling due to leaching, as shown by the occurrence of caverns and cavities underlying them. In other instances they are evidently due to the irregular floor upon which the sediments were laid down. I saw very little if any evidence from which one could conclude that these folds were due to orogenic movements.

The monoclinal folds or steep dips are apparently in some instances due to faulting, by which the beds on one side have been dragged down with respect to those on the opposite side. At least one instance of this was observed in this mine.

CAVITIES.

There are numerous cavities, vugs and caverns in the limestone which are wholly or in part filled with calcite, clay and galena. These are especially characteristic of this mine. Some of the caverns are five feet in diameter and from this the openings range down to a fraction of an inch. As a rule the clay which occurs in the cavities has a dark grayish to almost black color and is usually thickly studded with crystals of galena. Occasionally the clay has a greenish or light drab color. The walls of these "clay pockets" are frequently lined with crystals of galena, many of which are a combination of the octohedron and cube. Calcite is a usual accompaniment. The soft clay has every appearance of having been laid down at the time the limestone was deposited, altho it may have been introduced into the caverns at a later time, being transported to its present position by the groundwater circulation.

The calcite, pyrite and galena are all later than the limestone, and the calcite is mainly later than the galena, altho there is, in some instances, evidence of contemporaneity of deposition.

The larger cavities sometimes contain fragments of limestone and the beds above are frequently flexed, indicating a subsidence, probably resulting from the removal of the limestone. One instance was observed in which a cave ten feet in diameter was filled mainly with a limestone breccia. The fragments of limestone were cemented with "dog tooth spar" (calcite) and pyrite. This cave breccia was isolated and could in no manner be attributed to mechanical deformation.

WATER.

There is very little water entering this mine along joint planes or other openings. Water was observed entering the mine from some joints, chiefly those striking N. E.-S. W. and E.-W. Along several of these joints the rocks are stained yellow or reddish brown with iron oxide, and show leaching. Along others there is little or no evidence of oxidation. Some clay was also observed along two of the channels from which water was issuing. A part of the water from these channels undoubtedly enters the mine on its downward passage from the surface to the sand. The remainder by a somewhat circuitous route probably comes from the sand. The water entering the mine from some of these channels precipitates travertine which cements the debris into a mass of conglomerate. The travertine in this mine has a yellowish color due to the presence of iron oxide. The following is the result of an analysis of water taken from this mine:

	Grams per litre.		Grams per litre.
Lead Sulphate	0.00125	Magnesium Carbonate	0.08012
Zinc Sulphate	trace	Ferrous Carbonate	0.0003
Magnesium Chloride	0.0020	Alumina	0.00011
Magnesium Chloride	0.002	Silica	0.00733
Calcium Carbonate	0.13482		

The hole which was drilled into the Lamotte sandstone to a depth of 95 feet at the bottom of this mine shows that this formation differs sufficiently in texture and porosity to make the flow of water from different horizons very different. At a depth of 68 feet a coarse friable sandstone was struck, from which water flowed from a two inch orifice at the rate of about 150 gallons per minute. Above this the flow was only about 30 gallons per minute. From this one can readily understand how, through variations in structure or texture of the Lamotte sandstone, the water from this formation may enter the mine workings under either a high or low pressure. The pressure, of course, depends in the main upon the head.

BEDDING.

This mine is characterized by coarse and fine drained dolomite, either light or dark colored. There is some black or brown shale, but it usually occurs in non-persistent layers or lenses. There is comparatively little chlorite in any part of the mine. Between some of the thin, light colored dolomite beds, occur leaves of green shale. Rock of this character is usually barren, there being little or no galena either within the beds or along the bedding planes.

The bedding planes are, as a rule, irregular, having rough surfaces which are probably due mainly to processes of leaching and consolidation. Some of the beds thicken and thin, often dying out within narrow limits. Others are persistent and may be followed throughout practically the entire mine.

MANNER OF OCCURRENCE OF THE GALENA.

The ore body in this mine is characterized by extreme irregularity, being especially bunchy in the upper level. Rich and lean spots alternate with no apparent regularity. In the lower level the ore body exhibits greater regularity, altho having in general the characteristics of the upper level.

The galena in this mine occurs in the disseminated form; in sheets along the bedding planes; in veins filling joints; in cavities and small openings; and in aggregates of crystals along channels. A greater part of the ore is of the disseminated type, in which form the galena is a metasomatic replacement of the dolomite. It occurs mainly in the dark colored dolomite and black or brownish colored shale. The sheet galena is not important, the shale laminae along which it usually forms being an unimportant part of the formation. At certain horizons there are a great many thin veins of galena associated with calcite, which add an appreciable quantity to the available ore in this mine. The galena occurring in larger cavities, altho often furnishing rich pockets, is a minor source of supply of ore. The galena which has crystallized in small vugs, however, is of greater importance. Galena occurring in this form is often mistaken for the usual disseminated type which it resembles very closely. Aggregates of galena crystals in channels are not common, but were observed in several places.

The irregular, somewhat bunchy character of the ore may be attributed chiefly to the irregularities in the character and composition of the rock; to the absence of abundant prominent joints and channels; to the scarcity of black or brown shale; and to the leaching out of the galena subsequent to its introduction.

The illustrations on Plate LV. give a very good idea of the manner of occurrence of the galena in this mine.

FEDERAL NO.'S 2 AND 3.

These shafts are on property which was formerly owned by the "Derby Lead Company." They are located between the tracks of the Mississippi River and Bonne Terre and Illinois Southern railroads, nearly a mile south of the railroad stations at Elvins. Their location is shown on the geological maps accompanying this report. They were formerly known as Derby No's 1 and 2. These shafts are 10x20 feet in the clear and have three compartments. Number 3 was abandoned after being sunk to a depth of 527 feet. It is reported that the quantity of water entering the shaft was too great for the capacity of the pumps.

This mine was first operated in 1902, during which year the company reported an output of 534 short tons of concentrates. Since that year the mine has been operated almost continuously.

Shaft number 2 is 495.30 feet deep from the collar to the bottom of the lowest level. The collar of the shaft is at an elevation of 806.7 feet A. T., while the sea level elevation of the lowest level is 311.4 feet. This is next to the deepest operating shaft in the district, and the ore occurs nearer sea level than in any of the other mines.

The shaft starts about at the contact of the Derby limestone and the Davis shale. It passes through from 150 to 160 feet of Davis shale and goes into the Bonneterre limestone about 340 feet, stopping about 45 feet above the Lamotte sandstone. Two levels have been worked, an upper 470.4 feet below the surface and a lower 495.3 feet below the surface. The area of the underground workings of each of these levels up to 1908 is shown in Plate LVI. The relative position of the two levels in the formation is shown in the cross-sections, Plate LVII. Up to the time the above map was made nearly ten acres had been worked underground.

This mine differs from Mine No. 1 in containing very few vugs or other cavities. Most of the openings observed are along water channels. There is little evidence of leaching of either the limestone or the galena. In several places small vugs containing galena and calcite were observed, but their occurrence is exceptional. The ore body underlies the entire thickness of the Davis shale and can be in no way directly connected with shallow or surface deposits of ore such as occur near many of the other mines. No surface or shallow mining was ever carried on near this mine.

WATER.

From 900 to 1600 gallons of water enter this mine per minute, as shown by the following record of pumping, from June 1906 to February 1908:

Month and Year.	Shaft 2	Month and Year.	Shaft 2
June, 1906	1,456	May, 1907	1,066
July, 1906	1,490	June, 1907	1,148
August, 1906	1,578	July, 1907	1,120
September, 1906	1,240	August, 1907	1,120
October, 1906	1,092	September, 1907	1,230
November, 1906	1,040	October, 1907	1,270
December, 1906	990	November, 1907	1,217
January, 1907	1,002	December, 1907	1,221
February, 1907	1,000	Jan, 1908	1,200
March, 1907	1,024	February, 1908	1,045
April, 1907	1,266		

The mine workings intercept from twelve to fifteen channels, striking approximately N. E.-S. W., through which water under a strong head constantly enters the mine. Near both the east and west ends of the mine there are channels under which the water, when first encountered, showed a pressure of 90 to 100 lbs. per sq. inch. Some of the channels supply very little water, merely dripping from the roof. The water from these channels probably comes both from the underlying Lamotte sandstone and from the overlying Bonneterre dolomite. The water which enters along the inclined beds of the Bonneterre to the northeast is probably under considerable pressure at this place, provided it flows into the channels intercepted by the mine workings before entering the Lamotte sandstone. I believe, however, that the evidence at hand points to the probability that most of the channels have their origin at the top of the Lamotte sandstone and that if they were followed along this formation they would be found to expose a considerable surface of sandstone. In fact, in so far as I could observe, this is actually the condition.

FAULTING.

There are a number of recognizable faults in this mine but their throw is very slight, not exceeding a few inches. This minor faulting has occurred along joints striking N. 30°-33° E. and the downthrow in all but one case was to the southeast. The faulting is normal and the fault planes are vertical. In the east part of the mine, to which my observations were chiefly confined, the ore body does not appear to be in any way displaced as a result of faulting. These faults are a part of the general system of jointing in this mine, and as such are evidently younger than a part, at least, of the galena which occurs filling the spaces between the walls.

JOINTING.

The jointing is extremely well developed and maintains a persistency in direction not observed in many of the other mines. In the eastern part of the workings I observed thirty-five well defined joints having a strike of N. 30° to 45° W., chiefly N. 30°-33° W. Over the same area there were seven well defined joints striking N. 70°-85° W. and two striking N. 75°-87° E. Most of the joints were vertical or nearly so. The joints having a strike of N. 75°-87° E. were inclined to the north and south. Among the other joints the inclination is seldom more than 5° from the vertical.

The workings of this mine are practically all on one level and for that reason there is no evidence to show whether the joints originate at the surface or in the underlying Lamotte sandstone. It is clear, however, that the joints are extremely well defined at this level and it is doubtful if they continue upward to the surface. If they should continue to the surface, they would in all probability widen into channels but we have no evidence that such is the case. There is leaching and oxidation along the more prominent water channels but this in itself is no evidence that the water comes from the surface, in so much as the water from the underlying sandstone is oxidizing in character. It is also rather improbable that the channels observed in the mine continue upward through the Davis shale the full thickness of which overlies the Bonneterre limestone at this place.

The joints in this mine may be separated conveniently into three classes: 1st open channels; 2nd prominent joints, and 3rd short discontinuous joints. The first class includes the main water courses which contain occasional crystal aggregates of galena and calcite. They usually exhibit more or less oxidation along the walls due to the leaching of the adjacent dolomite.

The second class includes joints which may be followed for considerable distances, but which differ from the channels in being less open and in showing practically no decomposition along the walls. A prominent joint in one part of the mine may be a channel in another part, for which reason there is some difficulty at times in knowing in which class a joint should be placed.

In the third class I have included all joints which are confined to one or several beds. The so-called "slips" and "gash veins" would come under this class. These occur in different parts of the mine without any regularity. The openings which they make in the rock are often filled with thin veins of galena and calcite. Most of the joints carrying galena and calcite belong to the general N. E.-S. W. system.

There is no evidence in this mine of different generations of joints. Many of the joints are apparently tight but, when opened, galena is found adhering in thin films or spattered over the surface.

BRECCIATION.

No evidence of brecciation was observed in that portion of the mine which was examined. With the practical absence of faults and caverns such as occur in Mine No. 1, one would hardly expect to find breccias of any kind.

FOLDING.

The strata at this place have a general southwesterly dip. Other than this there is no evidence of folding. The bedding is undulatory, as is commonly the case, with the sedimentary strata of this area. The undulations or "rolls" occurring in this mine may be accounted for by original depressions in the oceanic floor and by the constant thinning and thickening of the strata as pointed out elsewhere. In the west end of the mine the roof is made up in part of a bed of dolomite, the under surface of which is very rough. This is probably due to both original and secondary causes, of which leaching and consolidation were especially important.

MANNER OF OCCURRENCE OF GALENA.

The ore body represented by the underground workings of this mine has been very regular, following very persistently the same general horizon. However, as shown by the cross sections, the ore body rises slightly to the west, altho the general dip of the formations at this place is to the southwest. Black shale occurs quite persistently throughout this mine, but otherwise the rock is a hard, tough dolomite, of a pinkish whitish or grayish, color. In the east part of the mine the ore follows close to a bed of "spotted" dolomite which looks much like a limestone conglomerate. The ore is sometimes a part of this bed and again it is above or below. This bed thins and thickens and in some places it is not associated with black shale. Everywhere in this end of the mine the galena is closely associated with black shale which occurs either in beds or in thin leaves between the thicker beds of dolomite. The rock above and below this horizon of spotted dolomite and black shale is, as a rule, a hard pink dolomite, having tight seams which are in places filled with galena. These seams filled with galena occur both above and below the spotted dolomite bed. The black shale, whether above or below, carries disseminated galena. The bulk of the galena, however, occurs above this bed. The spotted bed is somewhat shaly and usually contains some galena in a disseminated form. In several instances the galena was observed to occur along joints in this bed. Plate LVIII. shows the spotted bed with black shale, carrying disseminated galena both above and below. Where the little anticline shows the shale to be thickest, and extending upward from this into the overlying bed of dolomite, is a thin vein of galena. The galena above the spotted layer occurs chiefly disseminated through the middle of the layer of black shale. Underneath the spotted layer a ¾ inch layer of almost solid galena occurs between ¼inch laminae of very black shale. In the west part of the mine the galena is more generally disseminated through the dark colored shaly dolomite.

The richest portions of the ore body lie along well defined water channels which occur at irregular intervals. But even close to these channels the richness of the ore varies greatly. There is every reason to suppose that the solutions by which the galena was introduced into this horizon came from the Lamotte sandstone.

The galena occurs disseminated through the limestone and shale; in veins filling joints and cracks in the limestone; in sheets along the bedding planes; and crystallized in vugs. The galena frequently fills almost infinitesimally fine seams, the walls of which might deceive one as to the richness of the ore.

The wavy bedding planes, which are supposed to be due to sedimentation or perhaps in part to later solution and consolidation, are nicely shown in Plate LIX. Plate LX. shows examples of thinning and thickening of the strata such as are commonly exhibited in the mines of this district.

The manner in which the ore occurs in this mine is shown in Plates LVIII., LIX. and LXI.

MINE NO. 4.

The shaft of this mine was sunk in 1902 and in 1903 a main level was started at a depth of 390 feet. The shaft is located near Flat River about 3,000 feet a little north of west of shaft No. 1. The numerous mounds and cup like depressions on the hillside south of this mine give evidence of former activity in shallow mining in this vicinity.

The collar of this shaft is 800.42 feet above sea level. The sea level elevation of the upper level is 448.5 feet while that of the lower level is 411.7 feet. From the lower level there is an incline, the bottom of which is at a level of 383.5 feet. The upper level is 351.92 feet below the collar; the lower level is 388.72 feet below the collar; and the incline is 416.92 feet below the collar. A tunnel underground connects the workings of this mine with Mine No. 1.

This shaft passed through from 50 to 60 feet of Davis shale, the remainder of the distance being in Bonneterre dolomite. The "Incline" workings which run at an approximate elevation of 383.5 feet are only twenty to thirty feet above the Lamotte sandstone, while the bottom of the shaft is 40 to 50 feet above. This would make the thickness of the Bonneterre dolomite at this place about 385 feet. The main work up to this time has been at the 383 foot and 410 foot levels.

Plate LXIII. shows the outline of the mine workings up to the Summer of 1907. The cross sections Plate LXIV. show the relations existing between the different levels and the position of the ore bodies as developed to date with respect to the Lamotte sandstone.

Up to the time the mine map was made about six acres of ground had been mined, some of it at two levels.

WATER.

Considerable water enters this mine along the channels and other prominent joint planes, altho very little was encountered in sinking the shaft. Ten or twelve water channels were noted when the mine was inspected, and more may have been cut into since that time. At other places water was observed to drip from the roof. The water channels have a general strike of N. 75° to 88° W., and as a rule are open. The walls of the more prominent channels have been leached, the rock often being soft and whitish or yellowish in color.

Here again we have no means of knowing whether this water comes directly from the surface or enters by a circuitous route, first passing through the Lamotte sandstone. It is my impression that the joints in the main have their origin in the sandstone and die out as they are followed upwards into the Bonneterre dolomite. If such is the case much of the water probably enters from the underlying sandstone.

FAULTING.

There are several recognizable faults of minor importance in this mine. They all strike N. 80°-86° W. and have a throw of only a few inches, and with one exception the downthrow is to the south. This mine is situated just north of a fault zone which shows at the surface. The strike and throw of the faults recognized at the surface correspond with the strike and throw of the minor faults referred to above.

From the illustrations, Plate LXVII, one would infer that the faulting has in some instances been subsequent to the introduction of the galena. It is equally clear that calcite, pyrite and even galena have been introduced since the opening of these channels, since they were observed in crystallized masses within the openings. The determination of the age of the galena with respect to the faulting is uncertain, since it is difficult to tell just what effect the faults may have had in directing the circulation of the groundwater from which the galena was deposited.

JOINTING.

The main system of jointing is represented by the minor faults. In general this system strikes a little north of west, from 2° to 17°. Two joints carrying water were noted which strike N. 55° W. and N. 65° W. These have the greatest variation from the prevailing strike.

The short, tight seams are in the main parallel to the above system, altho an occasional N. 15° E. joint may be observed. The short seams are frequently filled or the walls lined with calcite and galena, in the manner described for the other mines.

There is no evidence in this mine of more than one generation of joints. Among these joints we have distinguished the three classes referred to in connection with the descriptions of the other mines, viz: 1st, open channels along which the rock shows evidence of active leaching or oxidation; 2nd, prominent joints along which the wall rock is fresh or but little altered; and 3rd, short, discontinuous joints, showing perhaps in one or several beds for a short distance and then dying out. There is no doubt but that joints of the first two classes may pass into each other, if followed a sufficient distance, just as they are known to appear in one part of the mine and to die out in another part.

BRECCIATION.

The only brecciation observed in this mine was such as occurs along the water channels. Here it is very subordinate and has every appearance of being the result of solution rather than mechanical deformation.

FOLDING.

The beds of dolomite exhibit occasional local dips and in several places gentle rolls occur in the roof. These are thought to be either the result of original sedimentation or subsequent solution and not due to thrust. There is a general northerly dip to the strata at this place.

MANNER OF OCCURRENCE OF THE GALENA.

The ore body in this mine has been of the normal type, showing only such irregularities as are common to most of the mines in the district. The richest ore has come from the deepest part of the workings. The mine contains a normal amount of black shale and the galena is quite uniformly associated with such horizons, altho not limited to them.

The galena occurs disseminated through the dark colored dolomite and blackish shale; in solid flat sheets along bedding planes next to the black shale; filling or partly filling open joints; and in caves, cavities and vugs with or without mud or calcite. The only associated minerals are calcite and pyrite. The calcite occurs chiefly with the galena in the open joints and cavities, while the pyrite occurs also with the sheet and disseminated deposits of galena. Very thin leaves and spatters of galena are of frequent occurrence along joint planes, as in the other mines.

The disseminated and sheet ore constitute the bulk of that which has been mined. The disseminated galena occurs chiefly in brown dolomite and dark brown or brownish black shale. The sheet galena occurs along bedding planes chiefly above or below the layers of dark colored shale.

Where the dolomite is broken with joints above or below the sheet galena these openings are often filled with galena. Calcite also frequently occurs with the galena.

There is considerable dense, light gray dolomite and greenish colored, shaly dolomite which contains very little galena except in thin seams. The soft decomposed dolomite adjacent to the channels is barren except where thick sheets of galena may persist up to the channels. Where this occurs the galena, as a rule, exhibits evidence of leaching.

One of the drill holes near the mine workings followed a thin vein of galena and calcite from near the surface into the upper ore horizon, which leads to the belief that a part of the galena may have been introduced directly by downward circulating water.

Plates LXV. and LVI. illustrate the manner of occurrence of the galena, these drawings being made from the richer parts of the ore deposit.

MINE NO. 5.

This mine was formerly owned by the Central Lead Company, having been acquired by them in 1898. It is located on a tract of land comprising 184 acres, then owned by "The Theodora Lead Co." With the other holdings of the Central Lead Company it passed into the hands of the Federal Lead Company in 1904.

The shaft leading to this mine is situated about 2000 feet

North 20° East of shaft No. 1. Between these two shafts there are a number of moderate sized sink holes into which water from the surface drains. Evidence of shallow mining may be observed not far from the shaft. The location of the mine and its position, with respect to the topography are shown on the map, Plate XLVIII.

The collar of this shaft is 799.56 feet above sea level. The sea level elevation of the top level is 590.1 feet while that of the lowest level is 466.8 feet. Between these, two intermediate levels have been worked by raises. The sea level elevations of these are 509.6 feet. The upper level is about 210 feet and the lowest level is about 333 feet below the collar of the shaft. A tunnel connects this mine underground with Mine No. 1.

This shaft was started and continued all the way in the Bonneterre dolomite. The collar of the shaft is just below the contact of the Bonneterre with the Davis shale, as shown on the geological map. Diamond drill holes indicate that the Bonneterre dolomite, near the shaft, is from 360 to 365 feet thick. The lowest level in the shaft is therefore about 30 feet above the Lamotte sandstone, while the other levels occur respectively 60, 71 and 151 feet above the sandstone. Both the upper and lower levels have been extensively developed. This ore body is connected with and is a part of the ore body mined by the St. Joseph Lead Company through their shaft No. 8, known as the "Crowley." There is evidence that it is also connected with the ore body at Mine No. 1.

Plate LXVIII. shows the outline of the mine workings up to the summer of 1907. The relations existing between the different levels are shown by the cross sections, Plate LXIX. Up to the time this map was made about six acres of ground had been mined, most of it at two levels and some of it at three.

The ore in the upper, or 210 foot, level is especially characterized by the irregular, bunchy manner of its occurrence. The ore in the lower levels has been more regular and persistent. In the upper level the ore body has run 80 to 90 feet in thickness in some places.

WATER.

This is what would be called, in this district, a dry mine. Very little water enters the workings either along open channels or along the ordinary joint planes. I have not recorded the entrance of water at any place in the 210 foot level, altho it is said that some water enters the mine at this level after rainstorms.

On the lowest, or 333 foot level, I have recorded the entrance of water into the mine mainly along two sets of joints, those striking about N. 70° W. and those striking about N. 35°-37° E. Two joints, one striking N. 60° W. and the other striking N. 52° E., also discharge water into the mine. Only a comparatively few of the joints striking in the directions indicated above carry water, most of them being relatively dry. The aggregate amount of water flowing out of these channels is small and varies with the rainfall. It is apparent that a considerable percentage of the water entering this mine comes from the surface, altho some of it may come from the underlying Lamotte sandstone.

FAULTING.

Altho there are a number of joints along which I am inclined to believe there is some displacement, I have a record of only two faults, one of which has a throw of a few inches to the south. This fault which is in the northwestern part of the 333 foot level has a dip of 10° to the south and a strike of N. 80°-85° W. The dolomite walls are leached and the rock in the vicinity exhibits abundant evidence of oxidation being partly filled with white clay.

In the northwest portion of the mine, in the 333 foot level, the ore terminates abruptly east of a N.-S. joint. A drift was run through about 400 feet of barren dolomite before this ore was encountered. This joint separating the barren rock from the ore is sharply defined and has a gentle inclination to the west. I examined this joint very carefully but was unable to detect any faulting. The ore body was later worked around to the east and northeast of the place where this joint was cut through. In this direction, however, the joint gradually died out. The ore body in this case was evidently not displaced by a fault but the lead-bearing solutions in their flow were directed along the opening formed by the joint, penetrating the rock on one side and not on the other.

The second fault referred to above occurs at the 210 foot level and consists of a much fractured zone. The strike of this fracture zone is about N. 40° W., but I was unable to determine the amount of displacement. The beds dip steeply at one place near this zone of faulting. Pyrite and calcite occur along the fault planes.

JOINTING.

The joints in this mine do not occur in such well defined systems as in some of the other mines already described. The most prominent system of joints in the lowest level strikes N. 70°-90° W., while the set next in importance strikes N. 50°-65° W. I observed in this level of the mine 17 joints striking N. 70°-90° W.; 9 striking N. 50°-65° W.; 1 striking N. 25° W.; 5 striking N. 50°-53° E.; 6 striking N. 25°-33° E.; and 3 N. 73°-83° E. The last set belongs with those striking N. 70°-90° W., making a total of 20 joints to be classified with the general E.-W. system. The N. 25°-33° E. and N. 50°-53° E. perhaps belong to the same general system, making in all eleven joints having a general N. E.-S. W. strike. Summarizing the jointing in this level we have 20 joints belonging to the E. W. system; 11 belonging to the N. E.-S. W. system; and 9 belonging to the N. W.-S. E. system.

In the upper level the N. W.-S. E. system totals eleven joints; the E.-W. system two; and the N. E.-S. W. system seven. The E.-W. system which is so well developed at a depth of 333 feet is the least conspicuous at the 210 foot level. It appears from this that the E.-W. system probably has its origin in the underlying Lamotte sandstone while the other systems which are about of equal importance at both levels probably persist to the surface. In fact the last two systems are better developed in the upper level, giving the appearance of increasing importance as the surface is approached. The joints are mainly vertical but may be inclined or irregular. They vary in strike, locally, as shown by the curved appearance of some of them.

Altho no attempt has been made to so classify them, the joints might easily be separated into, (1), channels; (2), prominent joints; (3), short discontinuous joints, as in the other mines. The channels show decomposition of the adjacent wall rock while the prominent joints do not. When followed vertically or horizontally one may pass into the other, depending upon whether they are closed or open. The short, discontinuous joints, have more the appearance of cracks and are usually confined to one or several beds, being entirely local.

BRECCIATION.

No brecciation was observed in this mine.

FOLDING.

In my examination of this mine I recorded a number of places at which the beds dip from 3°-25°, showing that in some parts of the mine they lie in irregular undulations. From these dips it has not been possible to determine any system of folding and from such observations as were made, it is evident that the dips observed at one level do not persist through the strata to the one above or below. In general, however, it appears that in the east part of the lowest level the dips are southeast, while on the west side of the upper level the dips are northwest. In the northwest part of the lowest level rolls with N.-S. axes were observed, as well as dips to the south and southeast.

It is difficult to make out any definite relation between the dips and the richness of the ore, altho in general one is left with the impression that the concentration is greater near the gentle arches or under the broader rolls of the strata.

MANNER OF OCCURRENCE OF THE GALENA.

The galena occurs in horizontal sheets along bedding planes; disseminated through the dolomite and shale; filling or lining the walls of joints; and in cavities, vugs and similar openings.

The horizontal sheets occur associated with thin laminae or beds of black or dark brown shale. The disseminated galena occurs chiefly in the dark colored dolomite, the chloritic dolomite and the brownish black shale. The veins or veinlets penetrate the light colored and greenish, shaly dolomite beds, as well as the darker colored dolomite. In these seams the galena occurs in the shape of "flat" cubes, usually associated with pyrite and calcite. In the more open channels along which the wall rock is decomposed the calcite is the preponderant mineral but embedded in it occur both galena and pyrite,—sometimes chalcopyrite. Where the galena is not enclosed in calcite it often shows leaching.

The ore in this mine contains a rather high percentage of pyrite, especially in the 210 foot level. It was observed in a great number of places, sometimes segregated in masses with very little galena. There are cavities filled with dark colored clay and galena, such as are illustrated in connection with the description of the ores at Mine No. 1.

In the 210 foot level there is more light colored dolomite and the ore occurs more in bunches than in the 333 foot level. In a number of instances the occurrence of beds of barren, light colored dolomite between dark colored beds of disseminated galena, apparently show the important part played by the dark colored dolomite in the abstraction of the galena from the groundwater. The shape of the ore body cannot be clearly understood from a mere examination of the mine maps, but it may be observed that in general the ore body at the upper level is much more irregular and bunchy than that at the lower level. This is also the case with the rich and lean spots in the ore body as pointed out in the general discussion of the origin of the ores.

In the lower level beds of chloritic dolomite and arenaceous, chloritic dolomite are encountered. Altho these beds are frequently rich in galena, I do not find any evidence in this mine to indicate that the chlorite has been in any way instrumental in bringing about this concentration.

There is no doubt but that in some places the galena occurs in a thinly disseminated form from the top of the upper level to the bottom of the lowest, as shown by drill holes in close proximity to this mine. However, the rock which occurs between the different levels is harder, denser and less shaly than that in which the ore occurs. The following drill record illustrates the continuity of the mineralization in places between the upper and the lower levels.

Depth in feet.	Description.
14-30	Yellow limestone.
30-82	White limestone.
82-137	Light gray limestone.
137-167	Gray limestone.
167-180	Light limestone.
180-194	Hard, dark gray limestone.
194-205	Porous, brown limestone.
205-207	Gray, shaly limestone. Well specked with galena.
207-211	Soft, shaly, white limestone.
211-212	Hard, light gray limestone. Well specked with galena.
212-213	Hard, yellow limestone.
213-214	Gray, shaly limestone. Well specked with galena.
214-215	Light gray limestone.
215-224	Dark gray limestone, considerable galena, 2 per cent.
224-231	Light brown limestone. Few specks galena.
231-239	Gray, shaly limestone. Rich galena.
239-242	Light brown limestone. Considerable galena, 2 per cent.
242-247	Brown limestone. Well specked with galena.
247-251	Gray, shaly limestone. Considerable galena, 3 per cent.
251-254	White limestone.
254-260	Shaly, dark gray limestone. Specks of galena.
260-290	Light brown and gray limestone.
290-292	Hard, gray limestone. Specks of galena.
292-351	Light, gray, shaly, chloritic, sandy limestone. Barren.

It is of interest to note that the lower sixty feet of the Bonneterre, where this hole was drilled, shows no galena. Were we to compare this with other drill records, it might be found that the galena occurs in the lower sixty feet of the formation, being absent entirely from the horizons which show the richest ore in this drill hole. Other holes would show little or no galena from top to bottom.

MINES NOS. 6 AND 7.

These mines were formerly owned and operated by the Central Lead Company, of which Mr. Arthur Thacher was president and under whose management the property was successfully developed. The shaft at mine No. 6 was known as the "Central," while that at Mine No. 7 was known as the "Rogers." The miners nicknamed the Rogers the "Tumble Bug." Shaft No. 6 is located about 2,580 feet S. 37°E. of Central station on the Mississippi River and Bonne Terre railroad. Shaft No. 7 is located about 1850 feet S. 55°E. of shaft No. 6. These shafts are located on the same ore body and the mine workings have been cut together.

Hundreds of shallow mines were worked in close proximity to these shafts, mining having been carried on here as early as 1820. The so-called Butcher diggings are located on the property formerly owned by the Central Lead Company. These shallow mines were seldom over fifteen or twenty feet deep, altho the crevices containing the red clay and aggregates of galena crystals are known to have persisted, in places, to a depth of sixty feet. An old shaft sunk by the Central Lead Company, prior to the sinking of the present shafts, followed a lead-bearing, clay filled crevice to a depth of sixty feet, where it opened into a large clay pocket containing massive galena. The crevice, altho contracting to about one foot continued below the clay pocket, keeping a general east and west direction.

I have carefully examined the location of these shallow diggings and with a few exceptions they are confined to the area over which the Bonneterre dolomite is the surface rock. Seldom were these shafts sunk through any considerable thickness of Davis shale and on this as well as on other lands in the district careful mapping of these ancient diggings would serve to locate approximately the contact between the Bonneterre and Davis formations.

To write the history of early mining on this property as well as to compile a record of production, distinct from that of the other mining properties of the district, would require more time than is at my disposal. Attention, however, should be called to the fact that the deposits of lead exploited by these shallow mines, were very rich and that the aggregate annual production should be thought of in terms of millions of pounds.

This land was first prospected with a diamond drill in 1876,

FEDERAL LEAD CO., SHAFT NO. 7.

As it appeared when owned by the Central Lead Co.

at which time some ore was encountered at a depth of 240 feet. A company was organized to develop the property but the attempt at that time was unsuccessful. However, in 1890, the company began sinking a shaft and at the same time resumed prospecting with a diamond drill. In May 1892 the shaft reached the ore body at the 242 foot level and upon this some drifting was done. In the meantime the diamond drill prospecting disclosed a richer and more extensive ore body at a depth of from 360 to 380 feet and it was decided to sink the shaft to this level. This shaft, the "Central," now "Federal No. 6," was completed during the Summer of 1893. The first production was in 1894. Shaft No. 7, formerly known as the "Rogers," was completed and in operation in 1901. From 1894 to 1904, when the Central Lead Company sold out to the Federal Lead Company, the total production, including that from the Theodora, was 38,700 short tons of concentrates valued at over three millions of dollars.

The collar of Shaft No. 6 is 791.84 feet above sea level. The floor of the main level at the shaft is 425.2 feet above sea level. The upper level (abandoned) is at 549.84 feet above sea level. From the lower level, one incline has been cut the elevation of the bottom of which is 397 feet. This shaft is 242 feet deep to the upper, abandoned level and 366.64 feet deep to the bottom of the lower or main level at the shaft.

The collar of No. 7 shaft is 776.71 feet above sea level and the bottom of the mine workings at the shaft is at an elevation of 427.7 feet. The shaft to the mine level is therefore 349 feet deep. There is only one level and as was stated above the mine workings are connected with those of Mine No. 6.

Both of these shafts were started and continued their entire distance in Bonneterre dolomite. Shaft No. 6 started about at the contact of the Bonneterre and Davis formations while shaft No. 7 started about 25 feet below the contact. The Bonneterre formation near No. 6 is about 385 to 390 feet in thickness, and in the vicinity of No. 7 it is 380 to 385 feet in thickness according to the records of drill holes. In the first case the bottom of the shaft is about 20 feet above the Lamotte sandstone while in the latter case it is about 16 feet above. The upper level at No. 6, which is 145 feet above the sandstone, was abandoned soon after the shaft was sunk. The lower level, which is the only one considered in this discussion, has been extensively developed as shown on the accompanying map. Mine No. 7 has been worked at the level of the lower workings of No. 6, with which it is connected.

Plate LXX. shows an outline of the mine workings at No's. 6 and 7 up to the Fall of 1907. Up to the time this map was made about 21½ acres of ground had been mined, chiefly at one level.

The ore in these mines is typical for the district. I found illustrated nearly all the variations in the character of the sedimentary rocks, and in the manner of occurrence of the galena that were later observed in the other mines. The jointing, flexuring and faulting are typically exhibited.

WATER.

Both of these mines receive considerable quantities of water which is discharged from channels into the mines and shafts. No. 7 receives more water than No. 6, especially after storms. In this mine there is evidence that some of the water comes directly from the surface through open channels. Not only does the amount of water pumped fluctuate with the rainfall, but following a heavy rainstorm the water entering the mine in some places is turbid with yellow clay. The mine workings extend under the bed of Davis creek, which, except after storms, is dry from a point some distance above the limits of the mine workings to where Shaw's spring empties into the branch. The water which flows in the creek above the southern limit of the mine workings disappears at a point where a fault zone is known to cross the stream bed. That the water actually enters the Bonneterre dolomite is evidenced by the fact that a part of the dry portion of the stream bed is massive limestone broken with well defined joints.

At one time an attempt was made to fill some of the channels at this place with cement concrete. In cleaning them out Mr. Frank Bellum, the mine captain, found large crystallized masses of galena between the walls. The attempt to shut out the water was only partly successful, since only a few of many channels in this zone were plugged.

During and after storms there is a considerable discharge of water into No. 7 shaft from a horizontal opening, at a depth of 90 feet. It has been suggested that the fluctuation in the quantity of water pumped from this mine may be due to the discharge through this opening. There is no doubt but that this water comes mainly from the creek, altho I do not believe that all the increased volume during the rainy periods can be accounted for in this manner. The discharge at this place is evidence, however, of a general surface circulation in a measure distinct from the circulation in the Lamotte sandstone and the base of the Bonneterre formation. There is likewise good reason to believe that there are channels through which the surface circulation may penetrate the lower part of the Bonneterre, and through which the circulation in the Lamotte sandstone, if under sufficient head, may reach the upper portion of the Bonneterre.

Altho a greater part of the water observed flowing into the mine has the appearance of coming from the surface, yet there are a number of places where the water appears to be rising from the underlying sandstone. I recorded an artesian flow from four or five holes drilled into the sandstone and from several open joints close to the wall. Altogether about fifty places were recorded where water was entering the mine along joints in the roof. Three or four localities were recorded where water was flowing out abundantly from between the beds.

The amount of water entering these mines is shown approximately by the record of pumping. The average quantity of water pumped per minute, monthly, is shown in the following table:

GALLONS PER MINUTE.

Month and Year,	Shafts 6-7	Month and Year.	Shafts 6-7
January, 1907	2,250	August, 1907	1,730
February, 1907	2,180	September, 1907	1,790
March, 1907	2,180	October, 1907	1,780
April, 1907	2,850	November, 1907	1,704
May, 1907	2,128	December, 1907	1,740
June, 1907	1,432	January, 1908	1,960
July, 1907	1,481	February, 1908	2,108

FAULTING.

Sixteen normal faults of greater or lesser magnitude were observed in these mines. The most conspicuous of these faults has a throw which was estimated at 20 feet. It strikes N. 83°-87°E. and dips to the north with the downthrow side in that direction. The beds on the downthrow side dip sharply away from the fault while those on the other side dip toward the fault. This is in fact a fault zone, of which two prominent planes of dislocation were noted. These planes converge downward and evidently unite not far below the bottom of the mine. This fault is shown in Figure LXXII. The other faults are much smaller, the throws ranging from a few inches to eight feet. Twelve of the faults have strikes ranging from N. 83° E. -N.73° W; one is N. 45° E.; another N. 55° E.; and the other two are about N. 65° W. The downthrow is in some instances to the south and in others to the north. The faults are as a rule vertical but in two instances dips of 20° and 30° respectively were observed.

In close proximity to the faults the rock is usually much decomposed and often broken. Water usually enters the mines abundantly along these channels. Frequently soft blackish or greenish shale fills the openings along these faults. This shale was probably in part dragged in from the shale beds through which the faults pass, altho it may have been washed in by the groundwater circulation. Slickensides have developed in a number of instances.

In two places I observed evidence of horizontal movement between the beds. In one instance a very much broken or brecciated bed was observed, the condition of which could only be accounted for by horizontal movement. In the second case I observed well marked striations on the under surface of a thick bed of brown dolomite. Their direction was such as to indicate an east and west movement between the beds, which is the direction of the strike of the principal faults and joints.

From the observations recorded, one would be inclined to the belief that most of the faulting was subsequent to the major introduction of the disseminated lead into the formation. From this, however, it should not be inferred that these channels are not avenues along which lead bearing solutions were introduced into the formation. This is refuted by the occurrence of galena in well crystallized cubes within the open channels.

It is possible, also, that in many instances the introduction of the galena is subsequent to the faulting, since the displacement of beds containing disseminated galena does not necessarily argue in favor of the introduction of the galena prior to the faulting. The galena would be deposited only in such beds as furnish the necessary reducing condition, irrespective of their position due to faulting or flexuring. Several of the faults in these mines are illustrated on Plates LXXII and LXXIII.

JOINTING.

As in the other mines, the joints may be considered in three classes, (1) channels, along which the rock shows evidence of active leaching or oxidation; (2) prominent joints, along which the wall rock is fresh and apparently unaltered; and (3) short, discontinuous seams, showing perhaps in one or several beds for a short distance and then dying out. As stated above joints of the first class may pass into those of the second class and vice versa, if followed far enough, either horizontally or vertically. This I have shown to be true by actual observation.

Of the first class I have observed and recorded thirty-four, exclusive of faults. These channels strike chiefly N. 83° E.-N. 83° W. Only a few vary as much as eight or ten degrees on either side of this zone. Of the second class I have observed seventy-five, most of which are approximately parallel to the channels. Likewise most of them are vertical or inclined only a few degrees. Among these joints I observed only one that approached near to having a N. and S. strike. Seven approached closely to having a N. 45° E. strike, while several had a nearly N. W.-S. E. strike.

I made twenty-eight observations on joints of the third class. These indicate that the strike of this class of joints is mainly about N. E.-S. W. or N. W.-S. E. A few having approximately E. and W. and N. and S. strikes were recorded. Most of the water entering the mine comes from the channels and prominent joints having an approximately E.-W. strike.

The joints occur in zones, some of which continue practically through the length of the mines. It is especially noticeable that the ore has been richer along, or in close proximity to these zones of jointing than elsewhere. So striking is this association that one is immediately led to presume that there is some connection between the two. It is also equally evident that the ground water traveling along the zones has in some instances abstracted the galena, as evidenced by its almost complete absence from the brown, yellow and white rock bordering these channels.

Altho there was no opportunity to observe the possible continuation of the joints and faults at higher levels, I am impressed with the belief that a considerable number of them have their origin at or below the top of the underlying Lamotte sandstone and that they do not continue to the surface. This is in accord with my observations in other mines of this district.

BRECCIATION.

In one place a bed was observed, which has every appearance of having been broken as a result of horizontal movement of some kind. In addition to this there is more or less brecciation of the dolomite adjacent to the major faults. This is evidently attributable, in part, to the movement through which the displacement was brought about, altho in some instances solution has played an important part. This brecciation, as a rule, consists merely of an occasional fragment of limestone embedded in shale or clay.

FOLDING.

No system of folding or flexuring could be worked out in these mines from the data which I gathered during my examination. Between No. 6 and No. 7 the workings rise over what appears to be a ridge but which is chiefly an expression of the position of the ore body. The beds are in a practically horizontal position, therefore the rise is not due to folding or flexuring. There is some evidence, however, that the Lamotte sandstone rises higher at this place than it does to the northeast or southwest, which might account for the position of the ore body.

Local dips of 5, 10 and 15 degrees are common but they do not persist for any great distance and in the main are the result of sedimentation and solution. The principal exception to this rule is in the case of beds that are in close proximity to a fault. In such cases the dips are undoubtedly due to the movement of the strata up or down with the resultant drag on the exposed ends of the beds.

In some places I had an opportunity to observe the so-called rolls in the roof in their entirety. They vary some in length and breadth but in amplitude they seldom exceed a few feet. Sometimes they are simple anticlines but more often they are of a monoclinal character. Their axes do not all strike in the same direction but east and west seems to be the most common.

The character of these flexures or rolls are well shown in the figures, Plate LXXI. They appear, in some instances, to have had a local but not persistent influence in the concentration of the galena.

MANNER OF OCCURRENCE OF THE GALENA.

The galena occurs disseminated through the dolomite and shale; in horizontal sheets along bedding planes; filling or lining the walls of joints; in vugs and cavities; and occasionally in cubes or aggregates of cubes in the red clay of the channels and larger faults.

The disseminated galena, which is everywhere the dominant type of ore, occurs as elsewhere chiefly in the dark colored limestone and shale. It also occurs in the chloritic beds and sparingly in the light gray limestone. It is frequently associated with pyrite which often predominates in the lighter colored varieties of chloritic limestone.

The horizontal sheets are chiefly associated with thin laminae of black or brown shale lying between beds of limestone. This is one of the important ways in which the galena has occurred in this mine, the sheets occasionally having a thickness of six or eight inches. There appears to be every gradation between shale with a little disseminated galena and galena with a little disseminated shale. In case the bed is practically all galena it is classed with sheet galena, even though it may be simply a very much enriched bed of disseminated ore.

The galena occurs less abundantly along joints than in some of the mines already described. The veins, however, contribute very materially to the output and may be considered one of the important modes of occurrence. Galena in veins is usually associated with calcite and occasionally with pyrite.

Vugs and cavities containing galena are not abundant, altho they were noted in the examination.

Crystals and crystal aggregates have also been obtained from the openings along channels and fault planes, usually embedded in the red clay. As a rule galena which occurs in these oxidized zones is more or less corroded, the corners of the crystals being rounded off and the whole frequently coated with a thin grayish white film of lead carbonate.

That portion of the ore body which is rich enough to be worked is very irregular in its vertical as well as its horizontal dimensions. The first ore encountered in sinking shaft No. 6 was at a depth of 242 feet and upon this some work was done prior to sinking the shaft to its present level. The lower level occurs at a depth of 366.62 feet or 124 feet below the first level. The drill holes likewise show a wide range in the vertical distribution of the ore. This is not shown on the mine map, which represents simply the lower level. The irregularities in the horizontal distribution of the workable ore are well shown on the map.

The manner of occurrence of the galena is shown by the drawings on Plates LXXIII. and LXXIV. These illustrate not only the position of the galena with respect to the several kinds of rock but also its relation to the joints and faults.

In a number of instances the galena was observed to die out as the decomposed zones adjacent to the channels were approached. In one instance the ore continued to within three feet of a fault, thin streamers alone reaching almost to that point. On the other side of the fault the character of the rock was different and there was no galena. In one place three joints striking N. 60° W. were followed to where they died out. The ore gradually decreased in thickness with the dying out of the joints giving one the impression that they bear some relation to each other. On the south side of a N. 83° W. joint having a dip of 40° N. to 5° N. the ore is about 15 feet higher than on the other side. At another place I have recorded a fault of 3 feet with a corresponding variation in the position of the ore. In this case the ore regains its normal elevation on the downthrow side a short distance from the fault as shown on Plate LXXIII. In another place I observed a fault of 6"-8", along the plane of which galena and pyrite occur. Galena occurs on both sides with no apparent difference in richness.

A vertical joint striking N. 73°-75° W. shows at two places with no change in the character of the ore. Another east-west, vertical, open channel passes through the ore body without affecting it. At the north end of what was known as the office drift of shaft No. 6 the rock became barren after crossing a zone of N. 85° W. joints, altho in places the ore continued beyond these joints 4 or 5 feet. These joints dip south about 20 degrees. At another place the joint noted above was vertical, the rock being barren on the north side. The beds dip 15° N. 55° W. on the north side at one place while on the south side at another place they were observed to dip to the south. Near the middle of the southeast side of this drift there is another channel from which water flows freely. Along this channel to the west the ore occurred with uniform richness on both sides but as it was followed to the east the ore gradually thinned on the south side until it finally died out. With the thinning of the ore there was a tightening of the channel. The channel to the west opens up and becomes very prominent. In the southwest end of this drift there is a N. 50° E. joint on the southwest side of which the rock is nearly barren, altho on the other side there is good ore.

The above illustrate the conditions present in these mines and show clearly the relations existing between the joints and faults and the ore. They indicate that the position of the ore has not only been influenced by faulting but that in some manner the joints and faults have directed the solutions carrying the lead salts, thereby determining the zones of local enrichment.

In discussing the sedimentation of the Bonneterre formation it has been pointed out that the rock changes horizontally, shaly beds giving way to hard dense dolomite and vice versa. This condition was observed in the mines under discussion and in every instance noted where this change occurs the galena also decreases in quantity or entirely disappears in the dense dolomite. Knowing as we do from observations that the composition of the beds controls to such a degree the occurrence of the galena, it is reasonable to infer that the faulting may have been prior to the introduction of the galena and at the same time the galena so deposited as to give the appearance of the ore having been faulted. The following figure illustrates a case in question.

It is not to be expected that the deposition of the galena would continue from a shale bed on one side of a fault to a finely crystalline dense dolomite on the opposite side. The solutions would in all probability follow along the fault, joint or bedding plane, abstraction of lead going on only where the composition of the rock is favorable. If faulting has caused these conditions to end abruptly the reduction and resultant concentration of the galena will end equally as abruptly. At least it has been observed in the mines, that, as a rule, as the composition of a bed changes horizontally, so does the percentage of galena.

There is evidence in these mines that in some places the galena continues for a few feet into the Lamotte sandstone However, it is not known to occur in quantity and richness sufficient for exploitation.

There is some evidence of leaching of the galena, this phenomenon being best exhibited in close proximity to the channels where the dolomite has been decomposed. Elsewhere, however, I have observed galena individuals with etched surfaces, which is taken as evidence of leaching.

MINE NO. 8.

This mine was opened after I had completed my examination of the other mines in the District. It is located just west of the Mississippi River and Bonne Terre Railroad depot at Central, on a forty acre tract which was a part of the land formerly owned by the Central Lead Company. The shaft was started in April, 1907.

The collar of the shaft at this place is 781.53 feet above sea level. There is only one level and this is at an elevation of about 328 feet A. T. The mine workings are therefore 452.83 feet deep.

The shaft passes through 100 feet of Davis shale, continuing the remaining distance in Bonneterre dolomite. The bottom of the mine workings is about 20 feet above the Lamotte sandstone, according to the records of drill holes in the immediate vicinity of the shaft.

There has been comparatively little ground mined at this place, the total area of the mine workings being about one and one-half acres. This ore body is evidently a continuation of that which is worked by the Doe Run Lead Company at their No. 2 mine, and occurs at about the same elevation above sea level.

MINES NO'S. 9 AND 10.

These might more appropriately be called Shafts 9 and 10, no ore having been mined since the sinking of the shafts in 1907. No. 9 shaft is located near the center of the S. W. 1/4 of Sec. 16, T. 36 N., R. 5 E., about 1½ miles in a direct line southeast of shaft No. 1. Shaft No. 10 is located near the center of the N. E. 1/4 of Sec. 21, T. 36 N., R. 5 E., and nearly 2½ miles almost directly southeast of shaft No. 1. Shaft No. 9 was started October 27, 1906, and shaft No. 10 December 15, 1906.

These shafts are both located in an area which only recently has been prospected. It is one of the very hilly portions of the county and owing to the yellow pine that grows on the hillsides, it has been known as the "Pinery." This area is especially characterized by a heavy mantle of residual clay and gravel, which, as explained in a preceding chapter, is thought to be Tertiary.

The collar of No. 9 shaft is 1093.5 feet above sea level. The bottom of the shaft is 591 feet above sea level, making the depth 502.5 feet. This shaft passed through 135 feet of residual material, 114 feet of Davis shale and penetrated the Bonneterre dolomite 253.5 feet. The bottom of the shaft is 127.0 feet above the Lamotte sandstone.

It is interesting to note that in this area the main concentration of galena occurs a hundred or more feet above the Lamotte sandstone. Out of the records of thirty holes drilled in close proximity to this shaft only two showed the presence of galena close to the Lamotte sandstone. These showed three feet of 1.5% ore and three feet of 10%. Two other holes encountered three feet of 3 to 4.5% ore fifty feet above the sandstone. The ore nearest the surface was encountered seventy-six feet from the surface of the Bonneterre dolomite. In a number of holes ore was encountered at depths of from 120 to 160 feet below the top of the Bonneterre.

The collar of No. 10 shaft is 1059 feet above sea level. The bottom of the shaft is 612 feet above sea level, making the depth 447 feet. This shaft passed through about 72 feet of residual material, 144 feet of Davis shale and penetrated the Bonneterre for-

ST. LOUIS SMELTING AND REFINING CO.

1600-ton concentrating plant.

mation 386 feet. The bottom of the shaft is 155 feet above the Lamotte sandstone.

The position of the ore with respect to the Lamotte sandstone is about the same at this shaft as at No. 9. In none of the holes drilled to the sandstone was ore encountered closer than 118 feet, and here in only one hole out of fifteen. The greatest concentration of galena appears to be from 135 to 165 feet above the sandstone, while galena has been encountered up to within 135 feet of the top of the Bonneterre.

The lower 100 feet of the Bonneterre presents as favorable rock for the concentration of galena as elsewhere in the district and there is no apparent reason why the ore should not occur at this horizon except that it has not been saturated with lead bearing solutions. The explanation must be either the absence of fracture zones connecting with the surface or deep circulation, or the absence of lead salts in the water circulating through that part of the formation. The condition presented in the area around Shafts No's. 9 and 10 is best explained by supposing that the lead was here introduced by downward circulating water. Decomposition has probably not progressed far enough to form channels reaching from the surface to the sandstone through which there might be a free communication between the circulation near the surface and that in the Lamotte sandstone.

The position of the main concentration of the galena in this area is shown by the drill hole records, Plate LXXVII., selected from various parts of the area:

ST. LOUIS SMELTING AND REFINING COMPANY.

This company, also known as the National Lead Co., owns 1284 acres of land all of which is located within a radius of two miles of Flat River station of the Mississippi River and Bonne Terre railroad. The present Superintendent, Mr. Charles Schwarz, informs me that this property was purchased from the Flat River Lead Company in May, 1898. At that time there was one shaft on the property, now known as shaft No. 1. This shaft has a depth of 332 feet. In 1894, the Flat River Lead Co. made 750 tons of concentrates valued at $22,500. This was the only production prior to the purchase by the present owners. Not long after the company began operations, the mine workings were flooded and no more ore was hoisted out of this shaft.

The St. Louis Smelting and Refining Co. purchased 690 acres of land from Mr. Wm. R. Taylor, in addition to that obtained from the Flat River Lead Co. All of this land was prospected with a diamond drill before being purchased. The office, mill and power plant of the company are located at St. Francois station on the Mississippi River and Bonne Terre railroad.

The present company began sinking shaft No. 2, August 28, 1898, and the first production from this mine was on July 28, 1900. Since that time the output has constantly increased until the value of the concentrates now exceeds a million dollars per annum.

The company now has five shafts on its property, four of which are being operated. Shafts No's 1 and 2 are located on the same ore body, about 690 feet apart. The mine workings at No's 1 and 2 are connected underground with Mine No. 3. Mines No's 4 and 5 are each separate.

All of the ore obtained from these several mines is concentrated at the mill, located just east of the office. The concentrates are sold to the National Lead Co., being shipped to their smelters at Collinsville, Ill. The plant is furnished throughout with electrical equipment, supplied from a central plant located adjacent to the mill. The mill has a daily capacity of 1,600 tons.

There has been produced from this property since the first shaft was sunk up to Dec. 31, 1906, 100,545 short tons of concentrates, valued at $4,622,798. Up to Jan. 1, 1908, the company had mined a total of about 47 acres.

MINES NO'S. 1 AND 2.

The shaft at mine No. 1 was sunk in 1893 to a depth of 332 feet. During 1904, 750 tons of concentrates were produced, after which the mine was flooded and permanently abandoned. This shaft was sunk when the property was owned by the Flat River Lead Co., but owing to its small size, it was not unwatered after the property was purchased by the present owners.

Shaft No. 2 was started August 8, 1898, and the first ore was hoisted May 27, 1900, from the 319-foot level. During that year, 3064 short tons of concentrates were produced. The plant connected with this mine was completed, essentially as it stands today, in July, 1901.

This shaft is located about 825 feet east of St. Francois station on the Mississippi River and Bonne Terre railroad. Shaft No. 1 is located 690 feet southwest of shaft No. 2.

Shaft No. 2 was sunk against a flow of 450 gallons of water per minute which came in from a horizontal channel 208 feet from the surface. That the water discharged from this channel came from the surface circulation is shown by the cinders and chat carried in with the water. This mine is now one of the driest in the district, some parts of the underground workings being actually dusty.

The collar of shaft No. 2 is 791.3 feet above sea level. The mine workings are at three levels, the ore lying chiefly at the two lower levels, the bottoms of which are respectively 384.3 feet A. T. and 472.3 feet A. T. The upper workings are known as the 319 foot level and the lower as the 407 foot level. This shaft is supposed to have started at about the top of the Bonneterre formation, altho its depth would indicate that it passed through about 30 feet of Davis shale. In either case the mine has been worked down to the Lamotte sandstone. Most of the ore from this mine has been obtained from the lower 150 feet of the Bonneterre dolomite, some of the lower beds of which are sandy, giving the impression that the galena extends into the Lamotte sandstone.

Plate LXXVIII. shows an outline of the underground workings of mine No's. 1 and 2 at the 319 foot level up to March 1, 1908. The cross sections accompanying this map show the general position of the ore body with reference to the Bonneterre and Lamotte formations. Up to the time this map was made about 19.7 acres of ground had been mined practically all from two levels. The ore occurs in essentially the same manner in these mines as it does in the mines which have been previously described. The character of the sediments; the jointing, flexuring and faulting; and the effects of solution are all fully illustrated in different parts of these mines.

WATER.

As noted above, a considerable flow of water was encountered in sinking both of these shafts, No. 1 having been drowned out after being operated for a short time. The quantity of water being discharged into these mines through channels, drill holes and other openings is not very great, being insufficient at times to supply the mill.

The seasonal changes have some effect upon the quantity of water entering these mines but we have no data to show the fluctuations. There is undoubtedly a constant supply of water from the Lamotte sandstone, the variation in the quantity pumped being mainly attributable to the surface circulation. It is interesting to note that twice the water in the pond located just south of the mill has flowed into the mine. This pond was actually drained through a channel into the mine nearly flooding it. After the water had been completely drained from the reservoir, the channels were closed by driving piles and filling with concrete, in this way effectually stopping the entrance of the water from the reservoir. This illustration in itself is conclusive evidence that the surface circulation enters the mine along channels.

Most of the water enters through channels which strike approximately east and west. Water also drips from the roof, seeps out along bedding planes, and issues from underground drill holes. In a number of places a dark red, iron oxide precipitate is deposited from the water entering the mine. In other places I observed a precipitate of calcium carbonate forming along the walls of some of the open channels and on the bluffs over which the water flows. In some instances this precipitate is sufficiently abundant to cement the fragments of rock on the floor into a mass resembling a breccia. In one place a crust, 1/8 to 1/4 of an inch in thickness, had formed over the surface of some soft, sticky red clay which had entered the mine from one of the channels.

There is very little evidence in this mine that the water comes directly from the underlying Lamotte sandstone. Nevertheless, the extensive oxidation and decomposition of the dolomite in the lower part of this formation, leads to the inference that a part at least of this lower circulation comes directly or indirectly from the sandstone.

FAULTING.

At six different places in this mine, faulting was recognized. In each instance the amount of throw was slight, not exceeding 1½ feet. In two or three instances, the throw could not be determined.

One of the faults has a strike of N. 83° W. with a throw of 2 inches to the north. There is considerable calcite between the walls of this fault. Another fault has a strike of N. 65° W. with a displacement of six inches. The rock parallel to this fault is badly broken with parallel joints. Another of the faults has a strike of N. 83° W., a dip of 30° N, and an undetermined downthrow to the north. Another of the faults has a strike of N. 83° W., a dip of from 5°-6° N. E., and a throw of from 16 to 18 inches, as shown in Plate LXXIX. Another of the faults has a strike of N.

40° W. and a dip of 6°-7° S. W. The amount of displacement could not be determined. The last of the faults recognized has a strike of N. 55°-60° W. and a dip of 10° S. W. Here also the amount of displacement could not be determined. The openings along the last named faults are filled with dark colored shale and galena. The galena in this instance appears to have been introduced since the faulting.

As the reader will observe, these faults do not differ essentially from any of those described for the other mines of this district. Part of them are characterized by smooth, even walls, while the walls of the others are rough and more or less irregular. The degree of dip changes from one place to another as does also the amount of displacement. I believe, that these faults have their origin at the base of the Bonneterre formation and that they do not extend to the surface. They are all normal and effect the formation only locally.

JOINTING.

The joints in these mines have been roughly classified as follows, viz: (1) channels along which the rock shows evidence of leaching or oxidation; (2) well defined or prominent joints along which the wall rock is fresh and apparently unaltered; and (3) short, discontinuous joints which show in one or perhaps several beds for a short distance. Joints of the first and second classes may pass into each other when followed from one part of the mine to another. It is also possible that in some cases joints of the third class may be merely continuations of joints of the second class. These joints, however, are generally found in the unaltered dolomite and seldom does one observe any water entering the mine through them.

I recognized six joints of the first class, none of which showed evidence of faulting. Five of these had strikes ranging from N. 85° E. to N. 80° W., while one had a strike of N. 63°-65° E. The channels therefore strike in general E. and W. With one exception they are vertical and in the exception noted, the dip was 10° N. This dip, however, may be local and the channel, as a whole, may be essentially vertical. Out of most of these channels, some water flows, altho not in such abundance as has been observed in other mines in the district. One of these channels is plugged with wedges in one place to confine the water.

Out of one of the channels, considerable broken rock had fallen, leaving openings of considerable size. The limestone close to the channels is usually badly decomposed and the channels frequently contain some soft red clay.

In these mines I located 65 joints of the second class, 28 of which had a strike of from N. 70° E. to N. 70° W. Seventeen had a strike of N. 50°-70° E. Sixteen had a strike of N. 50°-70° W. The remainder had varying strikes outside of those classified above. All of the faults observed were along joints of this class. As a rule, the joints are vertical, only seven or eight dipping from 2°-10° from the vertical. Some water enters the mine along these joints, but as a rule, they are comparatively dry.

These joints exhibit the same irregularities as those occurring in the mines previously described. The openings along some of them contain galena embedded in a matrix of calcite forming an irregular calcite-galena vein. These veins are sometimes an inch to one and a half inches in width.

I located 30 joints of the third class, ten having a strike of N. 45°-60° E.; eight having a strike of from N. 45°-60°W.; nine having a strike of N. 60°-75°W.; and three having a strike of N. 60°-75° E. Most of these joints are what might be termed gash veins. They are short and usually have their walls covered with calcite or galena with which they are sometimes filled. The joints are usually sharply defined and clean cut. The character of these veins is shown in Plate LXXX. In some parts of the mine they are very abundant but the quantity of galena which they contain is in the aggregate not very large.

All of these joints have assisted in the introduction of the lead bearing solutions into the horizons where reduction has been possible through the presence of organic matter.

BRECCIATION.

The only brecciation observed in these mines is that which has resulted from solution along the channels. The occurrence of fragments of limestone in the open parts of the channels has been noted above. In addition to this, there are occasional areas of broken limestone re-cemented with calcite. These are entirely local in extent and are altogether the result of solution.

FOLDING.

In many parts of the mines I recorded dips of from 5°-10°, but they were apparently local, extending only a short distance before becoming horizontal. In some places I observed well defined rolls in the roof some of which were due entirely to a thickening and thinning of the beds as a result of inequalities in sedimentation. These rolls vary considerably in length and breadth sometimes giving the beds simply a wavy appearance. The maximum dip observed was 20°, but this, as in the case of the gentle dips, was entirely local. That these dips are due chiefly to irregularities in sedimentation is well shown in Plate LXXIX. In some instances the dips are undoubtedly due to leaching, with subsequent settling, and to minor faulting. As a rule, however, they appear to have been occasioned by irregularities in sedimentation.

BEDDING.

In many places the bedding planes are rough and billowy in character. The beds in some places thin and thicken very rapidly, disappearing entirely within a distance of three or four feet. This is especially true of the beds of black shale, the distribution of which is often very irregular. In one instance I observed wave-like depressions filled with black shale. At another place I observed what appeared to be cross bedding. These irregularities in bedding are illustrated by Plate LXXIX.

The rock in this mine consists of light and dark colored dolomite, black, bluish and greenish shale, chloritic dolomite and arenaceous dolomite. Some of the dolomite beds have a conglomeritic appearance due chiefly to irregular laminae of shale distributed through the body of the rock. In some places the dolomite is dense and finely crystalline, while in other places it is coarsely crystalline and rather porous. The dolomite appears to have been thoroughly recrystallized since the sediments were deposited.

Adjacent to the channels and along some of the bedding planes the rock has been very thoroughly decomposed. Most of the galena contained in these beds has been removed, altho in some places it remains in the form of the carbonate. Near the bottom of the formation, I observed in several places, beds which were more thoroughly decomposed than any which have been observed in the other mines at this level.

MANNER OF OCCURRENCE OF THE GALENA.

The galena occurs in the following ways, namely: disseminated through the dolomite and shale; in horizontal sheets along bedding planes; in vugs and cavities; filling and lining the walls of joints; in aggregates of cubes in the channels; and in the form of lead carbonate in the decomposed dolomite.

As in the other mines, a greater part of the galena is obtained from the disseminated type of ore. The disseminated galena occurs chiefly in the dark colored dolomite and in black or brownish beds of shale. To a lesser extent, it occurs in the chloritic beds and in the light colored dolomite. The richest ore is everywhere associated with the black shale and the dark colored dolomite. This mine has been especially characterized by the thickness of the deposits of the disseminated ore. In some places this ore has a thickness of from 30 to 40 feet, the richness varying with the character of the dolomite. The lighter beds which occur at this horizon, usually contain very little galena.

Horizontal sheets of galena are not abundant in this mine. I noted several places where thin sheets occurred along the bedding planes, but this appeared to be the exception rather than the rule.

Occasionally, cavities and vugs lined or filled with crystals and galena, usually associated with calcite and embedded in black clay, were noted in different parts of the mine. In two or three instances chalcopyrite was also associated with the galena and calcite. The character of these pockets is illustrated in Plate LXXIX.

Some aggregates of galena crystals are reported to have been found in the channels, but I did not observe any during my examination. This is a very unimportant source of ore.

Short, discontinuous joints more or less filled with calcite and galena are common. In some parts of the mine, they are abundant. The calcite and galena are frequently smeared along the walls of very tight joint planes and in other cases the galena is spattered along the walls in extremely thin films. Plate LXXX. is a typical illustration of the manner of occurence of these veins. They constitute a somewhat important source of galena in some parts of the mine. In the case illustrated, the solutions evidently entered these joints from above, since they clearly die out below and I was unable to find any other avenue for the solutions to enter except from above. Associated with the calcite and galena, I frequently observed crystals of pyrite.

Samples from the decomposed beds of disseminated ore near the bottom, were analyzed and shown to contain a considerable percentage of lead carbonate. One sample showed 20.9 per cent of lead carbonate, another 5.5 per cent of lead carbonate, and a third 1.4 per cent of lead carbonate.

There are numerous illustrations of leaching of the galena,

ST. LOUIS SMELTING AND REFINING CO.—MINE NO. 3.
View of the underground workings.

especially of the disseminated type. In a number of places I recognized this as one of the reasons for the extremely lean character of the ore deposit in certain parts of the mine. In fact crystals of galena which were undergoing decomposition were observed in a number of places. Adjacent to the channels, the disseminated galena is almost entirely removed where the rock has been completely decomposed. In this mine, there is every evidence that the disseminated galena is taken into solution much more readily than that which is crystallized in openings such as solution cavities and joint planes.

MINE NO. 3.

This mine is located 2700 feet north of St. Francois station on the Mississippi River and Bonne Terre railroad and the same distance a little west of north of shaft No. 2. The sinking of the shaft leading to Mine No. 3 was begun June 14, 1899. Mining operations began in May 23, 1900. The collar of this shaft is 839.8 feet above sea level, while the bottom of the mine workings are 448.8 feet above sea level. The shaft is therefore 387 feet deep measured to the bottom of the mine workings. This shaft begins near the contact of the Davis and Bonneterre formations and continues almost through the entire thickness of the latter. All of the ore obtained from this mine has come from the lower 60 feet of the Bonneterre formation.

Plate LXXXI shows an outline of the underground workings of mine No. 3 up to March 1st, 1908. The cross sections accompanying this map show the general position of the ore body with reference to the Bonneterre and Lamotte formations. Up to the time this map was made, approximately 20 acres of ground had been mined, all at one level. The ore occurs in essentially the same manner as it does in the mines previously described. The relations which sedimentation, jointing, flexuring and faulting have to the distribution of the galena are well illustrated in different parts of this mine.

WATER.

It is impossible from any figures which we have at our command, to show the variation or the possible effect which precipitation has upon the amount of water pumped. It is evident, however, that the quantity of water entering the mine, which is relatively small, is in a measure proportionate to the rain fall.

The water enters this mine chiefly along the prominent seams, which have a strike of from N. 65° W. to E. and W. The heaviest flow of water observed was coming from an open channel having a strike of N. 87° W. In a number of places water drips out of joints in the roof. Water also seeps out along the bedding planes and occasionally flows from underground drill holes. Reddish brown iron oxide is frequently precipitated from the water flowing out of the drill holes. In one place, fine needle-like crystals of magnesium sulphate were observed on the wall and roof. A white efflorescence also shows on the shale in some parts of the mine. It is interesting to note that all of the underground drill holes from which water is flowing, do not show a precipitate of iron oxide. Neither is iron oxide precipitated from the water flowing out of the channels and prominent joints. For this reason I have been inclined at times to believe that the iron may be derived from fragments of a drill bit or cuttings from the rods remaining in the hole. Altho this may be a source of the iron in some of the holes, it is hardly probable that it would account for the iron in many of them. All of the water from which the iron oxide is precipitated comes from drill holes which are inclined downward, toward or into the underlying Lamotte sandstone.

FAULTING.

In the neighborhood of 20 different faults were located in this mine. All of these faults with the exception of three, have a strike of from N. 72° W. to E. and W. Two of the faults have a strike of N. 50° W. and another has a strike of N. 62° W. With the exception of five, they are all practically vertical. These five faults have a dip of from 15°-25° N. The faults are all normal and have a throw to the north of from one inch to 5½ feet. Along one of the fault planes, I observed a few crystals of galena that appeared to be striated, giving evidence that the faulting in this instance, at least, was later than the introduction of the galena. In another instance, I found crystals of galena which evidently had been formed in the shale, along a fault plane, subsequent to the displacement. In other cases I was unable to find evidence to indicate whether the faulting was prior to or later than the introduction of the galena. In one instance I observed that the decomposition along the downthrow side of the fault was greater than along the upthrow side.

Most of the faulting is in the north end of this mine where the ore body is very rich.

In addition to the displacements noted along vertical or nearly vertical joints, horizontal movement along bedding planes and lateral movements along joint planes were observed in a number of places. These movements are indicated chiefly by striations having in general a horizontal position. In some instances the apparent vertical displacement noted for the faults previously described may be due to a horizontal rather than a vertical movement. In rocks similar to those in this area, it is almost impossible to determine the extent of either horizontal or lateral displacements. In one place I measured the strike of the slickensides on the roof and found it to be N. 72° W.

JOINTING.

The joints have been separated into three classes, viz: (1) channels along which the rock shows evidence of leaching; (2) well defined joints along which the wall rock is fresh and apparently unaltered; and (3) short, discontinuous joints which show in one or perhaps several beds for a short distance.

Of the first class of joints I recognized three, while of the second class I located 174. Some of the joints belonging to the second class should probably be classified under the head of channels but the relatively slight amount of decomposition along the walls has led to placing them in the second class.

The three channels have strikes of E. and W., N. 78° W. and N. 87° W. The first has a dip of 15° N., while the other two are vertical. The last one discharges an abundance of water. The decomposition adjacent to these channels is well marked and essentially the same as that described for similar conditions in the other mines.

Of the prominent joints located in this mine,

73	have	a	strike	of	N. 70°-80° W.
46	"	"	"	"	N. 60°-70° W.
23	"	"	"	"	N. 80° W.-N. 80° E.
12	"	"	"	"	N. 50°-60° W.
7	"	"	"	"	N. 40°-50° W.
4	"	"	"	"	N. 50°-60° E.
3	"	"	"	"	N. 70°-80° E.
3	"	"	"	"	N. 60°-70° E.
2	"	"	"	"	N. 30°-40° E.
1	has	"	"	"	N. 8° W.

From the above it will be seen that in general the joints have a strike which is a little north of west, about two-thirds of the joints having strikes in this direction. All of the faulting is along these joints and most of the water dripping from the roof finds entrance to the mine along them. They have evidently been the main water courses at the horizon where the ore body occurs.

Very little attention was given to the short seams altho they occur quite abundantly in some parts of the mine. Several of those observed strike nearly northeast and southwest.

It is scarcely probable that the great number of prominent joints observed in some parts of this mine, in the north end for example, continue to the surface. It is believed that in the main these joints belong to the lower horizon of the Bonneterre formation and that they die out not far above the mine workings.

Some of the short joints contain calcite and galena forming veins which continue across one or perhaps several beds.

BRECCIATION.

The brecciation in this mine is all of a local character, resulting from solution either along fault planes or in the vicinity of solution cavities. In nearly every instance the interstices between the breccias are filled with either clay or calcite. In most instances is was possible to determine the limits of these breccias and where this was done, the dolomite beds above and below were found to be practically horizontal. In one instance the beds directly above the breccia, were flexured as indicated in Plate LXXXII. As in the case of the breccias observed in other mines in the district, these are best explained by solution with consequent settling of the overlying beds. Wherever horizontal movement was observed along the bedding planes there was no evidence of brecciation.

FOLDING.

In the western part of the mine south of the shaft, for a distance of about 500 feet, there appears to be a dip of from 8°-12° about S. 60° E. Also, in the northeastern part of the mine, I observed a dip of from 5°-6° N. 80° W., which was persistent for a distance of about 200 feet. These dips, however, do not persist over any considerable distance and should probably be considered local in character.

Anticlinal and synclinal rolls were observed in several places in the roof. The axis of one of these had a strike of S. 49° E. and another had a strike of N. 65° E. Local dips were also observed in other parts of the mine, but I was unable to work out any system of folding.

Developments which have been carried on seem to indicate that the ore increases in richness upward along the dip rather than downward. There is some evidence that where there is any flexuring, the ore is richer near the anticlinal arches rather than in the synclinal basins.

BEDDING.

The galena occurs in an horizon consisting of alternating beds of dark and light colored limestone, black shale, and chloritic dolomite. Both the black shale and chloritic dolomite are abundant at this horizon in this mine. Galena occurs very persistently in the black shale, while it frequently occurs in the chloritic beds. In addition to the rock above mentioned, there appears in this mine what I take to be a bed of limestone conglomerate. This conglomeritic bed, occurring in a number of different places, consists of lenses of dolomite in a matrix of shale and chlorite. In my notes this bed is spoken of in places as a shaly, dolomite conglomerate. In places this conglomerate bed contains galena and becomes a part of the ore body.

The bedding planes are often very irregular, thinning and thickening as illustrated in Plate LXXXII.

The rock is both fresh and decomposed, oxidation being conspicuously present adjacent to the channels. The dolomite is finely crystalline in some beds while in others it is porous and very coarsely crystalline. The chloritic beds are usually coarse textured and frequently contain some quartz sand and shale as well as dolomite. The beds of black shale are persistent over greater areas than in Mine No. 2.

MANNER OF OCCURRENCE OF THE GALENA.

The galena occurs in the following ways, namely: disseminated through the dolomite, shale and chloritic rock; in horizontal sheets along bedding planes; in vugs and cavities; filling and lining the walls of joints; and in the shale along fault planes. I have no record of any galena occurring in the channels in this mine. Neither do I know of any lead carbonate in the decomposed dolomite adjacent to the channels.

The disseminated galena occurs chiefly in the dark colored dolomite, the black shale, and the beds of chloritic rock. To a lesser degree it occurs in the light colored dolomite which is interbedded with the shale. The disseminated ore in this mine is especially characterized by the quantity of chlorite in the beds. I think that in none of the other mines on this property, does the disseminated galena occur so abundantly in rocks having a chloritic composition. This perhaps is not attributable so much to the chlorite as to the fact that these chloritic beds are associated with black shale which sometimes forms a part of them.

Horizontal sheets of galena are not abundant, altho they occur associated with thin laminae of black shale between some of the lighter colored dolomite beds.

There are occasional vugs and pockets in this ore body, some of which are 2 feet in diameter. These pockets are usually filled with a bluish shale through which is disseminated calcite and sometimes pyrite and galena. In one place I found a pocket filled with greenish blue clay containing neither calcite nor galena. In another case I noticed a cavity filled with yellowish green shale containing calcite, but no galena. In other instances I found cavities along joint planes, in which occur both pyrite and calcite, the former being older than the latter. Altogether these pockets are a very unimportant source of galena.

Veins of calcite and galena filling short, discontinuous joints are common in some parts of the mine. Frequently the galena and calcite occur in a thin film smeared along the walls of very tight joints. They are not an important source of galena, but are common wherever the disseminated deposits are associated with dense finely crystalline dolomite which has been fractured with short seams.

Along several of the fault planes there is considerable chlorite and black shale which has evidently been dragged in by the movement. In one case this soft chloritic shale was 4 inches in thickness. In another instance it measured about 1½ inches in thickness. In the shale along several of these fault planes, there were occasional crystals of galena some of which had the appearance of having been dragged into the fault with the shale. Other crystals appear to have formed in the shale since the faulting. In one instance where shale filled the opening along a fault plane it contained no galena, indicating that it may have been introduced subsequent to the faulting.

I observed occasional instances of the leaching of the galena in beds of disseminated ore which were adjacent to the channels where weathering had almost completely decomposed the rock. In some instances where the galena has evidently been removed, pyrite still remains. In fact, the persistence of the calcite and pyrite as compared with that of the galena is quite striking in this as well as the other mines examined.

Plates LXXXIII., LXXXIV. and LXXXVI. illustrates very well the manner of occurrence of the galena in this mine. These illustrations show the relations between the disseminated ore and the dark and light colored limestone; the occurrence of galena in short seams; its occurrence along bedding planes; and the occasional enrichment underneath locally thick parts of the shale seams.

MINE NO. 4.

The sinking of the shaft leading to Mine No. 4 was begun in June, 1902. The first ore was hoisted from the 327 foot level in March, 1903, and from the 262 foot level April 13, 1903. This shaft is located 2740 feet N. 70° E. of No. 2. The collar of this shaft is 764.3 feet above sea level, while the bottom of the lower level is 440.3 feet above seal level and the bottom of the upper level is 502.3 feet above sea level. The shaft is therefore 324 feet deep to the bottom of the lower level. The bottom of the upper level is only 262.3 feet from the surface. A third level was started in this mine. Two narrow drifts were run on either side of the shaft, but very little ore was encountered. This shaft begins about 60 feet below the top of the Bonneterre limestone and the bottom of the lower workings are close to the Lamotte sandstone. Most of the ore obtained from this mine has come from the 262 foot and 324 foot levels. The bottoms of these two levels are 62 feet apart, and all of the ore may be said to have come from the lower 120 feet of the Bonneterre formation.

Plate LXXXVII shows an outline of the underground workings of this mine up to March 1, 1908. The cross sections accompanying this map show the general position of the ore body with reference to the Bonneterre and Lamotte formations. Up to the time this map was made approximately 6.61 acres of ground had been mined, most of it at two levels. The manner of occurrence of the ore is not essentially different from that at the mines previously described. This mine exhibits the irregularities of sedimentation, faulting, folding, and flexuring essentially the same as described for the other mines of the district.

WATER.

No attempt has been made to keep track of the average amount of water pumped daily or monthly from this mine. We do not have figures at our command which give the daily variation or the possible effect which rainstorms have upon the amount of water entering the mine. Altho the amount of water pumped from this mine is small there is little question but that the rainfall effects the quantity of water in the mine, but the degree of fluctuation is not as great as in some of the other mines in this district. At the 262 foot level I found considerable water entering along one prominent joint and along two channels, while at the 327 foot level only from the roof near one of the prominent joints was there any considerable water entering the mine. In the uppermost level I observed one prominent joint striking N. 40° E. from which water was flowing in considerable quantity.

Altogether it appears from these observations that there is more water flowing into the two upper levels of this mine in proportion to their areas than in the lowest level.

FAULTING.

Only two minor faults were observed in this mine, both of which were at the lowest level. One has a strike of N. 55° W., a dip of 10°-22° S. W. and a throw of 12 inches; the other has a strike of N. 63° W. and a downthrow of one inch to the N. E. These faults occur in such positions that if they persisted upward they would show in the second level. However, I was unable to find them and am forced to conclude that they die out somewhere between the two levels. These faults are a part of the system of fracturing which characterizes the lower horizon of the Bonneterre formation. There is nothing to indicate whether they are prior or subsequent to the introduction of the galena.

JOINTING.

At the 262 foot level I observed two channels and nineteen prominent joints. The channels strike N. 73° W. and N. 63°-65° E. Of the prominent joints seven strike N. 10°-18° E., six N. 60°-77° E. and three N. 60°-77° W.

At the 327 foot level I observed no channels and nineteen prominent joints. Eight of these joints strike N. 10°-18° E., eight N. 60°-77° W. and two N. 47°-55° W.

Altho the area cut over at the second level is greater than that at the lower level there appears to be fewer prominent joints and channels, which bears out my conclusion that the joints are more numerous and better defined near the bottom of the Bonneterre formation than higher up. At both levels short, discontinuous joints occur, abundantly in some places, but apparently more numerous in the upper level. These joints are usually dry and clean cut, often filled with calcite and galena.

Curved joints and others having walls that are fluted horizontally were observed in a number of places at the 262 foot level.

BRECCIATION.

No brecciation was noted in this mine.

FOLDING.

At several places in the upper level the beds were observed to dip in various directions and at various angles. In the east part, the dips are mainly to the southeast while in the west part they are a little north of west.

In the 262 foot level the beds dip steeply in the west and northwest portions. In several places the beds dip as much as 20 or 25 degrees northwest. The dips at this level show in only one place in the lower level and there they are much less steep, being 2°-4° in the lower level and 10°-12° in the upper level.

As the ore was followed down along this dip in the 262 foot level it became leaner, being richest in the upper part of the limb of this monoclinal flexure.

BEDDING.

There is little in the bedding and sedimentation in this mine which is different from that in the mines previously described. At some horizons the beds are thick and at others they are thin. Shaly and chloritic beds alternate with light and dark colored dolomite. In some instances the bedding planes are smooth and regular and in others they are wavy and irregular. Such irregularities as have been observed, may be accounted for through sedimentation and solution.

I observed numerous instances in which the galena occurred mainly above or in the top of the shale and dark colored dolomite beds.

Several thinly bedded, shaly, chloritic dolomite areas were observed that peeled off of the roof very much after the manner of the layers of an onion. The shale and dolomite beds thicken and thin, sometimes disappearing entirely. A few of the irregularities in bedding are shown in Plate LXXXVIII.

MANNER OF OCCURRENCE OF THE GALENA.

The galena occurs disseminated through the dolomite, shale and chloritic rock; in horizontal sheets along the bedding planes; in vugs and cavities; and filling or lining the walls of joints. The disseminated ore is the chief type represented in this mine at both levels. The lower level is especially characterized by the quantity and persistence of the chloritic beds through which the galena is disseminated.

The horizontal sheets of galena are an important source of ore. The thing which is perhaps of most interest, is the association of this galena with thin laminae of shale, often between thin beds of light colored dolomite or chloritic rock. The occurrence of the coarser crystallization of galena at the top of the sheets and the almost uniform occurrence of the sheets above the shale are especially noticeable. These are nicely illustrated in Plate LXXXVIII.

There are occasional cavities in the rock at both levels and these as a rule contain dark, bluish black mud carrying galena and calcite, frequently pyrite. They do not differ essentially from those described and illustrated in other parts of this volume. I also observed coarse textured beds in which small vugs were numerous and in which small cubes of galena had formed. These, while not abundant, are probably more numerous than might be inferred from these descriptions.

Galena and calcite, filling or lining the walls of joints, are common at both levels, altho probably more numerous at the upper level. These seams sometimes contain pyrite and as a rule are relatively short and do not penetrate any very great thickness of strata. I observed at one place an exposed wall of a joint 3′ x 4′ which was covered with well crystallized galena. In some of the seams calcite and pyrite occur without galena but usually all three are present in some part. In one instance, Plate LXXXVIII., I observed irregular veins of galena, extending upward from a sheet of galena overlying a shale bed, through beds of white dolomite. In other instances the galena occurs spattered in very thin films on the walls of the joints. There is nothing unusual in these occurrences, they having been observed in many of the other mines.

In general this mine illustrates typically the relations of the galena to the various rocks and especially its close association with the dark colored shale and dolomite. The increased local enrichment of the ore as the dipping beds are followed upward is also beautifully exemplified in two places.

MINE NO. 5.

This mine is located 5130 feet S. 72° E. of Mine No. 2 near the right of way of the Illinois Southern railroad. The sinking of shaft No. 5 was begun Feb. 22, 1906. The company began hoisting ore from this shaft March 10, 1907, since which time about 1½ acres of ground have been mined.

The collar of this shaft is at an elevation of 779.1 feet above sea level and the bottom of the mine workings are 471.1 feet above sea level. This makes the bottom of the shaft at the track level about 308 feet from the surface.

The shaft was started about 20 feet below the top of the Bonneterre limestone and the bottom of the mine is 40 feet above the Lamotte sandstone.

The quantity of water pumped from this mine is small. The ore is essentially the same as that occurring at the other mines. The work at this mine was started after I had almost finished my examination of the district and therefore this report contains few details relative to the manner of occurrence of the ore. The accompanying map Plate LXXXIX. shows the area of the mine workings, while the cross section shows in general the relation of the ore body to the Lamotte sandstone.

Such examination as I was able to make of this mine gave me the impression that the rock, except where partly decomposed, is hard and rather fine textured. There are a few prominent joints and no channels as defined in this report. Only two or three of these joints carry an appreciable amount of water. Some water is coming out of surface drill holes, and about twenty to thirty feet below the cribbing in the shaft there is a horizontal opening through which considerable water enters the mine.

The ore occurs chiefly disseminated in a rather light colored limestone the beds of which are separated by thin shale seams often accompanied by thin sheets of galena. The thin streaks of galena between the beds are common in almost all parts of the mine. Some of the ore which has the appearance of being disseminated is, in reality, dolomite filled with minute vugs in which galena has crystallized.

The black shale, so common in some mines, is not abundant in this, altho its importance is easily recognized by the persistent manner in which the galena follows the thin shale partings and the darker colored dolomite.

I observed a cavity, having a diameter of about two feet, which was filled with soft mud, the upper one-third of which had been leached to a light gray while the lower two-thirds was a dark blue or slate color. In the light colored clay there was no galena but the dark colored clay was filled with small galena crystals not over 1/8 of an inch in diameter.

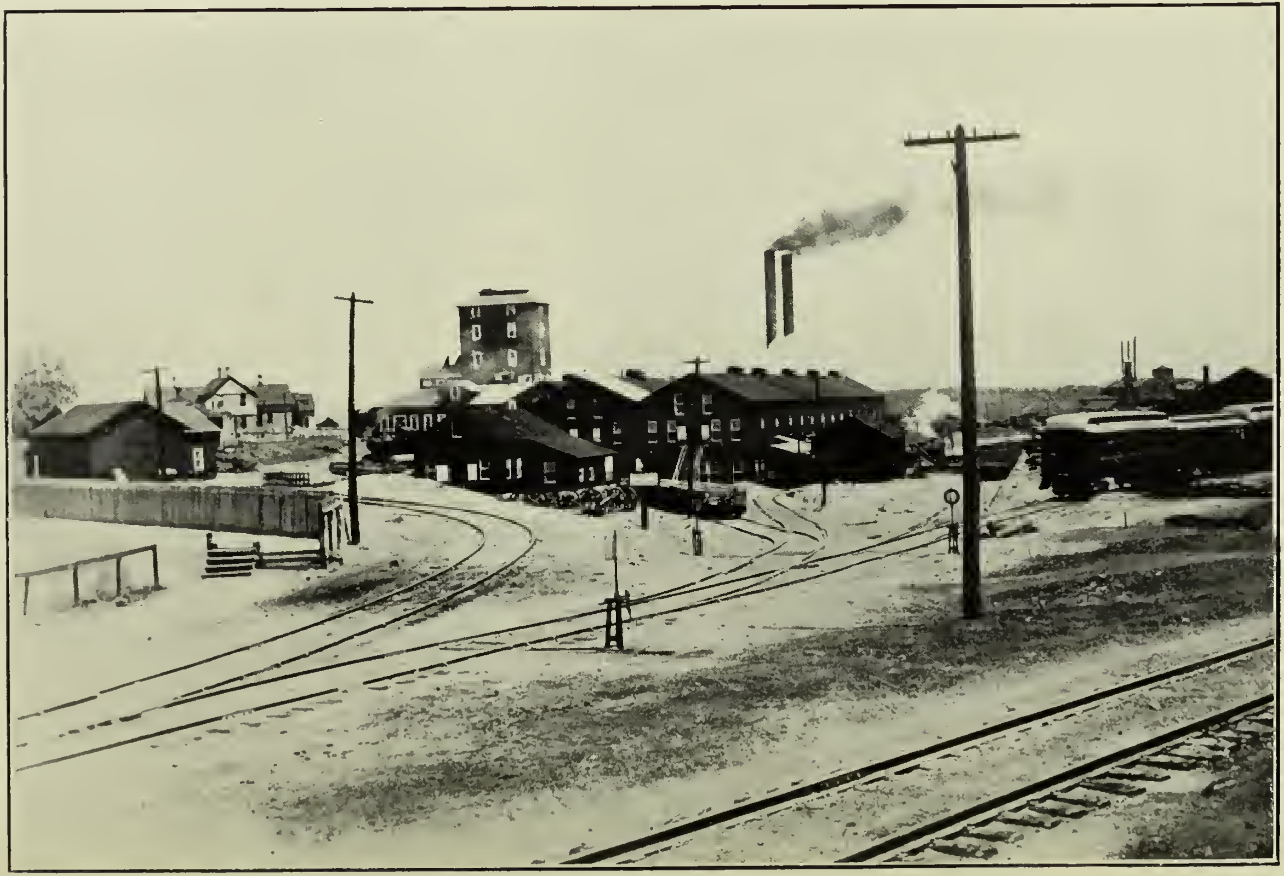
In another place I observed an open cavity having dimensions of about 2′ x 2′ x 1½′, which was lined with crystals of galena and containing occasional crystals of calcite. The galena crystals were about ¼ to ⅜ of an inch in diameter and had hexagonal, tetrahedral and dodecahedral faces well developed. In fact, wherever similar cavities have been observed in the district the galena occurring therein usually takes this combination of crystal forms. I was told that a great many mud pockets and open cavities have been encountered in the area thus far mined.

Some of the rock is soft and decomposed giving one the impression that oxidation is now in progress at this horizon. Some of the galena individuals are leached and certain zones in the rock give unmistakable evidence of decomposition since the introduction of the galena. In part, this is the reason for the lighter color of the rock, which is characteristic of this horizon. There is very little chlorite. Some calcite occurs with the thin sheets of galena along the bedding planes. There are very few sharp, clean cut veins of galena and calcite, most of the veins of galena being irregular and rather difficult to follow.

In spite of the general light color of the rock the ore occurs chiefly in the brown dolomite and along bedding planes associated with thin laminae of black shale. The disseminated ore is chiefly in coarsely crystalline dolomite. In general the ore is of the bunchy type, the rich areas occurring irregularly through a generally lean horizon.

ST. JOSEPH LEAD CO.

The St. Joseph Lead Company was organized in 1864 and began mining operations at Bonne Terre in 1865. The original tract



ST. JOSEPH LEAD CO.
Concentrating plant at Bonne Terre.

of land owned by this company was purchased from Anthony La-Grave. Prior to this, the property was owned by the Valle and Aubuchon families. Mining was carried on in this locality prior to the year 1820, the earliest operations being carried on at what was known as the Pratt mine.

Upon taking charge of the property, the St. Joseph Lead Company introduced many improvements, chief among which was the plan of prospecting with a diamond drill, which was inaugurated in 1869. It is claimed, however, that the deposits of disseminated ore were discovered through the use of the churn or drop drill. In 1880, a railroad was completed from this plant to Summit, a small station on the St. Louis, Iron Mountain and Southern railroad. In 1883 the works were almost completely destroyed by fire after which a new and better plant was erected. The Pen property, consisting of over 300 acres, was purchased in 1883, while in 1886, the adjoining Desloge mines, which had been operated since 1877, were also purchased. The year 1890 marked the completion of the Mississippi River and Bonne Terre railroad which connects the mines with the St. Louis, Iron Mountain and Southern railroad and the Mississippi river at Riverside. Following the completion of this railroad, the line to Summit was abandoned. During this period a large smelting plant was constructed at Herculaneum where all of the ores are now smelted, altho part are calcined at Bonne Terre and Leadwood.

This company has made additional purchases of land from time to time until it now owns in the neighborhood of 19,000 acres located mainly in St. Francois county. New shafts have been sunk from time to time at Bonne Terre and in other parts of the district until the company now has 21 shafts, nine of which were completed and used during the early history of the company, having long since been abandoned. Shafts No's. 1, 2, 3, 4, 5, and 6, are all connected with the same ore body located at Bonne Terre. Likewise, the underground workings of these mines are all connected as shown in Plate XC. The abandoned shafts are known respectively as the Jones, Parsons, Hoadley, Cottonwood, Clare, Clinton, Camp, Hathaway, Old No. 2, Pen diggings, Old No. 4, Pump and No. 13 (Air shaft). Most of these shafts were connected with the disseminated ore bodies which lay relatively near the surface.

Shafts No's. 7 and 9 are located about a mile and a quarter southwest of mine No. 1. They are, however, in the same general area as the main workings of the St. Joseph Lead Company's mines at Bonne Terre. Shaft No. 8, commonly known as the Crawley, is located about three-fourths of a mile almost due east of Flat River station on the Mississippi River and Bonne Terre railroad. Shaft No. 10, known as the Gumbo, is located in the N. W. 1/4 of Sec. 2, T. 36N., R. 4E., about four miles south of mine No. 1 and about 2 1/4 miles west of St. Francois station on the Mississippi River and Bonne Terre railroad. Mine No. 11, known as the Hunt, is located in the N. W. corner of Sec. 3, T. 36N., R. 4E., northeast of Leadwood near the Big river. Mines No's 12 and 14, known as the Hoffman shafts, are located at Leadwood, near the center of Sec. 4, T. 36N., R. 4E. All of these mines are connected by spurs or branches with the Mississippi River and Bonne Terre railroad. Up to date, the aggregate area of the mine workings is something less than 100 acres, nearly 2-3 of which area is included within the mines in the vicinity of Bonne Terre. Owing to the wide variability in the thickness of the ore, it is impossble for one to estimate the quantity mined from the area of ground work. It is interesting, however, to note that from this acreage 478,100 tons of lead concentrates have been mined having an approximate value of $21,410,000.

J. R. Gage in speaking of the St. Joe lead mines of southeastern Missouri, in 1873, says: "The principal mining operations are carried on at a depth of 85 to 90 feet in a bed of ore averaging two feet in thickness. Above this rich bed is an 8 or 10 foot bed of poor rock with some little galena very thinly disseminated. Overlying this comes a seam ranging from 4 to 10 inches of very rich disseminated ore, making a thickness of 11 to 12 feet of rock to be worked out." * * * * "There are 250 to 350 feet worked out" * * * * "On an average 120 pigs of lead are smelted each day."

MINES OF THE ST. JOSEPH LEAD COMPANY AT BONNE TERRE.

The mines at Bonne Terre consist of two groups, the first and most important being reached through No's. 1, 2, 3, 4, 5 and 6 shafts and the Jones, Parsons, Hoadley, Cottonwood, Clare, Clinton, Camp, Hathaway (Old No. 4), Old No. 2, Pen Diggings, Pump and Air (No. 13) shafts. This group of mines, the underground workings of which are all connected, have been reached at one time or another through eighteen shafts. In addition to these there are several shallow abandoned shafts, from which some ore was mined at an early day, but which have long since been abandoned and are probably now filled. These mines underlie the city of Bonne Terre.

The second group of mines are about 1¼ miles southwest of Mine No. 1 and are reached through two shafts known as No. 7 and No. 9. The two groups are separate but the mines of each group are connected underground at one or more levels.

The first group of mines is entered by a ladder way in the Camp shaft. The collar of this shaft is at an elevation of 800 feet while the bottom is 728 feet A. T. The depth is therefore 72 feet. From the bottom of this shaft the lower workings are reached by stairways and foot-paths down the somewhat steep bluffs, leading down about 320 feet farther from the surface. Shafts 1, 2, 3, 4, 5 and 6 are or have been used for hoisting the ore to the surface.

The locations of the several shafts leading to the underground workings of both groups of mines are shown on the accompanying maps, Plates XC. and XCII. At one time the shafts of group No. 1 indicated quite distinct and separate mines but at the present time most of them have been worked together, so that actually it is impossible to say where one mine begins and the other leaves off. For convenience the company has drawn arbitrary lines, thereby distinguishing the workings of the several mines represented by the six different shafts from which ore is hoisted. Likewise in the case of the second group, the company distinguishes two mines, altho they have been worked together in such a manner as to make it purely an arbitrary matter as to where the line of separation is drawn.

I have been unable to secure definite information as to when the different shafts were sunk. As stated above, this company began operations in 1866 following a period of desulatory shallow mining extending from before the year 1820. The first mine on this land was known as the Pratt; the latest shaft sunk is the new No. 2.

Shallow mining was carried on in this area sporadically for about half a century, but as nearly as can be estimated, the total output did not exceed several hundred tons. The galena obtained from these shallow diggings was of the massive variety and was obtained from channels and horizontal crevices in which it occurred embeddied in red clay or attached to the limestone walls.

Galena in a disseminated form has been found very close to the surface, in fact it occurs in small quantities in the limestone which actually outcrops at the surface. At the Clinton shaft it was mined at a depth of about 50 feet. Mining at the Parsons shaft was carried on at a depth of 95 feet; at the Camp shaft at a depth of 72 feet; and at the Jones shaft at a depth of 106 feet. Most of the mines in this group have been worked at several different levels as shown by the following table:

No. of shaft.	Elevation of Collar above Sea Level.	Elevation of Bottom of Mine Workings above Sea Level.				
1	812.77	707.92	667.92	621.32	....	....
2	776.33	....	....	....	....	406.33
3	821.61	687.61	673.61	656.61	618.93	602.01
4	800.65	665.40	619.82	689.4	564 32	530.
5	791.	....	....	....	....	541.93
6	824.67	688.17	610.92	....	....	539.

The deepest shaft in this area is 370 feet so that it may be said that the workable ore bodies in this area occur at intervals throughout the lower 300 feet of the Bonneterre formation. Altho there is no place in these mines where the ore body has actually obtained this thickness, there are places where it has been mined almost continuously for 250 feet. Altho the total area embraced in the mine workings of the first group of mines probably does not exceed 70 acres, the great thickness of this ore body as compared with that of others in the district has multiplied the production very greatly. The ore in some parts of these mines has been very rich.

WATER.

The water entering the first group of mines is pumped from three different shafts—the Hoadley, No. 3 and No. 2. The pumps in these three shafts are not required to handle over 800 gallons of water per minute in order to keep the workings dry.

There is abundant evidence in these mines pointing to both a surface and a deep circulation within the Bonneterre formation. It is clear that some of the channels continue from the surface to the mine workings. Near the Clinton shaft, for example, there is a channel crossing the mine workings at a depth of about 100 feet, which discharges considerable water especially after a heavy rainfall. It is very evident that this water enters the mine directly from the surface circulation. From a number of underground drill holes sloping upward, water is entering the mine and it is very probable that this water is also derived from the surface circulation. The reddish brown mud filling some of the channels, is very similar to that found at the surface, which naturally leads one to infer that it may have been brought to its present position by ground water entering these channels at the surface.

There is equally as good evidence that the water entering the mine at other places, comes directly from the underlying Lamotte sandstone. In Mine No. 5, there is a channel which evidently extends to the underlying sandstone. A heavy flow of water comes out of this channel at the bottom of the mine. East of the Cottonwood shaft, there is a diamond drill hole about 25 feet above what was the water level, at a time when this part of the mine was flooded. As long as the water remained in the mine workings, there was a constant flow from this drill hole. After the water had been pumped out, the water stopped flowing out of the drill hole. This is thought to be very good evidence that the water entering the mine at this place comes chiefly from the underlying Lamotte sandstone. In one of the drifts of the upper level of Mine No. 6, there are four diamond drill holes, three of which are slanting upward and are dry, and the fourth of which is slanting downward and is discharging a constant stream of water into the mine.

Besides the especially noticeable discharge of water from drill holes and channels, there is considerable water dripping out of the fracture zones and seeping out along the bedding planes where they are exposed in the walls of the mines.

There is abundant evidence similar to that given above to indicate that this formation, at the lower ore horizons at least, receives water both from the surface and from the underlying sandstone. It is also probable that along some of the major channels, there is a comparatively free communication between the Lamotte sandstone and the surface.

Where the water is discharged into the mine, it frequently leaves a deposit of yellowish brown iron oxide or travertine. In one place a black precipitate resembling soft carbonaceous shale was noticed. The travertine frequently covers the bluffs; forms a crust on the red clay from the channels; cements the debris at the bottom of the mine into a conglomerate; and forms stalactites on the roof or along the walls. In one place minute green colored stalactites are forming, the color being due to the presence of malachite acquired through the leaching of chalcopyrite which is quite abundant in that part of the mine.

FAULTING.

Nothing except minor, normal faulting was observed in these mines. Displacements of from 3 inches to 2 feet were observed in different places. The most prominent of these faults has a dip of 5° N. 55° E., a strike of N. 35° W., and a throw of 1 to 2 feet. Two other faults strike N. 60° W. and N. 20° E., respectively.

These faults are chiefly along channels and are usually filled with clay or thoroughly decomposed dolomite. The fault zone in one case is 12″ wide. The clay and shale occupying this zone contain galena, chalcopyrite and calcite.

In addition to the normal vertical faults referred to above lateral movement along joint planes and horizontal movements between beds were observed in a number of places. Here as elsewhere it is difficult to determine the extent of such movements, their presence being recognized simply by striations along the walls of joints and the surfaces of bedding planes.

JOINTING.

The three classes of joints recognized in the other mines of this district occur abundantly in these mines. Several hundred observations on the strike and dip of the joints were made and have been platted on the accompanying maps. Summarizing these observations, we find that in mines 1 to 6, inclusive, the channels, striking in various directions, occur in about the following proportions:

N.80°W. to N.80°E	40
N.65°-75°E	10
N.65°-75°W	9
N.10°E. to N.10°W	5
N.50°-60°E	4
N.50°-60°W	3
N.20°-40°E	3
Miscellaneous	9
Total	83

Likewise the prominent joints, striking in various directions, occur in about the following proportions;

N.80°W.-N.80°E	67
N.10°W.-N.10°E	61
N.65°-75°W	48
N.50°-60°W	23
N.25°-45°W	24
N.65°-75°E	15
N.50°-60°E	9
Miscellaneous	29
Total	276

In Mines No's 7 and 9, the following proportions exist between the various channels:

N.80°W.-E. & W.	6
N.60°-65°W	8

Likewise the proportions existing between the systems of prominent joints is about as follows:

N.80°W.-E. & W	6
N.60°-65°W	21
N.65°-75°W	20
N.15°E.-N.15°W	5
Miscellaneous	3
Total	55

Observations made on the channels and prominent joints indicate that those striking between N. 80° W. and N. 80° E. discharge the greatest amount of water into the mines. Altogether 19 channels and prominent joints striking in this direction were noted as discharging some water. Ten of the joints striking N. 65°-75° W.; six striking N. 65°-75° E.; five striking N. 50°-60° E.; two striking N. 10° W.-N. 10° E.; and four striking in other directions were discharging water into the mines.

The channels in these mines are characterized by a decomposed zone on both sides of the fracture plane. They are open a few inches or several feet, the openings in some instances being filled with soft red clay or decomposed dolomite. These channels are usually very irregular, opening and closing as they are followed either vertically or horizontally through the mines. Some of them evidently traverse the entire Bonneterre formation from the surface to the underlying Lamotte sandstone. Others extend from the surface into the Bonneterre limestone and die out before reaching the sand. There are still others where the evidence seems to indicate that they have their origin in the Lamotte sandstone formation and die out before they reach the surface. Followed horizontally, these channels frequently pass over into prominent joints along which the wall rock is little if any decomposed and finally die out. The decomposed dolomite adjacent to the channels may be either reddish brown, yellow, white or greenish colored, depending upon the original color and composition of the rock which the channel traverses. The decomposed dolomite and clay may contain unaltered boulders or smaller fragments of dolomite. Frequently there is some galena either in sheets or disseminated through the soft, decomposed dolomite adjacent to the channels, but in most places it is either undergoing decomposition or has been completely removed. It has been observed that the galena, which occurs in sheets, is much less quickly decomposed than that which is finely disseminated through the dolomite.

The channels occasionally contain aggregates of galena crystals of large size and one frequently finds masses of calcite, some pyrite and occasionally malachite in the openings along these channels.

There is every evidence that these channels have been prominent water courses through which lead bearing solutions have been introduced into the Bonneterre formation. At the present time they are water courses bearing oxidizing solutions through which the galena is taken into solutions and transported to other parts of the formation in which it is deposited.

Water often circulates freely through the prominent joints along which very little if any decomposition is taking place. The water traversing these openings is chiefly distributed along the adjacent bedding planes where the lead which it may carry in solution is deposited. As in the case of the channels these joints not only extend from the surface into the Bonneterre formation, but they also extend from the Lamotte sandstone upward, dying out before they reach the surface. There is every evidence that we have in this area, as elsewhere, a surface zone of jointing and a deep seated zone of jointing in the Bonneterre formation, the latter being directly above the Lamotte sandstone.

There are great numbers of short discontinuous joints in both the upper and lower levels, but no attempt was made to determine their strike. They occur abundantly at some horizons but at other levels they are unimportant. They frequently contain veins of calcite, galena and pyrite either smeared along the walls or completely filling the openings. The solutions have evidently traveled along these short discontinuous joints in their passage between the different beds. They constitute an important structural feature of the formation, since through their presence the solutions have been able to reach those parts of the formation distant from the major zones of jointing.

It is well to again call attention to the occurrence of the channels and joints in zones, in which the individual joints are relatively close together. Also that these zones are separated by areas which are little fractured except by short, discontinuous joints.

The above observations cover the jointing in all the mines in the Bonne Terre area. The jointing in mines 7 and 9 is essentially the same as that in mines 1 to 6, inclusive. The part which they have played in the formation of the ore bodies has been the same. In general, the jointing in this area is no different from that in the Flat River and Leadwood areas to the south and southwest.

BRECCIATION.

The only brecciation observed consists of irregular fragments and boulders along the channels, and irregular fragments in the calcite filled pockets and caverns. There is no evidence anywhere of breccias resulting from mechanical deformation. All the brecciation observed is clearly the result of solution and subsequent settling and cementation with calcite.

FOLDING.

The beds in this area have a general westerly and northerly dip. This dip is, however, so gentle as to be scarcely noticeable within the limits of the mines. Small synclinal and anticlinal flexures were observed at a number of places. Local dips occur in different parts of the mines. It is impossible, however, to determine any system to these local flexures, and it is thought that they are chiefly the result of uneven sedimentation and solution.

A small syncline occurs about 500 feet northwest of shaft No. 4. In another place the beds appear to be very undulatory making small anticlines and synclines with amplitudes of about a foot. At another place the beds have a similar undulatory character, the amplitude of the folds not exceeding 2 feet. A fold in another part of the mine was measured and found to have an amplitude of 2 feet and a length of 12 feet. Its major axis has a strike of N. 30° W. Parallel to this fold is a second one having an amplitude of 18″. Minor flexures of this character in different parts of the mines are most numerous in the lower workings, especially close to the Lamotte sandstone.

Observations were taken at different places to determine the dip and strike of the beds. The local nature of these dips is nicely shown by their variability as illustrated by the following observations:

Dip 10° S.30°E.	Dip 8° N.30°W.	Dip 4° S.80°W.
Dip 9°N.10°W.	Dip 4° N.45°W.	Dip 7°W.
Dip. 15°N.20°E.	Dip 3° N.45°W.	Dip 5° S.E.
Dip 5°-10° N.50°E.	Dip 4°-8° N.70°W.	Dip 15° S.
Dip 3°-4° N.65°E.	Dip 25°E.	Dip 4°-5° S. E.
Dip 2°-3° N.70°W.	Dip 20° S.80°W.	Dip 4°-7° S.25°E.
Dip 3°-4° N.45°W.	Dip 10° S.E.	Dip 15° S.

Some of the beds were observed to have a rather persistent dip for a distance of 300 to 400 feet, but as a rule, the dips were observed to die out within short distances. They resemble more nearly monoclinal flexures than anything else. The small synclines and anticlines are frequently superimposed on the gently dipping beds, altho they occur more abundantly where the beds are practically horizontal.

BEDDING.

The usual variations in the character of the rock occur in all of these mines. The dolomite is both coarsely and finely crystalline. In some places it is porous and in other places it is dense and compact. It may be either dark or light colored. Light colored dolomite may pass into that which is dark colored, while the coarsely crystalline type frequently passes into that which is fine grained. Black or brownish colored shale occurs in all parts of the mines, but it is most abundant in the lower levels. Its distribution is very irregular and uncertain. Sometimes the beds persist over a considerable area but in other instances they are of very limited lateral extent. The shale frequently wraps itself around lenses of dark and light colored dolomite imparting to the bed very much of a conglomeratic appearance. In one place a bed of shale, 8″ thick in the middle, was followed in two directions until it feathered out completely within a space of 20 feet. In the lower levels, chloritic rock is most abundant. In two of the mines the ore lies chiefly within this zone of chloritic rock which is directly above the Lamotte sandstone.

It appears from the examinations made that the finely crystalline dolomite often changes very abruptly into that which is coarse grained and rather porous. This change sometimes takes place after passing inclined joints, for which reason it has been thought that recrystallization of the rock may have brought about this change in texture. In many instances, however, it is more probable that the changes in texture within individual beds have been due to sedimentation and not to recrystallization. In one place a coarse granular textured bed of dolomite 8″ in thickness thins to one inch in thickness within a space of 8 feet. At another place a sheet of coarsely crystalline dolomite, having a thickness of 5″ and a breadth of 30 feet, was observed to lie between thin seams of black shale. At another place the coarsely crystalline dolomite was observed passing over into a fine grained dense type within a space of 6″ both horizontally and vertically.

In the chloritic horizon close to the sandstone, cross bedding was frequently observed.

The bedding planes are as a rule very irregular and wavy. The pinching out of beds of dolomite often gives one the impression that the beds are dipping gently either in one direction or another. The very irregular contact between beds also gives the impression that when deposited the sediments were more or less eroded by shore currents or perhaps that they were raised above the sea and in this manner slightly eroded. We have every evidence that these sediments were laid down near the shore line and that subsequently they have been modified by recrystallization, cementation and solution.

Solution has gone on very extensively in the lower as well as the higher levels. The dolomite has been completely decomposed along many channels, and even in the lowest level decomposition along bedding planes is in evidence. In the second level of shaft No. 4, there is a 6″ to 18″ bed of dolomite which has been almost completely decomposed. The only evidence of its original character is an occasional lenticular mass which has escaped decomposition. In some places openings occur along the bedding planes, evidently the result of solution. In some instances these openings have been filled with calcite and pyrite, and in other places galena has been deposited. Large openings along both jointing and bedding planes, filled with sheets of calcite, occasionally as much as 5 feet in thickness, were observed.

In some places it is noticeable that the leaching of the rock adjacent to the channels is more extensive on one side than on the other. This is probably due to a more abundant circulation on one side than on the other.

The least evidence of oxidation and decomposition is in the intermediate levels, altho in certain parts of the mine workings the oxidizing solutions have evidently traversed the entire thickness of the formation. The greatest amount of decomposition has occurred in the uppermost levels, near the surface, but considering the character of the intervening rock, one is specially impressed with the extent to which decomposition has gone on in the lowest levels, especially where the formation is traversed by numerous joints and channels.

MANNER OF OCCURRENCE OF THE GALENA.

In all of these mines there is a persistent association of the galena with the dark colored dolomite and black shale. All the various types of ore observed in the other mines occur in these. The galena occurs disseminated through the dolomite and shale; in sheets along bedding planes; in cavities and vugs; filling or lining the walls of joints usually associated with calcite; and in aggregates of crystals in channals. Associated with the galena are pyrite, chalcopyrite and calcite, while in the decomposed dolomite, malachite frequently occurs staining the walls.

The pyrite minerals appear to be more abundant in the upper levels, and where the dolomite or shale is rich in pyrite, it usually contains very much less galena. Where pyrite occurs associated with galena and calcite in veins, it usually lies next to the wall. Calcite lies next to the pyrite, while the galena is usually youngest. The pyrite occurs in the veins, in sheets along bedding planes, and also disseminated through the dolomite and shale with or without galena.

The coarse textured dolomite and the black shale appear to be especially favorable for the occurrence of disseminated galena. The richest rock obtained from these mines is soft and apparently somewhat decomposed.

There is every gradation between beds of disseminated ore and sheets of galena. A thin bed of disseminated ore may contain 50% of galena or it may contain 90% of galena. In case the ore is 70 per cent or more galena it is considered under the heading of sheet galena. The sheets of galena are sometimes 6″ or 8″ in thickness, altho locally greater thicknesses have been mined. The disseminated galena is especially rich in chloritic rock and shale where they occur together in contact with fine grained, dense dolomite. The galena is usually fine grained in case the dolomite is fine grained, but where the dolomite is coarse grained the galena individuals are proportionately larger. The disseminated galena occurs to some extent in the decomposed dolomite adjacent to the channels. Here, however, it frequently has the appearance of irregular bullets which have been shot through the soft rock. The shape of these galena individuals has probably resulted from leaching. In places, however, the decomposed dolomite adjacent to the channels is entirely barren, while the corresponding fresh rock outside of the decomposed zone is comparatively rich ore.

Some of the light, as well as the dark colored dolomite, contains very minute cavities in which occur crystals of galena. These small galena crystals scattered through the rock give it the appearance of disseminated ore, while in reality it has formed in a very different manner than the galena which is here spoken of as disseminated. Ore of this character constitutes quite an important source of the galena in these mines.

Everywhere, and especially in the upper and middle levels, there are veins of calcite and galena. Occasionally these veins are sufficiently abundant to constitute workable ore. These veins may terminate just above or just below the shale partings, or they may cut across them. At the same place one may frequently observe the galena in veins, in sheets along the bedding planes and disseminated through the rock. This condition is especially characteristic of portions of the mine where the joints are abundant and close together. In the fine grained, light and dark colored dolomite, the galena usually occurs in veins, altho in places it has been observed in sheets along bedding planes. A close examination of the beds of disseminated galena usually shows that they are connected with almost imperceptible veins of galena which sometimes extend not farther than the nearest bedding plane. Occasionally veins of galena were observed filling inclined joints, from which thin sheets of galena extend out along bedding planes and in places they penetrated the walls on either side.

Solid sheets of galena were observed, in several instances, to pass into a much thicker face of disseminated ore in places where the rock was intercepted by abundant joints. Frequently the rock above the intersection of inclined joint planes was observed to be exceptionally rich. At many different places in these mines the ore is much richer where the joints are abundant. This is especially true where bedding and jointing planes cross. At many different places the ore ends abruptly against joint planes, especially where they are inclined. There is apparently no displacement along these joints, altho sometimes there is a change in the texture of the rock. Several instances were noted in which coarse textured dolomite upon reaching an inclined joint changed to a fine grained dolomite, the former being rich in galena and the latter barren. It is quite probable that in such instances the dolomite was recrystallized before the introduction of the galena and that the recrystallization of the dolomite and the introduction of the galena were determined by the direction in which the lead bearing solutions traversed the formation. In some cases it is probable that there has been lateral movement along the joint planes but evidence of this is in most cases lacking. The low dipping joints appear to have had the greatest influence in the distribution of the galena and also in the recrystallization of the dolomite. They may have served to deflect the ground water circulation.

Throughout these mines and especially in the upper levels, there are large and small cavities and channels filled with calcite. Where the cavities are large, there is usually very little if any galena associated with the calcite, and where the cavities are small, the calcite frequently contains on its surface or embedded in it crystals of galena. Sometimes the cavities contain not only calcite and galena, but also chalcopyrite and malachite. The calcite frequently encloses irregular masses of dolomite. In one instance a mass of calcite from 2 to 3 feet in thickness was observed filling a crevice. In another place a calcite filled cavity 2½′ x 3′ x 3½′ was observed along a joint striking N. 60° W. This cavity occurs where the joint crosses a bedding plane. Veins of calcite from 2″ to 6″ in width are of frequent occurrence. The walls of some of these veins are sharp and clean cut, while others are irregular. Several instances were noted in which the calcite veins were smooth on one side and rough and irregular on the other sending off stringers along bedding planes. Calcite occurs not only in veins and in pockets, but also disseminated through the dolomite in a manner similar to the galena. At one place a vein of calcite crosses another vein in which both calcite and galena occur. It is probable that one of these veins is older than the other. Galena which occurs associated with calcite is usually coarsely crystalline and has crystal faces well developed. An instance was noted where the galena disseminated through a bed of shale was evidently displaced by calcite, the latter replacing the former very abruptly. Along a bedding plane above the disseminated calcite is a sheet of calcite and above this the rock is decomposed. It appears very much as if the galena from a portion of this bed had been removed and replaced with calcite. The calcite occurs in rhombohedral forms and also as dog-tooth-spar.

Another favorable place for the deposition of galena is at the contact between porous, granular textured dolomite and the finely crystalline compact dolomite. Where finely crystalline dolomite occurs in lenses within an horizon of coarsely crystalline dolomite, the galena is frequently distributed in veins forming a net work throughout the enclosed mass of fine grained dolomite. Where galena occurs in sheets along bedding planes it is usually above thin laminae of shale often not more than an eighth of an inch in thickness.

In the upper and lower levels and also in some parts of the intermediate levels, there has been extensive decomposition of the dolomite along jointing and bedding planes. Prior to the decomposition of the dolomite, these areas were evidently in many instances favorable places for the concentration of the galena. Since active decomposition set in the galena has been more or less oxidized and altho some of these partly leached zones are still rich in galena, they show almost everywhere evidences of leaching. In some places the galena has been completely removed from these zones, small cavities remaining which were at one time filled with galena individuals. It is evident that leaching and deposition are going on comparatively close together within these mines. The zone where galena is being formed is, as a rule, not far from the rock which is undergoing decomposition.

Everywhere we are confronted with evidence that the deposition of the galena has been determined by the presence of lead bearing solutions, which circulating along bedding and joint planes have permeated horizons of dark colored dolomite, black shale and recrystallized porous dolomite. The underground circulation, the jointing and bedding planes and the character of the rock have all had a part in controlling the position of the ore deposits occurring within these mines.

MINE NO. 8.

The shaft* leading to this mine is located about 2,000 feet N. 73° E. of Flat River station on the Illinois Southern railroad, and is the only mine operated by this company in the vicinity of Flat River. This shaft, which is commonly known as the Crawley, was completed in 1893. The mine is located on property from which galena was obtained from shallow mines at an early date. The ore body itself is a continuation of that which is being mined at Federal No. 5 and is probably also connected with the ore body at National No. 5 which is located a short distance to the southeast.

The collar of this shaft is 797.67 feet above set level, while the track level at the bottom of the shaft is 456.47 feet A. T. The

*A shaft is now being sunk on this land nearly south of No. 8.

bottom of the shaft is 24 feet deeper. The shaft, from the surface to the track level, is 341 feet deep. It was started near the contact of the Davis shale with the Bonneterre formation, and the track level near the bottom of the shaft is about 24 feet above the Lamotte sandstone. The mine workings are shown in Plate XCIII.

This mine has been worked at practically two levels, which over a considerable area have been cut together. All of the ore has been obtained from the lower 80 to 90 feet of the Bonneterre formation. Altogether about eight acres were mined up to 1907.

WATER.

A small amount of water enters this mine along the channels and joints, as in the case of the other mines of this area. The quantity fluctuates somewhat but it is not in excess of 200 gallons per minute. The channels striking N. E.-S. W. and E. and W. are the principal ones through which the water enters. It also seeps out along the bedding planes and drips from the short joints in the roof.

In a number of places calcium carbonate and iron oxide are being precipitated from the water which drips from the channels. The calcium carbonate forms a thin white coating over the debris of the mine, while the iron oxide is deposited either as a soft, flocculent mass or simply stains the rock.

FAULTING.

I did not recognize any faults in this mine, altho there may be some slight displacements along the numerous channels and prominent joints.

JOINTING.

Channels, prominent joints and short, discontinuous joints, all occur in this as in the other mines of the area. Channels, bordered by decomposed rock, are especially numerous. These were observed in about fifteen different places. Eight of these strike N. 35°-55° E., four N. 72° W. to N. 75° E., and three N. 60°-68° W. The N. E.-S. W. channels are most abundant and discharge the most water.

I observed prominent joints at 71 places. Of these, 42 had strikes ranging from N. 35° E. to N. 55° E.; 14 had strikes of from N. 55° W. to N. 70° W.; 7 had strikes of from N. 70° W. to N. 70°E.;

and 6 had strikes of from N. 35° W. to N. 55° W. Thus it is seen that there is a general parallelism between the channels and the prominent joints, the N. E.-S. W. system being by far the most important. Short joints occur in this mine but the direction of their strike was not recorded.

The joints are as a rule perpendicular or nearly so, such dips as were observed being local.

BRECCIATION.

No brecciation was observed, altho solution has resulted, in places, in separating fragments of rock from the walls along some of the channels.

FOLDING.

In the east end of the mine there are occasional rolls in the roof, but they have no general direction and were thought to be entirely local. They are evidently due to irregularities in sedimentation and subsequent solution. In the west end of the mine the beds have a general dip to the southwest.

In one place I observed an excellent illustration of the bending of thin beds of dolomite between pillars. The distance between supports was 18 feet and at the middle the beds were bent so as to leave an opening of six inches as shown in Plate XCIV.

BEDDING.

The usual varieties of rock found in the other mines occur in this. The dolomite varies in color from almost white to brown. In some places it is chloritic and in other places it is thinly bedded and interlaminated with green or black shale. Beds of black shale occur in the usual manner, thinning and thickening and often dying out within a short distance from where they are encountered in mining. The chloritic beds are chiefly near the bottom and carry both pyrite and galena. A conglomeritic bed occurs in a number of places. It consists of dark colored limestone and shale and is usually about ten inches thick. It resembles the conglomerate near the base of the Bonneterre formation in other mines of the district.

The bedding planes are, in places, smooth and even, but usually they are rough and irregular. The wavy character of the shale may be due in part to compression of the overlying sediments but it has probably resulted chiefly from inequalities in sedimentation and subsequent solution.

MANNER OF OCCURRENCE OF THE GALENA.

The galena occurs chiefly in the disseminated form, altho cavities containing cubes of galena, sheets along bedding planes and veins with galena and calcite are common. Everywhere the galena is associated with pyrite and chalcopyrite and in a number of places the latter predominates. It was observed in this mine, as has been noted elsewhere, that the coarser crystallization of the galena usually occurs in the upper part of the bed of dolomite or shale in which it may occur. Likewise, the galena is usually more concentrated near the top of the beds in which it occurs.

It was also noticeable that the galena in some parts of the mine is coincident with the black shale, disappearing where the shale dies out. The Mine Captain, Mr. Bell, informed me that in the old workings near the shaft this was an almost invariable rule. It is also his observation that in the east end of the mine the galena is richest under the rolls.

There has been a great deal of decomposition of the dolomite along the channels and bedding planes, chiefly along the former. Wherever decomposition has occurred there is evidence of the removal of the disseminated galena, and in several places I observed an alteration of the chalcopyrite to malachite.

Some of the dolomite is porous, containing many small cavities in which galena crystals have formed. There are also occasional clay pockets containing calcite, pyrite and galena.

Joints filled with calcite, galena and pyrite are common, usually occurring in the hard dense dolomite above or below and often connected with beds of disseminated ore.

The manner of occurrence of the galena in this mine is nicely shown in Plates XCIV. and XCV.

It is interesting to note that near the shaft, in the old part of the mine, the ore occurred in a "circle" having roughly the shape of an truncated cone. There seemed to be an area of rich ore extending from the bottom of the mine upwards a hundred feet toward the surface. Through the remainder of the mine the ore occurs at two horizons, the main one being about thirty feet in thickness.

MINE NO. 10.

This mine, commonly known as the "Gumbo," is located in the S. E. 1/4 of the N. W. 1/4 of Sec. 2, T. 36N., R. 4E., on the Gumbo branch of the Mississippi River and Bonne Terre railroad. It has been operated for about eight years during which time about five acres have been worked out.

The collar of this shaft is 814.44 feet above sea level, while the bottom of the mine is 428.13 feet A. T. The bottom of the mine at the shaft is therefore 386.31 feet below the surface. The shaft was started about 40 feet above the contact of the Davis shale and Bonneterre dolomite and the mine level must be about twenty feet above the Lamotte sandstone. The mine workings are shown in Plate XCVI.

This mine has some very prominent channels and joints which discharge a considerable volume of water into the mine. In some places there is evidence of minor faulting along the joints as shown in Plate XCVII.

The ore in this mine occurs in all the various forms so fully described in connection with the other mines. It is associated with the same kinds of rock and bears the same relations to the zones of jointing and bedding.

MINE NO. 11.

The shaft leading to this mine is located in the N. W. 1/4 of the N. W. 1/4 of Sec. 3, T. 36N., R. 4E., about 600 feet from Big river. It is on the Hoffman branch of the Mississippi River and Bonne Terre railroad about 6½ miles by railroad southwest of Bonne Terre. This shaft, which is commonly known as the Hunt, has been operated about eight years. Not far from the area underlain by the workings of this mine some shallow deposits were worked at an early day.

The collar of this shaft is 742.10 feet above sea level. There are two levels, the upper of which is 423.10 feet above sea level, while the lower is 411.20 feet above sea level. To the bottom of the lower level, this shaft is 330.9 feet deep. This shaft starts below the contact of the Bonneterre limestone with the overlying Davis shale and the lower workings are reported to be from twenty to thirty feet above the Lamotte sandstone.

This mine has been worked at two levels, but the upper was abandoned before very much of an area had been mined. Altogether about six acres of ground have been worked. The mine workings are shown in Plate XCVI.

WATER.

This is one of the wet mines of the district, the water coming through open channels, most of which have an approximately east and west strike. I am informed that the amount of water pumped varies from 1300 to 1600 gallons per minute. This water comes out of the channels in places under a pressure of from 90 to 100 pounds per square inch.

There is little doubt but that most of the water enters this mine through the underlying Lamotte sandstone, as evidenced by the water rising through channels in the floor. There is also evidence that some of the water may have come from the surface. For example, a perennial spring near the Big river was dried up when one of the major water channels was cut into in the mine workings. One of the channels when cut into contributed a flow of inky colored water, probably due to fine black mud carried in suspension.

In this mine there is an excellent illustration of the manner in which the channels open and close, showing the possibility of avoiding breaking into them when care is exercised in running drifts ahead. The case in mind is a large pillar which contains a water channel, but from which very little water enters the mine. Drill holes in this pillar show the water in the channel to be under a heavy pressure, but altho the pillar has been cut all around there is no evidence of this water on the outside.

Drilling in the vicinity of this mine developed the fact that at a depth of sixty to eighty feet there is a water bearing horizon, belonging to what is known as the upper ground water circulation.

Some attempts have been made to shut off the water entering the mine through the channels by driving wooden plugs and forcing cement into the openings. The result of this attempt has been satisfactory except that in some places there has been a noticeable increase in the flow from channels from which previously there was only a small discharge of water. In checking the flow of water from channels, the system of sealing employed by Mr. E. B. Kirby, of the Federal Lead Company, has been followed.

FAULTING.

I recognized some minor faulting along the major channels but nothing of importance. In a number of instances I observed a horizontal fluting of the dolomite, which has been considered evidence of lateral movement along joint planes. It is impossible to determine the amount of such movements but the result is shown by the abrupt termination of galeniferous beds against dense, compact dolomite, in places where there is no vertical displacement.

JOINTING.

There are many channels in this mine, some of which are open while others are closed where encountered in the underground workings. Some of the channels are open in one drift and closed where they cross the adjacent drifts on either side. Some are open at the bottom of the drift and closed at the roof. The passageways along these channels are evidently very irregular as evidenced by the above conditions. These channels have a general east and west strike, altho some trend nearly at right angles.

In addition to the channels there are zones of prominent jointing and short discontinuous joints as observed in the other mines. The short joints are frequently filled with thin veins of calcite and galena.

BRECCIATION.

The only brecciation in this mine is such as may be accounted for by solution. It is inconspicuous and occurs mainly along the channels where solution has detached small blocks of dolomite.

FOLDING.

There is some dipping of the beds and occasional rolls in the roof, but nothing was observed in this mine which could not be accounted for through sedimentation and solution.

BEDDING.

The varieties of rocks occurring in the other mines are common to this. The proportion of shale is less than in some of the mines and there is very little strongly chloritic dolomite. The beds thicken and thin as is usual in this part of the Bonneterre formation. At several places the shale contains lenses of dolomite giving it a conglomeritic appearance.

The galena has associated with it in places calcite, pyrite and zinc blende. These occur both in the veins and in the sheet ore.

The decomposed zones adjacent to the channels are very irregular, extending farthest away from the main fissures along the bedding planes. The channel rock is whitish, yellowish, greenish and brownish, depending upon its original composition and the extent to which leaching has taken place.

MANNER OF OCCURRENCE OF THE GALENA.

In one end of this mine the ore appears to occur at two quite distinct levels from 6 to 8 feet apart. The upper run of ore consists mainly of fine disseminated galena in brown dolomite, with thin sheets along the bedding planes. The galena in the lower run is coarser and occurs more in irregular bunches.

Very few pockets have been encountered in this mine, the superintendent informing me that he only recalled two. Likewise only two cavities of any size have been broken into. These were lined with crystals of calcite and a little galena.

Considerable of the galena occurs in thin veins along joints which cross only one or several beds. These are found in the brown dolomite through which the galena is also disseminated. The sheets of galena along the bedding planes are associated with laminae of black shale and are actually thin beds of rich disseminated ore.

The shale beds are not thick and the rich sheets of disseminated galena in shale, which characterize some of the other mines, do not show here.

The sheets of galena sometimes end abruptly, probably due to lateral movement along a joint plane and may have occurred either before or after the introduction of the galena.

There has been some leaching of the galena adjacent to the channels and along the decomposed portions of certain beds. Evidently both enrichment and impoverishment of the ore have been going on during recent years, probably by the same circulation.

It is interesting to note in this connection that in places considerable zinc blende occurs with the galena, usually in very finely disseminated particles. Some of the ore runs as high as 3 to 4% zinc blende as it comes from the mine. Between Mines No's. 10 and 11 the company drilled an area about 500 feet by 700 feet which was underlain with an horizon of zinc ore running from 5 to 7 feet thick and containing about 20% zinc blende. It is very finely disseminated and occurs at about the same level as the lead ore in No. 11 and No. 12 mines.

MINES NO'S. 12 AND 14.

These mines, known as the Hoffman, are located near the center of Sec. 4, T. 36 N., R. 4 E., near Leadwood station on the Hoffman branch of the Mississippi River and Bonne Terre railroad.

Shaft No. 12 was sunk in 1902 and shaft No. 14 in 1905. The mill began operations in the Spring of 1904. These two shafts are connected underground by a narrow drift. About five acres of ground had been mined at No. 12 and about one acre at No. 14, up to January first, 1908.

The collar of shaft No. 12 is 878.32 feet above sea level, while the bottom of the lower level is at an elevation of 398.77 feet A. T., which makes the bottom of the mine workings at the shaft 479.55 feet below the surface. The collar of shaft No. 14 is 847.21 feet above sea level, while the bottom of the mine workings is at an elevation of 409.01 feet A. T., the shaft being 438.2 feet deep to the bottom of the mine workings. Comparing the mine workings in the two shafts it should be observed that there is a difference in the depth of the bottoms of only about ten feet. The ore body is at essentially the same level, there being an apparently slight dip to the southwest. This dip shows at the surface and evidently persists throughout the thickness of the formation.

Shaft No. 12 starts near the contact between the Davis shale and the overlying Derby dolomite, passing through the entire thickness of Davis shale which, at this place, is about 120 feet, according to surface measurements. It passes almost through the Bonneterre formation, the ore horizon lying just above the Lamotte sandstone. Shaft No. 14 starts about 30 feet below the contact of the Davis shale and Derby dolomite and continues almost to the Lamotte sandstone. Some of the lower beds in the mine workings of No. 12 are quartzose and the ore evidently lies in and just above these transitional beds.

The channels and prominent joints discharge an abundance of water into the mine workings. The pumps discharge about 800 gallons per minute, which keeps the mines relatively dry.

The main ore body occurs in the lower 50 feet of the Bonneterre formation. The galena is chiefly in the disseminated form, altho horizontal sheets, veins and pockets occur as in the other mines. Some zinc blende and pyrite occur with the galena.

The beds in which the galena occurs are essentially the same as in the other mines. The dark colored, coarsely crystalline dolomite, the black shale and the coarsely crystalline shaly, chloritic rock constitute the richest ore bearing strata. The galena, in some places, occurs thinly disseminated through the upper portion of the Lamotte sandstone, as shown in the mine workings and drill holes. The galena in this mine is especially coarsely crystalline and the ore is rich. Altogether there is no essential difference in the manner of occurrence of the ore from that which has been observed in the other mines of the district.

THE DOE RUN LEAD COMPANY.

The Doe Run Lead Company was organized in 1887, the first production reported being 2,900 tons of concentrates in 1888. This was from mines located at Doe Run a few miles south of the area included in this report. About 1890 this company purchased a large tract of land in the Flat River area and began prospecting. Since that time the company has acquired the properties formerly owned by the Union Lead Company and the Columbia Lead Company, these purchases being made in 1907. The total holdings of this company now amount to about 5,000 acres.

The mines at Doe Run comprise four shafts, two of which are connected with workings from which the company obtained all of its ore up to 1892, during which year the first shaft in the Flat River area was completed. The mines at Doe Run continued to supply ore until 1895 when they were practically abandoned.

The first shaft which the Doe Run Lead Company attempted to sink at Flat River was abandoned at a depth of 200 feet owing to a heavy flow of water which was encountered at a depth of 96 feet. The second shaft, known as Shaft No. 1, is 376.43 feet deep, and was completed in 1892.

The company has eleven shafts on their property in the vicinity of Flat River. Six of these, No's. 1, 2, 3, 4, 8 and 9, are active, while the five remaining shafts have been abandoned, temporarily at least.

Another shaft was started near No. 8 in 1907, but work on the same was suspended before it had progressed very far.

The workings in Mines No's 1 and 4 are connected as are also those in Mines No's 2 and 3. Each of the other mines is reached by a single three compartment shaft. All of the operating shafts are equipped with modern hoisting appliances. Mine No. 6 was abandoned soon after the shaft was sunk, owing to the building of the Illinois Southern railroad which runs so close as to make a very inconvenient crossing for the Mississippi River and Bonne Terre railroad spur. Shaft No. 5 is a pump shaft, ninety feet from Shaft No. 4, which was sunk to drain the latter shaft after it had been drowned out by an extremely heavy flow of water from a channel.

THE DOE RUN LEAD CO.

No. 2 shaft and power plant (since remodeled).

No. 7 is an abandoned shaft near No. 2. One of the two remaining shafts is located on the property formerly owned by the Union Lead Company and the other is what was formerly No. 1 of the Columbia Lead Co.

The ore from these several mines is milled and roasted at Doe Run, where the company has a concentrating plant and furnaces. The matte is shipped to Herculaneum, where it is refined at the plant owned by the St. Joseph Lead Company. A new concentrating plant is being constructed south-west of Central station on the Mississippi River and Bonne Terre railroad, to supplement the one at Doe Run. The Doe Run plant has a daily capacity of 1100 short tons, while the new plant will have a capacity of 1200 short tons.

This company has produced from its several properties, including those at Doe Run, up to December 31, 1906, about 213,000 short tons of lead concentrates, valued at about $9,700,000. During the same period there was produced by the mines owned by the Columbia Lead Company, 18,112.5 short tons of lead concentrates, valued at $703,972. In 1900, the only year for which we have any record of production, the Union Lead Company produced 35 short tons of lead concentrates, valued at $1,585. This makes the total production of lead concentrates from the property owned by the Doe Run Lead Company, 231,000 short tons, valued at nearly $10,500,000.

In obtaining the ore included in the above estimates, the company has mined about fifty acres of ground.

MINES OF THE DOE RUN LEAD COMPANY AT DOE RUN.

Altho these mines are outside of the area included in this report, and were not in operation during the time that my investigations were being carried on, I believe it is important that some mention should be made of them in this place.

Prior to the organization of the Doe Run Lead Company, Mr. Wm. R. Taylor had sunk a shaft at Doe Run striking some disseminated lead ore at a depth of 40 feet. The present owners optioned, drilled and purchased the land, beginning active operations in 1887.

The company sunk two shafts, one 110 feet and the other 47 feet deep. The shafts are both close to where the pre-Cambrian granite outcrops, and the Bonneterre dolomite, in some places, lies directly upon the granite, the Lamotte sandstone being absent.

In some places a boulder conglomerate was found to lie between the dolomite and the granite. The mine workings are shown in Plate XCVIII.

The ore occurs both in the dolomite and in the conglomerate, the former being the main source. These mines were being operated at the time former State Geologist Arthur Winslow wrote his report on "Lead and Zinc," and the following is quoted from the 2nd volume of that report, as being the best general description of the formations and the manner of occurrence of the ore deposits at this place, that has been published.

"* * * The country rocks consist of the St. Joseph (Bonneterre) magnesian limestone, the Lamotte sandstone and conglomerate and of Archean granite, probably traversed by dikes of diabase, tho the latter are not exposed. The granite is of the common pink color, with a preponderance of feldspar over quartz, and with little or no black mica. The magnesian limestone is of the same character as heretofore described, often arenaceous and chloritic, and sometimes containing numerous fine scales of shale which the lens shows to be fragments of lingulella shells. The true shales are gray, drab and argillaceous, tho some thinly bedded, friable limestones are structurally to be classed as shales. The sands are granular, friable, and of white to yellow colors, sometimes with a calcareous matrix; the grains are small, and show secondary enlargements, and sometimes enclose larger, sub-angular fragments of quartz. The conglomerate consists of granite and diabase boulders and large pebbles enclosed in a limestone matrix, which is rich in chlorite; this conglomerate lies upon the granite floor, or is massed against the granite walls or in depressions of the old surface."

"* * * * the magnesian limestone and other clastics lie upon a very uneven floor of Archean granite, which crops out to the south, and is also encountered in the mine. The surfaces exposed in the mine are well rounded and decomposed, being bleached and partially kaolinized to depths of several inches. The conglomerate is stratigraphically the lowest member, but it is not always present. but occupies depressions and other favorable positions. Sandstone and other arenaceous limestones are the next in ascending order, but these are also principally developed in the basins; thus, on the slopes of the old granite surfaces magnesian limestone is frequently the only rock represented." * * * * "Over the sandstone, a series of magnesian limestone beds appear, which, in the lower part, frequently enclose non-persistent beds of sandstone. Beds of shale are also found within a short distance of the sandstone, but they are not generally represented in the sections at the mine, and are probably not persistent. * * * * *."

"* * * The ore is entirely galena disseminated in limestone, principally between depths of 50 and 90 feet. It is generally in layers parallel to the stratification, but is also along vertical and inclined seams or is uniformly disseminated throughout the rock. The accompanying accessory minerals are principally calcite and pyrite, which latter contains some nickel. Galena is also found in the matrix of the conglomerate between the granite boulders, which are, hence, excavated in mining. Crevices and joint-planes are frequently seen in the mine; many of these cease with stratification planes, while others continue across them, and are of undetermined extent. None are of very great magnitude, and they are generally quite tight with no measurable space between the walls, tho sometimes they open out to cavities of lenticular sections. The most prevalent direction is W. S. W., but others are found running nearly N.-S." * * * "Some present clear evidence that there has been no faulting along them, as the stratification is continuous from one side to the other, and horizontal seams of galena run directly across. At other points, the ore is cut off sharply at such places, but generally comes in again farther along horizontally, on the opposite side. Along one prominent and persistent crevice on the eastern side of the mine, indicated on the map, there is much soft material and dolomitic sand, and the surfaces of the rock are slickensided; certain beds of limestone here are more decomposed than others, and are represented by a soft sand carrying galena. Some galena was also found in the crevice itself."

The ore body at this place exhibits the same irregularities in both its vertical and horizontal dimensions as characterize the ore bodies developed at Flat River and Bonne Terre. There is likewise the same association of joints and channels, indicating the same probable origin. This area, however, is an exception to the Flat River and Bonne Terre, inasmuch as there has never been any surface or shallow mining. This, however, could scarcely be used as evidence against the descensional origin of the ores, since it is probable that the horizons, in which the shallow deposits of galena occur in the Bonne Terre area, have, long since, been removed through the ordinary process of erosion.

It is interesting to note that some of the granite in this immediate neighborhood carries micaceous hematite in a disseminated form and in veins, making it quite apparent that certain phases of the igneous masses were originally well mineralized at certain horizons and in some localities.

MINE NO. 1 (Flat River).

This mine was opened in 1891 after an unsuccessful attempt to sink another shaft about 600 feet south. This shaft, which is a little south of west of the Mississippi river, was operated for a short time and then abandoned on account of excessive water. It was opened again in 1907 and ore is now being mined from a lower level than that worked in the early nineties.

The fact that the mine was flooded during the time of my investigations in the District renders a description of the ore body at this place impossible. It is supposed, however, to be a part of the ore body which is being mined from No. 4 shaft, and if such is the case, my descriptions of that mine will in a measure be applicable to No. 1.

The collar of shaft No. 1 is 791.43 feet, and the floor of the mine is 415 feet above sea level. This makes the shaft 376.43 feet deep. The shaft starts in the Davis shale and from its position must pass through from 30 to 40 feet of this formation before entering the Bonneterre dolomite.

The bottom of the ore body which has been worked is therefore about 345 feet below the top of the Bonneterre formation and about 15 to 20 feet above the Lamotte sandstone.

MINES NO'S 2 AND 3.

Shaft No. 2 is located approximately 3080 feet S. 12° W. of shaft No. 1, while shaft No. 3 is located approximately 3630 feet S. 15° W. of shaft No. 1. Shaft No. 2 is on the east side of the tracks of the M. R. and B. T. railroad and just south of Central station, while shaft No 3 is just west of the same tracks and about one-third of the distance between Central and Elvins stations.

Shaft No. 2 was sunk in 1893 and 1894. Three pumps were required to handle the great volume of water encountered while sinking this shaft. Shaft No. 3 was put into operation in 1898, having been sunk to connect with a drift from No. 2 mine. It is interesting to note that, in spite of the fact that the lower part of the formation directly underneath the shaft was being drained by Mine No. 2, at a depth of 150 feet, the influx of water was so great that a drill hole had to be sunk in the bottom of the shaft to connect with the underlying drift to prevent the shaft from being flooded. The water was thus removed to Shaft No. 2 and pumped out at the surface.

This incident may have some bearing upon our conclusions as to whether the heavy flows of water encountered in sinking the shafts and in drilling in this area are essentially surface or artesian. To me it is substantial evidence that there is a great volume of water within the Bonneterre dolomite which is essentially surface, altho much of the water which finds its way into the deeper mine workings comes from the underlying Lamotte sandstone.

At an early day surface diggings were operated near these deep mines, but we have meagre records of their development and production. The sinking of Shafts No's. 1 and 2 was preceded by diamond drilling and it is reported to be during the prospecting of this land that the first holes were drilled to the Lamotte sandstone. Prior to this time the depth of drilling was limited to 300 feet.

The collar of shaft No. 2 is 758.98 feet above sea level, while the bottom of the mine workings at the shaft is 335 feet above sea level. The mine workings are, therefore, 423.98 feet below the surface. At the time this shaft was sunk it was the deepest in the District.

The collar of shaft No. 3 is 757.22 feet above sea level, while the bottom of the mine workings at the shaft are at an elevation of 354 feet. The shaft is therefore 403.22 feet deep. There are two levels in this mine, the upper of which lies between 354 and 370 feet A. T. and the lower between 321 and 360 feet A. T. The lower level is reached by means of an incline and is commonly known as the "Incline."

These two mines are connected with a drift about 475 feet long. The ore is obtained from practically the same level and it is thought that the workings are on different parts of the same ore body. Both of the shafts went through about 40 feet of residual clay and shale. The bottom of shaft No. 2 must be about 15 to 20 feet above the Lamotte sandstone, while the bottom of shaft No. 3 is evidently 30 feet above this sandstone. The incline or lower drift of No. 3, has in places been worked down to the sandstone at an elevation of about 321 feet. Most of the ore obtained from these mines has been taken from the lower 60 feet of the Bonneterre dolomite. It is interesting, however, to note that in mine No. 3 the galena also occurs in the upper 2 feet of the Lamotte sandstone.

Plates C. show an outline of the underground workings of Mines No's. 2 and 3 up to the latter part of 1905. Up to the time the map was made between 26 and 27 acres of ground had been mined, practically at one level.

The manner of occurrence of the ore in these mines does not differ essentially from that previously described for other mines in this district. The effect of changes in the character of the sediments, solution, jointing, flexuring and faulting are repeatedly illustrated in different parts of these mines.

WATER.

In sinking both of these shafts, as noted above, heavy flows of water were encountered. In 1902, the company was pumping from 1200 to 1400 gallons of water per minute. Altho the area of the mine workings has increased greatly since that time, it is reported that little, if any more, water is being pumped. During the summer of 1907, the amount of water pumped was less than at any former period. The pumping of water from many shafts in this area appears to have temporarily lowered the water level. The quantity of water also fluctuates some with the seasons, being in a measure proportionate to the rainfall. There has probably been no essential change in the quantity of water received from the underlying Lamotte sandstone, the lessened volume probably being due to the drainage of the surface circulation of the Bonneterre formation.

Reference is made above to the quantity of water which was encountered in sinking shaft No. 3. The formation through which the shaft was sunk was being drained below by a drift extending to shaft No. 2. It seems hardly probable that the water encountered while sinking shaft No. 3 could come from the Lamotte sandstone, altho it might have reached that part of the formation through a circuitous route, first through a channel and later horizontally along the bedding planes.

During the progress of the development of these mines, channels were encountered which contained water under heavy pressure. An east and west channel about west of shaft No. 3 has been plugged in order to prevent the water from escaping into the mine. Other channels discharging considerable water were observed in different parts of the mine. In several instances, where the mine had been worked to within 12 or 15 feet of a known water channel, the water gradually found its way out along the bedding planes. In a number of instances the wet walls and roofs of drifts indicate close proximity to water channels.

The nearness of these channels to the sandstone furnishes an excellent reason for believing that at least a portion of the water enters the mines from the sandstone under artesian conditions. It is also equally apparent that the surface waters find their way into the Bonneterre dolomite and also into the underlying sandstone along open channels of this character. The Bonneterre formation, where these mines are located, appears to have been heavily saturated with ground water. Out of 47 channels and prominent joints located in Mine No. 3, water was entering along 24 and in considerable quantity. The following analyses show the character of the water (1) which is supposed to be rising from the sand and of that (2) which is supposed to be coming in from the surface.

	Grams per litre. (1)	Grams per litre. (2)
Lead Sulphate	0.00037	0.00038
Sodium Chloride	0.04771	0.04127
Sodium Sulphate	....	0.01884
Potassium Sulphate	0.01881	0.01106
Magnesium Sulphate	0.11206	0.08586
Calcium Carbonate	0.19923	0.16875
Magnesium Carbonate	0.06092	0.08391
Ferrous Carbonate	0.00088	0.00070
Manganous Carbonate	0.00018	0.00030
Alumina	0.00104	0.00044
Silica	0.01008	0.01234

Some of the water entering the mine deposits considerable quantities of iron oxide, leaving a rich reddish brown precipitate. In one place calcium carbonate is being deposited, the broken dolomite at the head of one of the drifts being cemented into a breccia by this precipitate.

FAULTING.

Altho there are undoubtedly numerous minor faults in these mines, I have recorded the occurrence of only three, all of which are in Mine No. 3. A number of displacements were observed in Mine No. 2, but no record was made of them. Along some of the more prominent water channels there may be faulting, but displacements are difficult to recognize owing to the often complete decomposition of the rock for several feet on either side of the channel. All of the faults are normal.

One of the faults recognized has a throw of 15½ inches. The plane of the fault strikes N. 77° W. and dips 33° S. At the place where the fault was observed a six inch bed of dark brown shale, overlain with a two inch sheet of almost solid galena, was displaced in such a manner as to leave no doubt as to its magnitude. This fault had every appearance of being subsequent to the introduction of the galena, altho I observed nothing about the galena to indicate that it could not have been introduced after the faulting. The relation which this fault bears to the ore and dolomite beds is shown in Plate CII.

The second fault is of the "branching" type. The faulting, as usual, is normal. It has a downthrow of 3 feet to the north, a strike of N. 85° E. and a general dip of several degrees north. Here, as in the case of the first fault, there is every appearance that the movement was subsequent to the introduction of the galena. The only evidence to the contrary is the absence of galena along the fault plane, where one might have expected it to have been dragged in with the movement.

The third example of faulting is along a prominent water channel which extends through the north end of Mine No. 3. The fault strikes N. 87° W. and exhibits in places a throw of a few inches to the south. This channel has a variable dip, 15° south from the vertical being the maximum. The channel is open in places and the rock is frequently broken for a space of 1½ feet on either side. The openings are in places filled with dark clay in which are embeddied small cubes of galena, which appear to have been formed since the introduction of the clay.

The above are typical of the faults occurring in these mines and they do not differ essentially from those observed in the other mines of the district. At a number of places where the ore had evidently lowered or raised abruptly along a clean, well-defined, inclined joint, I was unable to detect any displacement. The elevation of the ore often changes in crossing these so-called "slips" but there is no evidence of faulting to account for it. I have discussed the reason for this change in the elevation of the ore horizon at another place.

JOINTING.

As in the case of the other mines, I have attempted to separate the joints roughly into three classes, viz.: (1) channels, along which the rock shows evidence of leaching or oxidation, (2) prominent joints, along which the wall rock is fresh and apparently unaltered and (3) short, discontinuous joints, showing in perhaps one or several beds for a short distance and then dying out. The joints of the first two classes often pass into each other when followed from one part of the mine to the other. Of these there are a great many in the two mines under consideration. Of the third class, I took very few observations. They occur in considerable numbers usually in quite well defined areas. They are often mere cracks in a single bed and frequently they are partly filled with calcite and galena. They are vertical and inclined and usually strike across the major joint system.

With regard to the joints of the first and second classes, it is especially noticeable that they occur in well defined zones, several prominent joints usually paralleling one another at distances of a few feet or yards apart.

I did not make observations on all the joints in Mine No. 2, altho some of the major channels were observed and their locations recorded. In Mine No. 3, I have a record of nine channels, two of which are faults. These channels strike from N. 83° E. to N. 83° W., being approximately east and west. All of these, with one exception, are vertical or nearly so. Some water flows from all of these channels and in two instances the quantity is so great that the openings have been plugged.

Just south of shaft No. 2 there is a "master" channel which evidently carries the strongest flow of water of any in these mines. This channel strikes approximately east and west, apparently becoming less important to the west. The mine workings follow along both sides of this channel for a distance of 900 to 1,000 feet, cutting through it in three places and nearly to it in several other places. The approach to this channel on both sides is marked with yellowish and whitish colored decomposed dolomite, known throughout the district as "channel rock." As a rule this decomposed dolomite is barren, altho the unaltered rock on either side may carry a high percentage of galena. Should the ore body, where it approaches the channel, contain any moderately thick sheets of galena, these often persist almost if not quite to the channel.

There are a number of other well defined channels in this mine, all of which exhibit practically the same characteristics as the one above referred to. One of these occurs about 385 to 390 feet south of the first channel. There are many prominent parallel or nearly parallel joints, and, in several places, zones of jointing having an approximately N. E.-S. W. strike were observed.

In mine No. 3 I located nine channels two of which exhibit faulting as described above. These channels have, in general, an east and west strike, varying not over ten degrees north or south. With one exception they are vertical. Water is entering the mine through all of them and each side is marked by light colored, yellowish green or yellowish brown decomposed rock.

As noted elsewhere the walls of these channels are usually rough and irregular and the strike varies from place to place often within narrow limits. They may be open in some places and tightly closed in others. In one of the channels there is some dark clay, containing small cubes of galena. Another channel contains pyrite and still others calcite. Altho well crystallized aggregates of galena are reported to have been taken from some of these channels, I did not observe any during my inspection.

Besides the channels, I observed and located thirty-one prominent joints striking in a general east and west direction, parallel to the channels. I also noted the occurrence of prominent joints striking N. 45° E., N. 52° E., N. 55° E., N. 65° E., and three N. 77° W. Water was entering the mine from seventeen of these. Most of them are vertical, only six showing dips of measurable magnitude. One had a dip of from 30 to 45 degrees, while the dips of the remaining five do not exceed ten degrees.

The third class of joints do not appear to be very abundant in these mines and such as were observed I did not consider of sufficient importance to make a record of. They are usually tight but where open they occasionally contain galena and calcite, especially the latter. As explained elsewhere, they are very local in their occurrence, being confined to one or several beds.

The channels and prominent joints appear to have had some connection with the concentration of the ore, as shown by the persistent association of the two. Particularly in Mine No. 2, the ore body appears to have been richest along the major zones of jointing and it seems to be perfectly clear that the local enrichment of this ore body has been in a general east and west direction.

Altho there was no means of determining whether these major joints had their origin at the surface or at the contact with the underlying Lamotte sandstone, the preponderance of oxidizing conditions in the lower beds and an apparent broadening of the zones of leached and weathered dolomite next to the channels, leads me to infer that, in part, at least, they originate at or below the contact with the underlying sandstone.

BRECCIATION.

I observed no brecciation in this mine that cannot be accounted for by solution and subsequent settling. Altho there may be some brecciation along the faults, I did not observe any.

FOLDING.

Altho the beds in various parts of these mines dip more or less, no folds of importance were noted. The usual apparent dips due to thinning and thickening of the strata were observed. In one place in Mine No. 3 I recorded the presence of a fairly well defined flexure, the axis of which has a strike of N. 65° W. One limb of this flexure had a dip of about 30° to the southwest.

I made no detailed measurements to determine the general dip of the beds in these mines, but the surface observations indicate a general inclination to the southwest.

MANNER OF OCCURRENCE OF THE GALENA.

The galena occurs in essentially the same manner that it does in the other mines of the district, i. e., disseminated through the dolomite and shale; in horizontal sheets along bedding planes; in vugs and cavities; filling and lining the walls of joints; and occasionally in cubes or aggregates of cubes in the channels.

The greater part of the ore is of the disseminated type. The galena occurs not only disseminated through the dolomite and dark colored shale, but also in the sandstone and chloritic beds lying at the base of the Bonneterre formation. At one place in Mine No. 3 I observed a twelve inch bed of almost solid galena resting upon the Lamotte sandstone, while the underlying sandstone, to a depth of a foot, was sufficiently rich to be mined. The disseminated galena is found very sparingly in the light colored, dense varieties of dolomite, being associated chiefly with that which is dark colored.

In many instances the galena is chiefly concentrated in the upper portions of the shale and dolomite beds and the galena is more coarsely crystalline the nearer the top of the bed is approached. My only explanation of this is that the solutions travel mainly along the top of the shale beds, the openings being above rather than below them. If a shale bed occurs between two beds of dolomite and the latter should shrink on account of solution or for any other reason, the shale would rest upon the underlying bed of dolomite, the opening being between the shale and the overlying bed. This hypothesis does not require that the solutions come from the surface, for an ascending as well as a descending circulation would enter and flow along the bedding planes. Plates CIII. and CV. illustrate this type of ore as it occurs in these mines.

Horizontal sheets of galena occur along bedding planes, usually associated with thin laminae of black or dark brown shale. The sheets of galena usually grade into the disseminated type of ore, and where the galena in the latter constitutes as high as 70 per cent of the ore it should probably be classed with the sheet ore.

It is not easy to make even an approximate estimate of the percentage of ore that occurs in this form, but from general observations I believe it is safe to say that it is next in importance to the disseminated. This type of ore is illustrated in Plate CV.

A few irregular cavities, filled or partly filled, with a soft, dark colored clay, galena, calcite and pyrite, were observed. I also noted the occurrence of an occasional pocket lined with calcite and galena. These are not abundant and are of very minor importance from a commercial standpoint. The character of these so-called "pockets" is well illustrated by the drawings reproduced on Plate CIV.

Next in importance to the sheet galena is that which has crystallized along short joints, which are abundant in some parts of the mine. These veins of galena, as a rule, do not persist through more than three or four beds and frequently are wholly confined to a single bed. It is chiefly in this form that the galena occurs in the light colored, compact dolomite. The veins, however, occur in all the varieties of dolomite within the horizon of the ore body.

They frequently occur in the dolomite beds above or below a shale bed. Every evidence seems to indicate that the short cracks in the adjacent dolomite beds, more particularly those above the shale, have resulted from a compression of the shale. In these instances the solutions evidently followed the bedding planes and entered the beds above and below the shale along cracks which were probably formed in the manner suggested above.

The manner of occurrence of the galena and its relation to the associated rock are nicely shown in the accompanying illustrations, Plates CI., CII., CIII., CV. and CVI.

It is interesting to note that in Mine No. 3, some lead carbonate was observed in one of the lower decomposed beds, while none was observed at other horizons. Underneath this layer of soft, white rock, occurs a two foot bed of soft, brownish dolomite, in which the galena gradually decreases in amount toward the bottom. In several places, where the dolomite was partly decomposed, I observed very clear cases of leaching of the galena, which has gone on so generally in close proximity to the channels.

The phenomenon of the ore horizon dropping in the direction of the dip along inclined joints was observed in Mine No. 3. Along these joints, known to the miners as "slips," there is no evidence of faulting, and I am led to conclude, here as elsewhere, that the position of the ore may best be explained by the deflection of the lead bearing solutions downward along these joints.

Faulting, however, does occur, the ore being apparently displaced. The faulting, as far as any evidence I obtained from these mines is concerned, may have been prior or subsequent to the introduction of the ore bearing solutions. The galena is deposited only in beds offering the proper reducing conditions and these may have been faulted prior to the introduction of the galena. When the lead solutions are introduced into the formation, reduction occurs only at favorable horizons. If these are faulted, the beds may have the appearance of having been faulted after the introduction of the galena.

It is extremely difficult to estimate the relative importance of the lead bearing solutions coming from the Lamotte sandstone and those coming from the surface, altho every evidence in these mines seems to emphasize the importance of the former. Likewise the ore bodies everywhere show the important part played by the dark colored shale and brown dolomite in the concentration of the galena. The almost constant association of the ore bodies with the channels and prominent joints is so striking in these mines as to give emphasis to the conclusion that the latter have been important factors in the concentration of the galena.

MINE NO. 4.

Shaft No. 4 is located approximately 825 feet S. 34° E. of No. 1. It is southeast of and near the Flat River station of the Mississippi River and Bonne Terre railroad.

The mine workings are reached through two shafts No's. 4 and 5, ninety feet apart. These shafts were sunk in 1899-1900.

Shaft No. 4 was flooded soon after it was finished and No. 5 was sunk to unwater it. The flooding of No. 4 was due to breaking into a channel, which discharged more water than the pumps, having a capacity of 1500 gallons per minute, could handle. No. 4 shaft has three compartments and is 6x18 feet in cross section. No. 5 shaft is 6x14 feet in cross section and is used exclusively as a pump shaft.

In sinking shaft No. 4, comparatively little water was encountered, but later the workings were flooded by breaking into a water channel in a drift near the shaft. This illustrates the importance of avoiding a direct connection between the channels and the mine workings where it can be avoided. Of course, when first broken into, the flow of water is greatly augmented by the pressure of the water filling these channels above the level of the mine workings. Later, when this water has been pumped from the mine, the pressure decreases and the quantity of water discharged is correspondingly lessened.

Altho there were no shallow mines on the land immediately underlain by this ore body, it is located in close proximity to land upon which shallow mining was carried on at an early day.

The collar of this shaft is 784.93 feet above sea level while the mine workings lie between 400 and 425 and between 380-390 feet above sea level. The lower level is reached by an incline from the upper and should probably be considered a part of the same ore body. The shaft is 385 feet deep while the bottom of the incline is 405 feet below the collar of the shaft.

The shaft passes through about 45 feet of Davis shale and the bottom of the incline is probably not much above the Lamotte sandstone. The ore occurs chiefly within the lower fifty feet of the Bonneterre dolomite, as in the case of the ore body at Mines No.'s 2 and 3. The mine workings are shown in Plate CVII.

The manner of occurrence of the ore, the composition of the rock, the jointing and faulting and the flowage of water are very similar to what has been described above for Mines No's. 2 and 3.

WATER.

As stated above, shaft No. 4 was drowned out shortly after the company began hoisting ore. In sinking the shaft no unusual amount of water was encountered, the flooding of the mine being due to breaking into a channel a short distance from the shaft. The volume of water discharged by this channel is not known, but it exceeded the capacity of the pump, which was 1500 gallons per minute. After No. 5 shaft was sunk, draining No. 4 shaft and workings, the channel was plugged with wedges, shutting off a considerable portion of the water. At the present time about 1400 gallons per minute are pumped from this mine.

The channel at the shaft has a strike of about N. 83°-84° W. and the opening between the walls is in places from 1 foot to 2 feet wide. This channel separates the mine into two parts, having been cut through in only one place. At another place in the mine this or a parallel channel was broken into and later plugged with wedges, shutting off most of the water.

Altogether I noted fifteen channels and joints through which some water is entering the mine. In most cases the flow is not very great, the main supply coming from three or four channels. One of the walls of the mine runs for a considerable distance parallel and close to the main channel, and from this wall considerable water seeps out along the bedding planes.

At one place, not far removed from this channel a "puncher" drill hole struck an opening from which there is an intermittent or periodic flow of water. The water flowed out of the hole every 18 seconds much after the manner of a miniature geyser. At a later time I made a second determination of the periodicity of this flow and found it to be once every 18½ seconds.

I obtained the impression that a greater part of the water entering this mine comes from the Lamotte sandstone, altho that which is carried by the main channel near the shaft is undoubtedly derived in part from the circulation in the upper part of the Bonneterre formation. That this water is oxidizing rather than reducing in nature is evidenced by the broad zone of decomposed dolomite adjacent to the channels. Dolomite carrying disseminated galena outside of the weathered zone is usually barren in the leached zone adjacent to the channels. Evidently the galena has been removed through the agencies by which the decomposition of the dolomite was brought about.

FAULTING.

Altho there may be some displacement along the major channel passing through the mine near the shaft, I was not able to detect it at the single place where it had been cut through. I noted several normal faults in this mine but none of them had a measurable throw of more than 12 inches. The throw of two of the faults could not be measured and it is possible that one, if not both, of these has a greater displacement than those for which the throw was determined.

In the case of four of the faults, the downthrow side is to the south, while in two instances the downthrow is to the north. One of the faults, illustrated on Plate CVIII., has a throw of 3 inches. The plane of the fault strikes N. 78° W. and dips 4 or 5 degrees south. A second fault illustrated on Plate CVIII., has a dip of ten to fifteen degrees south with an unknown throw. This fault is to fifteen degrees south with an unknown throw. Another fault strikes N. 63° W., has a throw of 12 degrees south and contains between the walls some calcite and pyrite. The fourth fault dips 5°-8° N., strikes N. 78° W. and has a vertical displacement of 12 inches. Another fault has a throw of about 2 inches to the north and a strike of N. 78° W.

In two instances the faults appear to have been formed later than the introduction of the galena. As explained elsewhere, the fact that the shale beds rich in galena are displaced, is not in itself sufficient evidence to warrant the statement that the introduction of the galena was subsequent to the faulting. In some places the ore appears to have been displaced along tight joints, but close observation often fails to reveal any faulting.

JOINTING.

Six channels were located in different parts of this mine. Faulting occurs along three of these channels, while the others show no displacement. Water enters the mine along most of these channels, altho several of them are comparatively dry. These channels are approximately vertical and have a strike which, with two exceptions, is within 10° of east and west. Two of the channels strike respectively N. 63° W. and N. 67° W. The main channel, which separates the two parts of the mine, covers a zone which in some places must be at least 50 feet wide. It evidently consists of a series of parallel joint planes which are open along different parts of their courses. They traverse a zone of oxidized and leached dolomite having a yellowish, brownish or greenish white color. This channel carries a strong flow of water and probably communicates in some manner with the underlying sandstone. The walls of the channel where it has been cut through near the shaft, are irregular and the openings vary in size in different places.

Along most of the channels I observed occasional aggregates cf calcite and pyrite crystals, these appearing to predominate in the weathered zone adjacent to the channels. In one instance I observed a few crystals of galena which were apparently formed between the walls of the channel.

I recorded the occurrence of 45 prominent joints, only one of which has a strike of N. 68° W. Fourteen have a strike of from N. 72°-78° W., while the remaining 30 have strikes which vary from N. 80° W. to east and west. Most of these joints are vertical, a dip of from 5° to 8° being noted in three or four instances. Water was entering the mine through twelve of these joints, the remainder being practically dry.

I did not record all of the short, discontinuous joints, having made a record of only nine. Three of these had strikes of from N. 40° E. to 57° E. Two of these had strikes of N. 55° to 57° W. The others had strikes of N. 70°-78° W. Galena and calcite frequently occur along the walls of these joints. They are often very tight, exhibiting a mere film of galena between the walls. They do not strike persistently in one direction, but are irregular and often branching. They occur chiefly in the harder, denser beds of dolomite. The manner in which the galena occurs in these short joints is illustrated in Plate CX.

It is interesting to note the degree of oxidation which occurs along channels and the apparent unaltered condition of the dolomite adjacent to the more prominent seams as well as along the discontinuous joints.

BEDDING.

In connection with the description of some of the other mines in this district, illustrations have been introduced to show the character of the bedding. The same irregularities illustrated by those drawings are present in the mine under discussion. The dark shale beds thicken and thin with no apparent regularity, often dying out completely within the mine. The same may also be said regarding the beds of light and dark colored limestone. This condition is well illustrated by Plate CIX. These illustrations show conditions as they were actualy observed in the mine. Here we have alternating beds of light colored dolomite, dark colored dolomite, brownish black shale, conglomeritic dolomite and chloritic, arenaceous dolomite. In this connection one should observe especially the influence which the composition of the rock has had upon the formation of the galena.

BRECCIATION.

Brecciation was not observed in this mine. Along the fault planes the beds are somewhat broken in places and there has been some slight disturbance due to solution. These phenomena, however, can hardly be considered under the head of brecciation.

I observed a number of beds which had the appearance of being conglomerates. One might perhaps consider their texture to be the result of compression, but I believe that the evidence is in favor of their sedimentary origin.

FOLDING.

Throughout this mine there seems to be a gentle dip to the south and southwest. In a number of places I recorded dips of from 5°-8°. These dips, however, are essentially local and do not continue for any considerable distance.

MANNER OF OCCURRENCE OF THE GALENA.

As elsewhere the galena occurs in essentially five ways, i. e., disseminated through the dolomite and shale; in horizontal sheets along the bedding planes; in vugs and cavities; filling and lining the walls of joints; and in aggregates of cubes in the channels.

The disseminated type predominates and the beds of shale are ofttimes so thoroughly impregnated with galena as to give the impression that the bed is a sheet of solid galena. It is noticeable that in the dark limestone the richest concentration is in the upper part of the bed, the dissemination gradually becoming thinner as the bottom of the bed is approached. This is illustrated in Plate CX. I also observe that where the galena is deposited next to a bed of shale or in the shale, it is richest just above or in the top of the shale. In the streak of ore itself, the galena is more coarsely crystalline at the top than at the bottom. This condition is illustrated in Plate CX.

In this mine there is considerable chloritic dolomite, which is often shaly. The galena is often quite uniformly disseminated through this rock as well as through the shale and dark colored dolomite.

In the decomposed rock adjacent to the channels much of the disseminated galena has been removed. Occasional flecks were observed in the chloritic beds where they contain some shale.

Horizontal sheets of galena 1″ to 4″ in thickness have not been uncommon in this mine and are second in importance to the disseminated deposits. I noted during my examination sheets of galena which were in places 6″ and even 8″ in thickness. These are almost invariably associated with thin laminae of blackish brown shale. In several places I noted calcite associated with the galena along the bedding planes. Plate CIX. shows the manner of occurrence of these sheets.

Cavities are not plentiful. I recorded their occurrence in only two places, one in the northwest and the other in the southeast part of the mine. In the first instance the bottom of the pocket contained black mud, while above it was a mass of calcite with crystallized galena and pyrite. The second pocket contained calcite and crystallized galena. There is every evidence in these instances that the pockets were formed first and that later, through the introduction of black mud, reducing conditions were established which resulted in the precipitation of galena and calcite which continued until the cavities were filled.

There are also occasional small vugs in dolomite, in which galena has formed. These, however, are not conspicuous features of the ore body.

In many parts of the mine calcite and galena line the walls of short joints, sometimes filling the openings. Some of these contain calcite alone, while in others both calcite and galena occur. In some instances the galena has been deposited as a thin film in roundish spots, heretofore spoken of as "spatters" of galena. It is thought that in the aggregate the galena which occurs in this manner makes up a very small part of the total output of the mine.

Plate CX. shows veinlets of galena in the dolomite underlying thin beds of brownish black shale. The veinlets of galena are associated with calcite and in one instance pyrite also occurs.

The galena occurring in crystal aggregates, altho noted in several of the channels, is very subordinate and unimportant. It usually occurs with calcite, much in the manner that it does in the pockets.

On the whole this has been what might be termed a rich body of ore. Some pyrite occurs with the galena but as a whole the mine has been remarkably free from this mineral. At the time of my examination the ore body was in places 20 feet thick. The general shape of the ore body, as developed by the mine workings, is shown on the mine map, Plate CVII.

MINE NO. 6.

This is represented merely by a shaft which was sunk to connect with an extension of the ore body from Mines No. 2 and 3. The laying of the Illinois Southern railroad tracks just west of the shaft resulted in its abandonment.

MINE NO. 7.

This is represented by an unfinished shaft near Shaft No. 2.

MINE NO. 8.

This mine is located on what is known as the Mitchell tract and is near the center of the S. W. ¼ of the N. E. ¼ of Sec. 10, T. 36N., R. 4E.

This mine was opened in 1907 and has been operated less than a year. The collar of the shaft is at an elevation of 862.43 feet above sea level, while the bottom is 427 feet above sea level. The shaft is therefore 435.43 feet deep. Provided the Davis shale is of normal thickness at this place the shaft must have passed through about 90 feet of shale and the bottom must be about 20 feet above the Lamotte sandstone.

I did not examine the ore body at this mine, but it is interesting to note that it is situated beneath a very considerable thickness of Davis shale and that it is a little over three quarters of a mile from the nearest shallow diggings. It is also of interest to note that it lies on the upthrow side of a fault of considerable magnitude which passes in a N. W.-S. E. direction about a half a mile to the north.

MINE NO. 9.

This mine is on the property lately purchased from the Columbia Lead Company and was known variously as the "Columbia No. 2," "Pim" and "Red Onion." It is located a little east of the middle and near the north line of Sec. 17, T. 36N., R. 5E. It is a little over 1½ miles almost directly southeast of Doe Run No. 1.

This mine was first put into operation in 1897-98 shortly after the sinking of Columbia No. 1. The shaft is located on what is known as the "Pim Tract" which lies east of Land Grant 3272, owned by the Federal Lead Company.

Altho the mine is located on land which has no known overlying deposits of surface galena, such deposits have been mined a short distance to the west, southwest and northeast.

The sinking of this shaft was preceded by diamond drilling through which the ore body was located. The collar of the shaft is 904.54 feet above sea level, while the bottom of the lower level is at an elevation of about 404.5 feet A. T. The mine workings are at two levels, the lower being about 500 feet below the surface, making this the deepest shaft in the area. The top level is about 380 feet from the surface. The shaft went through about 150 feet of Davis shale and the bottom is from 30 to 35 feet above the Lamotte sandstone.

This shaft is located on the downthrow side of a well defined fault zone, which lies southwest of the mine workings, as shown on the geological map. The mine workings are shown in Plate CXII., but this does not indicate the shape or position of the ore body. In some parts of the mine the ore lies above and in others it lies below the level of the workings.

Most of the ore taken from this mine has come from about 25 feet of the Bonneterre formation lying about thirty feet above the Lamotte sandstone. From this horizon about four acres have been mined. In addition to this some ore was taken from the upper level about 100 feet above the lower level. It is reported that the ore at this level is pockety, not occurring in a regular run.

WATER.

Considerable water enters this mine along the channels and joints, but nowhere is there a channel discharging the quantity of water recorded for the channel near the shaft of Mine No. 4. The quantity of water entering the mine does not appear to fluctuate materially with the rainfall.

During my investigations I noted between 15 and 20 prominent joints and channels through which more or less water was entering the mine. From one of the joints, which had a strike of N. 60°E., there is a strong flow of water apparently entering the mine under considerable pressure. From most of the other channels the water is either flowing gently or is merely dripping from the roof. In some places the back is constantly wet, the water appearing to be slowly entering along the bedding planes as well as along the joints. In other parts of the mine there are very few joints and consequently very little water.

I am inclined to believe that most of the water entering this mine comes from the underlying Lamotte sandstone rather than from the surface. In those portions of the mine which exhibit the greatest number of joints the rock appears to be extensively oxidized as shown by its yellowish, brownish and greenish white tints. The extent of decomposition is apparently too great to be accounted for by channels extending from the surface.

FAULTING.

I have recorded the occurrence of three minor faults in this mine, striking respectively N. 83° W., N. 73° E. and N. 23° E. The first has a throw of 1½ inches and a dip of 28° N. The second is vertical and has a throw of one inch to the north. The third is vertical and has a throw of 1½ inches to the southeast. The first fault is along a water channel, showing decomposition of the wall rock while the other two are along prominent joints which show no evidence of decomposition.

Where these faults occur there is no ore, for which reason it is impossible to draw any conclusion as to their age with respect to the introduction of the lead bearing solutions.

JOINTING.

As in the case of Federal Mine No. 1, the joints in this mine strike in many different directions.

Among the channels I observed five which strike N. 30° W.; three that strike N. 60°-63° W.; three that strike N. 23°-27°E.; and two that strike N. 53°-63° E. Out of 46 prominent joints, twenty strike from N. 25° E. to N. 40° E.; ten strike from N. 70° W. to E. and W.; seven strike from N. 25° E. to N. and S.; five or six strike from N. 40° E. to N. 65° E.; and three strike from N. 55° W. to N. 75° W. I observed a number of short discontinuous joints most of which have strikes ranging from N. 15° E. to N. 30° E., which is in general parallel with the more numerous prominent joints.

As in the case of the joints in the mines previously described, the walls of the channels are decomposed and discolored with red iron oxide. Several of them contain soft red mud which may indicate that the openings extend to the surface. Openings were observed along some of these channels which are from 6 to 8 inches wide. The decomposed zone was measured in several places and found to extend from 3 to 4 feet on either side of the channels.

Some of the short seams contain calcite and galena, but many of them are simply frosted with minute calcite crystals.

BRECCIATION.

No brecciation was observed in this mine except such as might be accounted for by solution and subsequent settling. The dolomite around some of the larger cavities has been broken and recemented, but this is merely a phenomenon of solution and settling.

FOLDING.

I observed several anticlinal and synclinal flexures, but they appear to be the result of sedimentation. The longer axis of one of these flexures has a strike of about N. 45° W. The others were not measured. In one of the drifts the beds appear to have a gentle dip to the southwest while at another place the dip appears to be to the northeast. The appearance and disappearance of a spotted bed of dolomite in this mine, leads one to infer that the beds are undulatory, but there seems to be no uniformity in the strike of the axes of the flexures or in the dip of the beds.

MANNER OF OCCURRENCE OF THE GALENA.

The galena occurs in the same manner as described for the other mines in the district, viz.: disseminated through the dolomite and shale; in horizontal sheets along bedding planes; in vugs and cavities; and filling and lining the walls of joints. I did not observe any crystal aggregates of galena along the channels.

I observed a bed of spotted dolomite 12 to 16 inches in thickness similar to a bed occurring in Federal Mine No. 2. It usually carries disseminated galena chiefly near the top and bottom. The disseminated galena is mainly in the brown dolomite, altho it also occurs in the thin laminae of shale which occur in some parts of the mine. As elsewhere, the disseminated ore is the predominant type.

Occasional horizontal sheets of galena from one to four inches in thickness occur over very limited areas. They are associated with thin laminae of black or brown shale, with which they appear and disappear.

Galena, associated with calcite and sometimes pyrite, occurs in some of the joints. These veinlets of galena are frequently connected with cavities or other openings. They supply only a very subordinate amount of the ore.

In my examination of the mine I noted fourteen or fifteen cavities of various sizes filled with a mixture of galena, calcite, pyrite and sometimes soft clay. The major constituent is usually calcite with galena and pyrite in subordinate amounts. In one instance I observed a pocket 2½ feet in diameter filled with a greenish clay through which was scattered crystals of pyrite and cubes of galena.

These cavities usually occur near the decomposed zones, and are evidence of leaching and subsequent filling with shale, in which galena, calcite and pyrite were precipitated.

In general this mine illustrates the influence of the sediments and the importance of the jointing in the production of the ore bodies. The ore, as a whole, has not been rich, but its richness has been in proportion to the abundance of dark colored dolomite and brownish black shale. There has been a generous circulation in most parts of the mine, and here the concentration is all that might have been expected.

In many places the rock has been decomposed and in these places, I observed very clear illustrations of the leaching of the galena. Partly decomposed crystals of galena were observed in a number of instances.

There appears to be an unusual amount of pyrite associated with the galena. It was observed in the disseminated ore and in the horizontal sheets, as well as in the cavities. In some places it constitutes as much as 25 to 30 per cent of the ore. Pyrite, however, appears to predominate at horizons where decomposition has progressed farthest and it has been my observation that where the pyrite and galena individuals are of the same size the pyrite is the more persistent of the two.

In the upper level the ore is very bunchy and contains a high percentage of pyrite. In the west drift a good bunch of ore 20′ x 30′ x 20′ was mined about 40 feet from the shaft, while some scattering ore was obtained from the south drift.

COLUMBIA NO. 1 (Doe Run Lead Co.).

This mine is at present flooded, not having been operated since it passed into the hands of the Doe Run Lead Company. The shaft was sunk in 1899 but operations were not started until January,

COLUMBIA LEAD CO. (Now owned by the Doe Run Lead Co.).
Shaft No. 1, with concentrating plant in the rear.

1900. This mine and the Columbia No. 2, have been operated somewhat intermittently, having been leased at one time by "The Commercial Lead Company." During the period of its existence the Columbia Lead Company produced from its two mines about 18,112 short tons of concentrates valued at about $704,000.

The collar of the shaft at Columbia Mine No. 1 is about 800.00 feet above sea level while the bottom is at an elevation of 513 feet A. T. The shaft is therefore 287.00 feet deep. These measurements are not exact, the topographic map indicating that the collar of the shaft is about 810 rather than 800 feet above sea level. The underground workings are shown in Plate CXII.

The shaft is entirely within the Bonneterre formation, starting about 35 to 45 feet below the top and bottoming about 25 to 40 feet above the Lamotte sandstone. This mine is located in the vicinity of a number of large sink holes, into which the water from the surrounding land drains. It is not known that they are connected with the mine workings altho the broad open channels would provide excellent avenues of communication.

In the early days there were a great many shallow diggings near this mine, but we have no record of their production or of the manner of occurrence of the ore. The ore body which has been worked in this mine is at about the same horizon in the Bonneterre formation as the ore body at Federal Mine No. 5. It lies very irregularly distributed through the lower 100 feet of the Bonneterre formation. The top of the so-called "Murray" raise is 104 feet above the track level at the shaft, while the high ground in the east end is about 80 feet above the track level at the shaft.

Instead of working at different levels in this mine the ore has been followed up from the main level by means of upraises which often have a winding course around the edge of bluffs. The mine map shows very well the complex character of the workings, which are the result of an attempt to follow the ore through a very much weathered and leached horizon, from which a portion of the galena has been removed by ground water.

WATER.

This mine does not receive a very heavy flow of water from the underground channels and joints, altho these are more numerous and more open than in any other mine in the district. There is considerable fluctuation in the amount of water pumped, due mainly to the rainfall, as is clearly shown by the turbid water entering the mine along the channels. The great quantities of soft red mud entering the mine along some of the channels and the increased discharge of water from these channels after storms are very good evidence that they communicate with the surface zone of oxidation.

I noted twelve or fifteen channels and prominent joints through which water was entering the mine. With two exceptions these were open, but in only one instance was any considerable volume of water being discharged from any of the channels. This channel is in the south end of the mine, but it is not sufficiently exposed to determine its strike.

The water deposits iron oxide in some parts of the mine and in others calcium carbonate. In the dry parts of the mine, especially where there is a little dampness, fine accicular crystals of magnesium sulphate are deposited. These are found on the walls and also on the bottom of the mine. They have very much the appearance of wads of cotton or growths of white fungus.

The broad zones of decomposed dolomite adjacent to the channels are evidence of the oxidizing character of the ground water. Undoubtedly these waters become reducing in nature locally where they come in contact with the dark dolomite or brownish black shale. The general barren character of the leached or weathered zones indicates the probable abstraction of galena by the oxidizing circulation.

FAULTING.

There is undoubtedly considerable faulting in this mine, but the extensive decomposition of the beds has rendered the identification of these faults a difficult matter. At one place a bed of black shale was followed up to a joint striking N. 33° E., but beyond this it could not be found. The limestone was somewhat brecciated along this joint and there is every evidence of a displacement. At another place I observed several joints the walls of which were slickensided. These joints have a N. and S. strike, but I was unable to determine the amount or direction of the displacement. At another place I noted a fault having a strike of N. 40° W. and a downthrow of 14″ to the N. E. The plane of the fault has a dip of 20° N. E. This fault is illustrated in Plate CXIII. In a number of other instances the beds were observed to be dipping toward channels, in places as much as 15°. These dips may be due entirely to settling as a result of solution, but, on the other hand, they may be due to faulting, as a result of which the ends of the beds have been dragged down on the upthrow side.

In one instance where I noted a discordance in bedding the details indicate that the condition is attributable altogether to sedimentation, as illustrated in Plate CXIII. The surface geology does not show fault zones of any considerable magnitude in the vicinity of this mine and I am inclined to believe that the faults are small. The extensive decomposition of the dolomite, which has been in progress at this horizon, might easily give rise to such faults in the lower part of the Bonneterre formation.

JOINTING.

During my examination of this mine I noted channels at 59 different places in the mine. The channels in one part of the mine are probably, in some instance, the continuation of channels noted in other parts. I found that 25 of these channels have strikes ranging from N. 20° E. to N. 20° W. Twenty-one have strikes ranging N. 30° E. to N. 55° E. Nine have strikes ranging from N. 55° W. to N. 30° W. Seven have strikes ranging from N. 60° E. to N. 60° W. Most of the channels are nearly vertical, the greatest dip noted being 20°. The dips are in various directions N. W., N. E., E. and W. The west and northwest dips predominate.

Many of the channels are open and in one case I measured a space of from 4 to 6 feet between the walls, from which a soft red mud had washed into the mine. Along these channels the dolomite is very much decomposed, forming a soft yellowish or reddish brown clayey, dolomitic sand. The decomposed zones adjacent to the channels are very irregular. In some, the dip varies from nothing to 15°. The strike varies 10°-15° from one point to another. In some places I observed branching channels. In other places the decomposed zone is made up of several channels one of which may be most prominent in one part of the mine and least prominent in another part. Channels filled with from 2 to 3 feet of soft, sticky red clay, similar to that at the surface, are common. In several exceptional instances I noted that the clay had a grayish brown color. In these channels galena and pyrite, both iron and copper pyrites, occur. Crystal aggregates of galena have been washed into the mine with the red clay and from two or three of the channels, boulders of dolomite occur embedded in the clay, having evidently been detached from the walls of the channel by solution.

In general, this mine exhibits better than any other in the district the extensive decomposition of the lower horizon of the Bonneterre formation, in which the ore bodies usually occur. This mine illustrates also, the fact that the presence of open channels may not be evidence of a heavy flow of water under present conditions. At one time these channels may have carried as much water as is now discharged from the prominent channels of Doe Run Mines No's 3 and 4 at Flat River.

I measured the strike and dip of about 140 prominent joints in different parts of the mine. These do not include all, for in some places six or more parallel joints occur only a foot or two apart, in which case I simply took the strike of the most prominent, and made a notation that others occur parallel with the one of which the measurements were taken.

About 46 of these joints strike between N. 30° E. and N. 55° E. Of these, twenty-nine strike between N. 30° E. and N. 38° E. About 52 strike N. 30° W. to N. 55° W., almost at right angles to those previously referred to. Twenty-eight strike between N. 30° W. and N. 38° W. Thirteen strike about N. 60° E. Twenty-one have strikes of between N. 30° E. and N. 30° W.

Among the great number of joints in this mine, I observed several that evidently had their origin in the Lamotte sandstone. At least the joints referred to are well developed at the bottom of the mine but die out before reaching the roof. Wherever these occur we have important evidence leading to the conclusion that many of the joints do not continue to the surface. Such evidence as I was able to gather, leaves no doubt in my mind as to the occurrence of surface and basal systems of jointing.

There are numerous short, discontinuous joints in all parts of the mine. The occurrence of these, however, were not generally recorded. My notes seem to indicate that these joints strike in various directions, much in the same manner as the prominent joints referred to above.

There are more inclined joints in this mine than in any of the others which I have examined. As a rule, the joints do not dip more than 10°, altho I have a record of a number in which the dip is from 20° to 30° from the vertical. These dips are not confined to any particular set of joints, but have been observed for those striking in general northeast, northwest, east and west and north and south. The dip in some cases is in one direction and in other cases in the opposite direction, there being no uniformity. The direction in which these joints dip may be due in a measure to the position of the beds which are not always horizontal.

BRECCIATION.

As noted elsewhere, the channels are frequently filled with mud containing boulders of dolomite. In some places along some of the less prominent channels, the dolomite is brecciated. The broken limestone which occurs within the channels, or adjacent to them, may be either the result of faulting or of solution. I believe, that it may be best accounted for by solution. In some parts of the mine the dolomite is broken into angular pieces by numerous short joints, which, probably through settling, have been slightly displaced. The amount of displacement in the case of these fragments is very little and probably should not be considered under the head of brecciation.

FOLDING.

I was unable to recognize any system of folding, altho the beds dip steeply in many places. I noted several flexures in the roof, the axes of which strike N. 70° E., N. 20° E., N. 33° W., and N.-S. These are apparently due to inequalities in sedimentation or to undulations in the underlying sandstone floor.

The beds dip as much as 20° in some places, but as a rule the dips do not exceed 8° or 10°. These dips do not continue far, usually flattening out or ending abruptly next to a channel or prominent joint. They do not appear to have any significant relation to the ore, altho it is reported that the rock is especially rich underneath the flexures referred to above.

As in the case of the faulting and brecciation described above, I believe that many of the dips recorded may be attributed to differential settling brought about by the decomposition of the dolomite adjacent to the channels.

BEDDING.

As observed in other parts of the district, the bedding in this mine is irregular and often wavy to such an extent as to impress one with the possibility that the rocks have been folded. The wavy character of the beds, however, is chiefly due to the thinning and thickening of beds such as may be frequently observed in sedimentary rocks at the surface. A rather peculiar example of the changes in sedimentation accompanied by thinning of the beds, is shown in Plate CXIII. This is a case in which white barren dolomite is replaced horizontally with black shaly dolomite. This is an excellent illustration of some of the peculiarities of sedimentation observed in the Bonneterre formation.

There is a great deal of yellowish, reddish brownish and whitish colored, decomposed dolomite in this mine, chiefly in close proximity to the channels. The beds of dark colored dolomite and black shale do not appear to be persistent. The black shale is frequently weathered to a blue or greenish blue, while the brown dolomite is often bleached until almost white. The beds of black shale are thin and do not appear to persist over a great area.

In one part of the mine, the ore is obtained about 80 feet above the track level at the bottom of the shaft. In this place, which is known to the miners as "Turkey Trot," the beds are badly broken with joints which strike in various directions. The beds also dip in various directions and the rock instead of being decomposed is in many places almost white from the abundant thin seams of calcite. The rock at this horizon is chiefly hard and finely crystalline, there being very little black shale or dark brown dolomite.

MANNER OF OCCURRENCE OF THE GALENA.

The galena occurs in this mine as it does in all the other mines in the district, namely, disseminated through the dolomite and shale; in horizontal sheets along the bedding planes; in vugs and cavities; filling and lining the walls of joints; and in aggregates of cubes in the channels.

A greater part of the ore is of the disseminated type. It occurs chiefly in the dark colored dolomite and to a lesser extent in thin beds of black shale. Some of the grayish brown rock contains sparsely disseminated galena. This mine contains excellent illustrations of dark beds of dolomite richly disseminated with galena bounded above and below by light colored dolomite beds in which no galena occurs. I also observed a few beds of light colored dolomite in which galena is thinly disseminated. As a rule the dolomite containing disseminated galena is barren where it occurs within the decomposed zones adjacent to the channels.

Horizontal sheets of galena are not abundant. They were observed in a number of places associated with thin layers of black shale, but it may be said, that this is an exceptional mode of occurrence. In two or three instances, these beds of galena were observed to persist into the zone of decomposed dolomite adjacent to the channels.

In some parts of this mine, there are numerous cavities and vugs filled or lined with crystals of galena usually associated with calcite. In quite a number of places, I observed bunches of calcite and galena apparently filling cavities in unaltered dolomite. The calcite and galena were also observed in cavities within zones of partly decomposed dolomite.

Throughout the mine the short discontinuous joints are more or less filled with calcite and galena. In the higher stopes, 60 to 70 feet above the track level at the bottom of the shaft, the dolomite is in places filled with a net work of calcite and galena veins. The joint planes sometimes contain a spattering of galena along the walls and in other places the galena occurs in well crystallized cubes.

The mud which comes out of the channels brings with it occasional aggregates of galena crystals. Galena and pyrite also occur in some of the channels embedded in calcite, by which it has evidently been protected from decomposition. This, however, is not an important source of ore.

There is an abundance of iron pyrites and chalcopyrite, occurring either alone or associated with the galena. The pyrite occurs not only in the dark colored dolomite and shale, but also in the light colored dolomite and in the decomposed rock. In several of the more thoroughly decomposed areas, I noted the presence of malachite. This only occurs as one of the latest products in the decomposition of the dolomite in this district, as far as my observation goes.

There are many illustrations of the leaching of the galena, especially of the disseminated type. The extremely bunchy character of the ore is in part at least, attributable to the leaching and removal of the galena. It is true that the percentage of black shale and dark colored dolomite is less than in some of the other mines of the district, but this in itself is not sufficient to account for the separation of the irregular rich pockets of ore by barren or very lean areas. I observed in this mine many places where it is evident that the galena has been removed. Here, as elsewhere, it is clear that the horizontal sheets and crystallized galena in veins resist longer the agent of decomposition than the galena which is a metasomatic replacement of the dolomite.

DESLOGE CONSOLIDATED LEAD COMPANY.

This company owns about 4800 acres of land in St. Francois county, most of which lies between Desloge and Leadwood stations on the Mississippi River and Bonne Terre railroad. The present company purchased the original tract of about 2,100 acres from the Bogy Lead and Mining Company. The remainder of the land has been acquired by purchase at different times since.

The company has six shafts, a concentrating plant, roasters, furnaces and refinery. Only three of the shafts are being operated at this time. The No. 1 shaft was sunk deeper and worked for a while after the property was purchased from the Bogy Lead and Mining Company, but when shaft No. 2 was sunk on the same ore body, No. 1 was abandoned. In sinking Shaft No. 5 such a heavy flow of water was encountered that it was abandoned. Shaft No. 6 has been sunk on the same ore body but up to the time of writing this report no ore has been hoisted. The present operating shafts are No's 3 and 4, work at No. 2 having been temporarily suspended.

In 1801 lead was mined from shallow depths at a number of places on the land owned by this company. The best known diggings went by the name of "Mine a Joe" and the land upon which they are located was later prospected by the Bogy Lead and Mining Company, whereby it came to be known as the "Bogy tract." The shallow diggings are reported to have been very rich, the ore bodies lying in an east and west belt about 300 feet wide and over a mile long. The galena occurred embedded in red clay filling crevices and lining the walls and roofs of caves and other horizontal openings along bedding planes. One of the men who worked in these mines nearly fifty years ago says that it was not uncommon to find large masses of galena in the form of aggregates of cubes hanging from the roofs of the larger caverns.

There is no way of estimating the quantity of galena obtained from the shallow mines up to 1887, when the Desloge consolidated Lead Company came into possession of the property. From 1894, when we have the first record of production from this company, up to Dec. 31, 1906, there has been produced from the disseminated deposits about 115,367 short tons of concentrates, valued at about $4,923,730. During this period in the neighborhood of 34 acres of ground have been mined.

DESLOGE CONSOLIDATED LEAD CO.

Concentrating plant and smelter.

MINES NO'S. 1 AND 2.

These shafts are located in the N. E. ¼ of Sec. 1, T. 36 N., R. 4 E., otherwise described as the S. E. ¼ of Land Grant No. 870. They are about 800 feet apart. Shaft No. 2 is a little east of south of No. 1. Shaft No. 1 is about 3600 feet S. 35° W. of Desloge station on the Mississippi River and Bonne Terre railroad. Records in the possession of Mr. Furnam Desloge show that this shaft was sunk in 1873 by the Bogy Lead and Mining Company to a depth of 224 feet. The Desloge Consolidated Lead Company began prospecting this land in 1887 and began operations in Shaft No. 1 in 1890. During the following year a number of headings were cut out from the shaft, one of the drifts being about 700 feet long. The ore taken out was placed in a stock pile to await the building of the mill which was started May 1st, 1893.

Jan. 1st, 1892, the company began sinking shaft No. 2 to connect with a drift from shaft No. 1. The collar of this shaft is 839.85 feet above sea level, while the bottom is 507.85 feet above sea level. The depth of this shaft is therefore 332 feet. This shaft starts near the contact between the Davis shale and the Bonneterre limestone and the bottom is about 60 feet above the Lamotte sandstone. The incline to the west is 16 feet above the sand. These figures are approximate, since we have no absolute data on the depth of the sandstone below the bottom of the mine workings.

The workings in this mine, which are shown in Plate CXIV., extend through an horizon of about 150 feet, being connected by upraises and inclines. The ore has actually been mined at about five different levels, the lowest being close to the Lamotte sandstone. South of this mine there is a well defined fault zone having an approximately east and west strike. Evidences of proximity to this fault are exhibited in the mine.

There is some water entering this mine, mainly along channels and prominent joints. When operating, about 150 gallons per minute are pumped. Most of this water evidently comes from the underlying sandstone while the remainder enters from the surface.

The channels and prominent joints have a general east and west strike, altho I have records showing others striking N. 63° W. and N. and S. Some faulting was observed, but the amount of displacement was in no instance absolutely measured. The faults observed were at the lowest level and had downthrows to the north. In one place I observed a channel along which the rock was almost completely decomposed for a width of four feet. At another place this channel tightened and the adjacent wall rock was very little decomposed.

Some dipping of the beds was observed and I noted that in several instances the dip was in the direction of the strike of the joints. No flexuring or folding of importance was observed.

I observed no brecciation other than what might have resulted from solution and consequent settling.

The bedding is in no way essentially different from that described for other mines in the district. It is wavy and irregular in places, while elsewhere it is smooth and even. The rock consists of alternating beds of dark and light colored dolomite, black shale and chloritic dolomite. These thicken and thin as they are followed from one part of the mine to another.

MANNER OF OCCURRENCE OF THE GALENA.

The galena occurs in the same manner as in other mines of this area. In the upper levels it is bunchy and irregular. The greater part of the galena is disseminated through the dolomite and shale, occurring chiefly as a metasomatic replacement of the dolomite. Occasional cavities occur which are filled with dark bluish shale, calcite and galena. Small vugs containing cubes of galena were also observed. As a whole the galena in this mine is finer grained and occurs in a much harder, finer grained rock than at Mine No. 3.

Horizontal sheets of galena do not occur as abundantly as in some of the other mines, but are associated with the black shale in the same manner as described for the other mines. The upper levels are especially characterized by short veins of calcite and galena, filling joints. These sometimes occur along two sets of joints crossing at right angles, giving the roof a checker board appearance. Such an occurrence in the uppermost level is illustrated in Plate CXV. The veins are frequently connected with horizontal beds of shale through which galena is disseminated, as shown in Plate CXV. Pyrite is associated with the calcite and galena, especially in the upper levels where it is relatively abundant.

In one part of the lowest level of this mine the ore appears to lie between two well, defined channels, extending beyond them on either side only where they are tight. I observed that in the weathered dolomite along the channels the galena had been removed by leaching.

This mine further illustrates the irregular bunchy character of the ore body at the higher levels, and its more uniform and persistent character at the lowest level. This is very similar to the manner of occurrence at Columbia No. 1, Federal No. 1 and Federal No. 5. In fact this mine has a very decided resemblance to Columbia No. 1, both in the character of the ore body and in the manner in which it has been worked.

MINE NO. 3.

The shaft leading to Mine No. 3 is located about 3300 feet a little north of west of Desloge station on the Mississippi River and Bonne Terre railroad. It was sunk in 1896. The collar of the shaft is 784.75 feet above sea level. This makes the shaft 286.50 feet deep. It was started about 50 feet below the top of the Bonneterre formation and was sunk to within about 28 feet of the Lamotte sandstone. In some parts of the mine the Lamotte sandstone occurs at a somewhat higher elevation, records of drill holes giving it as about 500 feet A. T. Thus it happens that altho no part of the mine workings are below an elevation of 490, they are in some places nearly if not quite down to the sandstone. In the neighborhood of 20 acres have been worked in this mine.

The ore has all been mined within the lower 130 feet of the Bonneterre formation, mainly from the lower forty feet. In only one place has ore been obtained as high as 130 feet above the Lamotte sandstone and this only over a very small area. There appears to be two ore horizons at this mine, separated by 75 feet of barren or lean rock. Disseminated galena rich enough to work has been encountered in drill holes at a depth of 80 feet. Some disseminated ore has also been found at the surface, but it is not sufficiently rich to mine. The area of the mine workings and the relation of the ore body to the Bonneterre and Lamotte formations are shown on the accompanying drawings, Plate CXVI.

Plate CXVII. shows the horizons at which galena was encountered in a group of holes on this property and illustrates the fact pointed out elsewhere, that in places the disseminated galena extends almost to the top of the formation. In this area the disseminated galena occurs at intervals from the surface to the underlying Lamotte sandstone.

WATER.

This mine receives water chiefly from joints and channels, some of which have become dry since opening the mine. The amount of water entering the mine varies with the seasons as shown by the pumping. In dry weather about 800 gallons per minute are pumped while in wet weather this increases to 1000 or 1200 gallons.

It is thought that this water is derived mainly from the underlying sandstone, altho some undoubtedly comes from the upper or surface circulation as shown by surface debris entering the mine with the water. At one time several car loads of chats came into the mine through one of the channels. Part of the water was also cut out of the mine by cementing several open channels crossing Mine a Joe creek at the surface.

FAULTS.

Minor faulting occurs in this mine as in other mines throughout the district, but the displacements do not exceed fifteen or twenty feet.

JOINTING.

Channels, prominent joints and short discontinuous joints occur in different parts of the mine. They usually occur in zones. In one place three parallel channels strike about N. 70° E., while in another place there are four or more channels crossing at angles of 20 to 30 degrees. These break the rock in such a manner as to render the roof unsafe.

The channels are open and on either side decomposition has rendered the dolomite soft and most of the galena once occurring in a disseminated form has been removed.

FOLDING.

Flexures in the roof and gentle dips attributable to irregularities in sedimentation and solution occur in some places. I did not recognize any flexures which might be attributed to compressive stresses.

BRECCIATION.

No brecciation was observed in this mine.

BEDDING.

This mine is characterized by the same varieties of rock as are found in the other mines at this horizon. Uneven bedding planes, thickening and thinning of the beds, and alternation of sediments are exhibited in many places.

MANNER OF OCCURRENCE OF THE GALENA.

The disseminated type of ore predominates, but with it occur veins of galena and calcite along joints; vugs and cavities with black mud, galena and calcite; and horizontal sheets of galena associated with thin laminae of black shale.

Everywhere, this mine gives evidence of the constant association of the galena with the black shale, dark colored dolomite and with the fracture zones.

The galena is coarser grained than in Mine No. 2 and occurs in a coarser grained, softer rock. As mentioned above, it occurs at practically two levels the upper one extending over the lower. Most of the pyrite on this property comes from this mine and is disseminated through the rock with the galena.

The removal of galena through the leaching process is also exhibited and the same relation exists between the ore body and the water channels as explained in connection with the other mines.

MINE NO. 4.

The shaft leading to Mine No. 4 is located about 4300 feet S. 83° W. of shaft No. 3. It is about 500 feet south of Big river and 900 feet west of Owl creek. The collar of this shaft is 760.25 feet above sea level, while the bottom is at an elevation of 445.75 feet above sea level. The shaft is therefore 314.5 feet deep. The shaft is in Bonneterre dolomite throughout its entire depth. The bottom of the mine workings is everywhere close to the Lamotte sandstone and in some places the sandstone itself is exposed near the floor. The sinking of this shaft was begun in 1902 and the first ore was hoisted in 1903.

All of the ore has come from one level comprising an horizon of not over 30 to 35 feet of the lower part of the Bonneterre formation. The ore body lies practically horizontal and has remained remarkably uniform in thickness and richness. I do not know the area worked out, but when I made my examination it did not exceed four or five acres, as shown by the mine workings, Plate CXVIII.

There is considerable water in this mine but not an excessive amount, considering the closs proximity of Big river. From 200 to 250 gallons per minute is the amount pumped. The water enters the mine along channels and prominent joints which probably obtain their supply chiefly from the underlying sandstone. One of the drifts now extends under the river, but where it crosses the rock is tight and practically no water enters at that place.

There are a number of well defined channels, three of which have a strike of N. E.-S. W. Another has a strike of N. 56° W. One of these channels was open at the bottom from 3 to 5 inches, but near the roof it was practically closed. I observed another channel, not so open, showing an oxidized zone of about a foot on either side at the bottom, but in unaltered dolomite at the top. These are clearly joint planes belonging to the basal system and the oxidation along the walls has been occasioned by the introduction of oxidizing solutions entering from the underlying sandstone.

I did not identify any faulting or brecciation in this mine, altho both may occur. In one place the sandstone appears to enter quite abruptly on one side of a well marked joint, giving the appearance of faulting, but I was unable to recognize any displacement.

The bedding is especially regular in this mine, altho the same alternation of sediments occur here as in other parts of the district. In the west end of the mine the bottom is worn, giving the impression that the underlying sandstone is undulatory.

The ore occurs chiefly in the disseminated form, altho sheets of practically solid galena occur to such an extent as to make this an important type of ore. Some galena and calcite occurs in veins along joint planes. Pyrite is less abundant than at Mine No. 3 altho associated to some extent with the galena. Zinc blende occurs in a finely disseminated form in some parts of the mine and is especially characteristic of the ore at this place.

Wherever decomposed zones occur, the ore approaches the channels in an irregular manner, indicative of the manner in which leaching removes the galena from the dolomite. The galena follows quite closely the black shale and brown dolomite beds, entering very little into the lighter colored dolomite or green shale. The chloritic beds, where they happen to be of a bituminous character, contain disseminated galena.

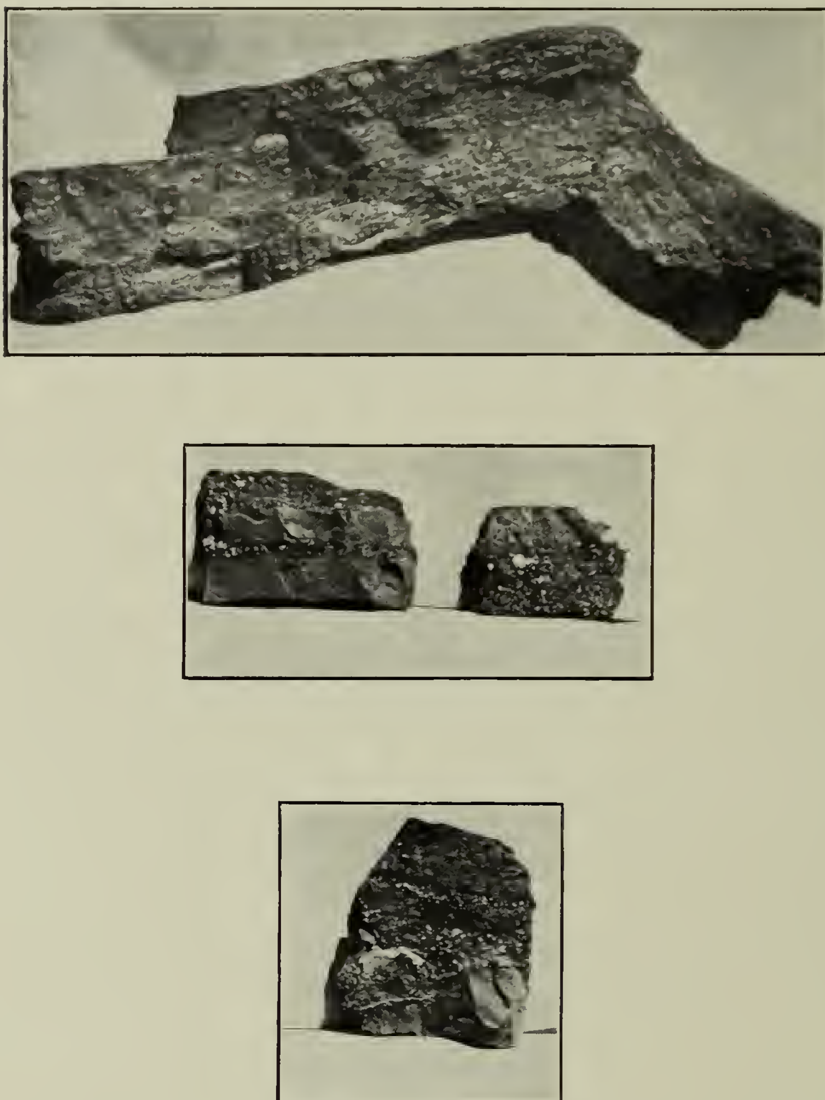
MINES NO. 5 AND 6.

Shaft No. 5 is located near the line between the N. E. ¼ and the N. W. ¼ of Sec. 9, T. 36N., R. 4E., about ¾ of a mile south of Leadwood. This shaft was abandoned before completion and Shaft No. 6 was started 1000 feet southeast of shaft No. 5. This shaft has been completed to a depth of 494 feet, the intention being to sink it eight feet deeper as soon as the water can be controlled. Shaft No. 5 was started at an elevation of 890.72 feet above sea level, while the collar of shaft No. 6 is 903.72 feet above sea level. Shaft No. 6 passed through from 160 to 170 feet of Davis shale and reached the Lamotte sandstone at a depth of about 500 feet making this one of the deepest shafts in the district. At a depth of 489 feet a one foot bed of black sandstone carrying a small percentage of disseminated galena was encountered. Beneath this occurs the main ore body which is eight feet thick and directly overlies the Lamotte sandstone. Drilling on this property developed the presence of galena thinly disseminated through the underlying gray sandstone to a depth of about 40 feet. The same condition was found to exist by drilling on the adjoining properties owned by the St. Joseph Lead Co.

In sinking shaft No. 5 a channel was encountered near the top of the Bonneterre formation and followed down to the bottom. This channel opened and closed at intervals throughout the depth of the shaft, discharging from 250 to 300 gallons of water per minute into the shaft. From such information as I could obtain it appears that this channel must extend to the Lamotte sandstone and that the water must enter the shaft under artesian conditions.

In sinking shaft No. 6 a vein of calcite about one inch in thickness was encountered in the Davis shale above the Bonneterre formation and followed to the bottom. This vein was on the whole vertical, altho its position shifted from one side of the shaft to the other. At a depth of about 260 feet the shaft was receiving from 60 to 70 gallons of water per minute. A pump station was cut and the water was hoisted from that level. All the remainder of the way there was a small seepage into the shaft totaling 50 gallons per minute at the bottom. Drill holes in the bottom now show a heavy flow of water in the underlying sandstone. The channel in No. 5 and the calcite vein in No. 6 strike about S. W. and N. E., which is parallel to a certain fault zone recognized at the surface.

Samples of ore from this shaft show it to occur in a dark colored dolomite and that it is coarsely crystalline. Drilling in this region indicates that the underlying Lamotte sandstone floor is very irregular, probably due in part to faulting and in part to a general dipping of the strata to the northeast and southwest.



SPECIMENS OF ORE.

The white spots are in the main galena. The folded bed was caused by settling due to solution. (From No. 3 mine of the St. Louis Smelting and Refining Co.)

CHAPTER V.

GENESIS OF THE ORES.

INTRODUCTION.

Our investigations have failed to produce evidence, which might indicate that the sedimentary rocks of this area were ever saturated with hot solutions or impregnated with gaseous emanations rising from known or unknown depths, from known or unknown sources. Pneumataltic action does not demand serious consideration in a study of the ore deposits of this area. The igneous rocks are all very ancient (pre-Cambrian) and volcanic activity had ceased long before the deposition of the middle Cambrian, in which the ore bodies occur. This is shown by the profound erosion which preceded the advent of the Cambrian sea. There is nowhere evidence that hot springs were active at any period in the history of the area. Neither have we evidence that these formations were buried, at any time, deep enough to materially increase the temperature of the ground-water.

There is no evidence that the galena, as now found, was deposited, mechanically or chemically in the dolomite except in minute particles as hereinafter described. The examination of thin sections of the ore under a compound miscroscope (See Plates XXXIV., XXXV. and XXXVI.) fully demonstrates the futilty of advancing this theory as an explanation of the origin of the ore bodies within the sedimentary formations.

PUBLISHED THEORIES.

It appears almost unnecessary to review in detail the various theories advanced as to the origin of the lead ores of this area, since no one, with the possible exception of Nason and Winslow, has entered into such a discussion with anything more than a few very general observations on the mode of occurrence of the ore bodies.

Arthur Winslow, who was at one time director of this Bureau, probably made more extensive observations than any one else up to the present time. His ideas bearing on the genesis of the ore are embodied in the following paragraphs quoted from Vol VII of the reports of this Bureau and Bulletin No. 132 of the United States Geological Survey publications.

Discussing the distribution and character of the disseminated ores of this district, on pp. 486 and 487, Volume VII, of the reports of this Bureau, Winslow says: "One of the principal determining causes, we think, was the original open structure or texture of part of the rock. This is often observable now, and specially characterizes ore-bearing strata. Second, a prevalence of organic matter in certain strata or along certain horizons, as indicated by a darker color now often seen, had doubtless influence. Further, the various shale beds probably limited and guided the solutions, as referred to in describing the Bonne Terre deposits."

"Numerous vertical crevices furnished channels for the flow of the solutions. The sheets of galena frequently found in these crevices prove that the solutions followed them. These were sufficient to supply the ore of higher-lying disseminated bodies. The contraction and disappearance of the crevices with depth, make them inadequate for the deep deposits such as prevail along Flat River. For these ores we are inclined to refer to the underlying sandstone, which is in close proximity, as the solution carrier. This is saturated with water, much of which flows directly from decomposing crystalline rocks. The sandstone itself contains particles and fragments of these rocks, which must hold more or less of the metals. A downward flow of water toward Flat River and Bonne Terre is induced by reason of the slope of the Archean floor, and also probably by the Farmington anticline to the east which we have described. The water is thus under pressure sufficient for it to rise up through the limestones, and where suitable physical and chemical conditions are reached the deposition of the ore will take place. We are inclined to think that the formation of the ore is still in progress; the finding of galena on calcite crystals, already referred to (p. 453), is evidence of this. In the southeast, as elsewhere, however, the Coal Measure epoch furnished probably the most favorable conditions. Decomposing organic matter was doubtless introduced into the rocks through solutions. The proximity of the Illinois coal field had probably also a localizing influence."

In Bulletin No. 132 of the United States Geological Survey, Winslow, in referring to his hypothesis of the origin of the disseminated ores, says: "It derives the deposits from the metals diffused through the country rocks, by means of the surface decomposition of the latter. Minute quantities of the metals being present in not only the limestones but the Archean rocks also, as has been demonstrated by analysis, the metals would naturally pass into solution on the decay of these rocks and be transferred in percolating waters through crevices and other openings to the underlying strata, where they would gather by segregation into deposits of various forms and kinds. In the case of the disseminated ores, the waters flowing from the underlying sandstone doubtless carry metals in solution in minute quantities, largely derived directly from the remains of decaying Archean rocks. These, on entering the limestones, find conditions (which were not afforded in the sandstone) suitable for the replacement of the country rock by galena and for the formation of ore bodies. The metal containing waters can have found access in other ways also."

W. P. Jenney, following Owen, Percival and Posephny, maintains that the ores have been derived from great depths, having been brought to their present position by waters circulating upward along fault planes. This hypothesis is based upon the theoretical occurrence of metallic minerals at some unknown point beneath the surface and the presence of conditions (unknown) through which these minerals are taken into solution. We believe that such a hypothesis, in which one is obliged to introduce hypothetical factors, is untenable in the face of others which involve well known and observable processes sufficient to account for the phenomena under discussion.

Recently Van Hise and Bain have sought to account for the occurrence of these ores through a combination "ascending and descending solution theory," basing the same almost entirely upon observations recorded in the reports of Arthur Winslow. They believe that all the lead and zinc ores of the Mississippi Valley have resulted from "a first concentration by ascending waters and a second concentration by descending waters." From page 55 of the "Preliminary Report on the Lead and Zinc Deposits of the Ozark Region," by H. F. Bain and C. R. Van Hise, the following is quoted:

"It appears perfectly clear to me that these facts indicate two concentrations. The first was effected by a deep circulation mainly between the shales near the bottom of the Cambro-Silurian limestone and the Devono-Carboniferous shales. At the time of this deep circulation the disseminated ores in the limestones and shales were deposited. The reducing and precipitating agents were clearly the organic matter of the limestones, and especially of the shales.

It is notable that the deposits in which there is evidence of a first concentration, with comparatively little effect by a secondary concentration, occur in the district in Missouri in which there has been the deepest mining."

"When the Devono-Carboniferous shales were removed by erosion, then began the second concentration by descending waters; and at this time the disseminated ores were taken into solution and concentrated in the crevices, as at places at the Mine La Motte and Bonne Terre areas. At this time the disseminated lead sulhide of the first concentration was oxidized to sulphate. The sulphate was largely carried downward by descending waters, and by reactions between that compound and the marcasite or organic matter reprecipitated as sulphide, thus resulting in a second concentration. At the upper levels, mainly above the level of ground water, lead carbonate (cerussite) was formed by reaction between lead sulphate and calcium carbonate" (Van Hise).

DEFINITIONS OF TERMS.

There has been so much indefiniteness in the usage of certain terms required in a discussion of ore deposits that I have attempted below to define such as are used in the following discussion. It is not expected that the usage herein adopted will find universal acceptance but it will have served its purpose if it makes clearer my own discussion.

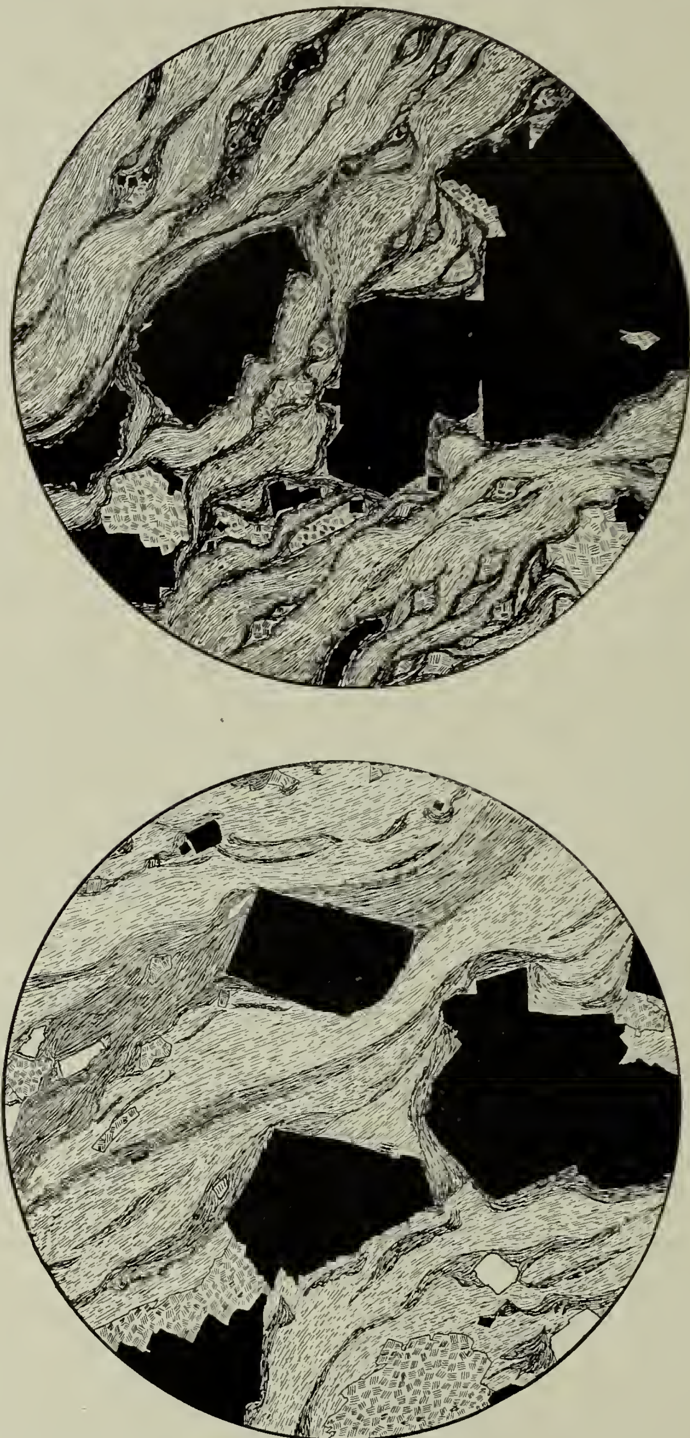
(1) *Original Separation* is applied to the process by which the metallic minerals are separated during the solidification of a magma. Minerals thus formed are known as *"Original."*

(2) *Contemporaneous Precipitation,* is applied to the process by which the metallic minerals are deposited at the same time as the sediments of which the enclosing rock is composed. Minerals thus formed are known as *"Contemporaneous"* minerals.

(3) *Concentration* is applied to the process by which metallic minerals are brought together from extraneous sources,—original, contemporaneous, concentrated or enriched. Bodies so formed are known as *"Concentration"* deposits.

(4) *Enrichment* is applied to the processes by which one portion of a deposit may be enriched at the expense of another part, or through the abstraction of associated minerals. Such bodies may be known as *"Enrichment"* deposits.

(A) *Descensional Ores* are those that have been transferred from higher to lower altitudes. During their transfer they may



Drawings showing the appearance of the galena when observed in thin sections through a compound microscope. These show galena in the more shaly layers. A few quartz fragments show in the lower section.

be carried by downward, upward and lateral moving waters but the sum total of this movement must result in bringing the ores to a lower plane with respect to the sea level. The transference may be from older to younger rocks or vice versa.

(B) *Ascensional Ores* are those that have been transferred from lower to higher altitudes. The transfer may be made by downward, upward and lateral moving waters, but the sum total of this movement must result in bringing the ores to a higher level with respect to the sea level. Under normal conditions the transfer must be from older to younger formations.

(C) *Lateral Secretional Ores* are those that have been deposited at the same level as that from which the mineral salts were derived. This transfer may involve downward and upward as well as lateral moving waters. These ores, in general, are supposed to be concentration deposits from the formation in which they occur or from a contiguous formation having the same elevation.

SOURCE OF THE ORIGINAL MINERALS.

The source of the original metallic minerals of this area is undoubtedly the igneous rocks. Upon this point, evidently all writers agree. We do not know how many kinds of igneous rocks there may have been at one time in this area, but at present there are three important varieties, namely, granite, rhyolite (porphyry) and diabase. About three-fourths of the area over which these rocks outcrop, is occupied with the rhyolite. Granite occupies one-fourth of the area, while the diabase occurs in the form of dykes which occupy such a small part of the area as to scarcely warrant consideration. The investigations made by James D. Robertson, formerly an assistant in this Bureau, show that the granite contains an average of 0.00219 per cent of lead and an average of 0.0021 per cent of zinc; the rhyolite 0.00502 per cent of lead and 0.01705 per cent of zinc; and the diabase 0.00646 per cent of lead and 0.0148 per cent of zinc.* These determinations were made upon specimens in which there was very little likelihood of lead and zinc occurring as secondary deposits. The diabase dykes appear to be more strongly mineralized than either the granite or the rhyolite. The Ein Stein silver mine was located on one of these dykes. In the fall of 1906, I examined a diabase dyke in Wayne county which was rich in both zinc blende and galena. Analyses

*Lead & Zinc, Vol. VII, p. 479, report of the Bureau of Geology and Mines 1893.

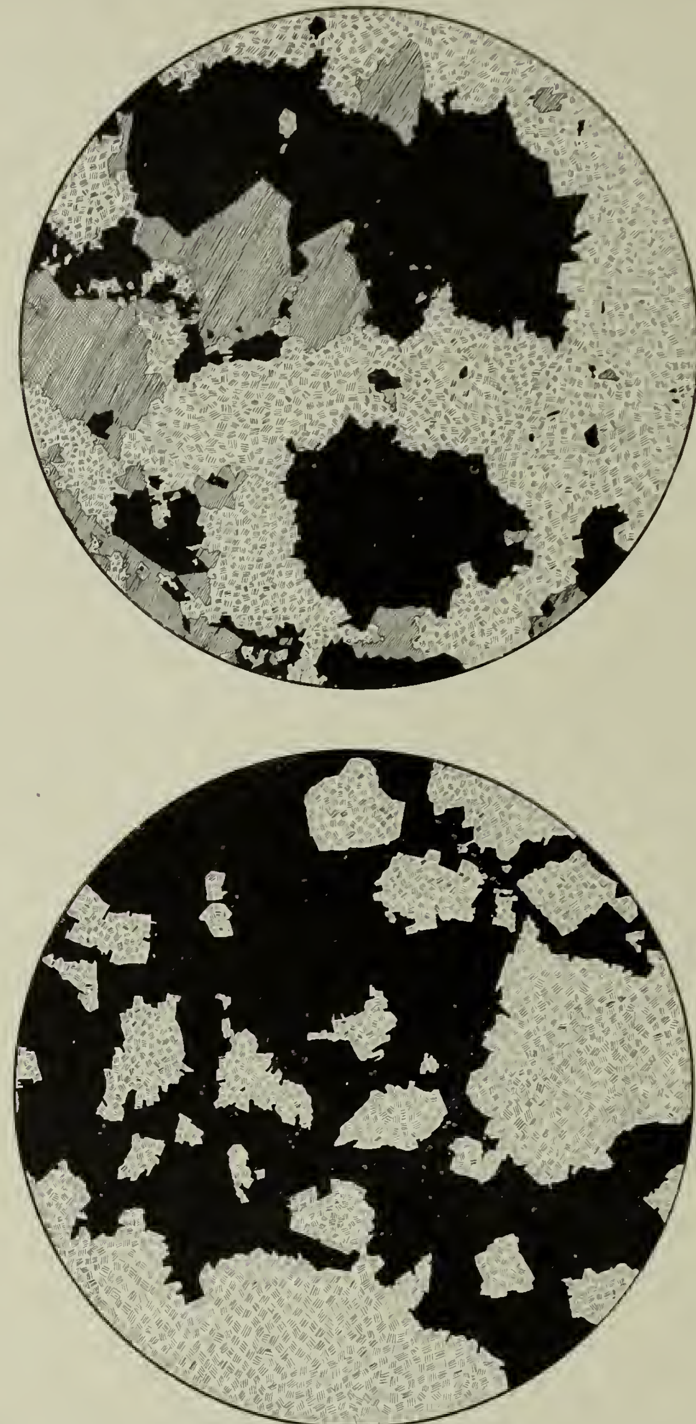
showed average specimens to contain 12 per cent of zinc blende. Deposits of this character, however, are probably a result of enrichment. They are probably analogous in many respects to the veins of galena occurring in the granite near Belleview. The galena and zinc blende in the diabase dykes and the galena veins in the granite, are not original but evidently enrichment deposits.

The igneous rocks of this area form an irregular group of hills and ridges commonly known as the St. Francois mountains. Some of the peaks are as much as 800 feet above the general land surface and have very much the appearance of mountains. The sediments laid down between these peaks during Cambrian time. have probably half filled what were during pre-Cambrian time deep inter-mountain valleys. Before the advent of the Cambrian sea, there was probably a difference of elevation between the highest hills and the deepest valleys of 1400 to 1500 feet. This extremely rugged mountainous surface may have been, in part, the result of mountain building forces. However, the sharp precipitous cliffs and the irregular floor upon which the sedimentary rocks were laid down, as revealed by drill holes, leads to the belief that the pre-Cambrian topography of this area was chiefly the results of a prolonged period of active erosion.

It is impossible to estimate the quantity of igneous rock which was decomposed and removed from the surface during this period. When the Cambrian sea first encroached upon these mountains, they must have been much higher than at present. During the entire Cambrian period, some portions may have been above the ocean and subject to atmospheric disintegration.

Provided these igneous rocks contain uniformly .002 per cent of lead, the removal of a thickness of 1400 feet over one square mile of area would liberate approximately 68,000 short tons of lead.

The lead thus liberated would be removed in solution either by surface or ground water. It is probable that a considerable percentage of the lead would find its way into cracks and crevices or along contact planes of the igneous rocks, where it would be for the first time concentrated. A part of the water permeating the decomposing mantle at the surface, and often that entering the cracks and crevices, issues again in the form of springs, before depositing its lead. In this manner the lead is probably in part transferred to the ocean after being abstracted from the igneous rocks through the usual processes of disintegration and decomposition. It has been estimated that in an area of igneous rocks about fifty per cent of the rainfall is removed by streams.



Drawings showing the appearance of typical disseminated galena in limestone, as observed in thin sections through a compound microscope. A few pyrite crystals show in the upper section.

It should be understood, however, that the quantities of lead and zinc found by analysis in the undecomposed igneous rocks outcropping in this region today does not necessarily represent the quantities of these minerals which may have been present in the igneous rocks through the decomposition of which the Cambrian and later sediments were derived. Neither must it be supposed that the metals, any more than the other constituents, were uniformly distributed through successive outpourings or intrusions of lava, or even that they were uniformly distributed through any single lava flow. Just as one sheet of igneous rock may be basic and another acid, so may it be expected that one sheet will be rich in iron, zinc, lead or any other metal, depending upon the source of the magma within the earth's crust.

From this it should be easy to understand my belief that not only were the igneous rocks the original source of all the metallic minerals, but that certain outpourings or injections of lava were the conveyors of the metals from deep-seated sources, while others were barren of these constituents.

A HISTORY OF THE PROCESS BY WHICH THE LEAD HAS BEEN CONCENTRATED INTO ORE BODIES IN THIS AREA.

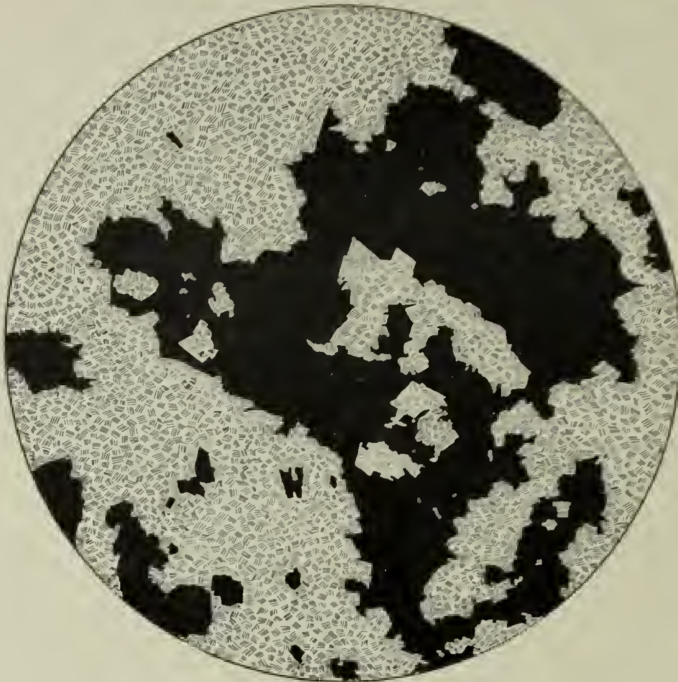
Throughout the following discussion, the reader should keep clearly in mind two important factors. First, that through the processes of disintegration and decomposition, the minerals at or near the surface are being, in part, taken into solution.—Second, that all materials within the zone of weathering are being transferred, either in suspension or in solution, from one place to another. Third,—That the removal of certain minerals results in the concentration of those remaining. Such portion as is being transferred in suspension is moved chiefly by streams flowing over the surface. However, a small percentage of the finely comminuted material finds its way into cracks, crevices and caverns, moving downward into the crust of the earth. That portion which is taken into solution is removed either by streams flowing off from the surface or is taken into the crust of the earth as a part of the ground water circulation. Minerals, such as galena, are probably removed chiefly in solution either by the surface or underground circulation. Barite on the other hand is, in a large part removed in suspension.

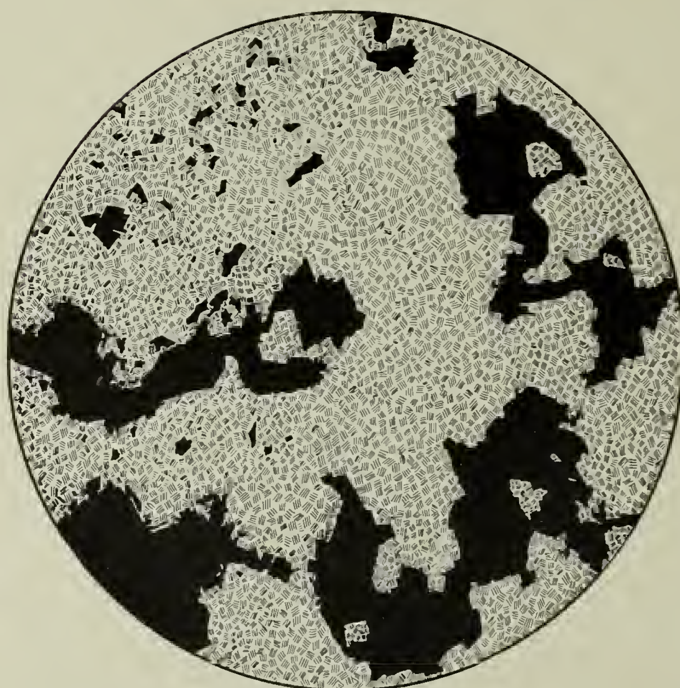
It is known that the igneous rocks of the area under discussion are of pre-Cambrian age. It is quite clear that these rocks do not belong to the great schist series of the Archean or Basement Complex. They probably belong to the granitoid series which is mapped as the upper portion of the Archean and sometimes known as the Laurentian. Following this period and older than the Cambrian, are the Huronian, Animikean and Keweenawan, only one of which has been tentatively recognized in this district.

The granite, rhyolite and diabase, representing the Archean, constitute the oldest rocks of which we have any record in this district. As a result of the disintegration and decomposition of these rocks, the lead was probably in a large part taken into solution and carried downward into joints or other openings where it was concentrated for the first time. That portion of the lead bearing solutions, which did not become a part of the general ground water circulation, probably issued again in the form of springs and was removed by the surface streams to the ocean. Here the lead, along with other metals, may have been deposited, provided conditions favorable for reduction were present, where the streams emptied their waters into the ocean. As weathering continued downward, the galena concentrated in veins was probably brought near the surface and again oxidized and taken into solution and distributed as before. In the igneous rocks that now outcrop over this area, there are occasional veins of galena, not sufficiently large to be of commercial value, which may be the roots of larger ore bodies resulting from this first period of concentration.

As noted above, this region is thought to have been submerged during one period prior to the Cambrian. It may have been submerged more than once, but of this we have no evidence. The first period of submergence resulted in the deposition of materials which are now represented by the quartzite, slate and conglomerate, associated with the iron ores of Pilot Knob. The position of these rocks leads one to suppose that the entre area was inundated by the ocean during that period. The deposits which remain are of such a fragmentary character, that it is impossible to estimate the duration of the period of submergence. For convenience we will speak of these rocks as belonging to the Huronian, altho their absolute strategraphic position has not been determined.

The sediments deposited in the Huronian sea were derived from the Archean granite, rhyolite and diabase referred to above. The lead contained in the Archean rocks was probably transferred, in part, at least, to the Huronian sediments. The presence of iron





Drawings showing the appearance of typical disseminated galena in limestone, as observed in thin sections through a compound microscope.

ores in this formation leads one to suspect that conditions favorable for the reduction of metallic salts were present, wherever the water from the land surface was added to the ocean. It is probable that most of the lead derived from the disintegrated igneous rocks which was not carried down and redeposited in openings beneath the surface, was deposited in the ocean close to the shore. The very limited areas of Huronian sediments limit very greatly our knowledge of the conditions present in the Huronian sea, but the impression prevails that the shales offered extremely favorable conditions for the reduction of metallic salts. In this region there are areas of igneous rocks through which particles of micaceous hematite are very uniformly disseminated. From such areas it is very probable that the iron ores of the Huronian were derived.

Providing we are correct in our supposition as to the transference of the metallic minerals during the pre-Cambrian times, one would naturally suppose that veins of galena would occur in the pre-Cambrian granite and porphyry underlying the Cambrian rocks, as well as in these rocks where they are exposed at the surface. This being the case one can imagine the existence of conditions whereby the lead contained in these veins might be transferred to the overlying sedimentary rocks by water rising under hydrostatic pressure whereby artesian conditions are established.

Following the Huronian period, this area became a part of the continent and was subjected to erosion for a period of sufficient duration to permit an almost complete removal of the Huronian sediments. All the evidence which we have, indicates that this area was a part of the continent up to the Middle Cambrian time. The erosion of this period must not only have removed the Huronian sediments, but must also have deepened the valleys which trenched the Laurentian during the pre-Huronian period.

Any lead which may have been deposited in the Huronian rocks during the period of formation or later, must have been transferred during this post Huronian erosion interval either into the underlying Laurentian rocks or removed to the ocean by the streams flowing over the surface.

Provided there were channels or other openings in the rocks and provided the necessary reducing conditions were present, it is thought that the transference of lead would probably be chiefly by migration downward. However, the igneous rocks of the Laurentian probably did not provide abundant channels for the escape below of the ground water. For this reason we are led to believe that a considerable part of the lead was probably removed in the spring waters and transferred to the ocean by the streams. The water flowing into the ocean would again deposit the lead wherever conditions favorable for reduction may have existed. We have no means of estimating the relative percentage of lead which was transferred to the ocean and which migrated downward into the underlying rocks.

During Middle Cambrian time, this area was again submerged and the St. Francois mountains were left as islands in the ocean. As a result of this submergence, the Huronian and Laurentian rocks were in part covered with a deposit of sand. This deposit constitutes what is known as the Lamotte sandstone, the oldest well recognized sedimentary formation of the district. This formation has a variable thickness. In some places it is absent and in other places it has a thickness of several hundred feet. The floor upon which this sandstone was laid down is extremely uneven, as a result of which the upper surface of the sandstone is frequently undulatory.

While this sandstone formation was being deposited, those portions of the St. Francois mountains which still remained above the ocean were being disintegrated and decomposed and the resulting products were transferred mechanically and in solution, as discussed on a previous page. As during the former periods, a part of the lead probably migrated downward the remainder being transferred by streams to the ocean. It is extremely doubtful if the ocean in which the Lamotte sandstone was deposited afforded conditions favorable for the precipitation of the lead which might be added to the sea water by the streams.

The appearance of the Lamotte sandstone at this time leaves the impression that the preceding erosion interval must have been a period of extensive disintegration with correspondingly slow transportation. In case this condition prevailed, a large part of the lead probably migrated downward being reconcentrated at lower levels in the underlying rocks. With the removal of the disintegrated mantle, there were probably inaugurated new conditions of sedimentation brought about by a subsidence of the land and the bringing in of water containing a higher percentage of materials in solution.

The Lamotte sandstone is overlain with a dolomite formation which is normally from 300 to 400 feet in thickness. Altho this overlying formation consists chiefly of dolomite, there are alternating beds of sandstone and shale near the bottom, constituting what might be termed a transitional zone. Thin laminae of shale also occur at widely separated horizons thoroughout the formation. This is the formation in which the disseminated lead ore which is being herein discussed occurs.

Figures 2 and 3 on pages 31 and 32 is a columnar section showing in detail the characteristics of this formation from the Lamotte sandstone below to the overlying Davis shale formation.

The water flowing into the sea, wherein were being deposited the carbonaceous shales and dolomites of the Bonneterre formation, was in part derived from springs fed by waters which had circulated through the upper weathering portion of the pre-Cambrian. These waters undoubtedly carried, in solution, lead salts which were thrown down in the presence of the organic matter of these shales and limestones. The lead was probably derived from the original source in the igneous rocks and from veins resulting from concentration by the ground water circulation. Some of the galena now found in the ore bodies of the Bonneterre dolomite may have been introduced into the formation at this time. If so, it was probably deposited in extremely minute particles in both carbonaceous shale and dolomite. The particles of galena which were deposited during the formation of these rocks may, through the action of chemical affinity, have exerted some control over the later concentration of the galena.

The deposition of the Bonneterre dolomite was followed by shallow sea conditions in which the Davis shale was deposited. As the name implies, the Davis shale is made up chiefly of shale. Limestone and dolomite occur abundantly in some parts of the formation, while sandstone is practically absent. Beds of conglomerate occur at intervals from the bottom nearly up to the top. This formation has an aggregate thickness of from 100 to 180 feet.

As in the case of the dolomite of the Bonneterre formation, lead may have been precipitated from the oceanic waters and deposited with these sediments. The character of the formation is such as to lead one to infer that there probably was some deposition of lead. We know that the land area, consisting chiefly of igneous rocks, was near at hand and that the streams probably derived their chief supply of water from the springs of this area. It is thought that the conglomerates which occur at a number of different horizons do not represent in any case erosion intervals of any considerable duration.

Above the Davis shale, and conformable with it, is the Derby dolomite, consisting of from 30 to 50 feet of dark, somewhat bituminous looking rock The ocean was still deriving sediments from the igneous rocks to the south as in the case of the preceding formation. Some lead may have been deposited with the sediments comprising this formation, but of this we have no direct evidence.

Above the Derby dolomite, there occurs a thickness of 45 to 100 feet of argillaceous dolomite known as the Doerun formation. The sea in which this dolomite was deposited, was probably also receiving water drained from the islands of igneous rocks. The presumption is in favor of believing that lead was introduced into this as well as the preceding formations.

Above the Doerun, the Potosi formation was deposited. Some lead may have been deposited with these sediments where the necessary reducing conditions were present. The islands of granite and rhyolite may have still towered in places above the ocean, contributing sediments as they had done to the preceding formations.

From the Middle Cambrian to the close of the Potosi we have, in this district, evidence of an almost continuous period of sedimentation. There was evidently a gradual subsidence of the area as shown by the advance of the sea over the land. Each of the successive formations, with the possible exception of the Davis and Doerun, overlaps the preceding and lies unconformable above a portion of the pre-Cambrian complex of granite and rhyolite. The formations naturally thin as the St. Francois mountains are approached, as a result of which they are not uniform in thickness.

It has been observed that the streams flowing into the sea during this period must have been fed by waters which had permeated the weathering zone of the igneous rocks comprising the land areas of that time. These waters undoubtedly carried lead, abstracted from the decomposing granites and rhyolites, depositing it again under the reducing conditions prevailing where carbonaceous or bituminous sediments were being laid down in the ocean. Attention has also been called to the probability that a part of the lead leached from the decomposing igneous rocks, migrated downward being deposited within the igneous rocks at depths beyond the zone of oxidation. The transference of the lead, in either case, must have resulted in a greater degree of concentration.

The geological history of this area after the deposition of the Potosi is extremely obscure. Blocks of sandstone and chert and a little kaolin belonging to younger formations occur with the residual deposits at the surface, but nowhere have we been able to discover their age or determine the relations which they may possibly sustain to the underlying formations. Along many of the hillsides deposits of water-worn gravel occur, which are thought to belong to the Tertiary.

These fragmentary records provide very little upon which to construct the remainder of the geological history of the area. We are left, practically, to conjecture what the history of this area has been from late Cambrian to the present time.

How long did this area remain submerged after the Potosi was laid down? Were all the successive formations now found in the Central Ozark region represented here? Did the erosion interval which preceded the deposition of the St. Peters sandstone—so well defined in other parts of the Ozark region—mark the first emergence of the land in this area? Was this area submerged during all or any part of the Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian or subsequent periods? Upon the answers to these questions depends in a measure the solution of the problem of the genesis of the lead ores of this district.

There is every reason to suppose that the remaining Cambrian formations, above the Potosi, represented in the Ozark region, were deposited in this area and that they were removed, in part, prior to the deposition of the St. Peters sandstone, which is the oldest member of the Ordovician recognized in this State.

Above the Potosi there was deposited an aggregate of 700 to 800 feet of dolomite and sandstone, which were in part eroded prior to the deposition of the St. Peters. These may have contained lead in finely disseminated particles, introduced in the same manner as described for the Bonneterre and other older formations.

As a result of the erosion, during the interval preceding the deposition of the St. Peters, the lead was disposed of in a manner similar to that which has been outlined for the older formations. Some was removed to the sea, while the remainder migrated downward and was concentrated in joints, cavities and other openings within the rocks below the zone of weathering.

The conditions were analogous to those which are supposed to have existed during the period when the pre-Cambrian rocks were being disintegrated; with the exception that the lead was probably distributed uniformly through the igneous rocks, while in the sedimentary rocks under consideration, the lead must have occurred only in such parts of the formations as were deposited under reducing conditions near where lead bearing waters from the land were emptied into the ocean.

The submergence of the land during the St. Peters terminated this process and everything was sealed by the overlying Ordovician formations. The thickness and number of the Ordovician formations represented in this area can only be conjectured. Not many miles east, the Ordovician is represented by limestone, sandstone and shale aggregating 640 feet in thickness.* These either thinned toward the west, or have been completely removed during the erosion intervals which have followed the Ordovician period. I think, however, that it is safe to assume that this area was submerged during a part, at least, of the Ordovician period and that formations equivalent to those represented to the eastward were laid down.

Probably the land area was to the westward, and if this were the case the Cambrian and possibly the pre-Cambrian formations contributed to the sediments of the Ordovician sea. If so, however, there must have been formations between the Jefferson City and the St. Peters, of which we have no record at this time, which were removed from the central Ozark region.

The Silurian is represented in the county east of this area by the Lower Helderberg and Niagara formations, consisting chiefly of limestone and shale aggregating 250 feet in thickness. There is no evidence that these formations extended westward over this area, altho they outcrop a short distance to the east, along the Mississippi river. However, in the light of the subsequent history of the region, I am inclined to the belief, as in the case of the Ordovician, that this area was submerged during a part of the Silurian period. The sediments must naturally have been derived from older formations, not far distant, as shown by the abundance of shale, a shallow water formation. In some places this shale gives evidence of having been deposited under reducing conditions, and if so, lead may have been abstracted from waters flowing into the ocean, and deposited along with these sediments. At the same time on the land areas lead may have been migrating downward into the underlying formations.

Thus the concentration of lead and other metallic salts was gradually being brought about through the circulation of the ground water and by surface drainage of the land combined with sedimentation in the ocean.

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*Geological Survey of Missouri, 1855-71, by Broadhead, Meek and Shumard, p. 292.

It may be well to repeat here that the catchment areas of some streams may be devoid of areas in which a similar process had been active during their formation, and therefore the water would be devoid of lead; also that streams supplied with water from areas of rock having earlier concentrations of lead might empty their water into the ocean at places where reducing conditions were absent. In either case there would be no concentration in the newly formed sediments.

Prior to the Devonian, or during the later part of Silurian and early Devonian, this region was probably undergoing denudation, and consequently the process of concentration by ground water was in operation. During what portion, if any, of the Devonian period this area was submerged we do not know. The carbonaceous or bituminous shales which occur in the eastern part of the state, when being deposited, afforded excellent conditions for the precipitation of lead and other metallic salts, provided the inflowing streams carried these in solution. The thinness of these shales, however, leads one to the belief that in the aggregate the quantity of metallic salts therein deposited was probably small. The Devonian strata were probably entirely removed from this area during the erosion interval which preceded the deposition of the Mississippian.

The pre-Mississippian erosion interval is one of the best defined in the geologic history of the state. In many places throughout the Ozark region remnants of the Mississippian, in the shape of small isolated areas of limestone or scattered boulders of chert, have been found. The fossils are of oceanic types, indicating that the water by which these deposits were laid down was not estuarine in its character but oceanic. It may be that, in this area, a large part of the Cambrian, above the Potosi, was removed during the pre-Mississippian interval. This would have resulted in the migration downward of a great part of the galena and concentration at lower levels, perhaps in the Potosi. How far this concentration extended downward is very problematical, since we do not know the extent of the erosion in this particular area during this period. A part of the lead contained in the rocks removed during this period of erosion was undoubtedly carried out of the area by the surface drainage.

As stated above, we have reason to believe that this area, during a part, at least, of Mississippian time was submerged. The thickness of the Mississippian over this area cannot be conjectured.

It was probably, as elsewhere, chiefly limestone. Some lead may have been precipitated from the sea water and deposited along with the sediments in the manner and under the conditions pointed out for the older formations.

Analyses of the Mississippian limestone seem to indicate that they may have contained some galena, as an original constituent. This, however, is difficult to prove by analyses, since analyses do not indicate whether the galena is contemporaneous or not. Conditions were present, at some stages, favorable to the precipitation of metallic salts but whether or not lead was brought in by streams cannot be determined. We presume, however, that the sediments were derived chiefly from Cambrian and Ordovician rocks, which probably contained in places contemporaneous and concentration deposits of lead. That part which was removed, in solution, by the streams, would have been deposited, under favorable reducing conditions, in the Mississippian.

Following the Mississippian there was another erosion interval during which time the rocks belonging to that formation were almost completely removed from this part of the Ozark region. This is shown by the fact that in numerous places the Pennsylvanian strata rest directly upon the Ordovician and Cambrian formations. During this interval, over this region, a portion of the lead was probably removed by streams, while the remainder migrated downward as explained for similar earlier periods of erosion.

The Pennsylvanian sea covered a large part of the Ozark region and I am inclined to believe that there was very little of that area which was not submerged during a portion of that period. During that time the water from the land areas must have met reducing conditions at almost every point where it reached the estuaries of the ocean. It is thought that the metallic salts carried by streams, must have been deposited everywhere before traveling far from the shore. If this were the case, there must have been very much restricted areas of lead precipitation, in estuaries into which streams, coming from catchment areas in which the rocks carried lead, were emptying. The streams probably derived most of their water from areas of Cambrian and Ordovician rocks in which lead occurred as either contemporaneous or concentration deposits.

The former existence of the Pennsylvanian over this area has not been proven by the discovery of remnants of this formation in the area discussed in this monograph. Yet it is necessary either to concede the presence of this or later formations or to believe that, through all the succeeding periods up to the Cretaceous, this portion of the Continent remained nearly at base level. We have no evidence that this area remained, during the Jurassic, Triassic and Cretaceous, at base level, altho it is believed by some that the close of Cretaceous time was marked by base level conditions. The occurrence of remnants of the Pennsylvanian on all sides and the absence of sediments of the succeeding periods, make it appear most rational that a part at least, of the Pennsylvanian at one time covered this area.

I am inclined to the belief, that, during the periods following the Pennsylvanian, this area was mainly undergoing denudation. It is highly probable that the first elevation of the Ozark plateau followed the close of the Pennsylvanian. As a result, the rocks must have been faulted, folded and fissured, increasing very greatly the capacity of this region for storing ground water.

The Pennsylvanian strata were deposited on an erosion surface of very great irregularity. In the course of the process of denudation there came a time when the surface was covered partly with carbonaceous shale and partly with weathered limestone, dolomite and sandstone. The surface water passing through the unweathered shale would take on reducing properties, while that passing through the oxidized shale and dolomite would be oxidizing in character. Somewhere below the surface the oxidizing and reducing solutions would mingle, and as a result the metals carried by the oxidizing solutions would be precipitated. This double underground circulation—oxidizing and reducing—has played a most important part in the concentration of the lead in this as well as other areas where the minerals have been introduced by a downward circulation.* In order to determine the probable occurrence of contemporaneous lead in the shales of the Pennsylvanian, analyses were made of sections of a diamond drill** core from a depth of 1300 to 1600 feet below the surface which it is believed has been entirely outside of the circulation of oxidizing solution. These analyses show measurable quantities of lead, zinc and copper. In fact the quantities of these metals as shown by the analyses are so great, that it has been thought prudent not to publish the results until confirmed by duplicate analyses.

Finally the Pennsylvanian and the underlying Mississippian were entirely removed, and this part of the continent was reduced

*See "Geology of the Granby Area" pp. 78-100, Vol IV, 2nd Series, Mo. Bureau of Geology and Mines, 1905.

**This drill hole is located near Forest City, Holt County, Mo.

almost to sea level. This is supposed to have been consummated near the close of the Cretaceous. At this stage the ground-water level must have been near the surface and it is doubtful if the metals which it carried migrated downward very far before being deposited. On the other hand, the percentage of the metals carried by the streams and ground-water must have been very greatly lessened by these conditions.

There was, however, a second uplift during the Tertiary period, since which time erosion has been almost continuous up to the present time. This period of elevation, like the former, probably increased the fracturing of the formations near the surface, providing more abundant openings for the circulation of the ground water. It is thought by some geologists that this portion of the state was submerged during a part of both the Cretaceous and the Tertiary periods. There is some evidence, in the gravels on the hillsides and in the peneplain topography, that this was the case.

We do not know how many fluctuations in the level of the land have occurred since the uplift near the close of the Tertiary period. There have, undoubtedly, been oscillations which have changed the level and flow of ground-water. Conditions near the close of the Pleistocene also may have had an effect upon the circulation of the ground-water. In many places one finds, in the deepest workings of the mines, evidences of alternating periods of solution and deposition. There is evidence that certain beds have been alternately under oxidizing and reducing conditions. Cavities and caves in the dolomite, filled with calcite and pyrite, give evidence of having been within the zone of weathering, later beneath this zone and again within this zone.

RESUME.

In general, the above is an outline of the geologic history of the Disseminated Lead district, without regard to the ore bodies as they occur at present in the several formations. The processes which are conceived to have operated in the past are operating today. With the disintegration of the dolomites at the surface, lead is being added to the surface and underground circulations. The water, from areas underlain with formations containing bodies of lead ore, takes into solution more of this metal than the water flowing from areas in which the rock is almost or entirely barren. A greater part of the lead taken into solution is transferred to lower levels and reconcentrated, but another portion after a short underground journey, issues in the form of springs and is removed by surface streams to the ocean. The processes operative during the very early periods in the history of this area are probably identical with those which we know to be active today.

The earth's chemical laboratory worked along essentially the same lines in the past as it does today. The leaching of the minerals near the surface, their transference to the ocean or migration downward, and their surface redeposition were accomplished in the same manner and through the same agencies.

The entire process has clearly been one of concentration, just as water underground or upon the surface is collected through myriads of channels into streams, after having been sprinkled over the surface from the clouds.

GENESIS OF THE GALENA CONCENTRATED IN THE DIFFERENT FORMATIONS OF THIS AREA.

The foregoing discussion leads directly to a consideration of the origin of the lead ores which occur in commercial quantities within the several formations of this area. The principal ore horizons are in the Potosi and Bonneterre formations, altho some galena has been mined from the upper part of the Lamotte sandstone. In the Potosi the ore occurs chiefly within the zone of weathering and is not confined to any particular stratigraphic horizon in the formation. In the Bonneterre the ore occurs near the top of the formation and near the bottom, altho in some places it continues with few interruptions practically throughout the entire thickness. The mine workings, as shown in the illustrations, do not indicate the size or shape of the ore bodies, but merely such portions of them as have been rich enough for profitable exploitation.

ORE BODIES IN THE POTOSI.

The upper 100 to 150 feet of the Potosi is especially characterized by channels and other openings, frequently filled with a sticky, reddish brown, clay derived from the mantle of residual material at the surface. These openings are frequently vertical, or nearly so, extending downward into the formation until they disappear. Other openings, irregular in shape, follow almost horizontally along the bedding planes at different horizons, constituting what are known as pipes.

The galena occurs in the residual deposits of clay and flint covering the surface, in the vertical channels and in the pipe veins.

Associated with it occur barite, iron pyrites (usually marcasite), limonite (pseudamorphs after marcasite), sphalerite, smithsonite, anglesite, cerrusite and calcite. The galena usualy shows roundish corners and corroded surfaces, both evidences of leaching. It occurs almost uniformly in cubes or aggregates of cubes, known locally as "block mineral." These blocks sometimes weigh several hundred pounds and frequently must be broken before they can be removed from the mine. The galena recovered from the residual clay is usually not attached to the rock, but is often accompanied with barite. As a rule the only cleaning required is the removal of the clay by washing. In the channels and pipe veins the galena is frequently embedded loosely in red clay altho it is also attached to the roof or the walls of the openings. The galena in these openings appears to have been formed much after the manner of stalactites.

Galena occurring in this manner has evidently been formed by downward circulating waters. At least all the evidence which we have points to such a conclusion. In the first place the ground water circulation in the Bonneterre and Lamotte formations is separated from that in the Potosi by a practically impervious horizon of shale and argillaceous limestone about 170 feet thick. The ore bodies do not occur, so far as we know, along faults or zones of faulting. Experience has shown that the richest deposits occur comparatively near the surface. The ores do not occur in any particular horizon of the Potosi but in that part of the formation which, through erosion, happens to have been brought near the surface. If the lead had been introduced through an artesian circulation it is very probable that it would have been abstracted while passing through the reducing mediums furnished by the underlying formations. True, there have been very few holes, perhaps ten or twelve, drilled through the Potosi formation into the Bonneterre, but those of which we have records give no evidence of ore bodies in the Bonneterre, altho the formation has essentially the same composition as in the Flat River and Bonne Terre areas.

The ore bodies in the Potosi are extremely irregular and, as far as one can make out, the areas in which the ores occur are distributed without any well defined system over the region underlain by this formation. The runs of ore worked in the mines usually follow channels or openings, along what were formerly joint planes spreading out laterally along bedding planes where openings have been formed through the removal of the magnesian limestone by circulating ground water. The galena is seldom a replacement product of the dolomite or of any other constituent of the formation. It has evidently crystallized from dilute solutions of lead salts.

The cavities in which the galena occurs were evidently formed prior to the introduction of the lead solutions. That portion of the Potosi in which the ore bodies occur was undoubtedly within the zone of oxidation for a long time prior to the introduction of the galena. That the existing silicification, resulting in the formation of the drusy flint or quartz boulders, so characteristic of the formation, antedates the introduction of the galena, is evidenced by the relations which they bear to each other. The history is about as follows: (1) Production of cavities by removal of dolomite accompanied by silicification; (2) partial filling of cavities by introduction of silica coating them with chalcedonic or crystallized quartz; (3) introduction of solutions carrying lead, iron, barite, zinc and calcite with which the openings were partly filled; and (4) oxidization of these minerals accompanied by their partial removal. This final period has resulted in covering the surface with a mantle of reddish brown clay studded with fragments of drusy quartz.

It is difficult to determine the geological age of the galena, altho it is evident that it is comparatively recent. This being the case we are led to conclude that the galena was derived chiefly from one of the more recent formations which has been removed. If it were derived from some deep seated source, there is no evident reason why it should not have appeared prior to the introduction of the drusy chalcedonic and crystallized quartz.

It appears probable, from the above analysis that, in the main, as above stated, the lead was originally contained in one of the late formations which has been removed. From such observations as I have thus far been able to make, I am becoming more and more inclined to believe that the chief contemporaneous deposition of lead was during the Pennsylvanian; that, altho there are no remnants of this formation in the area, that it at one time covered the region; and that through its decomposition the ground water obtained the lead which has been concentrated in the Potosi and other older formations. The continuous or interrupted degradation of the formations containing contemporaneous and concentration deposits of galena, evidently supplied the ground-water with lead, which, through a converging circulation, was carried into these openings and deposited. The horizons in which precipitation and solution of the lead were taking place may not have been far apart, but the plane separating these zones was evidently very irregular, and owing to fluctuations in rainfall, denudation, uplift and subsidence, it probably migrated up and down. The more extensive the denudation the greater is the tendency to localize the circulation of ground waters which travel chiefly along jointing and bedding planes. The localization of the ground water circulation would naturally result in a concentration of the lead.

The silicification of the dolomite and the formation of drusy quartz boulders included within the formation furnishes an interesting subject for discussion. However, it is not the purpose of this report to consider these problems except as they throw light upon the origin of the ore deposits. The extensive silicification of the Potosi shows that it must have been, during a long period in its history, saturated with solutions bearing silica. The nature of the silicification leads one to believe that there were two periods, one during which a process of metasomatic replacement of the dolomite was in progress and another during which the silica crystallized out from solutions. The latter may have been a continuation of the former, but of this we have no positive evidence. I am unable to say from whence the silica was obtained, but I am led to believe that it was supplied by waters migrating downward through the overlying weathered formations.

One of the interesting minerals associated with the galena is barite (barytes). The Potosi is the only formation in the area in which this mineral occurs very abundantly. Outside of the area included within this report, barite occurs in formations higher up in the geological section, but nowhere, to our knowledge, lower down. A greater part of the barite mined in the United States comes from the Potosi formation of southeastern Missouri. Barite is one of the most stable minerals, under normal atmospheric conditions, of any associated with the lead and zinc ores. It is taken into solution with very great difficulty, as evidenced by the freshness of the specimens obtained from the residual clay at the surface. It is so difficultly soluble that a greater part of that which reaches the surface through denudation, is removed mechanically by the streams. A very small percentage is taken into solution by the ground water and thus carried downward. Over that portion of the area from which the Potosi has been removed there is no evidence of barite, and our only conclusion is that with the removal of the Potosi the barite was carried away in suspension by the streams, as has evidently been the case with the silica, kaolin and other difficultly soluble minerals. No trace of barite is found in the mine waters, which in itself is evidence of its extreme stability under ordinary atmospheric conditions.

There are evidently conditions under which the barite may be taken into solution by the ground water and re-deposited elsewhere. This is shown by the coating of cavities and caves and the filling of veins and other openings with barite crystals. What the conditions are under which the transference and deposition take place I am unable to explain at this time.

Some sphalerite, or zinc blende, occurs associated with the galena of the Potosi and with the disseminated galena in the lower levels of the Bonneterre formation. This mineral occurs in very subordinate amounts and is recovered only from the ore bodies in the Potosi and the immediately overlying formations. That which occurs in the Bonneterre is not saved. Some of the mines in the Bonneterre formation do not contain any zinc blende but the mines in the vicinity of Leadwood show a very appreciable quantity disseminated through the ore with the galena.

Analyses of the igneous rocks by J. D. Robertson, referred to elsewhere, gave higher percentages of zinc than of lead. If this is generally true one is immediately confronted with the question of what has become of the zinc. The mine waters analyzed during this investigation show a very much less percentage of zinc than lead and for this reason we are forced to conclude that the igneous rocks which are now undergoing decomposition do not contain appreciable quantities of this metal. If the igneous rocks contained as much zine as shown by Robertson's determinations it has either been transported out of this area or carried to greater depths by the ground water circulation. This naturally opens a question as to whether or not there may be ore bodies in some as yet unexplored formation underlying the Bonneterre dolomite. The absence of zinc in the mine waters leads us to believe that there may have been some error in the determination of the zinc content of the igneous rocks and if this be true the presumption is against the discovery of bodies of zinc ore at some horizon beneath the Bonneterre. This question is not settled and further investigation will be required to determine it conclusively.

Another matter to which attention is directed is the apparent difference in the degree of solubility of the crystallized galena and that which is a metasomatic replacement of the dolomite. Observations have shown that the latter is more susceptible to weathering than the former and will tarnish after being exposed only a short time to the weather. On the other hand the crystalized galena remains fresh and unaltered for a relatively longer period. The reason for this is not apparent, altho it is believed to be due to a difference in the physical constitution of the two galenas. This condition, however, is an important factor in the leaching of the disseminated ores, which results in their more ready transference from one horizon to another.

ORE BODIES IN THE BONNETERRE FORMATION.

The earliest mining in the Bonneterre formation was shallow, the ore being very similar to that in the Potosi formation. It was found in crevices, cavities and caverns, either loosely embedded in reddish brown clay or attached to the roof and sides of the openings. The galena occurred in masses of crystal aggregates, usually having the corners rounded and the surfaces corroded. In some places lead carbonate (cerrusite) was encountered along with the galena near the surface. Hundreds of abandoned shafts mark the places where these early mining operations were carried on. Practically all the shallow mining has given way in this formation to the exploitation of the deeper disseminated deposits.

The crystallized galena, which predominates at the surface, gradually decreases in abundance with depth. Some of the crevices in which this galena occurred were mined to a depth of forty or fifty feet, altho as a rule the major deposits were mined within twenty-five or thirty feet of the surface. Pockets and seams coated with galena crystals occur throughout nearly the entire thickness of the formation, altho the major deposits, below a depth of 50 feet, occur in what is known as the disseminated form—as a metasomatic replacement of the dolomite.

The crystallized galena, occurring near the surface of the Bonneterre dolomite, was in aggregates of crystals attached to the roofs of caves and the walls of crevices, or embedded in the clay which usually covers the bottoms of caves or fills the crevices. The veins of galena gradually narrow with depth and I am told upon reliable authority that they frequently pinch out twenty-five or thirty feet from the surface. Some of the veins extend nearly to the underlying sandstone carrying crystallized galena at intervals wherever they have been encountered in the mine workings. The galena is frequently associated with calcite and iron sulphide minerals, but I do not know of an instance where barite constitutes the gangue.

It is very significant that the shallow mines rarely occur in the Bonneterre except where the overlying Davis shale has been removed. It is also noticeable that these mines are chiefly near the contact of the Bonneterre dolomite and Davis shale.

From these facts we are forced to conclude that the removal of the Davis shale has been an important factor in determining the location of the shallow ore bodies. The Davis shale has evidently been instrumental in directing the circulation of the ground water, and it may also have contributed elements to the downward circulating ground waters, whereby the conditions requisite for the precipitation of the galena were supplied. Further than this, channels and other openings probably formed more slowly beneath the shale than they did over the area from which the shale had been removed. This might be accounted for by the fact that such water as finds its way through the unweathered shale has probably lost its CO_2 before entering the Bonneterre, while that flowing off the shale into the dolomite holds its CO_2 which is the active agent in dissolving the dolomite.

The Davis shale evidently acted as an impervious cap through which the ground water circulated very slowly, being chiefly deflected along the bedding planes to places where erosion had cut into the underlying dolomite or where faults had so broken the impervious cap as to offer an avenue of escape for the ground water. That this condition prevails at present is shown by the springs that mark the contact of the Davis shale with the overlying Derby dolomite.

There is abundant evidence that the Potosi and other overlying formations contained sufficient lead to account for all that is now found in the Bonneterre formation, both the shallow and deep seated deposits. Lead has been mined from the Potosi formation of this area and from the overlying formations outside of this area for many years. It is usually corroded and everywhere shows the result of leaching by the ground water circulating downward from the surface. The lead thus leached must have been removed somewhere and it is our belief that a great part of it migrated downward.

The ground water passing through the oxidizing mantle of rock and residuum above the shale flowed along the top and down the weathered edges of the Davis shale into the Bonneterre dolomite where it passed into the crevices and other openings. A very small percentage of the ground water may have passed directly through the Davis shale and entered the Bonneterre in this way.

Such solutions would probably not be otherwise than reducing in their nature upon reaching the dolomite. The commingling of this circulation with the oxidizing circulation which entered the Bonneterre over the surface of the Davis shale and carrying lead in solution would supply the conditions for the deposition of galena. Where aggregates of crystals formed on the roof and sides of caves and fissures diffusion undoubtedly played an important part. Where crystals of galena began to form the lead would be abstracted from the surrounding solution and through diffusion a continual process of equalization would go on until either the reducing agent or the lead salts became exhausted.

The galena which occurs in the upper or shallow ore bodies is now being leached by the ground water and carried into the deeper parts of the formation. Also the galena which is being leached from the overlying Potosi is being transported to depths beyond the weathered zone of the Bonneterre.

The Disseminated Galena. The disseminated lead ore occurs at different depths from the top to the bottom of the Bonneterre formation. Some disseminated galena has been observed in the dolomite which outcrops at the surface and in the Lamotte sandstone which underlies the dolomite but workable deposits have not been mined at a less depth than forty or fifty feet. The most extensive of the rich ore bodies occur below a depth of 200 feet and above the Lamotte sandstone.

As pointed out in the descriptions of the individual mines, the bodies of disseminated ore thus far discovered, are with two or three exceptions closely associated with the ore bodies occurring near the surface. Near every mine, with the exception of Federal 2, are evidences of shallow mines which were worked early in the history of the district. This is so striking as to lead one to infer that the shallow and deep seated deposits must bear some relation to each other. The truth of this inference is borne out by the theory which is advanced as to the origin of the ores.

The galena in the so-called disseminated ore bodies does not occur exclusively in a disseminated form, altho this is the type which especially characterizes the deposits. From an extended observation covering all the mines now operating in the district I should judge that not to exceed 75 per cent of the ore mined could be classed as disseminated. The remainder of the galena occurs in the form of sheets, filling openings along joint and bedding planes and lining cavities in the rock. The bodies of disseminated ore contain both crystallized galena and that which is a metasomatic replacement of the dolomite. The manner in which the galena occurs in the dolomite is illustrated in the accompanying figures.

To one who has examined all the underground workings of the mines in this area, it is clear that the bodies of disseminated ore in the upper part of the formation are, as a rule, small and very irregular. Also that the deepest ore bodies have the greatest lateral extent and are most constant in the quantity of galena which they carry. The vertical range of the ore bodies is clearly exhibited in some of the mines, such as Mine No. 2 of the Desloge Consolidated Lead Co., in which mining has been carried on successfully at five different levels. In one place or another the ore has been followed and cut out between all these levels through a distance of nearly 200 feet.

In nearly all the mines, especially in the upper levels, I have observed crystals of galena which were partly removed, presumably by leaching. Places exhibiting such leaching are referred to in the descriptions of individual mines. The irregular bunchy character of the ore bodies in the upper levels is thought to be in part the result of leaching such as is exhibited by these crystals.

The ground water level has been influenced very greatly by the pumping of water from the mines in some parts of the area. In localities where an artesian flow of water was frequently encountered in drilling prospect holes fifteen years ago, the water no longer rises to the surface. In the lower levels of the mines the water flowing from channels often has a pressure of eighty to ninety pounds to the square inch. From observations in the mines it is clear that there is a surface and a deep ground water circulation and that these are connected through channels and fault zones extending from the surface to the sandstone. Water collected from both sources carries lead in solution, according to analyses made by the Bureau of Geology and Mines. (See Table I.) The mine waters contain not only lead but also iron, manganese, magnesium, calcium, sodium, potassium, silica and aluminum.

As explained in another chapter this area is traversed by zones of normal faulting which are well exhibited by the relations of the formations at the surface. It is also pointed out in the chapter referred to that part of the joints and faults have their origin at the surface and extend downward while the remainder begin in the Lamotte sandstone or at the base of the Bonneterre and extend to variable distances toward the surface. Thus we have in the Bonneterre formation a series of fractures extending downward from the upper surface and another series extending upward from the bottom of the formation. Some of these fractures, or zones of fracture, continue throughout the thickness of the formation, altho many of them are relatively short and are confined to the upper or lower portions of this formation. The rock walls bounding many of the joints and faults have been leached and weathered. In fact, ore bodies usually die out as these so-called channels are approached, owing to the removal of the galena by oxidizing solutions which have circulated abundantly through them. Some of the faults and joints extending from the Lamotte sandstone upward into the Bonneterre dolomite are bounded by leached and weathered rock up to the point where they begin to die out.

Thus it appears that the Bonneterre is provided with channels for free communication between the surface and the Lamotte sandstone. Also that the formation is well supplied with both upward and downward trending fissures along which the ground water may find entrance to all parts of the formation. Communication between neighboring fissures is provided by the bedding planes along which the water may readily find its way. In some places the rock along these horizontal bedding planes has been leached to such an extent as to carry the oxidizing solutions beyond the vertical fissures. Connection between the adjacent bedding planes is also supplied by short joints which may be confined to one or several beds.

It is interesting to note that near the mines, at the surface, there is usually a well-defined broad zone of close jointing in the Bonneterre dolomite, as is well shown east of Federal Mines Nos. 6 and 7.

The disseminated galena occurs chiefly in the shales and dolomites which are carbonaceous or bituminous. The dark brownish dolomite and the associated black shale provide a reducing medium in which the lead salts are precipitated.

The lead solutions supplied to this reducing medium come both from the dolomite above and from the sandstone beneath. However, the water in the sandstone comes originally from the surface, being introduced along channels, the walls of which are completely oxidized, or through the sandstone which outcrops between the Bonneterre dolomite and the bordering pre-Cambrian igneous rocks. A part of the ground water passing through the dolomite loses its metallic content before reaching the Lamotte sandstone, as is evidenced by the occurrence of galena at various horizons within the Bonneterre formation. On the other hand the metallic salts contained in the water rising from the Lamotte sandstone is not all deposited at the base of the Bonneterre, since it rises in some places along channels which are oxidized for a considerable distance into the overlying dolomite.

The conditions are about as follows. A zone of oxidation near the surface containing galena which is being abstracted by the ground water; a porous sandstone formation (the Lamotte) serving as an enormous storage reservoir of water containing lead in solution; and between the two a formation (the Bonneterre) containing carbonaceous or bituminous and chloritic shale and dolomite of a reducing nature, in which the galena has been and is being deposited. The oxidizing zone at the surface connects with the sandstone horizon by means of channels along which the rocks have been oxidized, permitting the direct introduction of oxidizing solutions, carrying lead from the surface into the sandstone. The water held by the sandstone is also introduced along the sandstone outcrops and undoubtedly comes in part from the circulation in the upper portion of the granite and rhyolite which outcrops along the margin of the sandstone.

It must be borne in mind that the dolomite which is now oxidized along these channels, was at one time unaltered and probably reducing in nature. This is evidenced by the galena which some of these channels contain. At such time any oxidizing solutions, carrying lead, which penetrated the lower horizon of the Bonneterre formation must have been brought in from other areas, chiefly through the rock outcropping near the areas of igneous rocks. The galena in the crevices may have been introduced by ground water from the surface or, in part, from water rising from the Lamotte sandstone. It is thought, however, that in the absence of oxidized channels connecting the surface with the Lamotte sandstone the water issuing from the sand would contain very much less lead than at present and that the ore bodies are mainly subsequent to the establishment of zones of communication for the ground water along oxidized channels from the surface to the Lamotte sandstone.

Numerous analyses of the mine waters from the Lamotte sandstone and from the dolomite show that the lead is carried in solution both by the water from the sandstone and by that from the surface in almost the same amounts. (See Table I.)

It is our belief that the Bonneterre formation, which furnishes abundant conditions for reduction, is a great reducing medium which under the physical conditions described above has become soaked in dilute lead solutions, the lead of which has been derived almost entirely from the successive decomposition of dolomite, limestone, shale, granite and rhyolite of the tributary catchment area.

The disseminated ore bodies were in part the result of the abstraction of lead from waters circulating along channels and bedding planes in their journey from the surface to the sand; and in part from solutions, under hydrostatic pressure, which rose along channels which extend upward into the dolomite, from the underlying sandstone. These channels, in some instances, may have reached to the top of the Bonneterre and the small irregular disseminated ore bodies of the upper levels may have been formed by these solutions. However, it is probable that the direct downward circulation in some cases contributed the lead. The irregularity and bunchy character of the ore bodies at the upper levels are not altogether due to the manner of their formation, because there is abundant evidence that galena has been abstracted from this horizon by the ground water and removed elsewhere.

Oxidation of the lower part of the Bonneterre has not progressed very far, and the ore bodies at the lower levels have not suffered very greatly in consequence thereof. Further the lower portion of the Bonneterre presents, through the carbonaceous or bituminous character of the dolomite and shale a more persistent horizon for reduction. These facts account for the better development of the ore bodies near the base of the Bonneterre dolomite. Furthermore, the fracturing of the dolomite is more general and better developed near the base of the formation than it is in the upper levels, permitting a more uniform saturation of this part of the formation with the lead bearing solutions from the sand.

The lead is not found associated with all the carbonaceous dolomite and shale. Some areas appear either to have been outside of the circulation or else the lead has all been abstracted from the ground water before reaching those parts.

There may have been some finely disseminated galena deposited in the carbonaceous horizons when the sediments were being deposited in the ocean, as elsewhere described. If this were the case, chemical affinity would have been active in abstracting, at such places within the formation, the galena carried by the ground water.

It is difficult to indicate the time when the solutions carrying lead were first introduced. There may have been several periods of concentration at the same horizons in this formation, scattered along from the Cambrian up to the present time. It is our belief, however, that the major part of the disseminated ore is of comparatively recent age, younger than Pennsylvanian.

My investigations indicate that the Davis shale, overlying the Bonneterre must have been removed, in part at least, prior to the introduction of the major lead bearing solutions. The impervious shale would not only prevent a free circulation of the oxidizing solutions from the lead bearing Potosi, but it would also interfere with the upward circulation from the Lamotte sandstone. Erosion may have cut through the Davis shale prior to the Pennsylvanian, but to substantiate this there is no good evidence. If this were the case, the disseminated ore bodies probably began to form during that period. Since Pennsylvanian time there have been several periods of elevation and subsidence during which the horizons which now appear at the surface, were alternately within the zone of weathering and within the zone of cementation.

The ores of this district, whether they be in the Potosi or in the Bonneterre—massive or disseminated—belong to the Descensional class as defined on a previous page. The ore bodies are the result of lateral secretion only in so far as portions of the dolomite may have come within the zone of weathering and thereby have had the galena abstracted and removed to other parts of the same formation.

CHEMISTRY OF THE ORES.*

Galena is practically insoluble in sodium sulphate, according to Becker. It is very slightly soluble in pure water. Water charged with oxygen and carbon dioxide will gradually take galena into solution, carrying it as the sulphate or carbonate. The following reactions are involved:

$$PbS + CO_2 + H_2O = PbCO_3 + H_2S$$
$$Pbs + 4O = PbSO_4$$

It is unnecessary to discuss this matter in detail, since the solubility of lead sulphate and lead carbonate has received ample demonstration in the laboratory. That lead is carried in water but slightly in the form of the sulphide has also been determined experimentally.

There is very little known about the chlorides, and nitrates of lead in this district. Chlorides and nitrates are present in the ground water but their quantity is so small as to practically remove them from consideration.

It has been pointed out in the report on "The Geology of the Granby Area," that there are four* well recognized conditions under which lead may be precipitated, as the sulphide from ground water. These are as follows:

"1st. By the introduction of hydrogen sulphide or soluble sulphides into either acid or alkaline solutions of lead salts, the lead is at once precipitated as the sulphide, viz.:

$$PbSO_4 + H_2S = PbS + H_2SO_4$$
$$Pb\ CO_3 + H_2S = PbS + H_2CO_3$$

The same reaction may be written by substituting for hydrogen sulphide, in the above equations, any soluble sulphide, the only difference in the result being the production of the corresponding salt of the above acid."

In this region where the solutions are constantly in the presence of dolomite they would be alkaline, in spite of the tendency of acidity as a result of the precipitation of galena. Then the dolomite taken into solution at the time of its replacement by galena, would tend to neutralize any acid liberated.

"2nd. It has been shown by Schurmann** that the metals have an increasing affinity for sulphur in the following order: manganese, thallium, arsenic, iron, cobalt, nickel, zinc, lead, tin, antimony, cadmium, bismuth, copper, silver, mercury and palladium. "He has also shown that the sulphide of any member of the series will react upon the oxidized salts of those members having a stronger affinity for sulphur and precipitate them as sulphides, the metal of the precipitating agent going into solution." (Granby Report p. 90). Lead has a greater affinity for sulphur than iron or zinc. As a result the sulphide of these metals might precipitate lead as the sulphide, according to the following reactions, viz.:

$$PbSO_4 + ZnS = PbS + ZnSO_4$$
$$PbSO_4 + FeS_2 + O = PbS + FeSO_4 + SO_2$$

Lead carbonate may be substituted for lead sulphate in writing each of these equations.

"3rd. It has been shown by Stokes,*** that lead corbonate may be precipitated, as the sulphide by pyrite, in the presence of sodium carbonate. The reaction involved is as follows:

$$14PbCO_3 + 8FeS_2 + Na_2\ CO_3 = 14PbS + 4Fe_2O_3 + Na_2S_2O_3 + 15\ CO_2$$

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*See "The Geology of the Granby Area," Vol. IV, 2nd Series, Mo. Bureau of Geology and Mines, pp. 91-93.

**Schurmann cited by Van Hise, Treatise on Metamorphism, Monograph XLVII, U. S. G. S., 1904, p. 1114.

***Stokes cited by Van Hise, Treatise on Metamorphism, Mon. 47, U. S. G. S. 1904, p. 1194.

The experiments through which this reaction was verified were carried on at a temperature of 100°C.

"4th. Lead salts may be reduced to the sulphide through the agency of organic matter. This may be accomplished directly by the abstraction of oxygen or indirectly by the generation of hydrogen sulphide. Hydrogen sulphide, in the latter case would be the direct cause of precipitation.

It is thought that in this area cases 1 and 4 have been chiefly operative. The hydrogen sulphide which would be invoked in both cases is probably a result of the action of acids upon soluble sulphides, according to the following reaction, viz.:

$$CaS + H_2SO_4 + 2H_2O = CaSO_42H_2O + H_2S.$$

The introduction of oxygenated waters, carrying a lead salt in solution, into carbonaceous shale and limestone should result in the decomposition of the carbonaceous matter. This decomposition would liberate C which on account of its affinity for O would abstract same from the Pb SO_4 precipitating the PbS. This process may be operative in this area, altho it is doubtful, from experiments lately conducted, if this reaction actually takes place.

It is more probable that the oxygenated waters carry $CaSO_4$ in solution. In which case the liberation of the carbon of the carbonaceous shales would result in the following reaction:

$$CaSO_4 + C + H_2O = CaCO_3 + CO_2 + H_2S$$

The H_2S immediately reacts on the $PbSO_4$ in the water as follows: $H_2S + PbSO_4 = PbS + H_2SO_4$. The PbS is precipitated in form of galena and the H_2SO_4 reacts on the calcium carbonate as follows: $H_2SO_4 + CaCO_3 = CaSO_4 + CO_2 + H_2O$. This is a return to the first condition resulting from the action of oxygen in liberating the C of the carbonaceous shales.

CHAPTER VI.

BARITE AND GALENA IN THE POTOSI FORMATION.

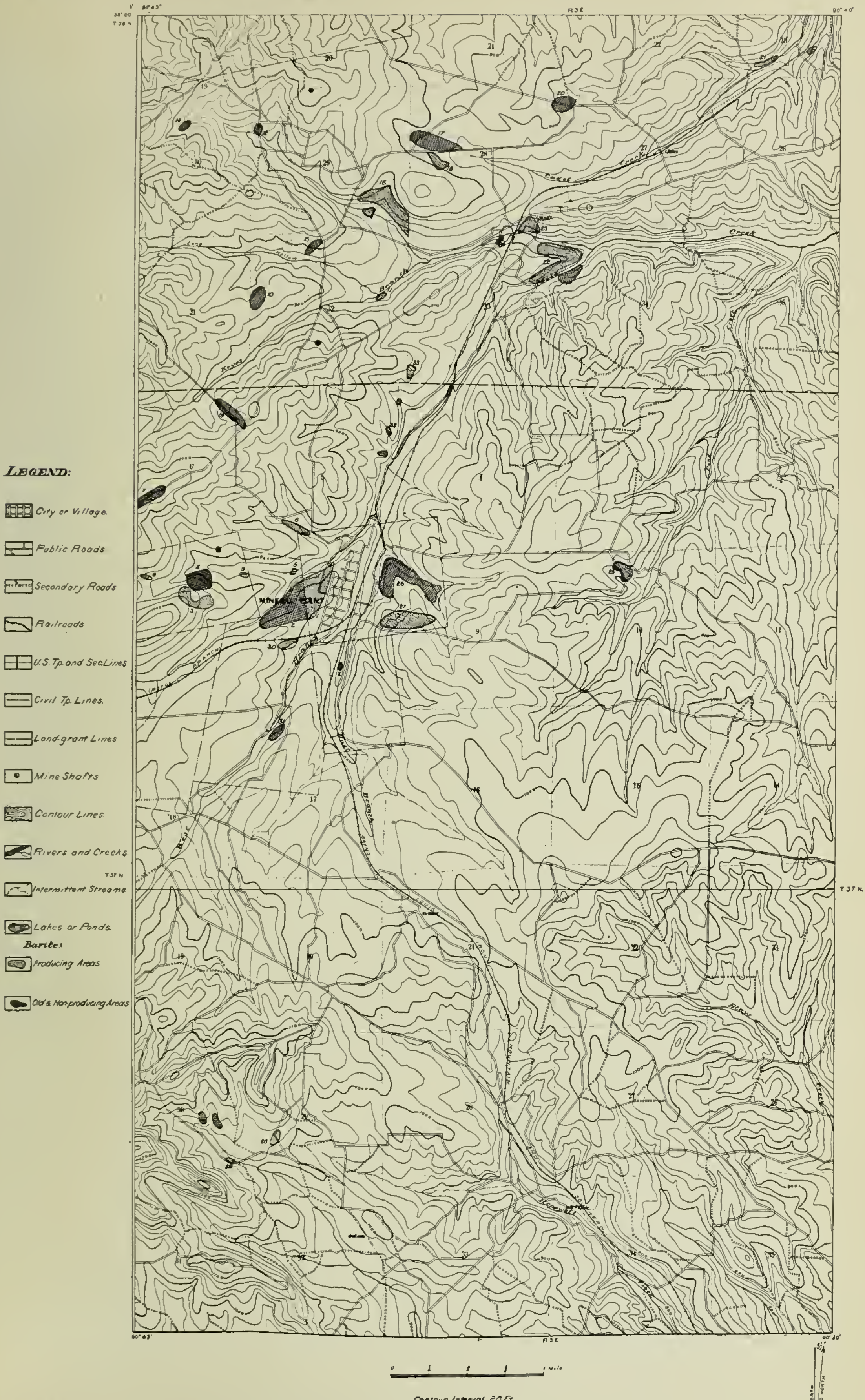
There are between 30 and 40 localities in the area included within this report from which barite has been or is being mined. In some of these galena occurs with the barite, from which it is separated by hand cobbing. In the progress of the field work, 32 of these localities have been examined. These deposits all occur in the northwestern part of the Bonne Terre sheet and in the area which is underlain with the Potosi formation. The distribution of the deposits, which are known as Barite Diggings, are shown on the accompanying map. These deposits are within the most productive area of barite in the state and are typical of what are known as the Washington County barite deposits.

The various localities are numbered on the map, Plate XXXVII. and the following descriptions conform in arrangement to this numbering:

No. 1.

These diggings are on property owned by the American Lead & Baryta Co., and are located west of Mineral Point.

The surface at this place consists of residual, red clay, having a depth of from 6″ to 6 feet. Beneath this clay occurs an undetermined thickness of residual material, consisting of drusy quartz, fragments of dense chert and masses of barite embedded in red clay. The barite occurs in bunches irregularly scattered through this cherty horizon and is always associated with drusy quartz. It has a milk white color and is opaque, altho frequently large masses are obtained which have a mottled appearance due to the presence of iron oxide along cleavage planes. In some parts of the diggings, both hematite and galena are associated with the barite and drusy quartz. In other places only one of these is found. The hematite usually occurs as a thin layer coating the drusy



Barite producing area near Mineral Point.

quartz, while the galena occurs chiefly in cubes disseminated through the barite. Wherever any of the galena occurs on the surface of the barite masses, it is oxidized and usually covered with a thin coating of lead carbonate.

The barite is mined by sinking a circular shaft 3½ to 4 feet in diameter. This shaft usually extends into the barite horizon from 3 to 4 feet. After it has reached this depth, the barite is removed with a pick and shovel for a distance of from 3 to 5 feet away from the circumference of the shaft after which it is abandoned and allowed to cave in. See Plates XXXVIII and CXX. Frequently several shafts are sunk close together and in these cases the barite horizon is usually mined out between the shafts. As a rule these shafts do not exceed 15 feet in depth. From those that are shallow the barite is thrown out by hand, but in the deeper diggings it is elevated with a hand windlass. In mining no blasting is required, the pick, shovel and windlass being the only implements employed.

The chert, drusy quartz and iron oxide are removed from the barite masses with a hand hammer after they have been hoisted to the surface. Fragments of dolomite are frequently found associated with the barite and flint in these diggings.

No. 2.

These diggings are a continuation of No. 1. They were at one time worked very extensively but are inactive at the present time. It is reported that the barite has all been removed from this locality.

No. 3.

This is known as the Higgins Barite Diggings. The southwest portion consists of close textured red clay, while the northwest portion consists of a yellowish brown clay. The barite from this place is tinged a yellowish brown or red as a result of being embedded in the clay. Galena and drusy quartz are both associated with the barite. The galena occurs in cubes from ½″ to 1″ in size and is usually disseminated through the barite masses. The shafts are as a rule from 4 to 16 feet in depth. None of them have reached the underlying rock.

No. 4.

This is an area of abandoned diggings. The material excavated from these shafts is a yellowish clay containing barite and drusy quartz.

No. 5.

At this place there is a shaft which has been sunk into the limestone to a depth of from 30 to 40 feet. The workings are now abandoned.

No. 6.

This place is known as the Higgins Lead Diggings. At this place galena occurs along the joints in the dolomite, the veins having a general east and west strike. The veins are from ¼″ to 1½″ in thickness. The dolomite is covered with from 5 to 17 feet of residual clay in which occur fragments of drusy quartz and chert.

The only barite in this mine occurs in thin seams in the dolomite. The sinking of this shaft was discontinued owing to the amount of water encountered. In the east end of the mine a north and south seam was encountered which contains galena.

No. 7.

The diggings in this locality have been abandoned. The material removed from the shafts consists of a red clay, fragments of chert and a yellowish white, sandy, crystalline dolomite.

No. 8.

The barite in these shafts is associated with drusy quartz, galena and hematite. The galena is partly oxidized as shown by the rounded corners of the cubes which occur on the outer surfaces of the barite masses.

No. 9.

The barite at this place occurs in red clay which contains fragments of chert, drusy quartz and sandy, crystalline dolomite. The shafts are only from 5 to 6 feet in depth.

No. 10.

These are old abandoned diggings in residual clay. Nothing could be learned as to the manner of occurrence of the barite.

No. 11.

The mines at this place are known as the White Diggings. In the eastern half of these diggings, galena occurs associated with the barite in residual red clay. The clay also contains fragments of chert and drusy quartz. The latter is frequently coated with an ⅛″ sheet of hematite. The intimate association of the barite and the drusy quartz makes it difficult to clean. The shafts at this place are from 3 to 6 feet in depth.

Over the western half of this area, barite occurs at the surface and is associated with drusy quartz and a small amount of iron oxide. A few crystals of galena have been obtained, all having slightly oxidized surfaces.

No. 12.

This is a group of abandoned diggings in which the barite is embedded in a yellowish brown clay, free from chert, drusy quartz or other materials which are ordinarily associated with it. The shafts are from 3 to 5 feet in depth.

No. 14.

Over this area and the surrounding hillsides there are numerous boulders of chert 2.5 feet in thickness and from 10 to 12 feet in width. They lie so close together as to give one the impression that they formerly constituted a bed which was continuous over the area. The barite is embedded in residual clay which lies beneath these boulders. There is no drusy quartz, but considerable galena occurs with the barite.

No. 15.

In this area the barite occurs in red clay and is associated with drusy quartz and chert fragments. The barite is closely associated with the drusy quartz, from which it is somewhat difficult to separate. The shafts are from 3 to 4 feet in depth.

No. 16.

The mines in this area are known as the Duffey diggings and are owned by White Bros. The barite occurs at a depth of from 1 to 4 feet and is overlain with a dark red clay, free from drusy quartz, chert or other fragments. It lies embedded in a residual red clay and is associated with fragments of drusy quartz and chert. Altho considerable of the barite occurs free from both drusy quartz and hematite, these are usually associated with it.

Galena has only been found in one shaft near the center of the area. At this place it occurs in cubes about ½" in diameter, disseminated through the masses of barite.

In the eastern part of the area barite is obtained by sinking shafts to a depth of from 2 to 3 feet. In the middle and western portions, shafts are sunk from 4 to 6 feet. In the west central part open cut mining has been resorted to. In this place, over an area 136 feet square all of the residual material has been removed down to the bed rock which consists of a sandy crystalline dolomite. In this dolomite occur masses of barite in quartz geodes. In the residual material overlying the rock, the barite occurs embedded in a coarse red clay and is associated with drusy quartz, chert and hematite. The excavation at its deepest point is about 10 feet. The barite is cleaned with a hand hammer and cradle such as is illustrated in Plate XXXVIII.

No. 17.

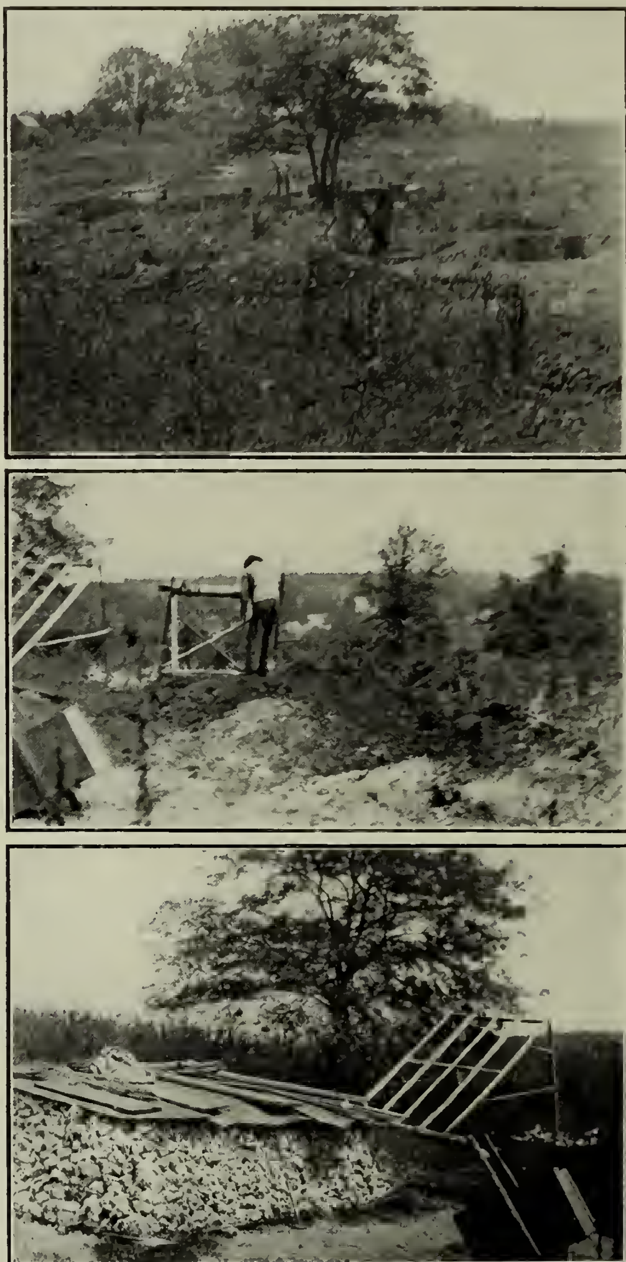
This is known as the Shibboleth claim. A section at this place shows 1 to 2½ feet of black soil, containing fragments of chert near the bottom; 1 to 3 feet of red clay; underneath which occurs a red clay in which are embedded fragments of barite, drusy quartz, chert and hematite. As is usual in these diggings the hematite occurs chiefly as a coating upon the drusy quartz. The shafts at this place are from 4 to 10 feet in depth.

No. 18.

This is known as Kelsey's claim. It lies on the north slope of the hill at the base of which shafts have been sunk to a depth of 4 feet in rich soil free from rock fragments. At the north end of the claim a shaft has been sunk 14 feet in depth which shows the following section.

5 ft. Soil with chert fragments at the base.
2 ft. Barite and finely crystalline drusy quartz embedded in red clay.
3 ft. Red clay, practically free from fragments of rock.
4 ft. Barite, drusy quartz and chert embedded in red clay.

The barite occurs in large masses usually associated with drusy quartz and sometimes with hematite.



Barite "Diggings," showing windlass, rocker and stock pile of barite.

No. 19.

At this place barite is mined from a ditch along the roadside. This ditch is about $3\frac{1}{2}$ feet in depth and exposes a residual red clay in which is embedded barite, drusy quartz, chert and hematite. The hematite occurs in the form of pipe ore and as thin sheets coating the drusy quartz. To the east of the road, there is an area of old lead and barite diggings about which no information could be obtained. The pipe iron ore is an alteration product of pyrite or marcasite.

No. 20.

This is an area of abandoned diggings, the dumps of which indicate a shallow depth. The barite evidently occurs in the red clay associated with drusy quartz and chert.

No. 21.

At this place the diggings occur on a steep hillside and the barite is associated with drusy quartz, chert and hematite, all of which are embedded in a residual red clay. The shafts are from 3 to 8 feet in depth. Near the base of the hill the bed rock occurs from 3 to 4 feet below the surface.

No. 22.

At this place the barite occurs in red clay and is associated with large masses of chert and boulders of drusy quartz. The barite occurs chiefly in the drusy quartz masses from which it must be separated by breaking with a hammer. Some hematite occurs with the barite chiefly as a thin layer coating the drusy quartz crystals.

These diggings lie chiefly on the top of the hill. Galena does not occur with the barite at this place, but from the older and lower area lying to the south some galena has been obtained. The shafts are from 3 to 10 feet in depth.

No. 23.

The diggings at this place are similar in every respect to those of No. 22. The shafts are shallow being from 3 to 6 feet in depth.

No. 24.

This area comprises a few scattered shafts from which barite has been obtained at a shallow depth. It occurs associated with large masses of drusy quartz and chert embedded in red clay.

No. 25.

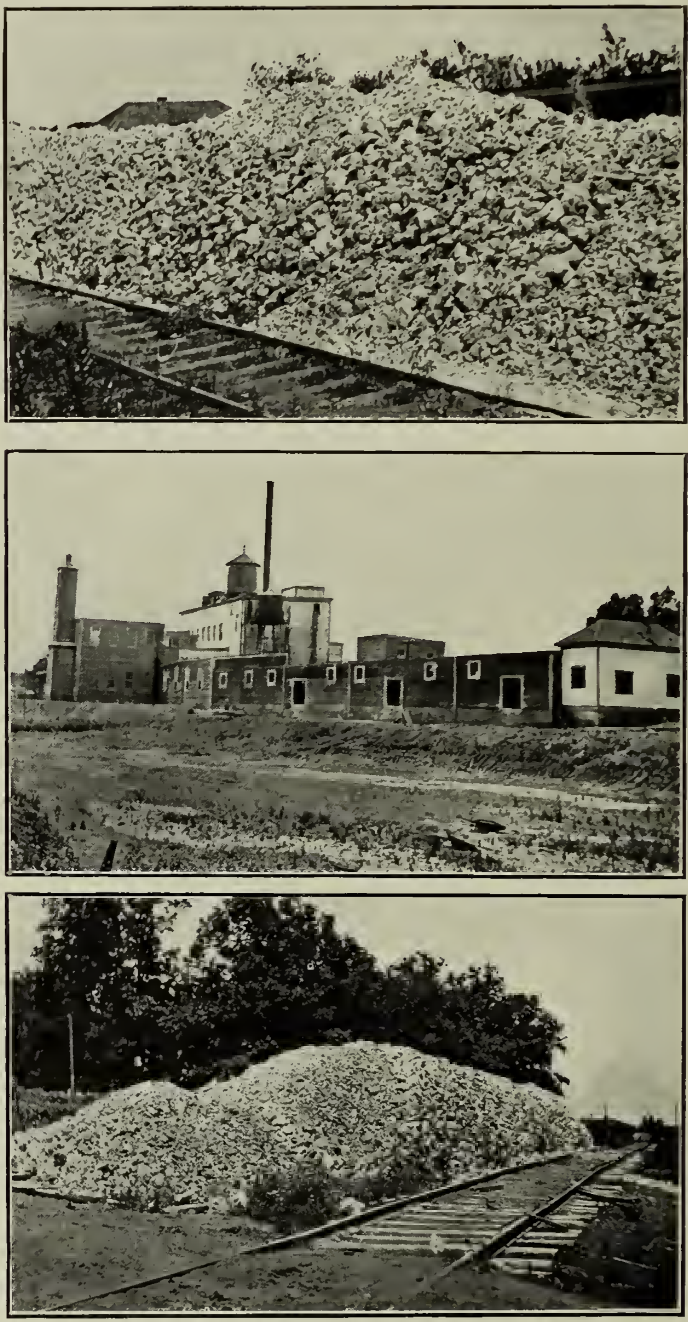
This area is known as the Harper diggings. The barite occurs associated with a large amount of drusy quartz and fragments of chert. Hematite frequently occurs in a thin layer between the drusy quartz and barite. As a whole the barite is very white and of excellent quality.

No. 26.

This area is known as Old Diggings. The property is owned by Mr. W. H. Walton. The mines have produced both galena and barite, which occur in a residual clay associated with drusy quartz, chert and hematite. The hematite occurs in thin layers coating the drusy quartz. The galena occurs in small cubes disseminated through the barite masses. The galena has been mined from two different veins in the dolomite. These veins consist of barite and galena, the latter occurring in small cubes embedded in the former. Mining has been carried on by sinking shafts 15 to 20 feet apart and connecting them by drifting along the vein. The two veins lie parallel and about 60 feet apart. They have a strike approximately N. 70° W. and have been mined for a distance of about 300 feet.

No. 27.

This is known as the H. Walton diggings. The surface of this area is covered with residual clay practically free from fragments of rock. Underneath this lies a bed of red clay in which are embedded masses of barite and fragments of drusy quartz, chert and hematite. The barite is almost universally associated with the drusy quartz over which the hematite forms a thin coating. In one shaft the barite occurs directly upon fragments of dolomite. In the northeastern part of the area, the barite has a pure white color, while in other portions it is tinged with red.



Point Mining and Milling Co's. Barite plant at Mineral Point, showing stock piles of barite.

No. 28.

In this locality the barite occurs in a yellow, sandy clay associated with small fragments of chert. The barite occurs in small lumps and on the whole, is free from associated rocks or minerals. There is a small amount of hematite coating the fragments of barite. The shafts are from 4 to 7 feet in depth.

No. 29.

In this locality the barite occurs in a manner similar to that at No. 28. The shafts are along a creek and the barite occurs in residual red clay at a depth of from 4 to 8 feet. There is a very small quantity of chert associated with the barite in this clay.

No. 30.

The diggings at this place are owned by the Mineral Point Mining Co. Barite occurs in a coarse, red clay and is associated with drusy quartz and chert fragments. It occurs at a depth of from 3 to 5 feet. The barite horizon is overlain with residual clay which is practically free from rock fragments. The barite has a reddish tint and is frequently covered with a thin coating of hematite. It frequently contains small cubes of galena.

No. 31.

This locality marks approximately the northern and northeastern limit of the area over which fragments of sandstone are found in the residual material at the surface. On the hill that slopes west from Hopewell, the sandstone fragments are more numerous and vary in color from white to yellow.

No. 32.

At this place there occurs an open crevice filled with clay, in which is embedded barite containing small cubes of galena. This deposit has been worked to a depth of about 4 feet and for a distance of about 25 feet. Above the dolomite occurs a residual deposit of red, sandy clay in which fragments of barite and drusy quartz are embedded. The barite in the residual deposits contains some galena in small cubes. The barite has a white color and occurs in scattered bunches.

No. 33.

At this place the barite occurs in a red clay and is associated with finely crystalline, drusy quartz and chert. The drusy quartz is coated with a thin film of hematite 1/32″ in thickness. The barite occurs at a depth of from 1 to 3 feet.

ORIGIN OF BARITE.

Bischof* says "Sulphate of Baryta, one of the most sparingly soluble and least changeable bodies in the mineral kingdom, is so perceptibly decomposed by a dilute solution of a carbonated alkali, even at a temperature of from 77° to 82° *F.*, that the change may be detected by reagents." He estimates that it must require 209,424 times the quantity of pure water for its solution. In another place** the same author refers to the occurrence of barite in granite showing that in the instances referred to it must have occurred as a silicate probably as a constituent of the feldspar. He says further that prepared silicate of baryta "dissolves in from 20,000 to 27,590 parts of cold water. In water at the temperature of 212° it is much more soluble, only 1000 parts of water being required. According to analysis, it consists of 1 equivalent of baryta, 5 of silica, and 3 of water. A cold solution of this silicate is decomposed by sulphates of the alkalies, by sulphate of lime, and by sulphate of magnesia; sulphate of baryta being precipitated, while a silicate is formed, which in the case of the two earthy silicates is precipitated along with the sulphate of baryta."

"The circumstance that the silicate of baryta is decomposed by all soluble sulphates is due to its being soluble, while the sulphate of baryta formed in such cases is insoluble. * * * * * * We must suppose that the frequent occurrence of sulphates in springs is that which renders a silicate of baryta impossible. Did this silicate occur in any rock, the percolating water would extract it, and so soon as such solution came into contact with any soluble sulphate, sulphate of baryta would immediately be formed. From this alone, it is obvious that silicate of baryta and any alkaline sulphate could not exist together in a rock, but only sulphate of baryta and silicate of the alkali. It is therefore a certain indica-

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*Elements of Chemical and Physical Geology, Gustav Bischof, 1854, Vol. I, p. 30.

**Ibid, p. 436.

tion of the absence of silicate of baryta in a rock when the springs proceeding from the latter contain sulphates."

Silicate of Baryta is not known to exist in nature, only the silicate compounds, Hyalophane $(K_2, Ba)\ Al_2Si_4O_{12}$, Edingtonite $BaAl_2Si_3O_{10}+3H_2O$, Harmotome $H_2(K_2,Ba)Al_2Si_5O_{15}+H_2O$, Brewsterite $H_4(Sr,Ba,Ca)\ Al_2Si_6O_8+3H_2O$ and Barylite $Ba_4Al_4Si_7O_{21}$ having been recognized and catalogued in Dana's "System of Mineralogy." Bischof remarks very pertinently that since sulphate of baryta cannot be decomposed by the silicates while silicate of baryta may be decomposed by all soluble sulphates, the latter is probably the salt employed by nature for the formation of the compound silicates above referred to as well as psilomelane.

Barium carbonate (Witherite) is soluble in 4300 times its weight of water and there are many recorded observations of the alteration of this compound into barite (barytes). Instances have also been recorded in which witherite has been only in part converted into barite, the remainder having been removed in solution.

Experiments by Bischof show that when water containing gypsum is permitted to flow over witherite for a long period, sulphate of baryta and carbonate of lime are formed, replacing the carbonate of baryta.

It is clear that warm waters from some springs contain carbonate of baryta in solution, depositing sulphate of baryta along with other mineral substances in consequence of a fall in the temperature. Some beds of barite may be explained in this way altho that which occurs in fissures can hardly be accounted for in this manner. Bischof says that to account for the barite veins "the only supposition that remains, is that ascending warm waters, which held in solution carbonate of baryta and sulphates of the alkalies, had, during their course upon the surface, trickled down the walls of fissures, and deposited on cooling, sulphate of baryta."

The barite of the area under discussion has probably been derived from barium carbonate which is soluble in 4300 times its weight in water, the solubility being increased through the addition of carbonic acid gas. The barium carbonate introduced, in solution, into the Potosi formation was probably precipitated through the mingling of barium carbonate solutions and solutions carrying an alkaline sulphate, perhaps calcium sulphate.

The original source of the barium was probably the feldspars of the igneous rocks, from which were derived the materials making up the sedimentary formations of the area.

The fact that barite does not occur in the formations beneath the Potosi, altho occurring in those above, seems to argue that the barite bearing solutions came from above and that during the period of introduction of the barite, the Potosi was the oldest of the sedimentary formations reached by the downward-circulating barite bearing solutions.

TABLE NO. 1.

ANALYSES OF MINE WATERS.*

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.†	12.	13.	14.	15.	16.
$NaCl$	0.06109	0.02237	0.04771	0.04127	0.06909	0.05260	0.04150	0.06470	0.00210	0.00380						
KCl	0.00029	0.00448	....	....	0.01290	0.00940	0.02340	0.00940								
$MgCl_2$	....	0.00053	....	....	0.01933	0.00130	0.02350	0.01230	....	....	0.00200					
$PbSO_4$	0.00110	0.00133	0.00037	0.00038	0.00060	0.00080	0.00070	0.00055	0.00030	0.00040	0.00152	0.00022	0.00077	0.00154	0.00031	0.00101
Na_2SO_4	....	....	....	0.01884	....	....	....	....	0.00960	0.01540						
K_2SO_4	0.01258	....	0.01881	0.01106	....	....	....	....	0.02750	0.00730						
$MgSO_4$	0.19064	0.19246	0.11206	0.08586	0.01470	0.01680	0.0790	0.04000	....	....	0.01060					
$CaCO_3$	0.11839	0.21000	0.19923	0.16875	0.01632	0.15420	0.16120	0.13620	0.14180	0.14400	0.13482					
$MgCO_3$	0.08122	0.05009	0.06092	0.08391	0.09360	0.08250	0.03530	0.04260	0.07430	0.07820	0.08012					
$FeCO_3$	0.00043	0.00168	0.00088	0.00070	0.00020	0.00045	0.00014	0.00029	0.00015	0.00027	0.00030					
$MnCO_3$	....	0.00008	0.00018	0.00030	0.00020	0.00020	....	....	....	0.00037						
Al_2O_3	0.00024	0.00144	0.00104	0.00044	0.00029	0.00020	0.00020	0.00030	0.00020	0.00030	0.00011					
SiO_2	0.01227	0.01420	0.01008	0.01234	0.01450	0.01410	0 01380	0.01190	0.01330	0.01180	0.00733					
Na_2CO_3	....	....	....	....	....	....	....	....	0.0362	0.02600						

1. National No. 3, from sand.
2. " " descending.
3. Doe Run No. 3, from sand.
4. " " descending.
5. St. Joe No. 1, descending.
6. St. Joe No. 1, from sand.
7. Doe Run No. 4, descending.
8. " " from sand.
9. Des Loge No. 3, descending.
10. " " from sand.
11. Federal No. 1, descending.
12. Federal No. 4, descending.
13. National No. 2, from sand.
14. " " descending.
15. Federal No. 2, descending.
16. " " from sand.

*Grams per litre, as whole numbers read parts per million.
†Alkalies not determined.

TABLE NO. II.

The following are analyses of the crude ore and concentrates from one of the mines in the district, representing respectively aliquot samples of the monthly output of ore and each car lot of concentrates.

	Crude Sulphide Ore.	Concentrates.
Pb	5 75	65.85
Cu	0.06	0.30
Zn	0.86	1.75
S	2.02	13.73
SiO^2	5.01	0.50
Fe	4.10	3.15
Mn	0.49	0.27
CaO	25.50	4.28
MgO	14.20	2.78
Al^2O^3	4.89	0.50
Co	36.17	6.37
Total	99.05	99.48
Ag	0.12oz	1.00oz
CO^2 calculated, considering CaO and Mgo as carbonates.		

In addition to the above assays of the concentrates were made for gold and silver with the following results:

Federal Lead Co. . . . . . . Silver . . . . 1,976 oz per ton of concentrates
Federal Lead Co. . . . . . . Silver . . . . 0.205 oz per ton of concentrates
Doe Run Lead Co. . . . . . . Silver . . . . 1.873 oz per ton of concentrates
Doe Run Lead Co. . . . . . . Silver . . . . 1.875 oz per ton of concentrates
Doe Run Lead Co. . . . . . . Silver . . . . 2.065 oz per ton of concentrates
St. Joseph Lead Co. . . . . . . Silver . . . . 1.327 oz per ton of concentrates
Madison Lead and Land Co. . . . . . . Silver . . . . 0.48 oz per ton of concentrates

Compiled from various sources.

Year	Derby Lead Co. Tons Concentrates	Derby Lead Co. Value	Irondale Lead Co. Tons Concentrates	Irondale Lead Co. Value	Federal Lead Co. Tons Concentrates	Federal Lead Co. Value	Central Lead Co. Tons Concentrates	Central Lead Co. Value
1869	...	...	...	...	...	...	...	...
1870	...	...	...	...	...	...	...	...
1871	...	...	...	...	...	...	...	...
1872	...	...	...	...	...	...	...	...
1873	...	...	...	...	...	...	...	...
1874	...	...	...	...	...	...	...	...
1875	...	...	...	...	...	...	...	...
1876	...	...	...	...	...	...	...	...
1877	...	...	...	...	...	...	...	...
1878	...	...	...	...	...	...	...	...
1879	...	...	...	...	...	...	...	...
1880	...	...	...	...	...	...	...	...
1881	...	...	...	...	...	...	...	...
1882	...	...	...	...	...	...	...	...
1883	...	...	...	...	...	...	...	...
1884	...	...	...	...	...	...	...	...
1885	...	...	...	...	...	...	...	...
1886	...	...	...	...	...	...	...	...
1887	...	...	...	...	...	...	...	...
1888	...	...	...	...	...	...	...	...
1889	...	...	...	...	...	...	...	...
1890	...	...	...	...	...	...	...	...
1891	...	...	...	...	...	...	...	...
1892	...	...	...	...	...	...	...	...
1893	...	...	...	...	...	...	...	...
1894	...	...	...	...	...	...	350.	$9,100
1895	...	...	...	...	...	...	3,833.	82,930
1896	...	...	...	...	...	...	5,470.5	128,060
1897	...	...	...	...	...	...	8 012.	192,294
1898	...	...	...	...	...	...	7 931.5	311,311
1899	...	...	...	...	...	...	6,698.3	267,932
1900	...	...	...	...	...	...	10,655.5	482,694
1901	...	...	...	...	...	...	9,221.0	414,930
1902	534	$22,970	790	$27,731	4,320	$161,827	10,553.0	422,100
1903	Purchased by Federal Lead Co		Purchased by Federal Lead Co		5,930	310,376	9,574.0	449,978
1904					10,404	400,131	6,397.0	307,061
1905					12,093	604,663	Purchased by Federal Lead Co.	
1906	...	...	...	...	21,270	1,376,624		
1907	...	...	...	...	20,212	1,293,572	...	...
Total	534	$22,970	790	$27,731	74,229	$4,147,193	78,695.8	$3,068,390

Total
Total

TABLE NO. III.

Production of the lead mines of the Bonne Terre, Flat River and Leadwood areas, from 1869 to 1907, inclusive. Compiled from various sources.

Year	St. Joseph Lead Co. Tons Concentrates	St. Joseph Lead Co. Value	Desloge Lead Co. Tons Concentrates	Desloge Lead Co. Value	Desloge Consolidated Lead Co. Tons Concentrates	Desloge Consolidated Lead Co. Value	Flat River Lead Co. Tons Concentrates	Flat River Lead Co. Value	St. Louis Smelting and Refining Co. Tons Concentrates	St. Louis Smelting and Refining Co. Value	Doe Run Lead Co. Tons Concentrates	Doe Run Lead Co. Value
1869	261.	$36,540										
1870	323.	40,052										
1871	859.	95,968										
1872	1,060.	116,600										
1873	1,080.	118,800										
1874	1,295.	141,725										
1875	1,963.	210,432										
1876	2,436.	257,242										
1877	2,051.	169,002	928	$76,467								
1878	2,819.	153,354	1,843	100,259								
1879	3,565.	228,160	2,332	149,248								
1880	4,254.	323,304	3,531	268,356								
1881	5,317.	348,795	4,646	314,778								
1882	7,304.	556,028	5,903	443,906								
1883	5,952.	380,928	6,770	509,104								
1884	6,804.	381,024	7,530	421,680								
1885	9,769.	593,955	5,458	331,846								
1886	7,372.	530,784	4,542	327,004								
1887	7,387.	508,226										
1888	13,027.	1,042,160	The above mines								2,900.	$232,000
1889	13,600.	783,360	were at Bonne Terre								5,243.5	302,026
1890	13,851.	952,000	and in 1887 were								5,516.4	280,000
1891	14,114.	1,094,381	purchased by St.								4,219.	217,600
1892	13,474.	896,098	Joseph Lead Co.								3,348.1	124,700
1893	14,421.	587,012									3,593.3	150,000
1894	18,089.	763,279			2,250	$67,500	750	$22,500			4,509.3	190,000
1895	20,411.5	563,910			4,200	126,000	Purchased by				5,700.	201,800
1896	21,908.5	659,451			4,650	129,732	St. Louis				10,342.	311,294
1897	23,087.	568,867			5,200	158,600	Smelting and				12,632.	343,595
1898	20,342.5	798,454			9,327	366 084	Refining Co				12,400.	487,093
1899	20,024.5	844,033			10 044	490 000					12 290.	518,189
1900	18,174.	823,282			14,929	477,371			3,064	$122,223.	19,075.	906,882
1901	23,417.	943,722			7,497	300,000			10,954	448,521.5	16,532.	804,961
1902	26,783.	918,668			9,950	417,900			17,534	664,123.	17,030.	810.350
1903	28,481.	1,381,328			9,449	400,000			16,701	704,782.	19,420.	946,548
1904	28,417.	1,059,158			12,742	555,359			15,511	698,002.	19,100.	933,839
1905	30,588.	1,529,435			13,488	661,864			17,528	876,404.	19,300.	1,001,476
1906	43,907.	2,853,966			11,641	773,320			18,503	1,086,242.6	20,032.	1,315,051
1907	33,000.	2,103,837			10,051	633,236			16,391	1,040,845.1	19,670.	1,284,878
Total	510,988.	$26,357,463	43,483	$2,942,648	125,418	$5,556,966	750	$22,500	116,186	$5,641,143.1	232,852 6	$11,362,282

Year	Union Lead Co. Tons Concentrates	Union Lead Co. Value	Columbia Lead Co. Tons Concentrates	Columbia Lead Co. Value	Leadington Lead Co. Tons Concentrates	Leadington Lead Co. Value	Derby Lead Co. Tons Concentrates	Derby Lead Co. Value	Irondale Lead Co. Tons Concentrates	Irondale Lead Co. Value	Federal Lead Co. Tons Concentrates	Federal Lead Co. Value	Central Lead Co. Tons Concentrates	Central Lead Co. Value
1869														
1870														
1871														
1872														
1873														
1874														
1875														
1876														
1877														
1878														
1879														
1880														
1881														
1882														
1883														
1884														
1885														
1886														
1887														
1888														
1889														
1890														
1891														
1892														
1893					187 5	$5.000								
1894					345 5	9,674							350.	$9,100
1895					Purchased by								3,833.	82,930
1896					Federal Lead								5,470.5	128,060
1897					Co.								8 012.	192,294
1898													7 931.5	311,311
1899													6,698.3	267,932
1900	35	$1,585	2,704.5	$122,514									10,655.5	482,694
1901	Purchased		5,925.	207,375									9,221.0	414,930
1902	By Doe Run		5,000.	175,000			534	$22,970	790	$27,731	4,320	$161,827	10,553.0	422,100
1903	Lead Co.		2,700.	119,631			Purchased by		Purchased by		5,930	310,376	9,574.0	449,978
1904			1,783.	79,452			Federal Lead		Federal Lead		10,404	400,131	6,397.0	307,061
1905			Purchased by Doe				Co		Co		12,093	604,663	Purchased by Federal Lead Co.	
1906			Run Lead Co								21,270	1,376,624		
1907											20,212	1,293,572		
Total	35	$1,585	18,112.5	$703,972	533.0	$14,674	534	$22,970	790	$27,731	74,229	$4,147,193	78,695.8	$3,068,390

Total tons concentrates 1,202,606.9

Total value $59,869,354

INDEX.

V