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UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

THE FLUORSPAR DEPOSITS OF SOUTHERN ILLINOIS

BY

H. FOSTER BAIN

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., July 16, 1904.

SIR: I have the honor to transmit herewith the manuscript of a paper entitled "Fluorspar Deposits of Southern Illinois," by H. Foster Bain, and to recommend that it be published as a bulletin. This paper embodies the results obtained in a detailed study of the fluorspar deposits of this important district, the study having been undertaken in connection with the investigation of the lead and zinc deposits of the Mississippi Valley region. The area covered is at present the most important producer of fluorspar in the United States.

Very respectfully,

C. W. HAYES,
Geologist in Charge of Geology.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

THE FLUORSPAR DEPOSITS OF SOUTHERN ILLINOIS.

By H. Foster Bain.

INTRODUCTION.

LOCATION.

The fluorspar mines which are the subject of this report are in Pope and Hardin counties, in the extreme southern portion of Illinois. The principal mines are near Rosiclare, Elizabethtown, and Cave in Rock, small towns on the Ohio River, in Hardin County. An important group of prospects is located in the northwest part of Hardin County and northeast part of Pope County, and there are minor occurrences at various other points in these counties and also in Saline and Johnson counties. The area forms the northern part of the Kentucky-Illinois district. Its outline and general situation are

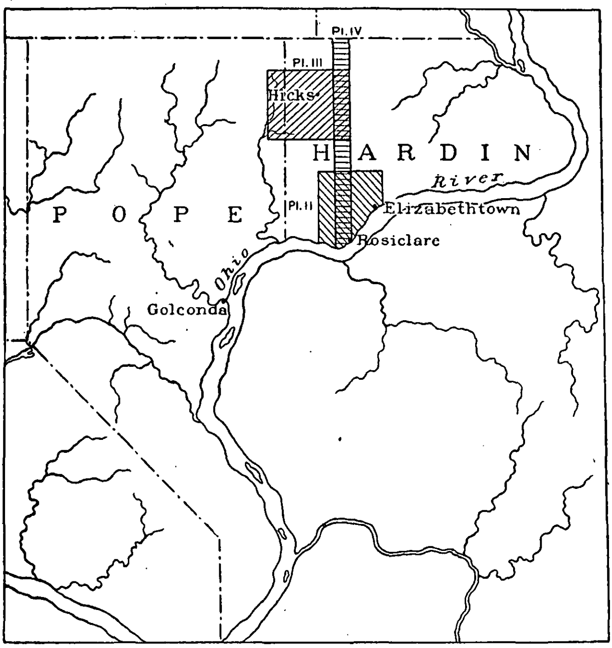

FIG. 1.—Sketch showing areas covered by detailed maps.

indicated on the accompanying map, Pl. I. In fig. 1 are indicated the particular areas surveyed in detail in the preparation of this report.

HISTORY OF DEVELOPMENT.

Attention seems to have been first attracted to the Kentucky-Illinois district by the occurrence of the brilliant colored fluorite. In early American geologic literature there are numerous references [a] to this fluorspar, or "fluate of lime," as it was then called. It was usually noted as coming from Shawneetown, Ill., since that was the nearest town of any size. The galena which occurs associated with the fluorite was probably noticed very early in the nineteenth century, but it was not until some years after the settlement of the country that any serious attempt was made to mine it. The first important mining venture seems to have been that of a company headed by President Andrew Jackson, which undertook development near the site of the present Columbia mines, in Crittenden County, Ky., in 1835. In Illinois the first mining was at Rosiclare in 1842. Lead was mined and smelted at various points in the district previous to the civil war, though it seems never to have been remunerative in a large way. Various observers speak of the mining as having been stopped, or as being carried on in only a small way from 1851 [b] to 1876.[c] As late, however, as 1884 competent observers considered some at least of the properties worthy of development for lead alone,[d] and there is even now a small output of lead.

In Illinois fluorspar seems to have been first discovered in place in 1839, when it was encountered with galena in sinking a well on the Anderson farm, now the property of the Fairview Fluorspar Company. In 1841 a second well not far from the first also encountered the lode, but no attempt seems to have ever been made to exploit either of these finds. In 1842 Mr. William Pell discovered spar and galena somewhere near the site of the present Rosiclare mine, and Marshall and White undertook its development. From that time on mining appears to have been carried on more or less continuously in this vicinity, at first under the direction of certain well-known Mis-

[a] Am. Jour. Sci., 1st ser., vol. 1, 1818, pp. 52–53; vol. 2, 1820, p. 176; vol. 3, 1821, p. 243. Schoolcraft, H. R., A View of the Lead Mines of Missouri, 1819, p. 191. Cleaveland, Parker, Mineralogy, 1822, p. 202. Brush, J. G., Am. Jour. Sci., 2d ser., vol. 14, 1852, p. 112.

[b] Norwood, J. G., Geol. Survey Illinois, vol. 1, 1866, p. 367. Owen, D. D., Geol. Survey Kentucky, vol. 1, 1856, p. 87. Whitney, J. D., Rept. Geol. Survey upper Mississippi lead region, 1862, p. 205.

[c] Norwood, C. J., Geol. Survey Kentucky, vol. 1, new ser., 1876, p. 493.

[d] Eilers, Anton, and Raymond, R. W., Manuscript report on the property of the Mineral City Mining and Smelting Company, Hardin County, Ill.

souri operators, Messrs. Valle, Anson, and others, and in recent years with the ownership in local and eastern hands.

Shipments of fluorspar began apparently in the early seventies, and since 1880 have been regularly reported. In 1891, when the district was visited by Mr. S. F. Emmons, large bodies of spar had been developed, though, as seems to have been usually true since the beginning of mining in this region, only one or two mines were actually shipping.

Zinc was early noted [a] in the district and from time to time small trial shipments were made. With the rise in the price of zinc in 1899, a period of active prospecting for zinc ore began. The discovery of the Old Jim mine in Kentucky stimulated the search and the whole district was gone over with considerable care by local prospectors. Very few important deposits of zinc ore were found, but the size and purity of the fluorspar deposits became for the first time adequately appreciated. There has since been an active and intelligent campaign to widen the market for spar and to increase its production. Incidentally some lead and zinc is being found and mined, though so far no important bodies of either have been developed in the Illinois portion of the district.

PREVIOUS GEOLOGIC WORK.

The Kentucky-Illinois district has been visited by but few geologists. The official reports of the States include brief reports [b] upon the district. Aside from these the most important paper is one by Mr. S. F. Emmons,[c] which was based upon a brief visit to the Rosiclare mines made in 1891. Mr. J. S. Diller [d] has published a description, with analysis, of the mica-peridotite forming the Flannery dike in Kentucky, based upon specimens collected by Mr. E. O. Ulrich. Brief notes upon the mining industry have been published by Mr. W. E. Burk,[e] and a description of the Old Jim mine has been given in the Engineering and Mining Journal.[f] Short notes on development of the district have been given in connection with the statistics of production annually published by the United States Geological Survey in the Mineral Resources, and notes on the fluorite as a mineral have appeared in other parts of these volumes.

[a] Owen, D. D., op. cit., p. 87.

[b] Kentucky: Owen, D. D., Geol. Survey Kentucky, vol. 1, pp. 87–88. Norwood, C. J., Geol. Survey Kentucky, new ser., vol. 1, 1876, pp. 449–493. Illinois: Worthen, A. H., Engelmann, Henry, and Norwood, J. G., Geol. Hardin County, Geol. Survey Illinois, vol. 1, 1866, pp. 350–375. Engelmann, Henry, Massac and Pope counties, Geol. Survey Illinois, vol. 1, 1866, pp. 428–495.

[c] Fluorspar deposits of southern Illinois: Trans. Am. Inst. Min. Eng., vol. 21, 1893, pp. 31–53.

[d] Am. Jour. Sci., 3d ser., vol. 44, 1892, pp. 288–289.

[e] Mineral Industry, 1901, vol. 9, pp. 292–295.

[f] Eng. and Min. Jour., vol. 74, 1902, pp. 413–414.

SCOPE OF THIS REPORT.

The present paper is essentially a preliminary statement of results based upon work done in 1903 in the Illinois portion of the Kentucky-Illinois district. In this work the writer had the field assistance of Mr. A. F. Crider, and the benefit of both field and office consultation with Mr. E. O. Ulrich, whose thorough familiarity with the Kentucky mines and the stratigraphy of the entire region contributed greatly to the work. Mr. Albert Johannsen has furnished petrographic notes, which are incorporated in the general description of the dike rocks. The report is intended to supplement the fuller discussion given by Mr. Ulrich and Mr. W. S. Tangier Smith of the district in general and the Kentucky mines in particular.[a] Brief statements concerning both portions of the district have already been published.[b]

PHYSIOGRAPHY.

GENERAL RELATIONS.

The Kentucky-Illinois fluorspar district lies well toward the middle of the Mississippi Valley, that great level-floored basin which occupies the continental interior of the United States. The district is somewhat nearer the Appalachian than the Rocky Mountain border of the valley and about midway between the Great Lakes and the Gulf of Mexico. The Mississippi Valley, though a monotonous plain when contrasted with its surroundings, has been differentiated into a number of physiographic provinces, which stand in somewhat marked contrast with one another. Of these, three—the Allegheny Plateaus, the Gulf Plains, and the Ozark Plateau—meet within this district, while the Prairie Plains join it on the north.

The Allegheny Plateaus are represented by the Interior Lowland, as defined by Mr. C. W. Hayes.[c] This occupies much of the mining district in Kentucky and includes the upland between the Ohio River and Karbers Ridge, in Pope and Hardin counties, Ill. The Gulf Plains include the southern portion of Pope and the adjacent part of Massac County, in Illinois, and that portion of Kentucky which lies west of the Tennessee River. The more exact limits are shown, covered with Tertiary and Cretaceous deposits, on the accompanying general geologic map of the district (Pl. I). The Ozark Plateau is represented by a long, narrow ridge of highland stretching across southern Illinois from about Grand Tower, on the Mississippi, to Shawneetown, on the Ohio. This plateau is represented in Pope and Hardin

[a] Prof. Paper U. S. Geol. Survey No. 36, in press.

[b] Ulrich and Smith, Bull. U. S. Geol. Survey No. 213, 1903, pp. 205–213. Bain, Bull. U. S. Geol. Survey No. 225, 1904, pp. 505–511.

[c] Hayes, C. W., Southern Appalachians: Mon. Nat. Geog. Soc., vol. 1, 1895, p. 310.

LEGEND

Cretaceous and Tertiary

Pennsylvanian (*Coal Measures*)

Mississippian (*Limestones, ore bearing*)

Devonian (*Blackslate*)

Dikes

1 ROSICLARE
2 FAIRVIEW
3 LEAD HILL
4 EUREKA
5 HAMP
6 EMPIRE
7 HUBBARD
8 STUART
9 PELL
10 McCLELLAN
11 PITTSBURG
12 WRIGHT
13 BAY CITY
14 COLUMBIA
15 MEMPHIS
16 OLDJIM
17 TABB
18 SATTERFIELD
19 DODDS
20 SENATOR
21 HODGE
22 ROYAL
23 MANN

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GENERALIZED GEOLOGIC MAP OF THE KENTUCKY-ILLINOIS FLUORSPAR DISTRICT

Scale

15 10 5 0 15 miles

1904

counties by Karbers Ridge, and its northern limit is defined by the South Fork of Saline River and certain tributaries of the Big Muddy.

The Interior Lowland has in this area a general altitude of 500 feet. It merges with the Gulf Plains along a sinuous line marking the overlap of Tertiary deposits upon an erosion plain beveling older rocks. It abuts sharply against the Ozark Plateau, which rises abruptly 200 to 250 feet above it, and which also overlooks the Prairie Plains to the north, which lies here at a general altitude of about 450 feet. Below the Interior Lowland and the Gulf Plains the Ohio and other rivers of the district have cut important channels to a general controlling base of 300 feet.

TOPOGRAPHY.

Karbers Ridge.—Crossing the northern portion of Pope and Hardin counties is a belt of high land presenting an abrupt escarpment face to the south. It is limited on the south approximately by the southern boundary of the Mansfield sandstone (see Pl. I). The escarpment rises 150 to 200 feet above the rolling plain at its base. The ridge itself is narrow and in Pope County reaches out in long, finger-like minor ridges between the southward-flowing streams. The main ridge rises to 700 or 750 feet above sea level, and is the most notable topographic feature of southern Illinois. As already indicated, it extends westward to the Mississippi, beyond which it is represented in the Ozark Plateau. To the east it becomes less and less distinct until lost in the uplands of western Kentucky.

In Hardin County it has a general east-west course and is excellently displayed. In T. 3 N., R. 8 E., and T. 3 N., R. 9 E., it is very sharply defined, the southward-fronting escarpment forming a great frowning wall. In Pope County the trend of the escarpment becomes more southwesterly. About 5 miles northwest of Golconda it is crossed by the road to Raum, the ridge here forming a narrow projecting point of high land between the branches of Lusk and Little Grand Pierre creeks. It rises here to nearly 800[a] feet above sea, approximately 230 feet above the general upland at its base and 500 feet above the river at Golconda. Farther west it has not been especially studied.

On the north side the ridge in Gallatin County presents an even more striking front. From its base stretches the great plain of central Illinois, underlain by the soft beds of the Coal Measures. Farther west the northern boundary is not so well defined.

Various names have been applied to this ridge at different points. There has been as yet no adequate physiographic study of the region as a whole, and for the present no attempt need be made to define and

[a] All elevations are based on barometer determinations and are approximate only.

name the entire ridge. For convenience that portion developed in Pope and Hardin counties will be called by the local name "Karbers Ridge," a name also applied to a small village at the base of its south front.

Upland plain.—At a lower level and extending southward from Karbers Ridge to the Ohio River is a rolling, broken plain sloping gently from about 600 feet elevation at the north to 500 feet at the south. While somewhat irregular in detail, it is in general a markedly level plain. The high Shetlerville Hills rise somewhat above it, but aside from them all the country south of Karbers Ridge in Illinois is at or below the level of this plain. In Kentucky there are several hills which rise above it, and in both States the rivers and their tributaries have reduced considerable areas to a lower level. Along the north side of the Ohio such a lower plain is locally developed between Elizabethtown and Cave in Rock. Here a strip approximately parallel to the river and 2 miles wide has been reduced to an altitude of about 440 to 460 feet. North of this strip the country rises very abruptly to 550 or 600 feet, after which the even upland plain is preserved, except for the interruptions due to river valleys, to the foot of Karbers Ridge. North of Golconda there is a distinct bench at about 480 feet above sea, while above that, at 550 to 575 feet, is the general upland plain.

The upland plain is developed upon various sorts of rocks. Limestones, sandstones, and shales outcrop at various points within its limits, and all have been cut down to a common level. Locally the individual formations influence the topography, as northeast of Elizabethtown, where the St. Louis limestone underlies the lower plain mentioned, and as in the case of the Shetlerville Hills, twin peaks, conspicuous from every point upon the upland, which are largely composed of the hard sandstone and conglomerate of the Mansfield. The plain is a true peneplain and marks an ancient base-level of erosion. It was formed at a time when the surface of the earth was undisturbed for so long a time that the streams broadened their valleys until the hills between were almost entirely cut away. The time at which this occurred is approximately fixed by the fact that in southern Pope County the plain passes very gradually beneath the gravels and sands which are believed to be of Tertiary age. In southern Illinois also this plain marks the northwestern limit of the Interior Lowland, whose age has been fixed as Tertiary at a number of points.[a]

River valleys.—Into the upland plain the rivers have cut their valleys. For the most part these are rather narrow and sharp walled. The Ohio, the master stream of the area, has a low-water level of 290 feet from Golconda to Elizabethtown. It flows between high rock

[a] Hayes, loc. cit.

walls for the greater part of its course. At 345 feet there is at several points a wide development of bottom land, as at Elizabethtown, Rosiclare, and near the mouth of Lusk Creek at Golconda. From Bay City the low land extends west in a broad belt, known as the Bay Bottoms, to Cache River, in Johnson County. In periods of flood an independent connection between the Ohio and Mississippi rivers is established by this route. At Rosiclare the bottom is likewise subject to overflow. The Ohio makes the impression of being very imperfectly adjusted to its valley. The great Bay Bottoms cut directly through the upland, but are traversed by only insignificant streams, while at various points along the Ohio the valley seems none too large for the stream. The arrangement of tributaries is also erratic. Near the mouth of Grand Pierre Creek are tributaries which head within a few feet of the Ohio, but flow northward and by a roundabout way into the minor stream. There are no topographic maps of the region and no good drainage maps, so that it is unsafe to make many generalizations. It seems clear, however, that the streams are poorly adjusted and that they show evidence of superposition. Their courses were for the most part determined when the present upland was a lowland, and with its uplift they have cut directly downward without much adjustment through hard and soft rocks alike. The most important tributaries of the Ohio—Big Creek, Grand Pierre Creek, and Lusk Creek—have cut back across the upland until their headwaters are at work upon the south slope of Karbers Ridge. At several places the tributaries of these streams on the south and those of the Saline River on the north have cut entirely through the ridge, forming passes or gaps. Packers Gap, near the headwaters of Grand Pierre Creek, is one of the best known.

GEOLOGY.

GENERAL STATEMENT.

Both igneous and sedimentary rocks occur in this district. The former are represented in a number of dikes found near the Ohio River and are all, so far as known, of the same general class of rocks. The sedimentary formations represent four different systems—Devonian, Carboniferous, Tertiary, and Quaternary. The Devonian outcrops are confined to a limited area in northern Hardin County; the Tertiary gravels are found only in southern Pope County; the Carboniferous occupies the larger part of the territory, while the loess loam of the Quaternary extends as a thin mantle over the whole. The Carboniferous rocks consist for the most part of formations belonging to the Mississippian series, the Mansfield sandstone alone representing the Pennsylvanian. In the division and classification of the Carboniferous, the scheme used by Mr. Ulrich in his discussion of the adjacent Kentucky district has been adopted in its entirety, with the exception that, as a matter of practical convenience in preliminary mapping, the dividing line between the St. Louis and the Tullahoma is drawn at a slightly higher horizon than the one recognized by him, and the Spergen Hill discriminated by him between the St. Louis and the Ste. Genevieve was not recognized in the course of this work. Mr. Ulrich considers the Birdsville and Tribune formations the equivalent of Kaskaskia as originally defined, and these with the Cypress and the Ste. Genevieve as making up the Chester. In the earlier work of Engelmann and Worthen[a] the lines were somewhat differently drawn, but for reasons which Mr. Ulrich has elsewhere discussed it is impracticable to follow them exactly. A general tabular arrangement of the formations is presented below.

Table of formations, southern Illinois.

System.	Formation.	Character.
Quaternary		Loess loam.
Tertiary	Lafayette (?)	Gravels.
Carboniferous	Mansfield	Sandstone and conglomerate.
	Birdsville	Sandstone, shale, and thin limestones.
	Tribune	Limestones.
	Cypress	Heavy-bedded sandstone.
	Ste. Genevieve	Oolitic limestones.
	St. Louis	Limestones and chert.
	Tullahoma	Chert and limestone.
Devonian	Ohio	Black shale.

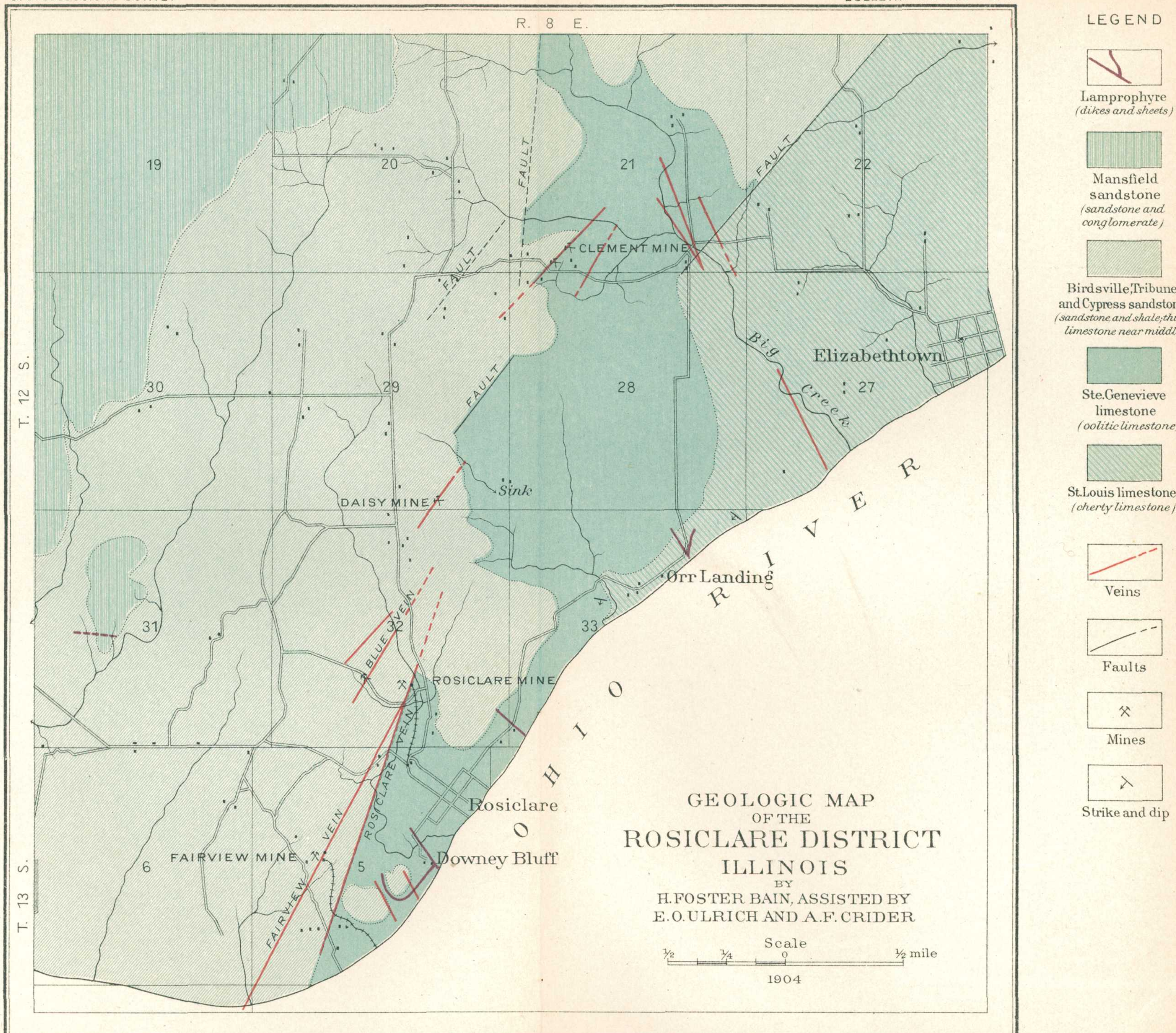
DESCRIPTION OF SEDIMENTARY FORMATIONS.

DEVONIAN ROCKS.

OHIO SHALE.

Character.—The Ohio shale as developed in this area is a black, fissile shale or slate. It splits in very thin sheets parallel to the original bedding and is very uniform in character. The only exception to this statement is that at the top a thin bed was observed which Mr. Ulrich considers the equivalent of a similar bed forming the top of the formation in middle Tennessee.[b] In it there are small, rounded

[a] Geol. Illinois, vol. 1, pp. 76–83, 348–495.
[b] Geologic Atlas U. S., folio 95, U. S. Geol. Survey, 1903, p. 2.



GEOLOGIC MAP
OF THE
ROSICLARE DISTRICT
ILLINOIS
BY
H. FOSTER BAIN, ASSISTED BY
E. O. ULRICH AND A. F. CRIDER

1904

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pebbles of black material, probably phosphate of lime. There is also a certain amount of a green, flaky material, probably glauconite. This bed is very thin and was observed at only one point.

Thickness.—The total thickness of the formation is unknown, as its bottom is not exposed and there are no drill holes passing through it. A careful estimate was made by Mr. Ulrich and the writer; at least 50 feet are exposed, and probably 100 feet or more are present. It is difficult to make an exact estimate owing to imperfect exposures and variable dips.

Distribution.—No exposures of the shale are known except in the vicinity of Hicks, in Hardin County. The shale here outcrops over two areas, as indicated on Pl. III. It is found here in the bottom of streams, but is covered by younger rocks of the hills. It occurs in a series of exposures showing dips outward from a common center and indicating that it is brought to the surface in a low dome. The general relations are indicated on the special map of the Hicks area and in the cross section from Rosiclare to Karbers Ridge (Pl. IV).

Name.—In the older publications this shale was referred to merely as the Devonian black shale. It is believed to be the equivalent of the Chattanooga shale of Tennessee, the New Albany shale of Indiana, and the Ohio shale of Ohio. The latter, being the oldest geographic name used for it, is adopted in the present discussion.

CARBONIFEROUS ROCKS.

TULLAHOMA FORMATION.

Character.—The Tullahoma, as developed in Hardin County, consists for the most part of flint or chert. It includes some shale and a subordinate amount of nonmagnesian limestone, but the latter is rarely exposed, as it has usually been dissolved, and merely a gentle talus slope of flint fragments remains. Mr. Ulrich, in discussing the formation as developed along Hicks Branch, recognizes the following divisions:

In the basal 50 feet the shales predominate in the ratio of about 2 to 1. In the next 50 feet the layers of shale and chert constitute about equal proportions of the mass, while an occasional layer of limestone is intercalated. In the third 50 feet the shale decreases to little or nothing, while the chert and limestone bands alternate and are about equally important. In the fourth 50 feet shales are practically absent, the limestone has become somewhat heavier, though irregularly bedded, and the chert is proportionately less abundant. At the top there are 25 feet or more of slightly cherty, light-colored, massive or laminated limestone, containing fenestellid Bryozoa.

In this report the line between the Tullahoma and the St. Louis is drawn at the top of these beds or at the lowest ledge marked by the common presence of the easily recognized coral *Lonsdalia* (*Litho-*

strotion). Mr. Ulrich would class the upper 25 feet of strata as above described with the succeeding formation rather than with the Tullahoma.

Thickness.—Exact measurements of the thickness of the formation are not available, but checked estimates, based upon dip measurements and barometer observations, place it at 200 to 225 feet.

Distribution and relations.—The Tullahoma outcrops in northwestern Hardin County in a belt around the dome of Ohio shale near Hicks. Its area of outcrop is limited in turn by a similar belt of St. Louis limestone, the next succeeding formation. So far as known the formation does not come to the surface elsewhere in these counties, though it is quite possible that small areas are exposed in the faulted region east of that represented on the Hicks special map. In Kentucky, Mr. Ulrich has recognized the formation near Smithland and near Princeton. It rests with slight uncomformity upon the Devonian shale below. The relations to the St. Louis are less clear, and it can only be stated that there is no obvious unconformity in the Hicks area.

Name and correlation.—The name Tullahoma is derived from a locality in Tennessee, where it was applied by Safford in 1900 to the equivalent beds. The formation represents early Mississippian time, including probably that within which the Kinderhook, Burlington, and Keokuk formations were deposited along the Mississippi. It shows only general faunal relationships to these formations, and it is impracticable to make detailed correlations with them.

ST. LOUIS LIMESTONE.

Character.—The St. Louis limestone is for the most part a fine-grained, dark-colored rock, breaking with a sharp conchoidal fracture. It is moderately thin bedded and apparently nonmagnesian. It is characterized by the presence of abundant chert nodules, which are irregularly rounded and are most marked along bedding planes. They frequently show a distinct concentric structure, and individual nodules 3 to 4 inches in diameter are very prominent and characteristic on weathered or fractured surfaces.

The St. Louis limestone is apparently exceptionally soluble, and its areas of outcrop are marked by numerous sink holes, which often contain ponds of water. The irregular surface and large number of ponds remind one strongly of a drift-covered surface.

Thickness.—A thickness of 105 feet of limestone is exposed at Jacks Point on the Ohio, near Elizabeth. The beds have a low dip, which, if maintained, would give a total of several hundred feet as the thickness exposed along the Ohio, but of this there is no certainty. Mr.

Ulrich estimates the thickness of the formation in this district at 300 to 400 feet.

Distribution and relations.—The St. Louis outcrops over a considerable area in Hardin County. In the vicinity of Hicks it surrounds the belt of Tullahoma, and is itself surrounded by the Ste. Genevieve. To the southeast of Hicks it is cut off by a fault (Pl. IV), which brings it into juxtaposition with the Birdsville and the Mansfield sandstones. To the east and beyond the limits of the detailed maps the relations are less certainly known, but faulting seems to have largely determined the boundary lines of its areas of outcrop.

The limestone covers a considerable area adjacent to the Ohio River and extending from Cave in Rock to Rosiclare. It extends from the river back to Lead Hill, a maximum distance of 3 miles, and its north boundary is in part at least determined by a fault plane. At Elizabethtown the limestone is well displayed in the river bank and may be seen immediately in front of the Rose Hotel. It is exposed at intervals down to the small stream entering the river a quarter of a mile below Orr's landing, where the Ste. Genevieve limestone makes its appearance. The relations of the two are not altogether clear. The rocks along the stream dip toward it on either side, and the presence of barite, fluorspar, and quartz seems to indicate a certain amount of fracturing of the rock. There is, however, no certain evidence of faulting, and the relations may be those of simple conformity. Between this point and Big Creek Bridge (Pl. II) there are practically no outcrops. At this point the relations of the St. Louis to the Ste. Genevieve are almost certainly those of faulting, such as quite certainly are the relations of the St. Louis and the Cypress sandstone.

Name and correlation.—St. Louis is a well-known name, long applied to the beds here mapped under it. Engelmann, in his early work in this region, correlated these beds with those exposed and studied at St. Louis, and there are no reasons for questioning his conclusions.

STE. GENEVIEVE LIMESTONE.

Character and thickness.—The Ste. Genevieve limestone is in many instances lithologically similar to both the St. Louis limestone below and the Tribune above. It is fine grained, medium bedded, and nonmagnesian. Its most common distinguishing characteristic is the presence of massive oolitic beds, which may easily be distinguished from the occasional beds of oolite in the other formations by their thickness, massiveness, and light color. The formation has also an abundant and characteristic fauna which is readily recognized. *Amplexus geniculatus* and *Platycrinus huntsvilli* may be mentioned among the most widespread of its characteristic fossils. Mr. Ulrich recognizes three members within the formation. They may be described as below:

Generalized section Ste. Genevieve limestone, southern Illinois.

	Thickness in feet.
Ohara member. Limestone, fine grained, thin bedded, in part shaly and always associated with shale	30–107.
Rosiclare member. Calciferous sandstone; in weathered exposures showing much sand and usually marked cross-bedding; in unweathered surfaces predominantly calcareous material and easily overlooked	1–25
Fredonia member. Mainly oolitic limestones, white and light blue, interbedded with crinoidal, crystalline, and fine-grained limestones	113
Total	144–245

While the whole of the formation is fossiliferous, the Ohara member is particularly so, the shaly bands being crowded with fossils. One of these bands, occurring usually about 30 feet above the Rosiclare sandstone and being about 8 feet thick, forms a horizon easily recognized and hence of considerable importance in stratigraphic work. From it at Shetlerville the following fossils, as determined by Mr. Ulrich, were obtained:

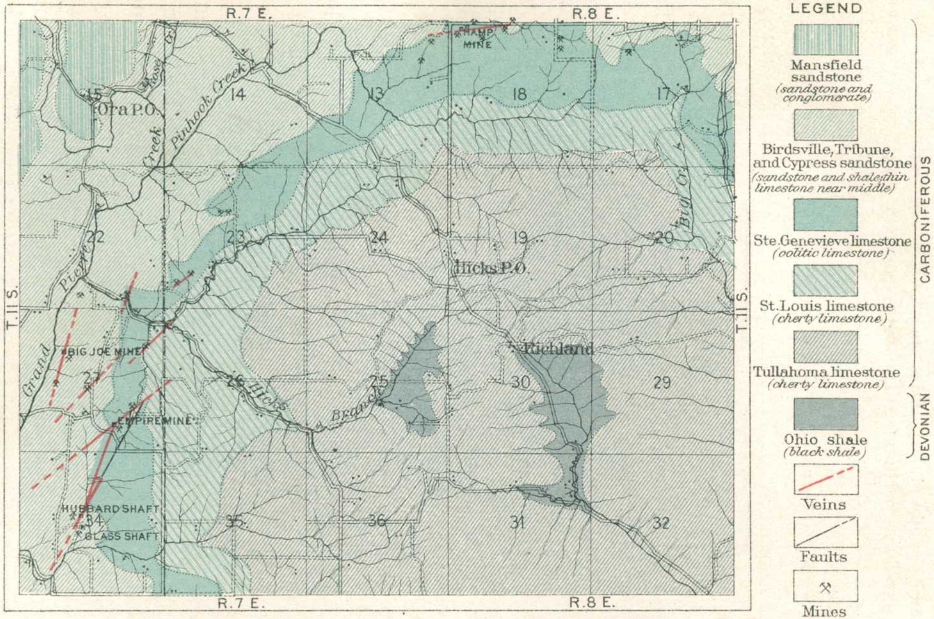
Zaphrentis pellæensis.
Amplexus geniculatus.
Pentremites florealis.
Spirifer leidyi.
Spiriferina norwoodi.
Spiriferina transversa.
Cleiothyris sublamellosa.
Cleiothyris hirsuta.
Seminula trinuclea.
Dielasma formosa.
Dielasma turgidum.

Distribution.—The Ste. Genevieve limestone is very widely distributed in both Pope and Hardin counties. It is shown on the accompanying maps (Pls. II and III), both surrounding the St. Louis limestone near Hicks and outcropping between it and the Cypress sandstone in the Rosiclare area. In addition, it occurs both east and north of Cave in Rock, near Shetlerville, Eichorn, and at various other points which will be more particularly noted in describing the various mines. Its significance in the present discussion arises from the fact that the important ore bodies so far found have been in most cases closely associated with this limestone.

Name and correlation.—In the work of Engelmann and Worthen the Ste. Genevieve limestone was not discriminated from the St. Louis and the general group to which the name Chester was applied. The Fredonia member seems to have been considered to belong with the St. Louis, while the Rosiclare and Ohara members were sometimes included with the overlying beds and sometimes not.[a]

These discrepancies came mainly from the fact that faulting was not recognized as important in interpreting the stratigraphy of the

[a] See sections, p. 78 and p. 397, Geol. Survey Illinois, vol. 1, 1866.



GEOLOGIC MAP OF THE HICKS DISTRICT

BY H. FOSTER BAIN

ASSISTED BY A. F. CRIDER AND E. O. ULRICH

Scale

1 ½ 0 1 mile

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district. Mr. Ulrich recognizes these beds as the equivalents of those to which Shumard originally gave the name Ste. Genevieve in Missouri, and that name is accordingly applied to them here.

Princeton limestone is a name for the beds which has obtained a certain amount of local use, but which is considered synonymous with Ste. Genevieve. On account, principally, of the affinities of its fauna, Mr. Ulrich regards the Ste. Genevieve as the base of the Chester group. Mr. Keyes[a] considered it to belong to the St. Louis, to which it is much more closely related lithologically than to the overlying Cypress sandstone.

CYPRESS SANDSTONE.

Character and thickness.—Above the Ste. Genevieve is a massive to heavy-bedded sandstone almost wholly quartzose. So far as has been observed, this formation contains very little shale or argillaceous matter. The lower portion of the sandstone is characteristically heavy bedded, but the upper portion is somewhat thinner bedded to flaggy. Near the middle is frequently a thin bed of chert-bearing limestone carrying a characteristic fauna.

The thickness of the formation in this area may be estimated at 80 to 100 feet.

Distribution and relations.—No attempt has been made in the maps so far prepared to separate the Cypress from the Tribune and Birdsville. It would be possible to do so only on good base maps and with time for detailed studies. The Cypress sandstone is doubtless present at many points in both Hardin and Pope counties, but may easily be confused with certain phases of both the Birdsville and the Mansfield. It may, however, be seen typically developed at both Rosiclare and Shetlerville. At the former locality it caps the Ste. Genevieve limestone in Downeys Bluff, the basal heavy-bedded sandstone being present. At Shetlerville these basal beds are less typically exposed, but the thin limestone member and the overlying flaggy sandstone were recognized by Mr. Ulrich.

Name and correlation.—Cypress sandstone is a name originally proposed by Engelmann[b] for this formation. Equivalent beds have been called Big Clifty sandstone by Mr. Norwood,[c] and Aux Vases by Mr. Keyes.[d] In the early geologic literature of the region most of the exposures of this sandstone were referred to the "Ferruginous sandstone," a term also applied at times to what is here called the Mansfield sandstone.

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[a] Geol. Survey Missouri, vol. 4, 1894, pp. 30, 76.
[b] Trans. St. Louis Acad. Sci., vol. 2, p. 189.
[c] Geol. Survey Kentucky, new ser., vol. 1, p. 369.
[d] Bull. Geol. Soc. America, vol. 3, p. 296.

TRIBUNE LIMESTONE.

Character and relations.—At the Fairview mine the foot wall of the vein at the surface consists of a coarse, crystalline, nonmagnesian limestone, light gray to white in color and containing minor quantities of oolite and of chert. The following fossils were collected from it and recognized by Mr. Ulrich:

Zaphrentis spinulifera.
Pentremites godonii.
Pentremites pyriformis.
Pentremites tuberculata.
Stenopora cervinus.
Zeacrinus manniformis.
Lyropora rana.
Lyropora subquadrata.
Spirifer increbescens.
Spirifer leidyi.

On the basis of these fossils he determined this limestone to be the same as that at Tribune, Ky., representing the middle Chester. It is impossible at Fairview to determine much regarding the relations of the limestone. It is cut off on all sides by faults, and its thickness is somewhat uncertain. The shaft at a depth of 200 feet shows similar limestone on the foot wall. Whether it is indeed the same or represents the Ste. Genevieve can not be positively ascertained, since it is impossible to make a complete examination of the wall rock from the top to the bottom of the shaft. At the first or 30-foot level Eilers mentions calcareous shale, and at the same level disintegrated sandy material may now be observed. This may possibly represent the Cypress sandstone, and, if so, the Tribune would here have a thickness of less than 50 feet. The Tribune limestone has not been definitely recognized at any other point in the two counties, though there are at a number of points thick limestones which may possibly represent it. At none of them, however, were the fossils found which are considered to be peculiarly characteristic of it.

BIRDSVILLE FORMATION.

Character.—This formation includes sandstones, shales, and limestones. In distinction from the Cypress sandstone below and the Mansfield above, the Birdsville sandstones are particularly thin bedded. They seldom show massive character, and do not, so far as observed, give rise to sharp bluffs and canyons. They frequently grade into shales, becoming less and less sandy until true argillaceous shale is found. The latter is occasionally thin bedded, black, and fissile, and contains thin coal beds. Interbedded with the shale and the sandstone are thin limestone beds. The latter are usually somewhat argillaceous and are chert bearing. They are usually only a few feet thick, though one body having a maximum of 50 feet occurs in the formation.

The general impression of the formation as a whole which one gains from traveling over it is that it is mainly a sandstone. It may usually be discriminated from the sandstones above and below by the interbedded limestones and calcareous shales, which are easily recognized by the common presence of various species of *Archimedes*.

Thickness.—Not enough detailed observations were made in Illinois to allow an estimate of its thickness to be made. Mr. Ulrich estimates it at 400 to 680 feet, and it can only be said that so far as general impressions go this estimate seems sufficiently conservative.

Distribution.—The Birdsville is the most widespread of the Chester formations in southern Illinois. It outcrops over much of Hardin, Pope, and various counties to the west. On the maps accompanying this report the greater portion of the area assigned to the Birdsville, Tribune, and Cypress formations, which for convenience are mapped together, is really occupied by the Birdsville. Outside of these areas the larger portion of the region shown on the general map (Pl. I) as underlain by the Mississippian has the Birdsville formation at the surface. The particular areas underlain by the earlier formation have already been described.

Since the Tribune limestone is not generally recognized, its absence is presumably due to faulting, by which the Birdsville and Cypress are brought together. Such faults are not easily detected, since rocks of similar lithologic character are brought into juxtaposition. In the Rosiclare area there are probably a number of such faults which are not indicated on the special map (Pl. II). The sandstone in the western part of section 28, for example, is presumably Cypress, since it rests in apparent conformity upon the Ste. Genevieve, and shows a normal erosion edge. In section 30 the sandstone at the surface is interbedded with thin limestones, characteristic of the Birdsville, and yet between the two there is neither any sign of the Tribune limestone nor of a fault such as the stratigraphy calls for. This raises a question as to the integrity of the Tribune formation, a question which can not be settled on the basis of the evidence locally available. The determination must accordingly rest upon Mr. Ulrich's wider studies, and on this basis faulting would have to be inferred as indicated.

Name.—The name Birdsville was given to the formation by Mr. Ulrich from the typical exposures near Birdsville, Ky.

MANSFIELD SANDSTONE.

Character.—The topmost member of the Carboniferous within the district is a massive to thick-bedded sandstone, which is especially characterized by the common presence of small well-rounded pebbles. These are mainly of clear white quartz, but some chert is also present. In the absence of the pebbles it is difficult to distinguish the Mansfield from the Cypress and certain beds in the Birdsville.

It is quite possible that outliers of it have been overlooked. It very commonly carries small flakes of mica, and these are rare, at least in the other sandstones. This fact is of material assistance in recognizing it. The formation seems to rest unconformably on the Birdsville.

Distribution.—The Mansfield sandstone outcrops around the northern and eastern sides of the district, and its edge practically marks the limit of the productive territory. It rises in sharp bluffs, forming Karbers Ridge, as already discussed. South of this escarpment there are a number of outliers formed of fault blocks let down into the older formations. A few of them are indicated on the general map. No attempt has been made to map all of them, and the Mansfield has not been especially studied in the course of this work, and no estimate of its thickness was made.

Name and correlation.—The name used here for these beds is that adopted by the Indiana geological survey. Formerly the beds were commonly referred to as the Conglomerate measures or the Millstone grit. The Mansfield forms the base of the Pennsylvanian series of coal measures and is regarded as of late Pottsville age.

TERTIARY DEPOSITS.

In the southern part of Pope County, including the highland south of Bay Bottoms, scattered pebbles and thin beds of gravel make their appearance on top of the Carboniferous formations. The pebbles are well rounded and seemingly waterworn. They vary in size from a half inch to two inches in diameter and exhibit considerable heterogeneity as to both composition and material. Pieces of quartz, quartzite, sandstone, and chert are common. The chert frequently contains fragments of fossils, so far as observed, of common Carboniferous species. The pebbles were not observed elsewhere in the district, but near the old shaft immediately east of the main working shaft of the Rosiclare mine there are numerous similar pebbles scattered over the surface. Among them was one rounded and apparently waterworn pebble of galena showing quartz crystals in a small druse. It is possible that these represent remnants of a former extension of the formation. In general all the pebbles observed are such as might have been derived from the destruction of local formations.

No special study of these gravels was made, nor were the green sands, said by Worthen to accompany them in Pulaski County,[a] examined. Worthen determined these beds to be of Tertiary age. Mr. McGee[b] has referred them more specifically to the Lafayette formation.

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[a] Geol. Survey Illinois, vol. 1, 1866, pp. 44–47.
[b] Twelfth Ann. Rept. U. S. Geol. Survey, pt. 1, 1891, p. 469.

QUATERNARY DEPOSITS.

LOESS LOAM.

Throughout the two counties there is commonly a surface material of light-buff, pebbleless clay or loam. This is spread as a thin mantle over the underlying rocks, and over the flat uplands, in particular, is widespread. On the slopes it is cut away or so mixed with residual material as to be indistinguishable. In places the sand contributed to it by the decomposition of the local rocks is very abundant. In other places, however, it exhibits all the characteristics of upland loess of the glaciated area farther north, and it is doubtless a phase of one of the older loess sheets which have been there discriminated.

ALLUVIUM.

Along the Ohio and many of its tributaries are numerous broad, flat bottom lands underlain by alluvium. No attempt has been made to discriminate them on the accompanying maps, nor has any study been made of the interesting and complex river history which they in part record.

DESCRIPTION OF IGNEOUS ROCKS.

GENERAL STATEMENT.

The discovery of intrusive igneous rocks in Illinois was very recent. In 1889 Mr. Ulrich, while working for the Kentucky Geological Survey, discovered the Flannery dike in Crittenden County, Ky., and in 1892 Mr. J. S. Diller described the rock. From time to time other dikes were found in that State, until now a considerable number are known. In 1902 Mr. W. S. Tangier Smith located the Mix dike above Golconda, that being the first found in Illinois. In the course of the work in 1903 a number of additional dikes were found, and there are doubtless others which as yet remain undiscovered. Near Hicks Mr. Crider found considerable mica in one of the streams, and Mr. F. Julius Fohs has furnished a specimen of a mica-bearing rock picked up nearby. So far, however, it has proved impossible to find material in place.

The dikes so far found are indicated on the accompanying maps. In no case has a dike been traced any considerable distance, and with two exceptions they are found only in the bluffs of the Ohio and for a short distance inland. The dike in Downey's bluff at Rosiclare sends off a thin sheet which is intruded into beds of the Ohara member of the Ste. Genevieve. The dike at Orr's landing has a thin stringer running off into the St. Louis limestone. With these exceptions the igneous rock so far as known occurs only in normal, vertical dikes.

The individual occurrences are described below, grouped by localities, the petrographic notes being by Mr. Albert Johannsen, of the United States Geological Survey. He makes the following general observations on the rocks, based on an examination of material from both the Kentucky and Illinois occurrences:

So far as they can be determined from the altered state of most of the rocks, they fall into two groups, mica-peridotites and lamprophyres, the majority of the specimens belonging to the latter. In all the specimens (of the lamprophyre) the original minerals are so much altered to calcite that subdivision is impossible, for in no case is there any of the feldspar remaining. It is possible that there was originally no feldspar, although the disposition of the particles and replacement products seems to point in some of the thin sections to a groundmass originally in lath-shaped crystals.

There is a sharp distinction between the mica-peridotites and the lamprophyres, however, in that in the former, olivine, either partially or entirely serpentinized, is clearly shown, while in the latter there is no indication of its ever having occurred; again, in the latter there is a remarkable and unusual occurrence of apatite. This occurs in nearly all of the lamprophyre slides in large, perfectly fresh, short, thick prisms, their unchanged condition making a striking contrast with the state of alteration of the remainder of the sections. The presence of phlogopite in both groups, rather than a more usual variety of mica, connects them in a manner.

Orr's landing.—About a quarter of a mile below Orr's landing (SW. ¼ NE. ¼ sec. 33, T. 12 S., R. 8 E.) the St. Louis limestone is cut near the water's edge by a vertical dike about 10 inches thick. This shows, on superficial examination, very little igneous material. The bulk of the dike is made up of clastic material, consisting of rounded pebbles of limestone and quartzite. These attain a maximum diameter of 6 inches, and, while the country rock is St. Louis limestone, they include lithologic types not found in that formation. The pebbles are in a matrix of dark calcareous material, in which, on examination, Mr. Johannsen found much pyrite, some magnetite, quartz, and large apatites. He regards it as a lamprophyre now nearly entirely altered to calcite. There are 3 to 4 inches of calcite parallel to the dike material and separating it from the wall, and in small seams intersecting the whole calcite and fluorite are developed together. On the east side of the dike a narrow irregular crack leads off through the limestone for a number of feet. Along either side of this crack the limestone is altered and darkened for about 2 inches.

This somewhat peculiar dike seems to represent the intrusion of liquid and not entirely dry magma into an open crevice partially choked by gravel and waterworn material washed in from above. There has been apparently some slight alteration of the limestone, though the nature of this alteration has not been studied, and whether the introduction of the fluorine was incident to it is wholly unknown.

Rosiclare quarry.—In the quarries in the Ste. Genevieve limestone immediately above Rosiclare landing there are two dikes which Mr. Johannsen describes as follows:

Megascopically the rock is much altered, and at first sight it appears to be a conglomerate with included fragments of shale. These shaly particles are, however, an alteration product of mica, as is shown by thin sections under the microscope. Microscopical examination shows the rock to be almost entirely altered to calcite. Large apatites, iron oxide, chlorite, and serpentine occur.

The two dikes are about 10 feet apart, and are each about 10 inches thick. They are vertical and apparently do not mark faulting planes. The limestone in contact with them shows no apparent alteration, but parallel with them and disposed on either side are a number of prominent veins of calcite carrying smaller amounts of fluorite. The whole system of veins and dikes has a course about N. 45° W.

A single specimen of ordinary diabase was obtained from near here in the town of Rosiclare. It was found in digging a well, but as the relations are not known it possibly represents material brought down the river during Glacial times, and until further data are available it can hardly be considered as representing another dike.

Downey's bluff.—In the high bluff between Rosiclare and Fairview landings is one of the most interesting of the occurrences. The rock is found here both in a well-defined dike, cutting the point of the hill with a course N. 31° 30′ W., and in a thin sheet intruded between beds of the limestone lying above the Rosiclare sandstone member. The dike itself is 4 to 5 feet wide. The main sheet running off from it is 6 inches thick, and about 3 inches above this is a second sheet barely 1 inch thick. The two are connected by very thin stringers of igneous material, indicating apparently a condition of high fluidity. The dike does not mark a faulting plane, though on the northwest side of the hill the sheet is cut off by an east-west fault of 70 feet, with downthrow to the north. The dike has been traced to the north about 1,000 feet to a spring, beyond which it is either cut off by the fault or fails to outcrop because of the presence of alluvium.

Despite the penetration of the rock into the thinnest crevices of the limestone, there is no macroscopic evidence of the alteration of the latter by contact metamorphism. Mr. Johannsen examined a number of specimens of the contact rocks, and notes that "there is nothing to indicate a change caused by the intrusion." His petrographic description of the rock, which he determines as a lamprophyre, is as follows:

Megascopically this is a very dark porphyritic rock, consisting of a fine-grained groundmass full of phenocrysts of dark mica and pyroxene. The mica generally occurs in basal sections of about 1 mm., though occasionally crystals of over a centimeter occur. The crystals of pyroxene are of small dimensions.

Under the microscope the structure is holocrystalline porphyritic, the groundmass being much less in amount than the phenocrysts. The phenocrysts are irregular in outline and of varying sizes, and are, in the order of their importance, mica, pyroxene, apatite, iron oxide, and, possibly, perofskite. The mica occurs in large crystals and is chiefly phlogopite, with biotite in lesser amount. The iron mineral is titanite and, possibly, considerable titaniferous magnetite. Pyrite occurs in several of the slides. The pyroxene is usually much altered, but in section No. 4 there are remnants of a pleochroic augite. The groundmass is largely altered to calcite. The secondary products are calcite, serpentine (from pyroxene), leucoxene, and quartz.

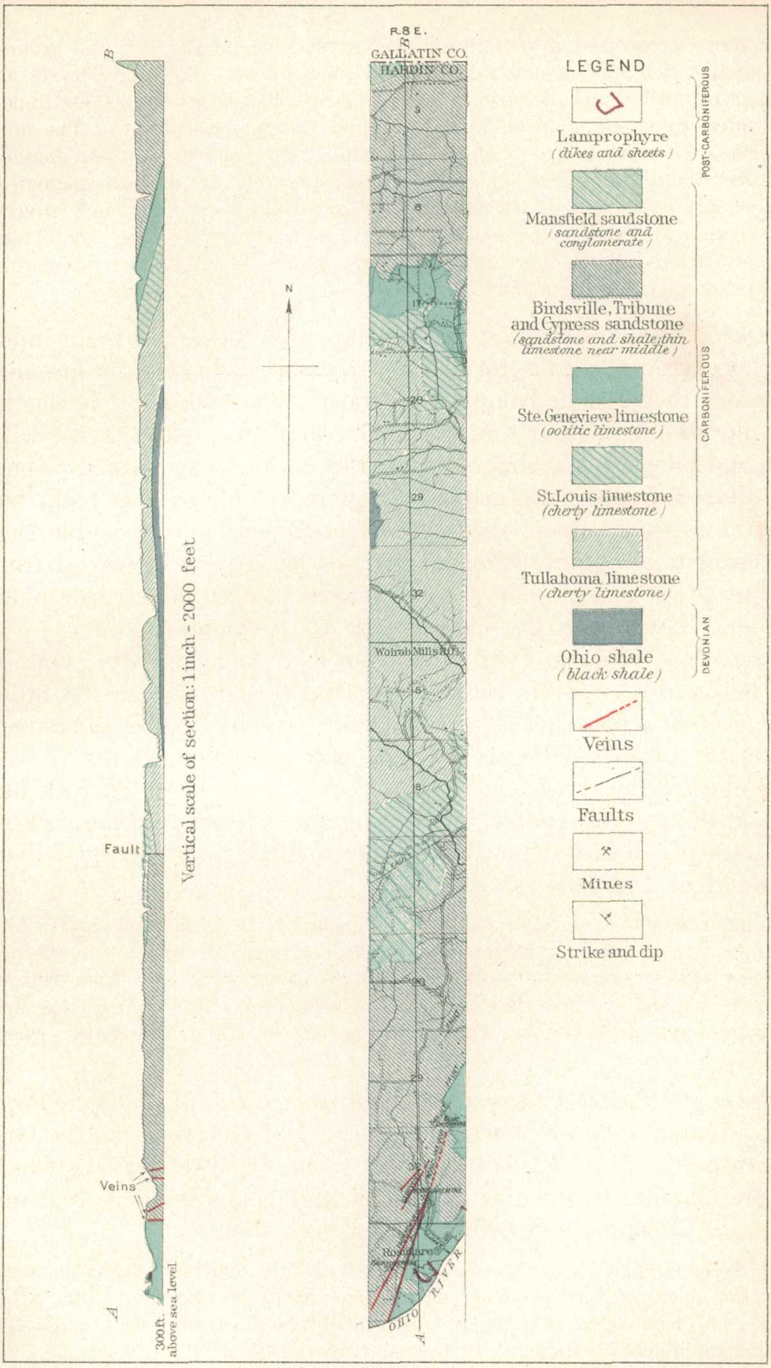
Soward farm.—Northwest of Rosiclare (W. ½ sec. 31) is an interesting occurrence of dike form which possibly indicates the presence of igneous rock a little below the surface. The rock itself is clastic, and shows both angular and rounded fragments of limestone, with flakes and bits of black shale cemented by a limestone matrix. Some very altered ferruginous material may represent igneous rock, but this is uncertain. From the mode of occurrence it is possible that this represents a fissure filling, largely of material brought up from below by the intrusion underneath. It is mentioned merely as a place at which it is thought igneous rock may yet be found in situ.

Mix farm.—There are two dikes known in Pope County. One of them is that discovered in 1902 on the Charles Mix farm, a few miles above Golconda (sec. 8, T. 13 S., R. 7 E.). It cuts Chester sandstone, presumably of Birdsville age, and has a course about N. 40° W. It shows only in the river bluff, and apparently the intruded rock has not been in any way altered. Mr. Johannsen determines the rock to be a mica-peridotite, somewhat similar to that described by Diller, and describes it as follows:

The hand specimen consists of a dark, granular, mottled black and white groundmass, with phenocrysts of mica and pyroxene. Under the microscope they very closely resemble the sections of the Flannery dike. They consist chiefly of phlogopite, serpentine, ilmenite, leucoxene, perofskite, magnetite, and a little pyroxene and olivine. The olivine is only partially altered to serpentine.

Golconda.—The second occurrence of dike material noted in Pope County is that found a short distance west of Golconda, at the Gilbert prospect. This dike is 4 to 5 feet thick, vertical, and cuts Chester—presumably Birdsville—sandstone and shale without faulting them. Mr. Johannsen describes the rock as follows:

A pyroxene-lamprophyre, consisting of much calcite, chlorite, iron oxide, some phlogopite, leucoxene, and some serpentine after pyroxene and, doubtfully, after olivine. The iron oxide is ilmenite, and probably some titaniferous magnetite occurring in cubical crystals. A little hematite occurs.



MAP AND CROSS SECTION, ROSICLARE TO KARBERS RIDGE, ILL.

BY

H. FOSTER BAIN, ASSISTED BY A.F. CRIDER AND E.O. ULRICH

Scale

0 ½ 1 2 3 4 miles

1904

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GEOLOGIC STRUCTURE.

GENERAL RELATIONS.

The structure of this district stands in marked contrast with that of the remaining portion of Illinois. The widespread presence of extensive faulting and the intrusion of igneous rocks set it off sharply from the general surrounding region. If the Kentucky-Illinois district be considered as a whole, it seems to represent a portion of an extensive northwest-southeast monocline or, possibly, the northeast half of a dome whose remaining portion has disappeared beneath the Tertiary deposits of the Mississippi embayment. To the north and east the Mansfield sandstone dips sharply away and becomes deeply buried beneath the Coal Measures strata. To the south and west the beds pass, with little dip and no uniformity, beneath the later sediments. Loughridge gives data suggestive of faulting along the contact,[a] and it may be that beneath the Cenozoic beds of that region there is deeply buried a structural remnant corresponding to that remaining on the other side of the district. Be that as it may, there are within the district many evidences of local disturbance. These include a sharply defined little dome near Hicks, in Hardin County, and numerous faults throughout the territory. (Pl. IV.)

HICKS DOME.

This is a nearly complete uplift about 7 miles in diameter. Since the black shale of the Devonian is brought up to the topographic level of the upper Birdsville within 3 miles, a vertical uplift of at least 1,000 to 1,500 feet has taken place. To the southeast the dome is cut off by a normal fault of 1,000 feet or more, by which Mansfield sandstone is brought into contact with St. Louis limestone. Around the edges of the dome, as in the vicinity of the Empire mines, there are numerous normal faults, though none of them, so far as has been determined, have much throw. Their presence none the less renders it improbable that the dome was raised by ordinary lateral thrust and indicates rather vertically acting forces. This conclusion is reenforced by the fact that normal faulting, almost exclusively, occurs in the district as a whole.

Around the edge of the dome the rocks have quaquaversal dips of high angle. Along Hicks Branch, in sec. 26, T. 11 S., R. 8 E., the dips are 10° to 20° to the south and west. On the northeast the dip in section 17 is 5°. On the southeast, in section 31, it is 11°, and on the southwest, in section 35, the dip is 8°. The dip decreases from the center outward. The occurrence of the St. Louis along Hicks

[a] Geol. Survey Kentucky, Jackson Purchase Region, 1888, p. 267.

Branch, and along a branch of Big Creek in section 20 (Pl. III), indicates a local irregularity in the dome.

There are no known occurrences of igneous rock connected with the Hicks dome, but the presence of unusual quantities of mica in the streams at one or two points lends color to the suspicion of their presence.

FAULTS.

Normal faults are found throughout the two counties. A number of these are represented upon the accompanying maps, and their particular relation to the ore deposits will be discussed later. The throw varies from an imperceptible amount to 1,000 feet or more. All the Carboniferous formations are affected. East of Cave in Rock the Mansfield sandstone and the Ste. Genevieve limestone are brought together. On Hog Thief Branch (sec. 30, T. 11 S., R. 9 E.) the St. Louis limestone is brought into contact with the Mansfield and with either Cypress or Birdsville sandstone. In the region beween Elizabethtown and Karbers Ridge there are many faults, and rapid changes in strata may be noted in traversing any of the roads. In Pope County, from the Ohio and the Bay Bottoms to the encircling escarpment of Mansfield sandstone, faulting is a common phenomenon, and in Gallatin County (sec. 21, T. 12 S., R. 7 E.) the Mansfield itself is cut by faults in numerous directions.

There is no regularity as to the trend of the fault planes, though a majority of those so far studied have a general course north of east. The individual fault planes are rarely traceable more than 1 or 2 miles, but along the same general course faulting occurs for 12 to 15 miles. For example, from the Empire mine (sec. 34, T. 11 S., R. 7 E.) to the Wright prospect (sec. 3, T. 13 S., R. 5 E.) there is a succession of prospects and evidence of disturbance of the beds, though there is small probability of a continuous fault. From the Rosiclare and Fairview mines the general course of the faulting may be projected southwest to Bay City, and along the line frequent evidence of disturbances will be found, while at Bay City there is also mineralization.

On the other hand, there is usually clear evidence that the individual faults are of limited length. They occupy en échelon positions and are by no means exactly parallel. This is illustrated on the special map of the Rosiclare district, where the various fault planes are offset as indicated, and vary in direction nearly 30°. This tendency of fault planes to take a course at a slight angle with what appears to mark the line of major stress is believed to be the expression of a general law. The reason is not well understood, but seems to lie in the character of the rocks and the direction of the stress. It is perhaps due to the presence of a slight horizontal element in the latter.

The fault planes are usually vertical. The Rosiclare vein, occurring along such a plane, has been mined to a depth of 300 feet, and in that depth is so nearly vertical that the shaft is still within the vein. The Fairview vein has an average dip to the west of 79° 30′. The Hamp vein dips S. 68°. The Empire vein dips E. 73°. Even these departures from the vertical seem, on the whole, to be exceptional, and the total effect of the faulting has been to divide the nearly horizontal rocks into a series of polygonal blocks, which have been raised or lowered with reference to one another, but with very little horizontal displacement. This type of structure, while perhaps common, has been but little discussed. Mr. G. K. Gilbert some years ago pictured[a] it, and Powell gave it the name "diverse displacement." It is, as he remarks, the Kaibab structure on a small scale. Recently Prof. W. H. Hobbs has called attention[b] to faulting somewhat similar in character; and in the Globe district of Arizona Mr. F. L. Ransome has described an intricate system of small normal faults, apparently very much like these.[c] In the Columbia folio,[d] Hayes and Ulrich have mapped one block of strata, evidently bounded by similar fault planes, but with this exception the structure has not been described from the Mississippi Valley. Its occurrence here is quite in keeping with the general peculiarities of the district, which set it off from the remaining portion of the geologic province within which it occurs.

QUARTZITE REEFS.

The fault planes are commonly marked by the development parallel with them of closely spaced fractures. Where these affect sandstones and the latter have been changed to quartzite by the addition of silica, reefs or ridges of quartzite, not unlike dikes in topographic expression, are formed. These afford the most obvious means of recognizing fault planes. The juxtaposition of rocks of diverse lithologic character, such as sandstone and limestone, is also indicative of faulting, though occasionally the outcropping edge of a limestone interbedded with sandstone and shale becomes deceptive.

DIP.

Near fault planes the rocks often dip at a high angle, and this seems to be especially true in the western part of the district, where

[a] Powell, Geology of the Uinta Mountains, 1876, figs. 4 and 5, pp. 16–17.
[b] Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 3, pp. 19–162.
[c] Geology of the Globe copper district: Prof. Paper U. S. Geol. Survey No. 12, 1903, pp. 97–106.
[d] Geologic Atlas U. S., folio 95, U. S. Geol. Survey.

deformation apparently has been accomplished in part through monoclinal folding rather than fracturing. At the Wright prospect, near Rock, the sandstone and shale in the creek strike N. 60° E. and dip 42° NW. About 500 feet farther west the strike is N. 45° E. and the dip 40° SE. About a mile and a half east of Resort (sec. 9, T. 13 S., R. 5 E.) there is a considerable belt of limestone striking N. 35° E. and dipping sharply to the southeast. Near the Luella mines (sec. 10, T. 12 S., R. 6 E.) dips as high as 50° were observed, and in a belt approximately parallel to the fault plane sandstone, shale, and limestone pass successively beneath the surface. Near Packers Gap (NE. ¼ sec. 16, T. 11 S., R. 7 E.) heavy beds of sandstone striking N. 80° W. have a dip SW. 49° and show evidence of some displacement between the beds. North of Elizabethtown on the Patton land (sec. 21, T. 11 S., R. 9 E.) there is a belt of rocks 1,200 feet across, dipping 10° SE. and striking N. 30° E. The rocks include sandstone, shale, and thin limestones, such as characterize the Birdsville formation. There are minor faults and local evidences of thrust.

These varying dips are notably irregular, and in no case studied did they indicate a regular system of folds. Occasionally, in connection with the displacement, comprehensive stresses have been generated, but these seem to have been entirely local in their effect and incident to the general deformation by diverse displacement.

GEOLOGIC HISTORY.

PERIODS OF SEDIMENTATION.

Of the pre-Devonian history of this area nothing is definitely known. There are no exposures of earlier rocks in the district and there are no drill records reaching below the black shale. In the adjacent Ozark region, resting on pre-Cambrian granites and porphyries, are Cambrian, Ordovician, and Silurian rocks, consisting largely of magnesian limestones, dolomites, and sandstones. The contemporaneous rocks in the region south and east are largely nonmagnesian limestones and shales. In the absence of data it is uncertain what kind of rocks were deposited here, and it can only be inferred that in pre-Devonian time the area was one of sedimentation, interrupted at intervals by periods of erosion. From Devonian until late in the Carboniferous at least, similar conditions prevailed. At times the area was covered by the sea and at times it formed part of the land. The details of this history have not been made out, and, so far as known, are not significant from the present point of view.

DEFORMATION AND INTRUSION OF IGNEOUS ROCKS.

At some time after the deposition of the Mansfield sandstone, and presumably after the deposition of a considerable thickness of coal measures, the region was uplifted and exposed to erosion. This may well have been merely a recurrence of uplift along a line marked out by previous deformation, since in the total unlikeness of the pre-St. Louis Carboniferous beds of this district to those along the Mississippi to the northwest there is evidence of an old barrier between the two provinces. However that may be, the particular uplift mentioned was either in the Carboniferous or later. It was accompanied or succeeded by fracturing and diverse displacement, and since this form of deformation probably occurs only when the beds are lightly loaded it took place either before any great thickness of coal-measure shales was deposited over the region or after they were eroded. If account be taken of the large amount of erosion which the Mississippi Valley has undergone in Mesozoic and Cenozoic time, it seems probable that this uplift occurred after a considerable thickness of rocks—later than any now known in the area—was deposited. In central and southern Illinois there are 1,000 feet or more of coal measures which are unrepresented in Pope and Hardin counties. As these beds are nowhere preserved in the fault blocks of the latter area, there would seem to have been first an uplift of the district as a whole, followed by erosion, and this in turn by fracturing and displacement of the individual blocks of strata.

While the hypothesis is not perhaps susceptible of absolute demonstration, the intrusion of the igneous material seems to have accompanied the fracturing and displacement. The relations of the dikes to the faults are not clear. In general the dikes seem to occupy fractures along which there is practically no faulting, and the deep fault planes are not occupied by igneous material, though they are frequently the locus of veins. The occurrence in the north flank of Downey's bluff of a fault cutting the small sheet of peridotite of course merely proves that some faults are later than some intrusions.

No attempt to fix more definitely the age of the dikes and deformation will be made, as any suggestion would rest wholly on analogy with neighboring regions showing similar phenomena, and there are none sufficiently close to give much weight to such suggestions.

PERIOD OF EROSION.

Since the deformation, the faulting, and the intrusion of the dike material there has been prolonged erosion of the area. It is extremely probable that this erosion has occurred in two or more cycles, but of the earlier ones there is now no demonstrable evidence.

The upland plain previously discussed marks the last of the important cycles of erosion, and its age has already been suggested to be Lafayette or late Tertiary. At the completion of this cycle Karbers Ridge, the Shetlerville Hills, and certain areas in Kentucky remained as monadnocks rising above the plain. Since its completion the country has been elevated as a whole 200 feet or more, and the streams have cut their present channels. This elevation seems not to have been continuous, since there are traces of incomplete peneplains below the main one and above the bottoms of the rivers.

THE ORE DEPOSITS.

GENERAL CHARACTER.

The ore deposits of Pope and Hardin counties are vein deposits occurring along faulting fissures. The vein material consists essentially of fluorspar and calcite, or "calc spar," as it is locally called. Associated with these minerals are minor amounts of the lead and zinc sulphides, galena and blende. There are also traces of other sulphides, notably those containing copper and antimony. Surface alteration is relatively unimportant, though some carbonate of zinc occurs, and in the adjacent portion of Kentucky one or two bodies of it have been mined. No traces of secondary enrichment have been observed. Within the area are certain bodies of limonite, which were formerly mined, but which are now unimportant. Fluorspar is the only mineral now mined in quantity, and the deposits afford, therefore, an instance of what is ordinarily, and was here originally, merely a gangue mineral, being the one which gives value to the ore.

MINERALS PRESENT.

GANGUE MINERALS.

Fluorite.—This district is characterized by the peculiar and remarkable abundance of the calcium fluoride, CaF_2, corresponding in composition to 51 per cent of calcium and 49 per cent of fluorine (specific gravity, 3.01 to 3.25). This mineral occurs in large bodies of unusual purity, shipments running 98 to 99 per cent being constantly made. Very little running less than 95 per cent finds sale except at reduced price. The mineral is crystallized, and in druses and open spaces well-developed crystals are not uncommon. On these the faces of the cube are best developed, but modifications due to the octahedron may be frequently noted. For the most part the fluorite occurs in great vertical sheets or veins clearly crystallized, but not showing crystal form. The octahedral cleavage is always well developed, so much so, in fact, that jig concentrates consist largely of imperfect tetrahedra and octahedra. Cleavage forms are easily obtained, and many very perfect ones adorn local cabinets. In the veins a ribbon structure giving the appearance of onyx is occasionally seen. This seems to be dependent upon the distribution of coloring matter. In general the spar is white, but purple, amethyst, green, and golden yellow are also present, in the order of abundance given. The cause of the color was not investigated. Mr. Tangier Smith, from his studies of the Kentucky fluorspar, concluded that the differences in color were determined by the condition of the coloring matter, probably hydrocarbons, present.

The fluorspar is almost universally known by the shortened name of spar, and the clear transparent varieties are known as glass spar. No fluorine minerals other than fluorspar were found in the region, except that in the dike rocks there are unusual quantities of apatite and mica, both of which usually contain fluorite.

Calcite.—The most universal accompaniment of the fluorspar is calcite or calcium carbonate, $CaCO_3$, corresponding to 56 per cent of calcium oxide and 44 per cent of carbon dioxide (specific gravity, 2.71 to 2.72).

This mineral in its impure form constitutes the larger part of the limestones of the region and also occurs in the shales and some of the sandstones. It is the common cementing material where the rocks have been brecciated or fractured, and occurs alone forming important veins, as well as with the fluorite. It is commonly not transparent and rarely occurs showing crystal form, though the usual scalenohedra with rhombohedral terminations occur. The mineral is not itself valuable. It is locally considered an indication of the presence of fluorite and the ore minerals, but occurs so commonly without them that it is of small value in this particular. Calcite is frequently referred to locally as "calc."

Quartz.—In connection with the mineralization of the veins, large quantities of silica, SiO_2, have been added to that already present in the sandstones and other rocks. This silica has been deposited especially between the grains of sand of the original sandstones along the veins, firmly cementing the rock and giving rise to the quartzite reefs already mentioned. In druses in the vein and elsewhere the silica has also crystallized, forming small pyramidal crystals, some transparent and others jet black.

Barite.—Somewhat widely distributed but in relatively smaller quantity than the minerals enumerated above is barite, the barium sulphate, $BaSO_4$ (specific gravity, 4.3 to 4.6). This occurs as a massive, white, crystalline substance intimately intergrown with the other minerals. Occasionally on the free surfaces of druses it shows crystal form, small tabular crystals clustered so as to form mammillary aggregations being characteristic. In this it resembles the barite occurring in southeastern Missouri. The larger clear crystals, such as occur in southwestern Missouri, were not noted, though possibly present. The mineral is locally known by the common name, heavy spar.

Dolomite.—The double carbonate of magnesium and calcium, while possibly present in occasional small quantities, was nowhere noted, though Mr. Fohs has shown the writer the iron-manganese-magnesium-calcium carbonate, ankerite, from one of the Kentucky mines. Dolomite is probably present, but only in very small quantity, a fact of some possible significance as related to the genesis of the ores.

Kaolin.—The hydrous silicate of alumina ($2H_2O,Al_2O_3,2SiO_2$) occurs near the Pittsburg mine in considerable quantity. It does not seem to be directly related to the ores, and its origin is in doubt.

ORIGINAL METALLIC MINERALS.

Galena.—The sulphide of lead, PbS, containing 13.4 per cent of sulphur and 86.6 per cent of lead (specific gravity, 7.6), is probably the most abundant and widespread of the original metallic minerals. It occurs in the usual cubical crystals, occasionally showing the faces of both cube and octahedron. It is intimately associated with other sulphides and with gangue minerals. The galena of this district is argentiferous, at least to a degree notably beyond that of other deposits in the Mississippi Valley. Whitney[a] gives an assay showing the presence of 9½ ounces of silver to the ton in galena from Rosiclare, and Eilers quotes the statement of the owners of the old Mineral City property to the effect that 8 to 14 ounces were commonly found in the ore yielding 12 to 20 ounces in the pig. Whether this amount is constant or not is uncertain, and no attempt has been made, so far as is known, to save the silver, nor does its presence affect the price of the lead.

The lead ore now obtained comes mainly from the jigs employed to clean the fluorite, and its production is incidental to the preparation of the latter for the market. Large bodies of galena corresponding to those formerly mined do not seem to be anywhere in sight at present.

Blende.—The zinc sulphide, ZnS (sulphur, 33 per cent; zinc, 67 per cent; specific gravity, 3.9 to 4.1), locally known as "jack," is, next to galena, the most abundant of the sulphides. It occurs crystallized but rarely with crystal form. The blende present is usually quite pure, being a brown "rosin jack," and apparently rather free from any admixture of pyrite. While many hand specimens and even small quantities of ore can be found running high in blende, no considerable bodies rich enough to warrant independent mining were exposed when the area was visited. At the Rosiclare mill middlings containing zinc are being accumulated with a view to possible future sale.

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[a] Whitney, J. D., Geol. Survey Illinois, vol. 1, 1866, p. 189.

Pyrite.—The iron sulphide, probably in the main pyrite, FeS_2, is as usual widely disseminated. It is, however, distinctly subordinate in quantity, and in this particular the district is in contrast with many of the mining districts of the West.

Chalcopyrite.—The copper-iron sulphide, $CuFeS_2$ (sulphur, 35 per cent; copper, 34.5 per cent; iron, 30.5 per cent; specific gravity, 4.1 to 4.3), occurs in minute quantities, and small crystals may frequently be observed by carefully examining the ores. It is not of any economic importance here.

Stibnite.—The antimony sulphide, Sb_2S_3 (sulphur, 28.6 per cent; antimony, 71.4 per cent; specific gravity, 4.52 to 4.62), has been reported by Mr. Bisland, of the Fairview mine, and Eilers mentions its presence and also that of a mineral taken to be jamesonite. He speaks of these as being in such small quantity as to interpose no difficulties in smelting and to be of no value.

SECONDARY MINERALS.

Cerussite.—The lead carbonate is reported to have been found in small quantities in the early days of the mining industry. It has long since disappeared and probably never was abundant.

Smithsonite.—Zinc carbonate, $ZnCO_3$ (carbon dioxide, 35.2 per cent; zinc oxide, 64.8 per cent; specific gravity, 4.30 to 4.45), occurs frequently in connection with the alteration of the blende. It is a rusty-looking material, not unlike some of the weathered chert in appearance, but readily distinguished by its weight. The only body of any size noted in the course of the survey was at the Empire mine, and the quantity present here, while undetermined, was not impressive.

Limonite.—The hydrous oxide of iron occurs in the region in considerable abundance, and formerly there were two furnaces—the Martha and the Illinois—making iron from it. The ores are low grade, as judged by present standards, and, as they bear no obvious relationship to the minerals under investigation, were not especially studied. Small bodies of impure iron oxide or ocher are here, as usual, widespread.

Malachite.—The copper carbonate, $2CuCO_3,Cu(OH)_2$, occurs as a greenish stain at a number of points, particularly at the so-called "copper vein" near Elizabethtown. The quantities observed were everywhere inconsiderable.

Copper.—Small flakes of native copper may be occasionally observed in the Rosiclare ores. They seem to be due to local reduction of the minute quantities of chalcopyrite.

PARAGENESIS AND ASSOCIATION.

No definite order of deposition of the original minerals can be made out. The various metallic sulphides and gangue minerals seem to have crystallized at the same time, and beyond the general fact of the replacement of calcite by fluorite there seems to be no system in their deposition. All of the sulphides occur completely surrounded by the fluorite. There are none of the common evidences of secondary enrichment, and in the veins the oxidation incident to the long period of erosion subsequent to the formation of the ore bodies has left few traces. Apparently the sulphides, being practically sealed up in fluorite, are, so long as they remain in the vein, almost entirely unaffected by surface waters. Minor exceptions are noted in the descriptions of the individual mines. In general the ore bodies are believed to be practically unmodified ores of primary deposition, or of first concentraction, as Professor Van Hise defines the term.[a]

MODE OF OCCURRENCE.

Form and character of the ore bodies.—The deposits of this district form typical fissure veins. The ore bodies are tabular; they occur along planes that mark extensive faulting and that cut across the strike and dip of the strata. Ore and gangue minerals in considerable variety are present, and both fissure filling and metasomatic processes have operated in their formation. The ore bodies are unusual in respect to thickness—frequently 10 to 12 feet, and occasionally 25 feet or more—and in the great purity and abundance of the fluorite.

The development work at Rosiclare gives some idea of the size of at least one of the ore bodies. Mining has been carried on for practically the whole distance of three-fourths of a mile along the vein. For the greater portion of this length the stopes have been 10 to 20 feet wide in very clean ore. In the Fairview shaft, at one end, levels at a depth of 200 feet show the presence of a vein of undiminished strength and an ore body of the full normal thickness. At the other end the Rosiclare shaft shows the same thing to a depth of 300 feet. Beyond these shafts very little work has been done, but even if the vein or ore shoot—the two terms here seem almost synonymous—goes no farther laterally, a very large body of spar is shown.

This is the largest body of fluorspar yet developed in the two counties, but it is also the only place at which any considerable sinking and drifting have been done. As the mine descriptions show, there are a number of other points at which present indications point to large ore bodies.

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[a] Van Hise, C. R., Some principles controlling the disposition of ores: Trans. Am. Inst. Min. Eng., vol. 30, 1901, p. 173.

In general the great width of the vein is probably due to the facility with which the less soluble calcium fluorite is formed in the place of calcium carbonate whenever fluorine is available. This has resulted in extensive replacement of the limestone wall through metasomatic processes, as was long since pointed out by Emmons.[a] The detailed microscopic evidence of this is given in connection with the description of the Lead Hill mine. This process is not believed, however, to have operated to the exclusion of normal vein filling in open cavities, since, for example, in the McClellan mine, later described, there is a considerable body of clear fluorspar where both walls are sandstone and where, accordingly, there is little opportunity for simple replacement. The occasional banding of the ore, while not conclusive evidence, and often, indeed, the reverse, points, nevertheless, to the same conclusion. The cooperation of the two processes of open fissure filling and metasomatism is, as Mr. Lindgren has shown,[b] normal and quite in accord with what should be expected.

In connection with the veins, the wall rock, where composed of sandstone, is commonly converted to a quartzite. As this is a local phenomenon, the quartzite occurring only along the veins, it points apparently to the introduction of considerable amounts of silica at the time the ore bodies were found—a conclusion apparently confirmed by the presence of crystals of quartz intimately intergrown with the ore minerals.

Ore shoots.—So far as is known, the ore does not occur in regular ore shoots. In view, however, of the small amount of development work and the smaller amount of mining so far done, this appearance may be deceptive. The Fairview-Rosiclare ore body, if it be regarded as a single ore shoot, is certainly one of unusual size.

Structural relations.—The veins are developed, as already indicated, along fault planes, but these are neither necessarily nor frequently planes of major faulting. The Hamp mine, which shows an excellent body of ore, is in a vein where there has been very little faulting. At the Empire mine, while there has been considerable faulting in the vicinity, the ore body is found along a plane which seemingly marks very little displacement. This is, however, a common phenomenon. For some reason not well understood, the large faults do not form the locus of ore bodies any more commonly than smaller faults in their vicinity.

The ore bodies so far developed are usually found where one wall is a sandstone and the other a limestone, generally the Ste. Genevieve. The Fairview and Rosiclare may be cited as examples. They also occur where both walls are limestones, as at the Hamp and Empire,

[a] Loc. cit,. p. 51.

[b] Lindgren, Waldemar, Metasomatic processes in fissure veins: Trans. Am. Inst. Min. Eng., vol. 30, 1901, pp. 578–692.

and where both are sandstones, as at the McClellan and probably the Daisy. Since the faulting is deep enough to cut a considerable succession of sandstones and limestones, it is obvious that if the ores continue to any depth the relations at the surface may change, even to the point of reversal. In such a region as this it is also true that the fault planes which bring limestone into contact with sandstone are most easily recognized, and hence are the ones first prospected. Under the circumstances the seeming close relation of the ores with the Ste. Genevieve limestone may be deceptive, though in the absence of deep mining judgment on the point must be suspended.

Relations to topography and underground water level.—The ore bodies do not seem to bear any close relation to topography. They are found on the upland, as at the Empire; in hillsides, as at the Lead Hill mine, and under bottom land, as at the Rosiclare. In general they are on the slope, since there is very little level ground in the district. There is not, however, that close relation to topography which, for example, is characteristic of the ore bodies of the Lake Superior iron ranges.[a]

The relations to underground water level appear to be equally fortuitous. In general, the mines are relatively dry and the small amount of water handled seems to be entirely of local origin. At the Rosiclare mine it is clearly oxidizing and varies with local rainfall. As this is the deepest mine, it would presumably have tapped any deep waters which might occur in the veins, and yet the total amount of water pumped under ordinary conditions is very small, being estimated at 75 gallons per minute. In general, the mines, where of any depth at all, are below the local level of underground water.

Alteration of ores.—The ores are very little altered. Beyond the occasional occurrence of small bodies of zinc carbonate near the surface, there are none of the usual signs of decay and alteration common to sulphide ores. Even where oxidation has been carried to some depth, as at the Hubbard and Cook mines, it has not much affected the vein matter, but has proceeded rather along cross fractures or through the country rock. In the long period of erosion in which the upper portion of these veins was cut off, very little material was carried down into the vein. That which was eroded seems to have been mechanically broken off or to have been dissolved and carried away without local reconcentration. In the presence of the more easily soluble limestone, surface waters do not attack with any vigor the fluorite or the minerals confined within it, and so the vein material as now exposed is practically unaltered. The bodies of zinc carbonate occasionally found mark local and exceptional reconcentrations.

[a] Van Hise, C. R., Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 3, 1901, pp. 329–330.

Age.—The ores were formed after the period of deformation, which, as has already been shown, was late in the Carboniferous or after the close of that period. They originated before the Lafayette peneplain was cut, and they do not seem to be forming now. They may be as old as the Permian or as young as middle Tertiary, but it is impossible to fix their age more definitely on the basis of local evidence.

Genesis and value.—These topics will be discussed in detail after the description of the individual mines.

DESCRIPTION OF MINES AND PROSPECTS.

ROSICLARE AREA.

Résumé of geology.—The formations exposed near Rosiclare have already been discussed, but a brief résumé with certain additional details will help in understanding the mine descriptions.

The southeastern portion of the area (Pl. II), extending from Elizabethtown to Orr's landing and back to the crossing of Big Creek by the Golconda road, is underlain by the St. Louis limestone. This formation is brought into faulting contact with the Chester formations, though probably in part at least the boundary between it and the Ste. Genevieve is a normal erosion boundary. So far as known no ore bodies have been found in the St. Louis of this vicinity. Small amounts of fluorspar occur in cavities in the rock, and there are several well-developed veins of calcite, the more prominent ones being represented on the map.

The central portion of the area is underlain by a broad belt of Chester formations trending northeast and southwest. These are in part in faulting contact with each other. Only the Ste. Genevieve limestone is mapped separately. The beds have a very gentle dip to the northwest, the highest beds noted being in sections 30 and 31.

The Mansfield sandstone occupies the northwestern corner of the area, and the irregular boundary, the presence of outliers, and the absence of faulting phenomena indicate that it rests upon the Chester with a normal erosion contact.

Igneous rocks outcrop at three points along the Ohio, cutting the St. Louis and Ste. Genevieve limestones. There are two other doubtful occurrences known.

The veins occur along fault planes having in most cases a northeast-southwest trend and falling within a single vein system crossing the area from section 8 to section 21. The area has up to the present proved the most productive in the whole district, but this may have been due as much to the nearness of the mines to the river as to the size of the ore bodies.

Fairview mine.—The first discovery of fluorspar in place and the first attempt to mine it seem to have been made upon the property now owned by the Fairview Fluorspar Company. There are several veins on the property, and ore is reported to have been discovered in 1842. No attempt seems to have been made to operate until 1862, when the Good Hope shaft was started. From that year until 1874 the work was practically continuous, the ore being smelted as well as mined on the property. Three successive smelters were built; two were destroyed by fire, and the third was torn down about fifteen years ago. The dumps of fluorspar which accumulated during these years when the lead alone was of value were worked up and sold in the years 1889 and 1890. From 1891 to 1895 the property was operated under lease by the owners of the Rosiclare mine, and a large tonnage of spar was disposed of. The Good Hope vein is now being reopened, and in the course of the present survey a number of the old stopes on this vein were visited. Since the reopening of the mine had only begun at the time it was visited, the following notes are based to some extent upon the published descriptions of J. G. Norwood [a] and S. F. Emmons [b] and an unpublished report on the property made in 1884 by Messrs. Anton, Eilers and R. W. Raymond and courteously placed at the disposal of the Survey by the present manager, Mr. T. P. Bisland.

The Good Hope vein occurs along a fault trending N. 21° E. and dipping 79° 30′ NW. The hanging wall is composed at the surface of a coarse sandstone showing no pebbles and believed to belong to the Chester. The foot wall at the main shaft is the Tribune limestone, as determined by Mr. Ulrich. A short distance to the southwest a shaft near the sawmill shows the foot wall to consist of a sandy shale similar to that occurring normally some distance above the Tribune limestone. This would point to a cross fault between the two shafts with a downthrow to the south. The downthrow of the main fault is to the west. The amount of the displacement is unknown, but is certainly 100 feet and probably much more. The walls underground are marked by vertical striations near the main shaft and in the north drifts. In the south drifts the striations are at angles to the northeast. The hanging wall is sandstone or very sandy shale to a depth of 150 feet at least. The foot wall shows limestone at the surface and again at 210 feet, but a considerable portion of the wall between is unbroken, and sandy material occurs at a depth of 30 feet.

The underground workings show a clean, hard hanging wall. The foot wall is usually less well defined and is broken by a series of

[a] Geol. Survey Illinois, vol. 1, 1866, pp. 366–372.
[b] Trans. Am. Inst. Min. Eng., vol. 21, 1893, pp. 31–53.

splits running off from the main vein. These have a course about N. 39° E. The old working extends to a depth of 213 feet, and drifts have been run in both directions at depths of 30, 60, 135, 160, and 210 feet. At present such of these stopes as can be entered show considerable bodies of clear fluorspar, mainly white, but with subordinate amounts of purple. In the fluorspar are small bunches of galena and blende. Minor amounts of pyrite and chalcopyrite occur and stibnite and jamesonite are reported. While the sulphides occasionally occupy distinct veinlets or occur in definite bands, they are more commonly completely intergrown with the spar. Calcite is also extensively developed, especially in the foot wall. No distinct crustification indicating a definite order of deposition of the various minerals can be made out, and there are no satisfactory evidences of differences in the character of the ore body at different levels. Certain of the old stopes showed chambers of considerable size, 15 to 16 feet wide, 20 to 25 feet high, and 40 feet or more long, with roof and face of fluorspar. In view of the fact that the property was formerly worked for galena alone, these chambers corroborate the statements made by Norwood and others as to the large size of the bodies of lead ore formerly found. Mr. Eilers estimated that at the time of his visit there was in one stope a body of ore 20 feet wide, 20 feet high, and 50 to 60 feet long, which would run 10 to 15 per cent galena. At the same time another stope 138 feet long was yielding ore which the owners stated ran 13 per cent of dressed galena. At present there are no considerable bodies of galena in sight, as all available ore of that kind had evidently been removed before mining stopped. It has been estimated, however, that there are reserves of 25,000 tons of fluorspar in the ground now open.

From the main shaft the vein has been opened a distance of approximately 150 feet in each direction. To the northeast, however, the vein has been mined through a number of other shafts up to the boundary line of the property, and practically continuous stoping has been done from the Fairview to the Rosiclare shaft. While the ore body is thus continuous from one mine to the other, the recent work indicates that the two mines are on separate fault planes. If the Rosiclare vein be projected to the southwest on an accurate base it passes through one, at least, of the shafts which mark the Anderson Well vein, the first to be discovered. The course of the latter as generally given in N. 3° E., while the Rosiclare vein runs N. 18° E. (true). Since, however, the Anderson Well vein was never worked, not much importance is to be attached to the early determination of its course.

Rosiclare mine.—The Rosiclare mine has probably the longest record of nearly continuous production in the district. It is also the deepest, the shaft now being down 300 feet, and for many years it was the only important producer of fluorspar. It is located about a half mile back from the Ohio and slightly farther from the Fairview mine. As already stated, it is believed to be on a different vein, though the ore body continues from one mine to the other.

The hanging wall consists of the same sandstone as at the Fairview. Samples taken from below the surface show that it has been altered to a hard quartzite by the deposition of silica between the sand grains. The foot wall at the bottom of the shaft is a fine-grained "plucky" limestone, which Mr. Ulrich considers to be probably St. Louis. At the surface the foot wall is not exposed, but from general relations it is presumed to be Ste. Genevieve. At a shaft across the road and to the northeast of the main working shaft, the dump shows fragments of limestone of possibly Tribune or Birdsville age, but it is impossible to determine the relations. Still farther to the northeast sandstone covers the whole surface.

The shaft is 300 feet deep, and development has been carried both to the northeast and to the southwest with underhand stoping. The vein is vertical and the walls where uncovered are well defined. The hanging wall is extensively exposed and shows numerous striations, which are horizontal. The foot wall is usually covered by a thick body of calcite.

The vein stuff consists essentially of fluorspar and calcite, with minor amounts of lead and zinc sulphide and occasional specimens of pyrite and chalcopyrite. Near the hanging wall there is ordinarily a band 1 to 2 inches thick of the sulphides, but they also occur throughout the fluorspar and intimately mixed with it. On one specimen of the blende a greenish-yellow material suggestive of greenockite (cadmium sulphide) was observed, and a small flake of native copper was also seen. The sulphides occur intimately intergrown and also intergrown with the gangue minerals. Along water channels the blende is occasionally altered to zinc carbonate, and in druses crystals of quartz occur frequently. No special order of deposition of the sulphides can be made out, and no differences in character with depth are apparent, either in them or in the fluorspar. The fluorspar occurs in great thickness and makes up the greater portion of the vein. This is usually 10 to 12 feet wide, but stopes 26 feet wide are now open. The whole face of such a stope is made up of practically clear fluorspar, with some intergrown calcite, particularly toward the foot wall. Ordinarily the calcite occurs for the most part back of a facing or fault plane, showing striations and separating the cleaner fluorspar from the mixed spar and calcite. A thickness of 14 feet of the latter between this facing and the true limestone foot wall has been observed.

The vein shows numerous slips and minor fault planes between the main walls. These seem to represent post-mineral fracturing, though the main facing mentioned above would more probably represent an original foot wall, back of which fluorspar and calcite have metasomatically replaced the limestone. Within the vein the fluorspar shows in great clear banded surfaces resembling onyx. If these represent replacement of the limestone instead of cavity filling, the material has so completely recrystallized as to destroy all evidence of the bedding. Running through the ore body are druses and channels lined with crystals of fluorspar, calcite, and quartz. These are water channels and seemingly carry surface oxidizing waters, as is shown by their action on the zinc and iron sulphides. The whole of the workings are below water level, and approximately 75 gallons per minute are pumped in ordinary seasons. In wet weather this amount is materially increased.

Blue vein.—Northwest of the Rosiclare mine and on the property of the Fairview Fluorspar Company is the Blue vein, one of the first known in the district. Norwood describes it as 6 to 11 feet wide, with a sharp dip to the east and a course N. 29° E. He also mentions a cross vein, about 100 yards to the west, with a course N. 35° E. and a thickness of 3 feet. Neither of these veins has been worked for some time, and at present the dump shows only fragments of sandstone, shale, fluorspar, calcite, galena, and blende. The vein took its name from the quantities of blue fluorspar found in it.

Daisy vein.—A shaft on this vein was open at the time of Mr. Emmons's visit to the region, and he speaks of it as being 40 feet deep. The vein is said to have been very productive, but the workings have been abandoned for some years. At present fluorite may be seen on the dump and in small bunches attached to the quartzite foot wall. The vein has an apparent course N. 38° E. and a dip to the northwest of 69°. The hanging wall is apparently composed of shale, and there are no fragments of limestone on the dump. These relations suggest that the Daisy vein marks the position of the fault supposed to cut off the Cypress sandstone from the Birdsville formation, and to account for the absence of the Tribune limestone over most of the area.

A short distance northwest of the Daisy vein a fault is indicated on the special map as marking the boundary between the Ste. Genevieve limestone and the sandstone. There is no direct evidence of faulting here, but the abrupt termination of the sandstone along a sharp line is very suggestive of it.

Clement vein.—This vein occurs along the contact of the Ste. Genevieve limestone to the east and the higher Chester beds to the west. There seems, however, to be but slight faulting. The vein has a general course N. 45° E. Near the fault and on the hanging-wall side the sandstone is tilted to an angle of 44°. The old Eureka workings, which were open at the time Mr. Emmons visited the area, were on this vein. A large amount of spar was shipped from them and the vein was proved to a depth of 80 feet.

At present the Marion Mineral Company is sinking a shaft farther to the northeast. The vein stuff consists of brecciated limestone with purple and white fluorspar crystallized with calcite. In druses the spar, calcite, and some small quartz crystals are crystallized together.

In the vicinity there are several faults and a number of small prospects. These are represented on the map. One of the most interesting of the faults is east of Big Creek and is locally known as the "Copper vein." It has a course N. 37° W., and shows limestone on both walls. At the surface is a reef of highly silicified limestone projecting above the ground. The vein is about 6 feet wide and consists of a breccia of limestone cemented by calcite and with some crystals of quartz. Stains of malachite occur, but no other metallic mineral was observed. The surface outcrop shows cavities left by the leaching out of some flat, tabular crystals, possibly barite. The vein is of interest because of the unusual character of its contents and its course, nearly at right angles to the others discussed. It has not, so far, proved of any value and seems to belong with the barren calcite veins near by.

HICKS AREA.

Résumé of geology.—The Hicks area includes the greater part of a small structural dome in which beds from the Devonian black shale to the Mansfield conglomerate are exposed. The mines are confined exclusively to the area of outcrop of the Chester formations, and to a very notable degree the ore is developed in or near the Ste. Genevieve limestone (Pl. III).

Empire mine.—The Empire is perhaps the best known of the mines back from the Ohio River. It has been worked at different times for a number of years and has made several shipments. In the vicinity there are a number of faults which for the most part seem to be of small throw. The more important ones only are represented on the accompanying map. The Empire vein follows a fault with a course N. 48° E. and a dip 73° SE. At the shaft limestone is found on both sides of the vein, and the amount of faulting does not seem large. The fault is normal, with downthrow to the east. This is indicated by the upturning of the shale partings in the beds of the hanging wall and by the general relations of the rocks. In the field north of the mine the Rosiclare and Ohara members of the Ste.

Genevieve limestone may be identified, and near the shaft sandstone, presumably Cypress, rests on the limestone with a normal erosion boundary. In some open cuts, and in the bed of the stream crossing the vein northeast of the shaft, limestone may be seen on both sides of the fault, and while the identification of the hanging wall is not positive the rock is apparently the Ste. Genevieve. Still farther to the northeast shaly and cherty beds take their place. Mr. Ulrich identifies them as probably Birdsville, and this would require a small block of higher strata faulted down to the general level. This block is indicated on the map, but with no pretensions to accuracy of outline.

From the shaft the Empire vein has not been traced far to the southwest, the presence of sandstone on both sides making surface identification somewhat uncertain. Fluorspar is, however, reported from its probable extension in section 34. From the shaft south the sandstone seems to be cut off to the east by a second fault extending from the Empire to the Hubbard shaft, and at a number of points along this line fluorspar has been found.

The workings of the Crystal Fluorspar Mining Company consist of a large open cut and a shaft sunk on the vein, which was 127 feet deep when visited, and has since been continued to a depth of 160 feet. In the open cut a wall of solid white fluorspar was at one point exposed, dipping to the east parallel to the hanging wall of the vein. Against it and in the V-shaped angle between it and a perpendicular plane to the surface was a body of zinc carbonate. This is said to run 38 to 40 per cent of metallic zinc, and has the appearance of being of fair grade. The amount exposed was not large, and the total amount present is wholly unknown. It is associated with residual clay, and seems to represent surface concentration against the hanging wall of the vein.

In the shaft a vein usually from 6 to 10 feet wide and with well-developed walls is shown. The vein matter consists of brecciated limestone cemented by fluorspar and calcite intimately intergrown. In this matrix galena, blende, pyrite, and chalcopyrite occur, the two first named being frequently in considerable abundance. The sulphides, particularly the blende, show a tendency to replace the fragments of limestone and also to some extent the wall rock. Occasionally they are segregated in a distinct band, which in one place is as much as 4 inches thick and occurs along the hanging wall. It is rather noticeable that the sulphides are for the most part very fine grained and are intimately associated with the wall rock and the gangue. The dark shaly material found in the hanging wall is rather widely distributed through the breccia.

The fluorspar occurs largely interbanded with calcite, but a band of clear spar from 1 to 4 feet wide is found almost continuously from the top to the bottom of the shaft, either on foot wall or hanging wall. A total thickness of 6½ feet is reported from one point in the shaft. The workings are now some distance below water level. There are no marked differences in the character of the ore at different levels except the presence of the zinc carbonate in the open cut, and there are no evidences of secondary enrichment or redistribution of the ores. As no drifts have been run and no stopes opened, it is impossible to make any estimate of the amount of ore opened. A considerable amount of the fluorspar seen could be shipped as mined, but to save the zinc and lead and the remaining portion would require careful milling, with rather fine crushing and concentration.

In the field north of the mine, as well as the fields to the south, fluorspar occurs in the soil at a number of points, but the development work is not sufficiently advanced to show the character and relations of the veins. In the SW. ¼ NE. ¼ sec. 34 the hillside is literally covered with clear glassy spar in a great variety of beautiful colors. A number of shallow pits here show its wide distribution.

Hubbard shaft.—In section 34, southwest of the Empire, is the shaft being put down by Mr. H. B. Pierce and his associates of the Grand Pierre Mining Company. This shaft is about 60 feet deep and in limestone, apparently the Ste. Genevieve. This was encountered at a depth of 12 feet. In an open cut near by are sandy beds belonging to the higher formations. The shaft seems to be on an intersection of two or more crevices, the main one, as shown in the open cut, having a course N. 45° E. The crevice is vertical and the amount of faulting does not seem to be great. In the shaft the vein was obscured by the presence of red surface clay, but brecciated limestone with a matrix of calcite and fluorspar was made out. A short distance to the northeast, near the creek, is a reef of brecciated quartzite with some fluorspar in the cementing material. In a trench cut across the reef the beds are seen to dip to the southeast. At a number of points over the low ground adjacent large quantities of "glassy" spar have been dug from shallow depths. The spar is variously colored and is so widely distributed as to indicate the presence of a few cross fractures.

Big Joe mine.—In section 27, northwest of the Empire mine, spar has been found at a number of points. At the Big Joe the surface formation is sandstone, probably belonging to the Birdsville formation. The vein has a course N. 15° E. and has been developed to a depth of 60 feet. There are apparently two veins, with a block of quartzitic sandstone between. At a depth of 20 feet the quartzite gives place to black sandy shale, which occupies the space between two veins of fluorspar, each 8 to 12 inches thick. Apparently the shale has been thrust upward, or rather both the foot wall and hanging wall of the vein as a whole have moved downward, leaving the shale as a wedge between the two walls. There are small veins of galena one-fourth inch thick which come down to the shale and are there cut off abruptly. It is reported that 200 pounds of lead were shipped from a surface pocket at this shaft. A small amount of blende and occasional pieces of pyrite have been found in the vein. It is said that the last work done on this property showed fluorspar, calcite, and galena distributed pretty well over the bottom of the shaft.

The same vein, presumably, has been opened on the ground south of the Big Joe and has yielded several hundred pounds of lead ore. There are there, as at the Big Joe, parallel crevices, and fluorspar, calcite, galena, and blende occur, intimately intermingled in crevices in the quartzitic sandstone.

Two small prospects have also been opened near Mr. Jesse Crab's house, not far from the Big Joe. They show the usual association of ores, a small vertical vein about 2 feet thick crossing the quartzite.

In the northeast quarter of the same section a vein 2 feet or more in width of deep-purple spar shows in the bed of a small creek. The vein has a course N. 58° E. and lies between the St. Louis and Ste. Genevieve limestones. No work has been done on this vein, but the spar has the appearance of being very clean.

Hutchinson mine.—In SE. ¼ SW. ¼ sec. 22 Mr. James Hutchinson has an open pit, in which are a series of parallel crevices running through the sandstone with a course about the same as at the Big Joe. The crevices are vertical and narrow. White, purple, and green fluorspar occur, with a minor amount of galena.

Rainey mine.—In SW. ¼ SE. ¼ of the same section (22) is an open pit located on the contact between the Ste. Genevieve and the Birdsville formations. Limestone shows on both sides of the pit, but in the hill above to the west is blue shale, and a short distance beyond sandstone occurs. There seems to be some slight faulting here, with downthrow to the north. The course of the vein is N. 25° E. The vein is 12 to 18 inches wide and shows fluorspar, galena, and blende. Minor amounts of zinc carbonate have been formed by the alteration of the blende.

Baldwin mine.—This is located in SW. ¼ SW. ¼ sec. 23, and consists of an open cut about 10 feet deep. It exposes a vertical vein about 6 inches wide cutting the Ste. Genevieve limestone and having a course about N. 40° E. The limestone is slightly brecciated, but the bulk of the vein stuff consists of purple fluorspar and white calcite, with minor amounts of galena and blende.

Hicks mine.—This is in the same section as the Baldwin and is supposed to be on a continuation of that vein. When visited it was a prospect only, the fluorspar having been located by means of a post-hole digger. A body of clear spar somewhat over 2 feet thick was indicated.

In another portion of the SE. ¼ NW. ¼ sec. 23 two small open cuts show the presence of a 3-inch vein of purple spar, with considerable calcite, cutting across the Ste. Genevieve limestone with a course N. 20° E. Slickensides indicate some faulting, and the downthrow is apparently to the west.

Hamp mine.—On the northeast flank of the Hicks dome is a second group of prospects, of which the Hamp mine is the most important yet developed. This mine is on a well-developed fissure cutting the Ste. Genevieve limestone with a course N. 60° E. There seems to have been very little displacement, since the Rosiclare sandstone member of the formation occurs at nearly the same elevation on both sides. The vein dips SE. 68° and crosses the beds on both dip and strike, the dip of the strata being 10° NW. The vein consists of very clean "ribbon" fluorspar, mainly white in color, but with some purple near the surface. There is very little calcite developed with it. Some galena is found and very subordinate amounts of blende. The property is being developed by two shafts, the deeper being at last accounts 61 feet down, and showing at the bottom 6 feet of clear white fluorspar.

East of the Hamp mine there are a number of small prospects showing spar, as indicated on the map. None of these have been developed enough to make clear the relations of the ore bodies. Northwest of the area also (sec. 11, T. 11 S., R. 7 E.), on the Wright land, some prospecting has been done in an area of complexly faulted and slightly folded rocks.

SCATTERED MINES IN HARDIN COUNTY.

General statement.—At a number of points throughout the county and outside of the areas specially mapped there are occurrences of spar and lead, and at a few places some mining has been carried on. As many of these places as possible were visited in 1903, and brief notes on a number of them are given below. The largest number of these mines is near Eichorn, which is located in sec. 11, T. 12 S., R. 7 E. The Pell, Stewart, Cook, Oxford and Watson, Parkenson, and Gordon are in this vicinity, the two last named being in Pope County. At Lead Hill, north of Cave in Rock, mining has also been carried on at a number of points. In the country back of Lead Hill, extending to Rock Creek, are a number of prospects, including the Showalter, Patton, and a second Eureka. This enumeration does not exhaust the list, but includes most of those personally visited.

Pell mine.—This property is located in sec. 24, T. 12 S., R. 7 E., on Threemile Creek, near St. Joseph Church. There is a well-equipped hoisting plant and concentrating mill, not now in operation and said to have been run but a short time. The shaft is reported to be 95 feet deep and sunk on the vein, which apparently dips to the east. The course of the vein seems to be about N. 20° to 30° E. The dump pile consists mainly of limestone, with some sandstone. The vein stuff evidently includes brecciated limestone, with calcite, fluorite, galena, and blende acting as the cementing material. The sulphides occur also in cracks in the limestone, and to some extent disseminated in and replacing the rock. The stock pile shows some fluorite of good grade, and a small amount of zinc carbonate with occasional stains of malachite. The ore bins show a fairly clean grade of rosin blende and some well-cleaned galena. Financial difficulties and dissensions in the management are given as reasons for the property being idle.

Stewart mine.—This property, operated by the American Mines Company, is located northwest of the Pell, in section 14. Several small shafts have been sunk on a nearly vertical vein running N. 20° E. between Cypress sandstone on the east and Ste. Genevieve limestone on the west. This vein has been traced for about a half mile along its course, and where seen showed from 2 to 3 feet of purple and white spar with small amounts of barite and some small black quartz crystals.

Oxford and Watson mine.—This property is near the Stewart, in SW. ¼ NE. ¼ and NW. ¼ SE. ¼ sec. 13. A small prospect shaft has been sunk in the limestone, probably Ste. Genevieve, and near the sandstone. It has developed the presence of a breccia of which the fragments are limestone and the cementing material is mainly calcite. A few crystals of blende and galena were observed, but no considerable body of ore has been found.

Cook mine.—This is a small prospect shaft 70 feet deep about a half mile northeast of the Oxford and Watson. It is on the contact between the sandstone and limestone and shows considerable calcite and some fluorite in the north side of the shaft. At 56 feet the east side of the shaft was entirely occupied by red clay.

Parkenson mine.—This property is a couple of miles southwest of the Stewart and just across the line in Pope County (NE. ¼ sec. 27, T. 12 S., R. 7 E.). The country rock here is sandstone, presumably belonging to the Cypress formation, and while there has evidently been some faulting, it has not been enough to bring the limestone to the surface. The property was not in operation when visited, but the dump showed the presence in small quantity of fluorite, blende, and barite. The course of the vein seemed to be N. 30° E.

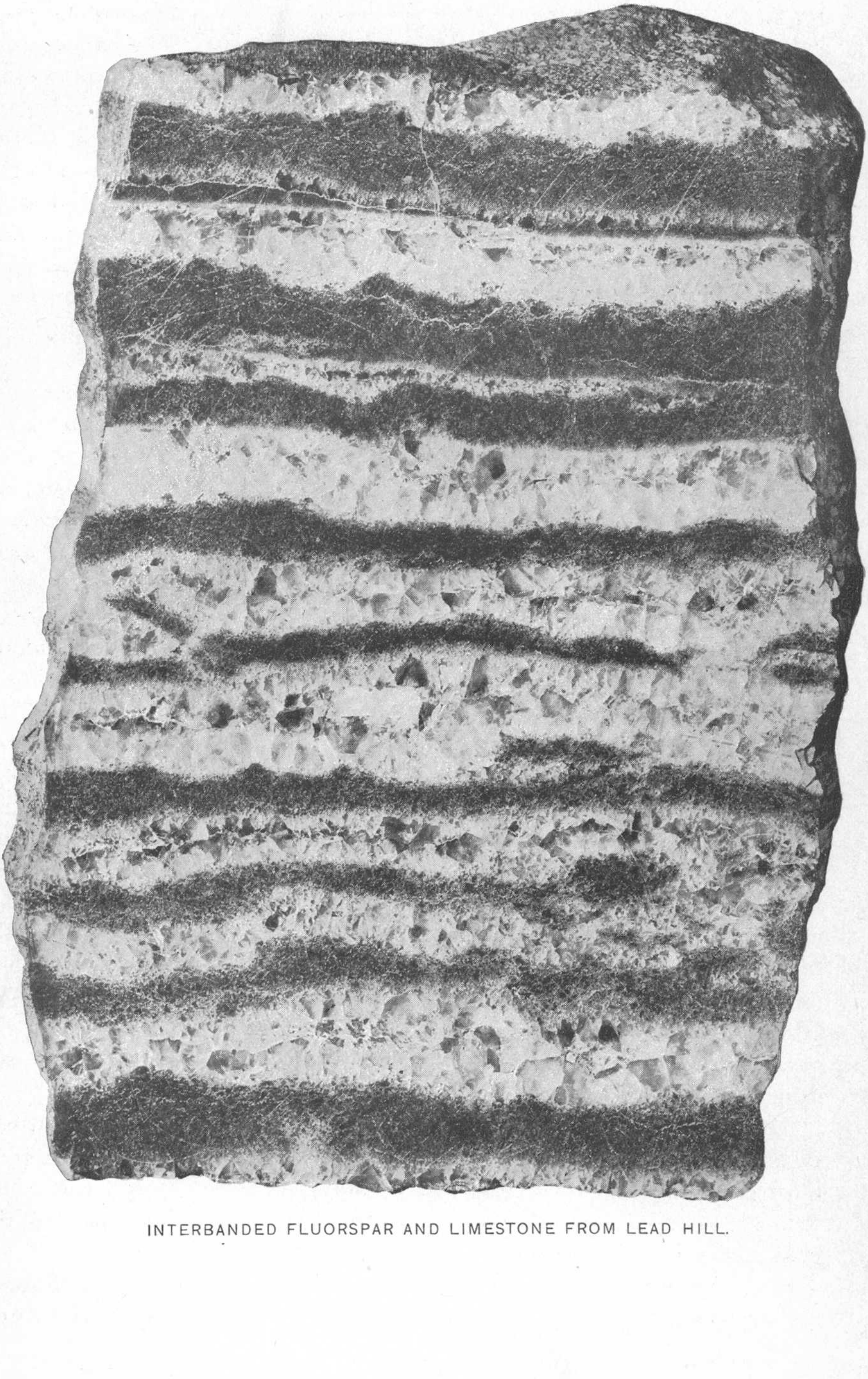
Gordon mine.—On the same quarter section and possibly on the same vein as the Parkenson is the Gordon shaft, also not being worked when visited. Here, again, the sandstone shows some brecciation, and fluorite, calcite, barite, blende, and galena occur. The barite and blende seem to be especially abundant and are apparently of good grade.

Lead Hill.—About 3 miles from the river, at Cave in Rock, there is an abrupt rise of 80 feet and a mural escarpment fronts the irregular plain developed over the area of St. Louis limestone. At the foot of this escarpment and parallel to it is a fault which may be traced somewhat south of east for nearly 3 miles. Along this escarpment, particularly in sections 3 and 4, T. 12 S., R. 9 E., mining has been carried on for a number of years, and formerly enough lead was taken out to give its name to the locality.

In 1903 the Cleveland-Illinois Fluorspar Company was operating a mine about on the line between sections 2 and 3. The company was working a bedded or sheet deposit in the Fredonia member of the Ste. Genevieve limestone and just under the Rosiclare sandstone. A number of short drifts were run into the hill, and the workings were conducted on a modified room-and-pillar system. The ore body varies in thickness from 18 inches to 6 feet, thinning as the workings extend into the hill. The vein stuff consists to a minor extent of brecciated limestone, but for the most part of interbanded limestone and fluorite with minor amounts of calcite and galena. At the top of the ore there is a band of green sandy shale a few inches thick, and the fluorite extends into this between the laminæ. Breccia is only locally developed, and banded limestone and fluorite, such as is illustrated in Pl. V, is more common. In this specimen the individual bands of purple and white fluorite are one-half to three-fourths of an inch thick, and are separated by layers of equal thickness made up of very impure limestone containing notable quantities of silica and iron oxide. This banding represents horizontal bedding, and the fluorite has evidently been introduced along the stratification planes, uniting with the calcium of the limestone and excluding the impurities. These were partly, no doubt, carried off, but also in part remain trapped between the growing crystals of fluorite and in the bands of unreplaced limestone.

These relations are perhaps made clearer by the photomicrographs of Pl. VI. In *A* is shown, in natural light, a portion of one of the fluorspar bands. Traces of bedding may be observed, and the iron oxides and other impurities are so arranged as to mark the outlines of granular material, presumably the original calcite.

In *B* the same section is shown between crossed nicols. The fluorite appears entirely black, while the small points of light indicate



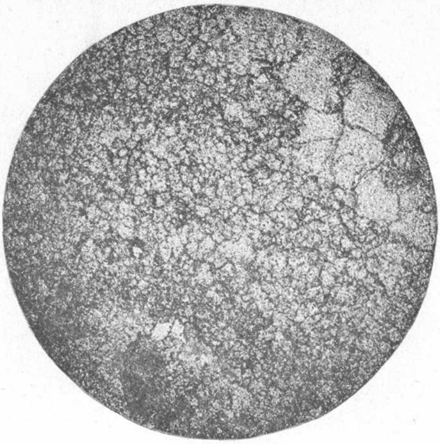
INTERBANDED FLUORSPAR AND LIMESTONE FROM LEAD HILL.

PLATE VI.

PLATE VI.

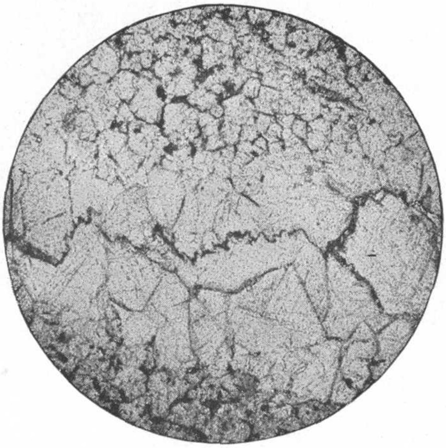
PHOTOMICROGRAPHS OF FLUORSPAR BANDS IN ORE BODY AT LEAD HILL.

A.—Natural light, showing granular outline of original calcite particles.
B.—Polarized light, showing complete penetration of original calcite (white) by fluorine now forming fluorspar (black).
C.—Natural light, showing preservation of original bedding plane in clear fluorspar.



A

B



C

PHOTOMICROGRAPHS OF FLUORSPAR BANDS IN ORE BODY AT LEAD HILL.

the presence of minute grains and crystals of calcite and quartz. The bedding may still be made out, but the outlines of the calcite crystals are completely obscured. The very intimate association of the calcite and fluorite are notable and indicate the entire penetration of the rock by the fluorine. The calcite of the large crystal in the lower portion of the field has been partly replaced by fluorite, the bounding planes being evidently determined by the cleavage planes of the calcite. The calcite is under strain, as is indicated by the undulatory extinction

In *C* a view is shown, in natural light, of the central portion of one of the bands of fluorite. Running through this band is an irregular plane, which might readily be mistaken for such a surface as is produced by the interlocking of crystals making up the comb structure of ordinary banded ore deposits. In this case, however, the irregularities of the line bear no relation to the optical orientation of the crystals, and the line is furthermore of the exact character common in sedimentary beds between individual layers, particularly where the beds have been under slight pressure, so as to produce stylolites.

The above evidence warrants the conclusion that in this ore body the fluorine has been introduced along horizontal bedding planes and that fluorite has metasomatically replaced the calcite of the limestone, producing a banded structure without crystallization in free spaces. On the whole it forms an interesting and typical example of the phenomenon of pseudo-crustification, discussed some years ago by Mr. Emmons.[a] In this case horizontal bedding planes rather than vertical shearing planes are concerned.

With the metasomatic replacement of the rock there has been also some free growth of crystals wherever space has been available in druses or the brecciated rock. Very beautiful specimens of golden, purple, and white fluorspar occur, showing the cube with occasional modifications by octahedral faces.

The introduction of the fluorine solutions was doubtless from the main fault along the foot of the hill, and occurred before the development of the present topography. The calcareous sandstone forming the Rosiclare member of the limestone was the particular localizing agent, as it forms a firm roof over the mine, and, being of unusual thickness, 25 feet, was a competent stratum under mild stresses. This had the effect of opening up the upper bedding planes of the limestone and allowing slight local brecciation, so as to afford entrance to the solutions.

The main fault at the foot of the hill is complicated by the presence of a number of minor faults. Along one of these near the mine is an

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[a] Structural features of ore deposits: Trans. Am. Inst. Min. Eng., vol. 16, 1888, pp. 804–839.

important development of barite, which is particularly interesting in view of the absence of that mineral in the ore body on the hill. The relations of the two were not made out.

South of Lead Hill, near Cave in Rock, and between that place and Elizabethtown, there are a number of faults and some prospecting has been done. So far as could be learned no considerable bodies of ore have been found.

Eureka mine.—North of Lead Hill the rocks are faulted and disturbed at a number of points and prospecting has been carried on, without, however, so far as known, developing any ore bodies of consequence. A possible exception is the old Eureka mine, not the same as that near Rosiclare (sec. 23, T. 11 S., R. 9 E.), which is said to have yielded several tons of galena. The works are now abandoned, but at the shaft a fault plane running N. 60° E. may be seen separating sandstones believed to be Mansfield to the north and Chester to the south. The dump shows small pieces of galena, fluorspar, and calcite.

SCATTERED MINES IN POPE COUNTY.

General relations.—Much the larger portion of Pope County north of Bay Bottoms is underlain by sandstones of the Mansfield and Chester formations. The general absence of the Ste. Genevieve and lower limestones makes it difficult to recognize faulting, and so, while disturbances of the strata have been noted at a number of points and prospecting is widespread, relatively little has been determined with regard to the stratigraphy of the region. There is one belt of mines extending from the vicinity of the Empire mine to the "Old Clay diggings" of the Pittsburg Mining Company near Raum. A second, or possibly a continuation of the first belt, includes a number of prospects near Allens Spring. Near Golconda there are a few veins and some prospecting has been done, and northeast of town are the Parkenson and Gordon mines, already discussed. Near Bay City considerable lead ore is said to have been mined. These mines and prospects will be discussed in the above order.

Pittsburg mine.—The Pittsburg Mining Company has sunk two shafts and driven one tunnel into a narrow belt of limestone outcropping in the general sandstone region near Raum. The limestone is dark, flinty, and not very fossiliferous. It seems to be of St. Louis age. It outcrops in a belt about 200 feet wide, having a general course N. 35° E., and is said to be traceable for several miles. The sandstone to the northwest, at least, is probably Mansfield. That to the southeast is of undetermined age. The limestone is much broken and there are considerable bodies of breccia. Galena and blende occur in small veinlets through the limestone and in the matrix of the breccia. They are associated with calcite and white and purple fluorite, which form the main cementing material. The blende is a bright rosin "jack," and the company is now reported to be erecting a mill for concentrating the ore.

Near the works is the kaolin pit from which the property takes its local name, "Old Clay diggings." The pit has been abandoned for a half century, but its size indicates that considerable bodies of kaolin were shipped. The kaolin occurs apparently on the contact between the limestone and the sandstone, which, as now exposed, has weathered to a bright-red color. The origin of the kaolin is unknown. No igneous rocks have been found in or near the mine.

McClellan mine.—Northeast of the Pittsburg mine (section 11) limestone is again seen, but its age was not determined. The general country rock is sandstone. A shaft 40 feet deep has developed evidences of faulting and a body of very clear fluorspar 6 to 7 feet thick. No sulphides were noted. There seems to be a system of veins running from N. 15° E. to N. 35° E. These mark fault planes, some of which bring limestone to the surface and some do not.

In an adjacent section (3) there is a well-developed quartzite reef, marking a fault plane in the Chester sandstone and shale. A small body of zinc carbonate was found near it.

Luella mine.—Southwest of the last-mentioned locality (sec. 10, T. 12 S., R. 6 E.) and apparently on the same belt of faulting the rocks are disturbed and fluorspar is introduced along the sides of an infaulted block of limestone. A considerable amount of white spar appears here at the surface, some of which seems to be sandy. There is also a pit showing a small body of kaolin, but the relations could not be determined owing to the limited amount of development.

Taylors Spring.—Comparatively little prospecting has been done in the region about Allens Spring and Rock, though faulting is common and float mineral has been found at several points. Near Taylors Spring (sec. 31, T. 12 S., R. 6 E.) the sandstone has a dip of 22° S., strike N. 55° E., and shows quartzitic facies. In the field near by small pieces of fluorite and galena have been found.

Moore mine.—On the Moore farm, near Taylors Spring, an open cut has been made in sandstone and shale, and small pieces of fluorite and galena have been found.

Wright mine.—In section 3, T. 12 S., R. 5 E., a small shaft has been sunk in shales and sandstone, probably of Birdsville age. The rocks dip at high angles, 30° to 47°, and in conflicting directions in this vicinity, and evidently have been considerably disturbed. Calcite and pyrite were the only minerals found in sinking, and no well-developed vein was located.

Southwest of this work, in section 9 (NE. $\frac{1}{4}$ NE. $\frac{1}{4}$), the beds are again disturbed, and belts of Birdsville of considerable width are given high angles of dip. A number of prospect shafts have shown some brecciation of the rock and the presence of calcite as a cementing material.

Golconda prospects.—About a mile south of Golconda, on the river bank, faulting has brought the Mansfield sandstone of the bluffs into contact with the Chester formations. Parallel to the fault the sandstone is sheeted or sheared and a minor amount of barite has been introduced. No other minerals occur.

West of Golconda the Chester comes in abruptly, replacing the Mansfield, and there seem to be several minor parallel faults and crevices. In one of the latter, showing in the first railway cut west of the town, is the Gilbert dike, which was prospected for mineral to a depth of 70 feet in 1903 without favorable results.

Bay City mine.—Near Bay City the rocks are broken by fault planes presumed to represent the Rosiclare-Fairview system of faulting. Along these planes fluorite, galena, and blende have been deposited, and an effort is being made to mine them. The Black mine is located in section 26, T. 14 S., R. 6 E., on a low hill rising about 25 feet above the Ohio River bottom land and cut off from the main bluff by a low col. Near the old shaft there are clear evidences of faulting in the sandstone which forms the surface material. The dump shows a brecciated limestone cemented by calcite and fluorite and carrying galena and blende. A small amount of zinc carbonate also occurs. The vein dips to the west, and a new shaft was being sunk to intersect it. In the hillside near by there is a narrow belt of limestone running about parallel with the fault upon which the ore has been found.

MINES IN SALINE COUNTY.

General relations.—Near the southern border of Saline County, not far from the Pope County line, small quantities of galena and fluorite have been found and some prospecting is going on. The country is rugged, the area including a part of Karbers Ridge. The rocks consist mainly of Mansfield sandstone, with subordinate areas of the later coal measures and some infaulted blocks of Chester limestone.

King and Fergusen mine.—This property is in section 21, T. 10 S., R. 7 E. The surface rocks consist mainly of sandstone, with subordinate amounts of black shale and limestone. They have been considerably disturbed and dip occasionally at high angles. There are three shafts. At the first the beds strike nearly north and south and dip 52° to the east. This shaft has been sunk on a thin bed of black shale, and there is apparently no displacement, though a minor amount of dip faulting may be present. Barite and fluorite are found in small amounts crystallized together in broken quartzitic sandstone. There are a few small crystals of galena. Calcite seems to be entirely absent. In the second shaft a limestone is present and small amounts of galena and fluorspar show. In the third, located farther south, near a contact of limestone and sandstone, small amounts of galena, pyrite, and fluorspar occur in cracks in the limestone.

Big Four mine.—On the Miller land, section 32, a shaft has been sunk 30 feet in Chester limestone. This rock is apparently in place and undisturbed, though near it pieces of brecciated limestone cemented by calcite were picked up, and in the same vicinity there are small pieces of blende and evidences of faulting. In general it may be said that in the vicinity small quantities of the sulphides and of fluorspar are widely disseminated and the rocks are faulted and broken in a manner favorable to ore deposition. At the time the area was visited, however, no considerable bodies of ore had been located. Later prospecting is said to have given more encouraging results.

GENESIS OF THE ORES.

It is impossible in the present condition of knowledge to make an exact and final statement as to the origin of the ores of this district. The best that can be done is to indicate certain alternative hypotheses and to discuss their possible conflicts and agreements. In view of the unusual character of the ores and the interest attaching to them, it is believed worth while to do this, even though it be admitted at the outset that the explanation offered is founded on hypothesis, though in accord with the facts as known.

ORIGINAL SOURCE OF MATERIAL.

The ore bodies represent concentrations of material normally present in rocks in a disseminated form. The minerals entering into their composition must have come either from the sedimentary rocks exposed at the surface and continuing for some depth below, or from deeper lying igneous rocks of which the dikes present at the surface represent offshoots. Neglecting calcite, pyrite, and other minerals widely distributed, attention may be concentrated on the rarer metallic sulphides—galena, blende, and stibnite—and on the fluorite. The discussion of their possible origin will be taken up in order.

ORE MINERALS.

The common ore minerals of this district, neglecting secondary and derived forms, are galena and blende. These sulphides of lead and zinc occur in both igneous and sedimentary rocks and are widely disseminated. Large bodies in unaltered limestone are especially characteristic of the Mississippi Valley and they show throughout the world a tendency toward segregation in dolomite and limestone. The lead and zinc deposits found at other points in the Mississippi Valley, excluding those of southwestern Arkansas, are believed to represent concentrations from the surrounding limestone brought about by the activities of ordinary meteoric water. Specifically, it is believed that they represent material originally deposited in the dolomites of the Cambro-Silurian and later concentrated in their present situations.[a] The evidence for this will not be reviewed here. In certain particulars the ores of this district differ from those found elsewhere in the valley, and this raises a question as to the applicability to them of the theories worked out from a study of the others. These differences are as follows:

(1) The antimony occurring in connection with the lead is found elsewhere in this region only in southwestern Arkansas, where the relations are entirely distinct from those normal to the Mississippi Valley. The lead ores of the valley are always particularly free from antimony, so much so as to class them as soft ores in distinction from the western or hard ores.

(2) The fact that the galena is slightly argentiferous is also distinctive. The amount of silver present is not great, but is none the less large when contrasted with that found elsewhere in the region. The following analyses made by Messrs. Chandler and Kimball were published some years ago by Whitney,[b] and indicate the amount of this difference.

Analyses of galena from southern Illinois.

	Troy ounces silver per 2,000 pounds lead.
Rosiclare, Ill	$9\frac{1}{2}$
Massac County, Ill	$1\frac{2}{5}$
Mineral Point, Wis	3
Rockville, Wis	$\frac{1}{8}$
Marsden lode (near Galena), Ill	$\frac{1}{14}$

The amount of silver is small and its occurrence seems irregular, but that it is ever present to the amount indicated is striking. H. A. Wheeler has recently discussed this point in connection with the occurrence near Fredericktown, Mo., and in Algonkian felsites of a narrow vein of nonargentiferous galena.[c] He argues from this that the neighboring lead deposits in the limestone were deposited by ascending waters of presumably deep-seated origin. If it prove gen-

[a] Preliminary report on lead and zinc deposits of the Ozark region: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 2, pp. 23–227.

[b] Whitney, J. D., Geol. Survey Illinois, vol. 1, 1866, pp. 188–189.

[c] Wheeler, H. A., Eng. and Min. Jour., March 31, 1904.

erally true that the galena of the older rocks in this region is nonargentiferous, this would seem to emphasize the unusual character of the conditions under which such deposits as those of southern Illinois originated and would point to the improbability of the whole of the material entering into the composition of the ore bodies being derived from the normal rocks of the region.

(3) The marked development of fluorite in connection with the lead and zinc is wholly exceptional for this region. In none of the other lead and zinc districts has this mineral ever been noted, despite its showy character; and in the Joplin district the country rock, so far as Mr. Steiger's analyses go, fails to show a trace of fluorine. While any negative evidence derived from country rock is not considered strong evidence, it is at least suggestive.

(4) The presence of numerous and important fault planes and the association of the ores with them are peculiarly characteristic of this district. While faulting is not absent elsewhere, and, indeed, is believed to have a high significance as regards the genesis of the Joplin ores, it is nowhere as important as here, and in none of the other districts do the ores so persistently follow the fault planes. In this particular the ore bodies found here are more like those of the Western States than like those of the Mississippi Valley generally.

(5) The presence of igneous rock in the vicinity of the ore bodies is, so far as known, wholly restricted to this particular district.

These various facts point to the conclusion that, while it would perhaps be possible to consider the lead and zinc found here as being in the same category with that found elsewhere in the Mississippi Valley, the probability is that either its source was unusual or the conditions under which it was concentrated were entirely different from those prevailing elsewhere. The most notable peculiarities in each particular seem connected with the presence in the district of igneous rock.

GANGUE MINERALS.

The gangue minerals associated with the ore bodies of this district are those common in the Mississippi Valley, with the exception of the fluorite. Calcite, quartz, and barite are found in all the districts, though not in equal amounts. There is a striking and peculiar absence of dolomite, which elsewhere is a constant associate of galena and blende. Whether this absence is due to the derivation of the ores from the immediately surrounding rocks, which are nonmagnesian, or from some entirely new source, or whether the Cambrian and Silurian rocks underlying the district are here nonmagnesian, is uncertain. The greatest peculiarity of the ore bodies, however, is the presence of large quantities of fluorite. This mineral is somewhat widely distributed, principally in metamorphic rocks. In the United States it occurs from Maine to Virginia in the Piedmont and Appalachian areas.[a] In the Western States it is not uncommonly found in small quantities in connection with metalliferous veins. In the Mississippi Valley it is exceedingly rare. At one or two localities in central Kentucky and Tennessee it occurs in nonmagnesian limestones. From Tennessee it is now being shipped. It is reported to occur in druses in the St. Louis limestone at St. Louis, and Mr. Ulrich has observed a few crystals in the Ste. Genevieve limestone at the type locality for that formation. With these exceptions it is not known to occur at any point in the valley, and it is entirely absent from all the lead and zinc deposits of the region, except those of this particular district and the small deposits in central Kentucky near Lexington.

Abroad the most important localities for the production of fluorspar are the north of England and certain Saxon mining localities in Germany. The English deposits occur in limestones of about the same age as those of southern Illinois, and in many particulars the occurrences are similar. This extends even to a close similarity in the dike rocks present in both districts. In Saxony the fluorspar occurs near Freiberg in veins and druses in gneisses, schists, and slates, cut by dikes of quartz-porphyry and by gabbro. It is associated with argentiferous galena, blende, stibnite, and many complex compounds not found in the Kentucky-Illinois district.[b]

Fluorine itself has been found in sea water, in boiler incrustations of ocean vessels,[c] and Dana found it in calcareous corals. It occurs in the bones of marine animals, and was found in small quantities in the manganese nodules brought up by the *Challenger* nets from a depth of 2,375 fathoms.[d]

From these notes it appears that fluorite may well be expected to occur in small quantity in limestones and other sedimentary rocks, but that its presence in unaltered limestones is very rare, and that the only important bodies of fluorite known and worked commercially are in limestones which have been intruded with igneous rock. Both Mr. Emmons and Mr. Tangier Smith have shown that the apparently unaltered limestones of this district contain small quantities of fluorine.

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[a] Dana, Mineralolog
y, 6th ed., 1892, p. 163.
[b] Von Cotta, B., Treatise on Ore Deposits (Prime translation), 1870, p. 98.
[c] Pumpelly, Raphael, Geol. Survey Kentucky, 2d ser., vol. 2, pt. 8, p. 46.
[d] Deep-sea deposits, Report *Challenger* Expedition, p. 421.

Mr. Smith's analyses, made by Mr. George Steiger, of the United States Geological Survey, are quoted below.

Analyses of limestone from Kentucky and Missouri.

	I.	II.	III.	IV.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
MgO	0.15	1.48	0.19	1.33
CaO	55.16	51.75	49.94	52.24
F	.04	.10	.10	None.
BaO	None.	None.	.02	None.
Organic matter	Trace.	([a])	----------	([a])

[a] Doubtful trace.

I. Ste. Genevieve limestone from near View, Ky.
II. Ste. Genevieve limestone from near Crider, Ky.
III. St. Louis limestone from Crittenden County, Ky.
IV. Limestone from Shoal Creek, southeast of Joplin, Mo.

While there is always doubt attaching to the origin of these minute quantities of material, and it is impossible to make sure that they do not represent secondarily-introduced material, it would seem that the limestone is at least a possible competent source of the fluorite.

As a constituent of igneous rocks fluorite is common. It enters into the composition of a number of widely disseminated minerals, including the common variety of apatite, certain micas, and topaz. Of these the first two named occur in unusual abundance in the dike rocks of this vicinity, though it is not certain that the particular minerals found here are fluorine bearing. Analyses of the freshest dike rock available, made in the Geological Survey laboratory by Mr. George Steiger, gave the following results:

Fluorine in analyses of dike rock of southern Illinois and Kentucky.

	Per cent.
Downey dike, Rosiclare, Ill	None.
Mix dike, Golconda, Ill	0.13
Hard dike, Marion, Ky	None.

It is of interest to recall in this connection the fact that in even the most altered of the igneous rocks the apatite, presumably the mineral carrying the largest amount of fluorine, is fresh and unaltered.

Fluorine has commonly been observed in connection with volcanic outbursts, and fluorite is one of the most common minerals connected with volcanic rocks. At Cripple Creek, Colorado, and many other western camps it is abundant in intrusive and extrusive rocks of Tertiary age.

So far, then, the igneous rocks form a very probable source of the fluorine, but the evidence that the material did actually come from them is weak. If it is of any such origin, it presumably was not segregated during the weathering of the rocks and, recalling the field evidence, there seems little connection between particular dikes and individual ore bodies.

PROCESS OF CONCENTRATION.

There are two broadly contrasted methods by which the present ore bodies may have been concentrated. The first is by the action of the normal meteoric waters of the region, which may here, as in other districts, have gathered the disseminated material from the country rocks into the veins. The second is by the action of heated waters, either originally meteoric or derived from the intruded igneous rock, or in part from each source. It is believed that the evidence points to heated waters having been the agency by which the ores were segregated and that they obtained an essential portion of their load from a large mass of lower-lying intruded rock, of which the dikes are the offshoots.

It has already been pointed out that the ore bodies show no sign of secondary enrichment, and apparently the surface waters now in the region can only operate to destroy rather than re-form the ore bodies. As compared with limestone, fluorite is relatively insoluble in cold water, though still more soluble than barite, which is very commonly concentrated by such waters. In the presence of an abundance of calcium carbonate in the surface waters mass action would demand that the waters largely exhaust their powers in working upon the country rock rather than the vein minerals. This seems to accord with the facts of the field, since the crystals of fluorspar in druses, which might be considered to represent reconcentration, are relatively rare, and, as has been seen, the sulphides, which are very delicate indices of the process of reconcentration, show no clear evidence of such action, but point rather to its absence. It is difficult to believe, therefore, that such waters have gathered minutely disseminated quantities of fluorite from the surrounding limestone and formed the veins as they now occur. It is also to be remembered that in other districts of commercial importance in the Mississippi Valley, where such waters have been shown to be effective, both the ores and the gangue differ in the important particulars already enumerated.

If it be held that the waters which formed the ores were heated waters, but that they derived their load from the St. Louis, Ste. Genevieve, and surrounding limestones, it may be pointed out that the normal tendency of heated waters rising along faulting fissures would undoubtedly be toward deposition and dissemination of material rather than toward its segregation. This would seem to indicate that the waters were loaded before reaching these horizons rather than the reverse, and would make the association of the fluorspar with the Ste. Genevieve a matter dependent upon the precipitating action of the latter rather than the reverse. This does not exclude the possibility of minor contributions to the veins from the surrounding country rock, though it may be pointed out that it is to the lower-lying Cambrian, Ordovician, and Silurian rocks that one would look for any considerable quantity of lead and zinc if the general analogy of the other districts in the Mississippi Valley be considered important. This was indicated in an earlier general paper on the lead and zinc deposits of the valley.[a] The published data then available prove to have been somewhat misleading, and the analogy is now believed to be less close than was suggested.

It is probable that the unusual quantity of apatite in the dike material, and to a less extent the large micas, indicate a magma in which fluorine was present, and that this fluorine was given off to the underground waters during the period of cooling and consolidation of the underlying mass of rock.

The association of the minerals and the common phenomena of marked silicification of the hanging wall are interpreted as indicating deposition from heated ascending solutions carrying fluosilicates of zinc, lead, copper, iron, barium, and calcium. These are believed to have been broken up and precipitated by descending cold waters, which possibly also furnished the sulphur to combine with the metals, though it is not improbable that sulphur was an original constituent of the rising solutions.

ECONOMIC IMPORTANCE AND FUTURE OF THE DISTRICT.

SOURCES AND USES OF FLUORSPAR.

The Kentucky-Illinois district is not only the main American source of fluorspar, but is the only one from which spar reaches the general market. Since 1882 the district has produced 260,000 tons of spar, having a total value of $1,521,029.

There are no data for determining the production of the Illinois mines separately. For many years they produced practically all the output. Recently the Kentucky mines have been developed, and now are producing more than those north of the Ohio. In the following table are given the output and value of fluorspar in the United States for 1902 and 1903, the figures being taken from Mineral Resources of the United States, 1903.

[a] Van Hise, C. R., and Bain, H. Foster, Lead and Zinc Deposits of the Mississippi Valley, U. S. A., read before the Institution of Mining Engineers, London, 1902.

Production of fluorspar in the United States in 1902 and 1903, by States.

State or Territory.	1902.		1903.	
	Quantity.	Value.	Quantity.	Value.
	Short tons.		*Short tons.*	
Arizona and Tennessee	628	$6,872	275	$2,037
Kentucky	29,030	143,410	30,835	153,960
Illinois	18,360	121,532	11,413	57,620
Total	48,018	271,814	42,523	213,617

The spar is shipped in part by the Illinois Central Railway and in part on the Ohio River. Prices are fixed by Pittsburg quotations, less freight and commissions. At Pittsburg the American spar comes into competition with English and German material imported through New York. The American mines supply the western trade and about half of the Pittsburg demand. The importers control the eastern trade and determine prices at Pittsburg.

There are three main uses for fluorspar. The highest grade, running less than 1 per cent of silica, and white in color, is sold either ground or in lump, for use in the enameling, chemical, and glass trades. It brings the highest price, recent New York quotations being $8 to $10 a ton unground and $11.50 to $13.50 ground. The price at the western mines is about a dollar less per ton than the New York price, to offset differences in freight rates to competing territory. There is a limited market for this grade of spar, and it probably would not be extended much even at lower prices, since the amount used is determined by conditions wholly outside the cost of the spar. On the other hand, it is a question whether even a higher price could not well be obtained for this grade.

The second grade of spar is used in steel making, and is sold unground as lump or gravel. It includes colored spar and may run as high as 4 per cent silica, though mostly sold with a 3 per cent guaranty. It is demanded for open-hearth work because of the great fluidity which it gives the slag. At present at least 20,000 tons are used annually in this work, at a cost to the user of from $6 to $8 per ton. Importers have now a slight advantage in the Pittsburg market on this grade of ore. It is probable that when a steady supply of fluorspar at the present or slightly lower prices can be guaranteed in steel-making centers the market can rapidly be expanded, and this affords the most hopeful outlook for spar producers. In many ways fluorspar has advantages over other fluxing materials now used.

The lowest grade of spar, including all running over 4 per cent silica, or spar mixed with calcite, can be used in foundry work, and while the price is and always must be low, there is possible an almost unlimited market. It is probable that systematic efforts to introduce the low-grade material into this trade would be highly beneficial to the industry as a whole. While there would be little profit in mining foundry spar, it would allow the production of No. 2 spar in quantity and at prices demanded by steel makers. With the exhaustion of bessemer grades of iron there will be an increased demand for fluorspar, though even now demand is ahead of supply for steel-making grades. Since at any increase in prices it becomes cheaper to use less efficient fluxes, it follows that while the output can be increased prices probably can not be much changed.

With these facts in mind it is seen that the fluorspar mines of the Kentucky-Illinois district will have for many years a large and growing market to supply. Their only competitors are the importers, and competition with them is mainly a matter of transportation costs. It is not certain that this competition will always be keen as now, since foreign producers have an important and growing trade outside the United States. Mines in the Rocky Mountain region and other Western States can not be expected to disturb the fluorspar market. Such fluorspar as occurs in connection with the ores of that region will probably always have a sufficient local market. The quantity present is not important in any western district yet described, and local smelters make an allowance for lime, which, entirely aside from the cost of transportation, is likely to prevent shipments of spar to the East.

FUTURE PRODUCTION.

The opinion already given as to the genesis of the ores indicates the belief of the author that they will prove permanent in depth to horizons below which they can not be worked because of increasing cost. The low value of the ore places a somewhat severe limitation upon the future depth of mining, and it is possible that this feature alone will in most situations preclude work to a depth greater than 1,000 feet. It is also possible that changes in the character of the country rock may influence disastrously the size and character of the ore bodies. It has been impossible to get any data on the character of the rock which occurs in this area beneath the Ohio shale. Normally a considerable thickness of dolomites and limestones would be expected to be present, but they may be absent, and it is not impossible that the supposed igneous mass occurs below the shale. In all the mines so far located in Illinois the shale lies 500 to 1,000 feet or more below present workings.

There are no data at hand for predictions as to change in character and richness of the ores with depth. Changes in the country rock may be expected to have an important influence, and so far the Ste. Genevieve and other Chester formations have proved most favorable. In the Illinois mines nothing suggesting rearrangement of the ores and secondary enrichment coincident with degradation of the surface was observed. At the Empire mine carbonates gave place to sulphides within the first hundred feet, and below that level no change was observed.

In the Kentucky mines a number of deposits of first-grade fluorspar are said to have given out or lost grade with depth. The significance of this fact is uncertain. Whether it is to be correlated with change in wall rock, or indicates only the usual irregular distribution of ore in depth as well as along a vein, is not clear. In no case was development carried on to determine whether the ore would come in again at lower levels. If it be true that the diminution in size of the ore bodies was related to topography rather than stratigraphy, it can only be stated that the best obtainable evidence in Illinois does not warrant the belief that the rule is universal. The character and size of the ore bodies certainly do not bear any constant relation to the present land surface.

In the light of these facts and the wide prospecting which has been going on in the district, little encouragement is offered to the hope of finding important bodies of lead and zinc on the northern side, at least, of the river, but it is believed that the fluorspar deposits afford the basis for an important and growing industry.

GUIDES FOR PROSPECTING.

Fluorite is such a distinctive and easily recognized mineral that it is not often overlooked. Its presence, or that of galena or blende, is usually sufficient to warrant careful prospecting for an ore body. Calcite, on the other hand, is so common that its presence is not often significant. The presence of faulting fissures may usually be recognized by the fact that rocks of unlike character are brought into contact along straight lines or by the presence of the quartzite reefs already discussed. To a less extent any disturbance of the strata is in this district probably connected with faulting. When a body of spar has been formed along a fault contact it should first be prospected by a few shallow shafts along the strike to determine its extent. That proving favorable, regular sinking may be undertaken with some confidence. In general it is to be remembered that the material is of low value and expensive installations are not warranted. While some lead and zinc may be saved in mining the spar, it is not thought that they are generally of first importance.

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