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DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

THE LEAD, ZINC, AND FLUORSPAR DEPOSITS OF WESTERN KENTUCKY

BY

E. O. ULRICH and W. S. TANGIER SMITH

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., June 8, 1904.

SIR: I have the honor to transmit herewith the manuscript of a report on "The lead, zinc, and fluorspar deposits of western Kentucky," by E. O. Ulrich and W. S. Tangier Smith, and to recommend its publication as a professional paper. Field work was carried on during the summer of 1902 under cooperative agreement with the State Survey of Kentucky, and a brief summary of the results was published in Bulletin No. 213, "Contributions to Economic Geology for 1902." Prior to the investigation in 1902, however, Mr. Ulrich spent the greater part of two years (1889 and 1890) in the same territory, while attached to the Geological Survey of Kentucky. The field was again visited by Mr. Ulrich in 1903, and the results of all these studies are brought together in this paper. The district is one of peculiar interest, having a complicated fault structure and unique lithologic and mineralogic associations. While the report contains much matter of purely scientific interest, it has been prepared with especial reference to the needs of the mining industry, and in such form that its conclusions should be of great practical benefit in developing the industry in this district.

Very respectfully,

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

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

LEAD, ZINC, AND FLUORSPAR DEPOSITS OF WESTERN KENTUCKY.

Part I.—GEOLOGY AND GENERAL RELATIONS.

By E. O. ULRICH.

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GENERALIZED GEOLOGIC MAP OF THE KENTUCKY-ILLINOIS FLUORSPAR DISTRICT

Scale

0 5 10 20 30 miles

1904

Dikes | Devonian | Mississippian | Pennsylvanian | Cretaceous and Tertiary

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THE LEAD, ZINC, AND FLUORSPAR DEPOSITS OF WESTERN KENTUCKY.

By E. O. Ulrich and W. S. Tangier Smith.

PART I.—GEOLOGY AND GENERAL RELATIONS.

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CHAPTER I.

INTRODUCTION.

LOCATION AND GENERAL FEATURES OF THE DISTRICT.

Geography and distinctive characters.—The fluorspar, lead, and zinc deposits that were the subject of the investigations reported in this paper are situated in Livingston, Crittenden, and Caldwell, and adjacent portions of Christian, Trigg, and Lyon counties, in western Kentucky, and in the counties immediately across the Ohio River, in the extreme southern portion of Illinois. This area, constituting what may be aptly termed the Kentucky-Illinois fluorite district, contains also lead, zinc, and other minerals in subordinate quantities and values. It is usually considered a minor division of the lead and zinc districts of the Mississippi Valley, but is in some ways rather sharply distinguished from the other districts of the valley. It differs from the other districts chiefly in the following respects: (1) In the presence of basic igneous dikes; (2) in the abundance of fluorite and its almost constant association with the lead and zinc ores; and (3) in the mode of occurrence of the ores, which are found principally in true fissure veins that have resulted from fracturing and subsequent faulting. In the other districts the lead and zinc are of primary importance, while in this region the igneous dikes and the fluorite are the primary or predominant features and the lead and zinc are only incidental.

Topography.—The surface of the area is generally rolling and more or less irregularly broken. Some comparatively level uplands occur, but they are always of rather small extent. The irregularities are due primarily to conditions resulting from the abundant faulting to which the region has been subjected. Of these conditions the principal one is that beds with very different powers of resistance to erosion were brought to the same level by faulting. Among the less important factors that have locally determined or modified the topography is the underground-drainage system that prevails in the heavier limestone formations—a system that is in some places conspicuous in its processes and results.

As a further result of the faulting it is found that none of the various topographic types that would have been produced under more normal conditions could attain more than very limited local development here. Faulting has also caused more frequent combinations of types than occur in unfaulted areas that expose the same or similar geologic formations. An interesting fact in this connection is that most of the downthrown blocks, which at first must have formed more or less sharply defined depressions, now form the most prominent hills and ridges. These therefore afford excellent examples of the varying effects of erosive agencies on rocks of different capacities to resist decomposition and removal.

Although the superficial inequalities produced by the faulting of the region may never have been entirely obliterated, yet it is believed that the whole area was at one time reduced to a nearly level or only gently undulating plain. This plain probably extended over a large part of the Ohio basin and, when formed, occupied a position near sea level. Subsequent elevation caused increased, and, according to the kind of rock encountered, differential erosion, the streams gradually cutting their channels and dissecting the plain until now only small remnants of it are left in the highest knobs. These remnants may be considered as outliers and projections from the highland rim that incloses the district on the north and east sides.

EXPLORATION AND DEVELOPMENT.

Literature.—The earliest available published records of the occurrence of fluorspar and its associated mineral galena in the Kentucky-Illinois fluorite district appeared in the first, second, and third volumes of the American Journal of Science, published in 1818, 1820, and 1821. These notices gave brief descriptions of specimens of fluorspar obtained from some unknown locality near Shawneetown, Ill.

In 1819[a] Henry R. Schoolcraft described the occurrence of fluate of lime in association with galena, blende, and pyrites about 3 miles back of Cave in Rock, on the Ohio River. He found it at abandoned diggings embedded in stiff red clay resting on oolitic limestone, and in a second description, published two years after,[b] speaks of it as the "detritus of preexisting veins." In the second edition of Cleveland's Mineralogy, published in 1822, other localities in southern Illinois are men-

[a] A View of the Lead Mines of Missouri, by Henry R. Schoolcraft, New York, p. 191.

[b] Travels in the Central Portions of the Mississippi Valley, by Henry R. Schoolcraft, U. S. I. A., New York, 1825, pp 189-196.

tioned where these minerals had been found "in the alluvial soil and sometimes in veins in limestones."

In 1846[a] D. D. Owen published a paper on lead deposits in southern Illinois.

In 1852[b] Prof. George J. Brush published a brief notice of his visit to the mines near Rosiclare, Ill. He described the galena as argentiferous, his specimens having yielded 4 ounces of silver to the ton, and says that "an immense amount of remarkably fine quality of fluorspar could be obtained from these veins."

The preceding notices refer only to occurrences of fluorspar and galena on the north side of the Ohio River. Others mentioning galena only were published during the same period, but on account of the wide distribution of that mineral are not deemed of sufficient interest to be noted here. For the Kentucky side of the district the earliest recorded geologic investigations in which the presence of fluorite and, for the first time in the district, of blende, was recognized seem to be those carried on in 1854-1857, during the progress of the first geological survey of the State of Kentucky, by David Dale Owen and his assistant, Sidney S. Lyon. These investigations were merely reconnaissances incidental to the determination of the western margin of the western Kentucky coal field, which extends into the territory that forms the subject of the present report. The results of these casual examinations are embodied in brief notes and references which, with chemical analyses (made chiefly by Robert Peter) of limestones, iron ores, and other materials from the region, are scattered through the four reports of Owen's survey of Kentucky. The notes having principal interest in this connection occur on pages 86 to 88 of Volume I, Geological Survey in Kentucky, 1856. Here Owen speaks first of the deposits of iron ore, which he found to extend in a direction ranging from N. 18° to 20° E., and which he was inclined to believe "had their origin in fissures or lines of fracture of determinate course and of large dimensions, whence an inexhaustible supply may be obtained if ever the superficial masses fail."

Concerning the metalliferous veins he says:

"Immense veins of fluorspar, sometimes 50 feet in width, traverse the southwestern belt of the sub-Carboniferous formation. Two systems of veins are recognizable; one set having a bearing N. 18° to 21° E., and cross courses running N. 54° to 58° E.; the former of these systems has, therefore, the same course as the veins of iron ore previously noticed. Both systems of veins afford sulphuret of lead; and the former contains sulphuret of zinc, and probably also sulphuret of antimony. * * *

"It is important to observe * * * that the lead mines of Derbyshire are in a limestone underlying the Millstone grit, as in Crittenden County, and that the sulphuret of lead is accompanied by the same veinstones. * * *

"As yet I have not observed any trap or toadstone, either cutting the sub-Carboniferous limestones of Kentucky in dikes or insinuated horizontally into the

[a] Quart. Jour. Geol. Soc., vol. 6, p. 438.

[b] Am. Jour. Sci., 2d ser., vol. 14, July, 1852, p. 112.

stratification of the beds. The presence of such igneous rocks in the Derbyshire lead region is the only important traceable difference in the otherwise strong analogy existing between the two formations. * * *

"The richest argentiferous galenas of this State which we have tested up to this time, for the percentage of silver which they contain, have yielded about one part in a thousand, or 32 ounces to the ton."

Of Owen's observations on the lead and zinc district of western Kentucky, only his comparison with the Derbyshire deposits, which perhaps are closer than he knew, and his recognition that the deposits occur in fissure veins, have proved to be of permanent value. His statement concerning the highly argentiferous character of the galena doubtless rests upon error. According to the best evidence now available the maximum amount of silver to the ton of galena is probably less than 5 ounces, and as a rule it seems not to exceed 2 ounces.

A. H. Worthen, in 1866,[a] published a report on the geology of Hardin County, Ill., embracing the results of examinations made by himself and Henry Engelmann and a report by Dr. J. G. Norwood on the Rosiclare lead mines. Norwood's investigations were made several years prior to 1858, probably about the same time that Owen and Lyon were at work in western Kentucky. From these reports it appears that the first discovery near Rosiclare of a vein containing galena and fluorspar was made in 1839 in a well on the Anderson property at Fairview. In 1841 the same vein, apparently, was found in digging another well, but, as in the first instance, little attention was paid to it. The first attempt at mining was begun in 1842–43, on a deposit discovered about two-thirds of a mile northwest of the town of Rosiclare. Desultory operations continued on this, the Pell (or Rosiclare) vein till the close of 1849. In the meantime some work was done on the Anderson or Good Hope (now Mullin's) vein, some 350 yards west of the Harrison diggings on the Rosiclare vein, but all operations in the region were suspended in or before 1850. Doctor Norwood's report mentions four veins in the vicinity of Rosiclare, bearing from N. 30° to N. 35° E., and briefly describes the work done on each. In conclusion, he advises "the prosecution of the work, provided a sufficient amount of capital can be invested to insure the veins being worked in a proper manner." Worthen adds certain details and also notes on other galena and fluorspar prospects in Hardin County. He regards the veins as "probably *gash veins*, formed by the shrinkage of the strata, and consequently as confined to the group or set of strata in which they appear; but as this group may be as much as 300 or 400 feet thick in this county, it affords an ample field for mining operations." An analysis of the galena by Prof. J. D. Whitney is said to have afforded silver "amounting to as much as 9 ounces to the ton of ore."

The next study of which we have any published account was made by Charles

[a] Geol. Survey Illinois, vol. 1, 1866, pp. 350–375.

J. Norwood in 1874.[a] His report is entitled "Report of a reconnaissance in the lead region of Livingston, Crittenden, and Caldwell counties, including a sketch of their general wealth." The more important conclusions reached by Norwood are contained in the following quotations from his report:

"There appear to be two classes of veins in the lead region of southwestern Kentucky, both deriving their lead from the same source. In one the lead occupies the upper part of a true vein, as is the case at the Royal mines, Livingston County, and in the other the metal fills incidental cracks, fissures, and cavities in the limestone. This latter class is not so persistent in longitudinal distance as the former, nor is there any definite calculation to be made as to the depth to which the lead extends. But when at all rich in lead, they seem to be more valuable, in proportion to their extent, than the first class, in that the lead is more concentrated."

Speaking of the Columbia mines he says:

"My opinion is, however, that the lead does not occur in true vein fissures, as is generally supposed. We may reasonably suppose cavities and long fissures, extending in various directions, to have existed in the limestone previous to the formation of the lead deposits as they now exist. There is scarcely any other way to account for the fissures, and, consequently, to determine the nature of the deposits, than to suppose that they are due in part to shrinkage of the strata and in part to the action of water in washing out cavities and cutting channels through the limestones, as the rocks in which the greater portion of the lead occurs are nearly horizontal, showing no evidence of disturbance. These fissures may extend for a mile or more or for only a few hundred yards, and, similar to caverns, have a general though irregular course. From the manner in which the lead has been obtained at these mines I am induced to believe that the greater portion, if not all of it, associated with fluorspar, calc spar, and blende, occupies just such irregular fissures and openings in the limestone, forming what may be termed segregated veins and deposits. This would lead to the conclusion that the galena was originally inclosed in the overlying rocks, which have wasted away and allowed the lead to be precipitated in solution, filling the cracks, cavities, and fissures in the rocks below."

While a member of the Geological Survey of Kentucky the writer made an extended investigation of the geology and mineral resources of the field under consideration. This investigation began in the fall of 1888 and continued through the greater parts of the following two years. Unfortunately the survey was discontinued on account of lack of funds before the reports on Caldwell and Crittenden counties, which were nearly completed, could be submitted for publication. That the people chiefly interested might have some benefit from the work, arrangements were perfected between the management of the Crittenden Press, of Marion, Ky., and the writer, in accordance with which that newspaper published, December 18, 1890, a map of Crittenden County and a brief report on the geologic formations and the veins and mineral deposits found in the district. Several editions of this

[a] Geol. Survey Kentucky, 2d ser., vol. 1, 1876, pp. 449–493.

map and report have been issued since that date. The map located nearly all of the principal fault lines along and in which the mineral deposits occur, and proved particularly useful to prospectors in Crittenden and Livingston counties.

In 1893 S. F. Emmons published an important paper on fluorspar deposits of southern Illinois.[a] Beginning with a brief history of mining in the region, the paper then devotes nine pages to a description of the geology of the region and a résumé of the opinions of previous observers concerning the character, distribution, and origin of the deposits of lead and associated minerals in the Mississippi Valley. In the remaining eleven pages the author briefly states the results of his own investigations in the region and mines around Rosiclare under the following subheads: "Surface features," "Mines," "Underground development," "Continuity of fissures," "Manner of formation of deposits," and "Origin of vein materials." All of the original observations in this paper are interesting and most of them are probably of permanent value. The recognition of the breaking up of the general line of fracture en echelon is a discovery of some importance in the economic development of the whole district. The observations of this writer, especially those of a more theoretic nature, are discussed in some detail by Doctor Smith.

The above list and digest of the printed record of the discovery of minerals and the mining operations in this district is probably incomplete, yet it is believed to contain all papers or books having either scientific or economic value in the development of the district. Subsequent to 1893, and more especially during the past five years, numerous relatively unimportant newspaper articles treating of the district as a whole or in part and a few detailed descriptions of certain mines in Kentucky, notably the Old Jim,[b] have appeared. Some of these doubtless exerted considerable influence in the way of interesting capital, but they are not of a kind to require notice here.

Mining.—Lead was obtained from this region in a primitive manner by the early settlers, and most of the earlier mining was for this mineral, though the Columbia mine and the Royal mines were first worked for silver. The first fluorspar shipped was from the Yandell mine, about 1873 (?), and in the following year fluorspar from the Memphis mine was put on the market. Lack of transportation facilities, which had resulted in the abandonment of lead mining as unprofitable on the lowering of the market value of that mineral, soon caused the interest in the working of the fluorspar deposits also to abate, and it is only within the last five or six years that activity has been renewed. The years 1900, 1901, and 1902 saw the organization of the majority of the companies now working in the district. Many of the old mines have been reopened and extended, and more or less system-

[a] Trans. Am. Inst. Min. Eng., vol. 21, pp. 31-53.

[b] Eng. and Min. Jour., vol. 74, 1902, pp. 413-414.

atic prospecting is being done. Further details of the past and present operations at some of the more important mines are given by Doctor Smith in Chapter III of Part II.

Recent geologic work in the district.—During the summer and fall of 1902 a party consisting of the writer and Dr. W. S. Tangier Smith, with two field assistants, Messrs. A. F. Crider and F. Julius Fohs, was engaged in an extended investigation of the fluorite, zinc, and lead deposits of western Kentucky, and, in less detail, of those occurring on the north side of the Ohio River in Pope and Hardin counties, Ill. This work was carried on under a plan of cooperation between the United States Geological Survey and the State of Kentucky. In July, 1903, the writer again visited the Illinois side of the district, in company with Mr. H. Foster Bain, who is preparing a similar report on the Illinois mines, and then crossing over into Kentucky spent a final week there in the determination of doubtful points.

Prior to these investigations by members of the Federal Survey, the writer spent the greater part of two years (1889 and 1890), while attached to the Geological Survey of Kentucky, in the same territory. By combining the results of these disconnected studies it is now possible to describe in considerable detail the ore deposits and the systems of fractures and faults in and along which they occur, as well as the geologic formations and their geographic distribution. In the absence of satisfactory maps, especially topographic maps, some inaccuracies of delineation and description are to be expected. It is, however, believed that these imperfections are confined to points of minor consequence, particularly to a lack of detail in presentation, and that they include only a small proportion of errors of observation and interpretation of important facts.

It is a pleasant duty to acknowledge that during the course of the writer's recent and earlier work he has met with hearty encouragement from all persons interested in the development of the district. To many of them he is indebted for material assistance and for information that could not have been procured except through their kindness.

CHAPTER II.

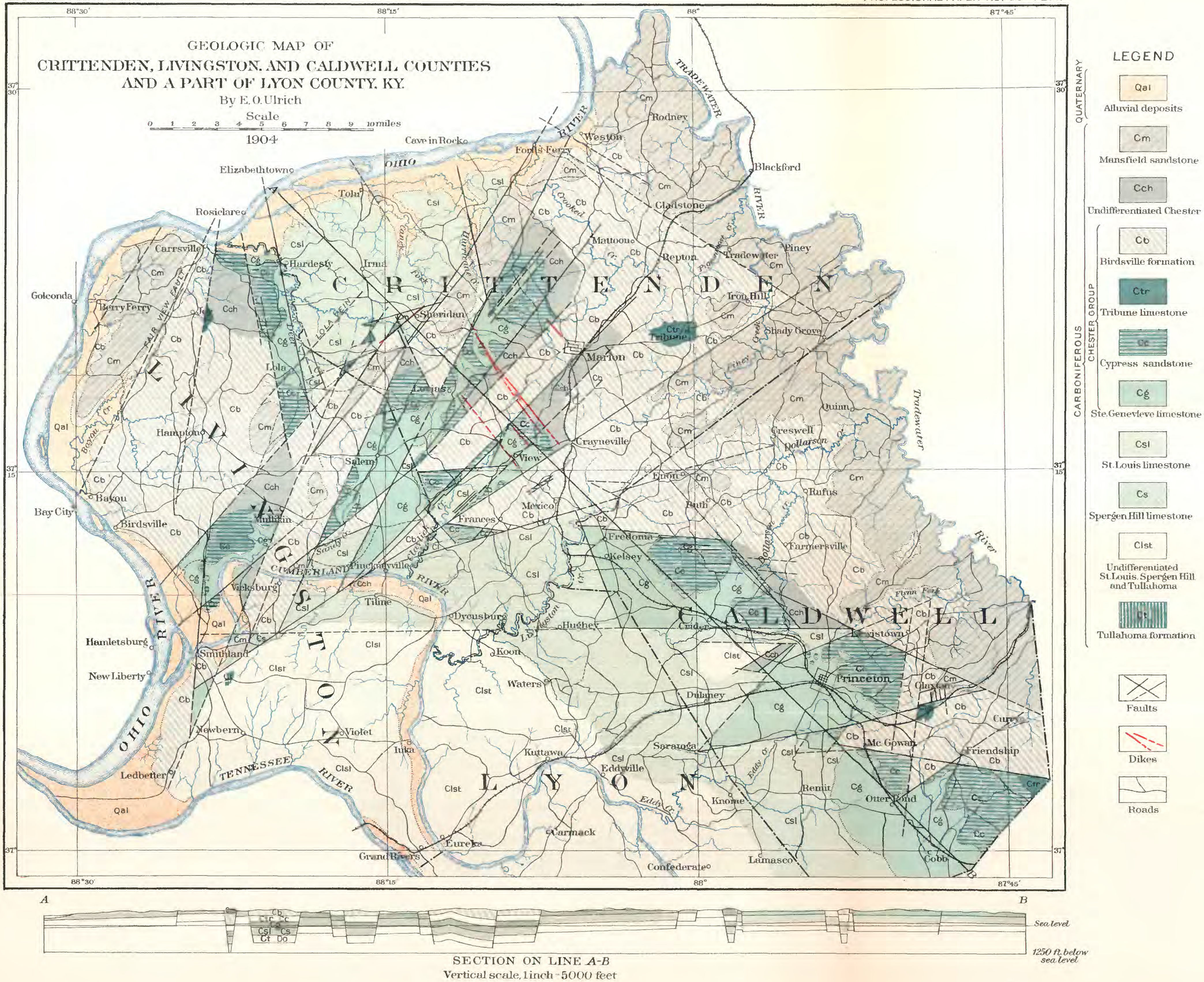
STRATIGRAPHIC GEOLOGY.

GENERAL STATEMENT.

Although based chiefly on the fuller investigations carried on in the southern half of the Kentucky-Illinois lead and zinc district, the following description of the stratigraphic geology applies also, though in less detail, to Hardin and Pope counties, Ill. These two counties embrace the more important parts of the northern half of the district.

No complete section of any of the Mississippian formations, save in the Tullahoma outcrop, on the south side of the Ohio shale areas, in Hardin County, Ill., has been observed within the region that forms the subject of this report. This is due partly to lack of exposures, but more especially to the extremely faulted character of the area. Owing to this faulting, the areal distribution of the formations is very irregular and patchy. By means of careful paleontologic and lithologic comparisons, however, it has been possible to determine the sequence of the disconnected beds and thus to construct columnar sections that, it is believed, will serve the purposes of fairly accurate stratigraphic work. The results of the stratigraphic investigations in the district have been checked with published sections of the formations represented in neighboring parts of Illinois, Kentucky, and Missouri, but more particularly with the writer's own studies of the Mississippian rocks in the same areas and elsewhere.

No rocks older than Carboniferous outcrop on the southern side of the Ohio River in this district. On the Illinois side, however, Devonian black shales, doubtless representing the Ohio shale of Ohio, Indiana, and eastern Kentucky, and the equivalent Chattanooga shale of eastern and western Tennessee and Alabama, come to the surface in two small areas, apparently at the top of a dome-like stratigraphic elevation near the middle of the western fourth of Hardin County. Encircling these Devonian shales are rough hills, composed principally of siliceous shales and limestones, with very abundant layers of chert belonging to the Tullahoma formation, which here, as in western and middle Tennessee, constitutes the basal division of the Mississippian series of rocks. The Tullahoma formation is the oldest of the rocks outcropping in the Kentucky counties of the district, but even this formation has been definitely recognized at only a few points in the territory covered by this report.



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The succeeding group of rocks, for which the new name of Meramec group is proposed, constitutes the surface formation over several large and many smaller areas, all together aggregating nearly one-third the area of the entire district. In previous reports the rocks of this group have generally been correlated either as strictly equivalent to the St. Louis limestone or as equivalent to only part of it; but, as was shown by a study of the rocks in the vicinity of St. Louis, Mo., and corresponding beds elsewhere, the common broad conception of the St. Louis is based on faulty correlation and an unjustifiable downward extension of the limits originally assigned to that limestone.

Following the St. Louis limestone, which is the upper member of the Meramec group, came the first deposits—generally oolitic limestones—laid down in the greatly restricted sea with which the Chester age began. These earliest deposits of a group of rocks that subsequently attained wide geographic distribution form the Ste. Genevieve limestone, a formation described by Shumard many years ago from exposures at Ste. Genevieve, Mo.

The second formation of the Chester group is a sandstone, usually massive and sometimes divided into an upper and lower member by a thin limestone. To this, the "Ferruginous sandstone" of Swallow, have since been given several geographic names, the oldest of which, Cypress sandstone, of Henry Engelmann, is here adopted. Like the Ste. Genevieve, it also is restricted geographically when compared with the succeeding formations of the group.

The third formation of the Chester is again a limestone, to which the new name Tribune limestone is applied. So far as geographical distribution, persistence of lithologic characters, and volume are concerned, it is the principal limestone of the group. It forms a recognizable part of the stratigraphic column in most areas in which the Chester group has been found. In the Mississippi and lower Ohio valleys the Tribune limestone is a well-developed lithologic unit, with heavy sandstones beneath and mostly arenaceous and shaly rocks above. Along the edges of the Cumberland Plateau, however, it is not easily distinguished from calcareous beds that are equivalent to the overlying Birdsville formation.

The fourth formation of the Chester group, and the last of the Mississippian series, is a locally important but extremely variable succession of sandstones, shales, and limestones, for which the name Birdsville formation is proposed. The top of the formation in particular varies greatly in different sections, some containing at least 100 feet of strata that are lacking in others. This variation at the top doubtless is due mainly to erosion to which the surface was subjected prior to the deposition of the next succeeding strata, but also, no doubt, to shoaling and consequent cessation of deposition locally indicated in the final stages of the group.

Except possible small outliers of true Coal Measures near the Tradewater River, in Crittenden County, Ky., the highest Paleozoic formation in the district is a variable, generally coarse, and often conglomeratic sandstone of Pottsville age, for which the name Mansfield sandstone, used in recent reports of the Indiana Geological Survey, is adopted.

TABLE OF FORMATIONS.

The following table shows the stratigraphic relations and the equivalents of the Paleozoic rocks of the district:

Table of formations in the Kentucky-Illinois fluorite district.

System	Series		Group	Names of formations and members used in this work.		Synonyms and equivalent formations in the Mississippi and Lower Ohio valleys.[a]	
Carboniferous.	Pennsylvanian.		Potts-ville group.	Mansfield sandstone.		Mansfield sandstone of Indiana. Coal Measures conglomerate of western Kentucky.	
Carboniferous.	Mississippian.	Tennesseean.	Chester group.	Kaskaskia limestone.	Birdsville formation.	Kaskaskia limestone of Hall. Chester limestone of authors. Huron formation of recent Indiana reports is same as Birdsville formation.	
					Tribune limestone.		
				Cypress sandstone.		Aux Vases sandstone of Keyes. Probably also Big Clifty sandstone of Norwood.	
				Ste. Genevieve limestone.	Ohara limestone.	Two upper members referred to as lower Chester by Worthen and Engelmann. Entire formation referred to as St. Louis by Norwood.	
					Rosiclare sandstone.		
					Fredonia oolitic limestone.		
			Méramec group.	St. Louis limestone.		St. Louis limestone of most authors, but not of Engelmann, Shumard, and Swallow, who do not include two lower formations in the St. Louis limestone. The two upper formations equal, respectively, the Mitchell limestone and the Bedford oolitic limestone of recent Indiana reports.	
				Spergen limestone.			
				Warsaw formation—*lacking*.			
		Waverlyan.	Osage group.	Tullahoma formation.		Keokuk limestone.	Harrodsburg limestone (typical) and Knobstone of Indiana.
						Burlington limestone.	
			Kinder-hook group.			Various formations of the Kinderhook group.	
Devonian.			Chemung group.	Ohio shale.		New Albany shale of Indiana reports. Chattanooga shale. Grassy Creek shale of Keyes.	

[a] The matter in this column is generalized and incomplete. It will be given in greater detail in a work on the Paleozoic section in the Mississippi Valley soon to be published by the writer.

The classification of the Mississippian formations in the above table differs in several respects from any heretofore published. Full arguments favoring the innovations will be presented in a work on the Paleozoic section in the Mississippi Valley, now being prepared for publication. This work will contain also a discussion of all the broader stratigraphic problems, so that the following description of the formations embraces little matter that is not required to show their strictly local characteristics.

DEVONIAN.

OHIO SHALE.

This is a black or dark-gray fissile shale that comes to the surface in two small, irregular, basin-like areas in the western part of Hardin County, Ill. These two areas occur apparently at the summit of a single, dome-like elevation of the strata, the separation of the shale outcrops, if there are not really two subordinate summits, being the result of incomplete erosion, which left a ridge or divide composed of the rocks of the next higher formation between them. In the western of these areas the shale is exposed at short intervals, aggregating perhaps a half mile, along Hicks Branch of Grand Pierre Creek. In these exposures it seems as a rule to dip strongly, but the direction of the dip is so variable and the exposures are so limited that the total thickness of shales brought to the surface can not easily be estimated. According to Worthen and Engelmann[a] "the entire exposure does not exceed 20 or 25 feet in thickness," but Mr. H. F. Bain and the writer, who visited the locality together, estimated the thickness at not less than 50 feet and as possibly more than 100 feet.

At the western edge of the outcrop a layer was observed that is regarded as representing the one commonly found at the top of the formation in middle Tennessee.[b] It is only a few inches thick, contains nodular masses, and a variable quantity of grains of glauconite. The latter impart a more or less distinct greenish tint to the layer. Next above it come gray shales. No fossils were observed.

Although there is little besides stratigraphic position and lithologic characters on which to base the reference of this black shale to the Ohio formation, it is so referred with the utmost confidence. In every feature this Hardin County shale is practically identical with many of nearly a hundred exposures of this formation examined by the writer in Kentucky, Tennessee, and Ohio. From Lake Erie southward to northern Georgia and westward to this district the Ohio shale is remarkably constant in its lithologic characters. Despite this constancy the formation has received a number of names. The name Ohio shale, proposed by Andrews,[c] the oldest of the geographic names applied to this formation, is here adopted.

[a] Geol. Survey Illinois, vol. 1, 1886, p. 352.
[b] Description of the Columbia quadrangle: Geological Atlas U. S., folio 95, U. S. Geol. Survey, 1903.
[c] Geol. Survey Ohio, Rept. Prog. for 1869, p. 62.

CARBONIFEROUS.

TULLAHOMA FORMATION.

Lithologic characters.—The Tullahoma formation in this district is at the bottom a gray, clayey shale, that farther upward gradually includes more and more siliceous and calcareous matter until, from about the middle of the formation upward, it is a highly siliceous and more or less earthy limestone. In exposures of its lower half or two-thirds the silica is contained chiefly in plates of often flinty chert, averaging about 4 inches in thickness, separated by from 2 inches to several feet of shales. By dividing the total thickness—from 200 to 250 feet—observed along Hicks Branch in Hardin County, Ill., into 50-foot intervals, the change in lithologic character may be expressed as follows: 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 alternating limestone and chert bands 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 proportionally rather less abundant and inclined to form flattened nodules instead of even plates. At the top there are 25 feet or more very slightly cherty, light-colored, massive or laminated limestone, containing fenestellid Bryozoa. These probably pass into semioolitic limestones.

The light-colored, subgranular, and only very slightly cherty limestones observed at the top of the formation in Hardin County, Ill., do not strictly belong to the Tullahoma. As understood by the writer, they occur above the unconformity separating the Tullahoma from the formations of the succeeding Meramec group, and should therefore be referred to the latter group. However, in mapping the area in Hardin County containing the Ohio shale and Tullahoma formation, Mr. Bain found it convenient to draw the basal line of the overlying formation at the horizon of the first appearance here of a common and easily recognized genus of corals (*Lonsdaleia* or *Lithostrotion*), and to refer these earlier limestones of the Meramec group to the underlying extremely cherty and shaly formation, which alone should bear the name Tullahoma. Had the upper limit of the Tullahoma chert been drawn also, the interval between it and the fossiliferous chert of the St. Louis limestone above would have corresponded with the Spergen oolitic limestone, which in this area forms the base of the Meramec group. In the proposed final mapping of the area the lower line should be traversed and the Spergen limestone eliminated from the area of the Tullahoma as now mapped.

The topographic aspect of the typical Tullahoma is extremely rugged. The undecomposed stratified rocks themselves are but rarely seen, having been observed only in the beds of the streams that cut through the rims of the small areas of Ohio shale in the western part of Hardin County. Generally the surface of the ground is covered with blocks of dense chert. The residual clay containing the liberated chert is commonly of a yellowish-gray color, sometimes with a tinge of red, but the red is never so pronounced as in the residual clays of the overlying cherty members of the St. Louis and Ste. Genevieve limestones. As to the loose blocks of Tullahoma chert, they may generally be distinguished by their brick-like form, showing as a rule quite clearly that they are fragments of even plates and not of rounded nodules, like those characterizing the St. Louis. In certain parts of the Ste. Genevieve limestone plates of chert occur also, but in this case the chert is nearly always porous.

Occasionally the layers of limestone and apparently the shale as well are entirely decomposed in situ, exposures in such cases appearing as generally yellowish clay seams, often gritty, alternating with thinner and thicker layers of dense chert. Such an exposure occurs opposite the mouth of the Western Tube Company's fire-clay mine near Smithland. In other cases, notably in the Tullahoma outcrop, 3 miles west of Princeton, the whole of the decomposed siliceous mass has the appearance of a homogeneous bed of tripoli-like material.

Fossils occur so rarely in this formation that to call it barren would fall little short of strict truth. But their very absence gives us one of the best means for discriminating between similarly chert-covered areas of this formation and the St. Louis. In the latter a search of only a few minutes will rarely fail to be rewarded by the discovery of at least a few fossils.

Outcrops.—The largest and most satisfactory outcrop of this formation in the Kentucky-Illinois district forms a rim of hills inclosing the two Ohio shale valleys in the western part of Hardin County, Ill. So far as known the formation does not reach the surface at any other point within this and the adjoining county of Pope, in Illinois. On the south side of the Ohio River there are several outcrops within the counties embraced in the area mapped, but in the limited time that could be devoted to the work it was not possible to distinguish them satisfactorily from the overlying formations of the Meramec group. Only two outcrops, therefore, are indicated on the maps, and these without any intention to delineate their borders. One of these includes the fire-clay mines of the Western Tube Company, located about 2.5 miles southeast of Smithland. The other is in Caldwell County, 3 to 4 miles west of Princeton. Still other Tullahoma areas occur "between the rivers" in Livingston and Lyon counties.

Contemporary formations in other regions.—This formation was first studied by Safford in middle Tennessee, and for nearly a half century it constituted the lower or "Protean" member of his Siliceous group.[a] In 1900 he proposed to distinguish

[a] Geology of Tennessee, 1869, p. 338.

it under the name Tullahoma formation.[a] Except the shaly basal member, which is generally wanting in that region and which was not included in that formation, the Tullahoma is equivalent to the Fort Payne chert of the southern Appalachian region. It represents also in time, though it is very different lithologically, the whole of the Waverly series of Ohio and eastern Kentucky, the Knobstone and the Harrodsburg limestone of Indiana, and the Kinderhook and Osage divisions of the lower Mississippian series of rocks as developed on the southern, western, and northern flanks of the Ozark uplift and in the upper Mississippi Valley. The type of deposits of this time that is distinguished as Tullahoma seems to be limited to an area lying southwest of an irregular line connecting eastern Tennessee and St. Louis, Mo. Along the western half of this line the cherty rocks of the Tullahoma merge rather gradually into the more argillaceous and arenaceous Waverly and Knobstone groups lying farther north.

MERAMEC GROUP.

Of the three divisions of the Meramec group named in the table of formations on a preceding page, only the Spergen oolitic limestone and the St. Louis limestone are distinguishable in this district. The lowest division, the Warsaw formation, is possibly in part equivalent to the lower part of the Spergen limestone, but as the occurrence of rocks of that horizon in the outcrops of Spergen limestone southeast of Ste. Genevieve, Mo., can not now be either definitely denied or affirmed it seems best provisionally to regard the Warsaw as restricted to areas north of Ste. Genevieve. Along the Meramec River west of St. Louis all three divisions of the group occur in direct sequence.

SPERGEN LIMESTONE.[b]

Lithologic characters.—The Spergen limestone is distinguished from the typical St. Louis limestone, with which it has heretofore been generally grouped, by its more or less oolitic character. In this district it has very nearly the same characters as the equivalent Bedford oolitic limestone of Indiana, but the proportion of the oolitic layers to the whole mass is less than in Indiana. The oolitic layers are commonly of lighter or darker shades of gray, or of buff or drab, the color as a rule contrasting very well with the nearly white or very light gray color of the later oolitic limestones of the Ste. Genevieve and Tribune limestones. The comparatively dark color of the Spergen oolitic limestone in this area and in Indiana is caused by a liberal sprinkling of small black or dark-gray specks through the mass of the rock. Interbedded with the oolitic layers, which are generally massive, are usually thinner layers of various kinds of limestone, and occasionally thin seams of yellowish shale. At the base of the thickest sections there may be as much as 20 feet or more of

[a] Elements of the Geology of Tennessee, 1900, p. 143.
[b] St. Louis limestone, in part, of authors, and includes Bedford oolitic limestone of Indiana geologists.

subgranular or fine-grained, often laminar and very light gray limestone, filled with fenestellid Bryozoa. Outcrops of the formation are easily distinguished from the formations next above and beneath it by the comparatively small amount of chert contained in its residual clays. As it is an overlapping formation its total thickness varies greatly in different localities. In Indiana this ranges from a few feet to over 80 feet. In this district it may reach 125 feet, but as a rule it probably does not exceed 100 feet in the outcrops.

Topography.—On account of the comparatively small amount of chert liberated in the superficial decomposition of this formation, its outcrop usually forms a relatively even band between the chert-covered and often rugged outcrops of the formation on each side. However, since the abundant faulting of the district prevented the occurrence of large areas of this usually deeply buried formation, it can have no very obvious effect upon the topography of the district as a whole.

Paleontology.—This is the formation from which was procured the well-known Spergen Hill, Indiana, fauna, consisting of a large number of mostly diminutive species of gasteropods, pelecypods, and brachiopods, with fewer bryozoans, corals, ostracods, and trilobites.

The fauna of the Spergen limestone was originally described by Hall[a] without illustrations, but in 1882 Whitfield[b] republished the descriptions, together with good illustrations of the species. In the following year Whitfield's plates were again published by Hall[c] with the original descriptions, but the latter are much improved by the addition of comparisons hitherto unpublished. It is to the last work, then, that the attention of the student wishing further knowledge of this interesting and in many respects remarkable fauna is directed. It has a special interest for this region, because it reappears with very slight modifications in the Fredonia oolitic member of the Ste. Genevieve limestone, and again in the similarly oolitic part of the Tribune limestone.

This fauna, however, can not by any means be said to be evenly distributed geographically, and in this district it seems to occur only sparingly. Nor can it be procured anywhere else in the Spergen limestone so abundantly or in as good free specimens as at the localities in Indiana from which were obtained the specimens originally described. These remarks apply more particularly to the diminutive mollusks which are found locally in Indiana in great abundance. The larger species, especially of the Bryozoa and Brachiopoda, are more generally distributed, but, unfortunately, these types, with few exceptions, occur also in the overlying St. Louis limestone. Of these larger species the following are the most frequently

[a] Trans. Albany Inst., vol. 4, 1856, pp. 3-34.
[b] Bull. Am. Mus. Nat. Hist. No. 3, 1882.
[c] Twelfth Ann. Rept. State Geologist, Indiana, for 1882, pp. 319-375.

found, those prefaced by an asterisk (*) being, so far as known, restricted to the Spergen limestone:[a]

Monilopora, sp. undet.
Lithostrotion? prolifera (Hall).
Pentremites conoideus Hall.
*Fistulipora spergenensis Rominger.
Stenopora tuberculata (Prout).
*Dichotrypa flabellum (Rominger).
*Glyptopora michelinia (Prout).
Fenestella serratula (Ulrich).
Hemitrypa proutana Ulrich.
Fenestralia st. ludovici Prout.
Polypora biseriata Ulrich.
Polypora varsoviensis Prout.
*Rhipidomella dubia Hall.
Productus punctatus?
Spirifer keokuk littoni Swallow.
*Spirifer tenuicosta Hall.
Dielasma formosum Hall.
Dielasma turgida Hall.

Distribution.—As stated on page 26, the Spergen limestone is included in the Tullahoma formation in the provisional mapping of the west-central part of Hardin County, Ill., by Mr. Bain. It there forms a narrow band on the outer border of the underlying true Tullahoma, and this in turn surrounds the Ohio shale outcrops, which occur near the apex of a truncated dome. On the Kentucky side of the river several areas were observed in the southern parts of Livingston and Lyon counties; also one in the northern part of Crittenden County, where it outcrops as an oolitic limestone for a mile or two along the west side of the Larue fault. The last area is indicated on the map, but without any attempt to delineate its borders. Because of the unusual difficulties encountered in mapping the areal distribution of the formations in this district and the short time at disposal the differentiation of the formations beneath the Ste. Genevieve was not attempted except in the case of a block of this limestone at Livingston chapel, in the region south of the Cumberland River. North of this river only a single outcrop of Spergen limestone (above mentioned) is known. Though not observed, it is believed to occur in the undifferentiated Meramec-Tullahoma area west of Princeton.

Nomenclature.—This formation takes its name from Spergen Hill, near Harristown, Ind., where the fossils known as the Spergen Hill fauna were procured and described by Hall nearly fifty years ago. Until recently the formation was not distinguished, the limestone bed, which is mainly oolitic, being referred sometimes to the underlying Keokuk, or, more commonly, to the overlying St. Louis. As the fauna characterizing the bed has always been, and doubtless will continue to be, known as the Spergen fauna, the same name is preferred for the formation. In recent reports of the Indiana Geological Survey, Hopkins and Siebenthal employ the name "Bedford" for the formation. As this name has been in constant use for another formation in Ohio since 1871, Cumings rejects "Bedford" and proposes "Salem" instead. However, both of these names are objectionable as formation names, for they are widely and consistently employed as trade names of quarried stone.

[a] The paleontologic determinations in this work were nearly all made fifteen years ago. Time was lacking to revise these for the present report except to the extent of bringing most of the generic references up to date.

ST. LOUIS LIMESTONE.

Lithologic characters.—As developed in this region, the St. Louis limestone consists of at least 300 feet, and possibly as much as 400 feet, of chiefly dark-gray, rather heavy-bedded, and highly siliceous limestone. Interbedded principally in the lower half are more pure, gray, crinoidal, and subcrystalline layers. Some of the layers in the lower fourth contain small quartz geodes and often exhibit a tendency to become shaly. The limestone of the upper half is on the whole much finer grained than that of the lower half, and usually is also of lighter color. All parts of the formation liberate chert on decomposition, but chert is particularly abundant in the upper half.

These limestones are more readily decomposed than any other in Kentucky. In consequence of the relative ease with which decomposition takes place, it frequently extends to considerable depths, the chert-bearing residual mantle sometimes reaching a thickness of 50 feet or more. For the same reason the limestone itself is rarely seen in natural outcrop except along rapidly eroding streams. As a rule, therefore, the age of the St. Louis limestone areas in this region must be determined chiefly by the character of the residual mantle. This, as stated, generally contains chert in great abundance, and it is by the character of its chert that the formation may be recognized. It is usually of dense structure—occasionally flint-like, rarely cellulose—yellowish or of various shades of gray, and occurs mostly in rounded lumps ranging from 2 to 6 inches in thickness. Any exposure in this area that exhibits a considerable number of such rounded, often ball-like masses of dense chert, may be confidently referred to the St. Louis limestone. Similar rounded lumps of chert may occasionally occur in exposures of decomposing Ste. Genevieve limestone, but these can always be distinguished by their cellulose character.

In but gently hilly St. Louis areas, as in the vicinity of Irma, chert and rocks of any kind are comparatively rare at the surface. This is probably due chiefly to the proportional scantiness of wash on such areas and the consequent long continuance of the decay of the surface. Occasionally, however, it may be due to the less cherty nature of some of the beds of the formation, which in such cases may be at the surface. In such gently undulating areas the soil is of lighter color than usual, being yellowish rather than red, and this feature joins the topography in denoting areas underlain by the Birdsville formation of the Chester group.

Topography.—As a rule, the topography of areas exposing the St. Louis limestone, especially if they are small and contiguous to Chester sandstone areas, is rather rugged. When they are of large size and contain parts distant from main drainage lines their surfaces are sometimes so well protected from erosion by the residual chert mantle that comparatively gentle undulations may prevail. However, on account of the readiness with which the limestone decomposes and the

EXPLANATION OF PLATE III.

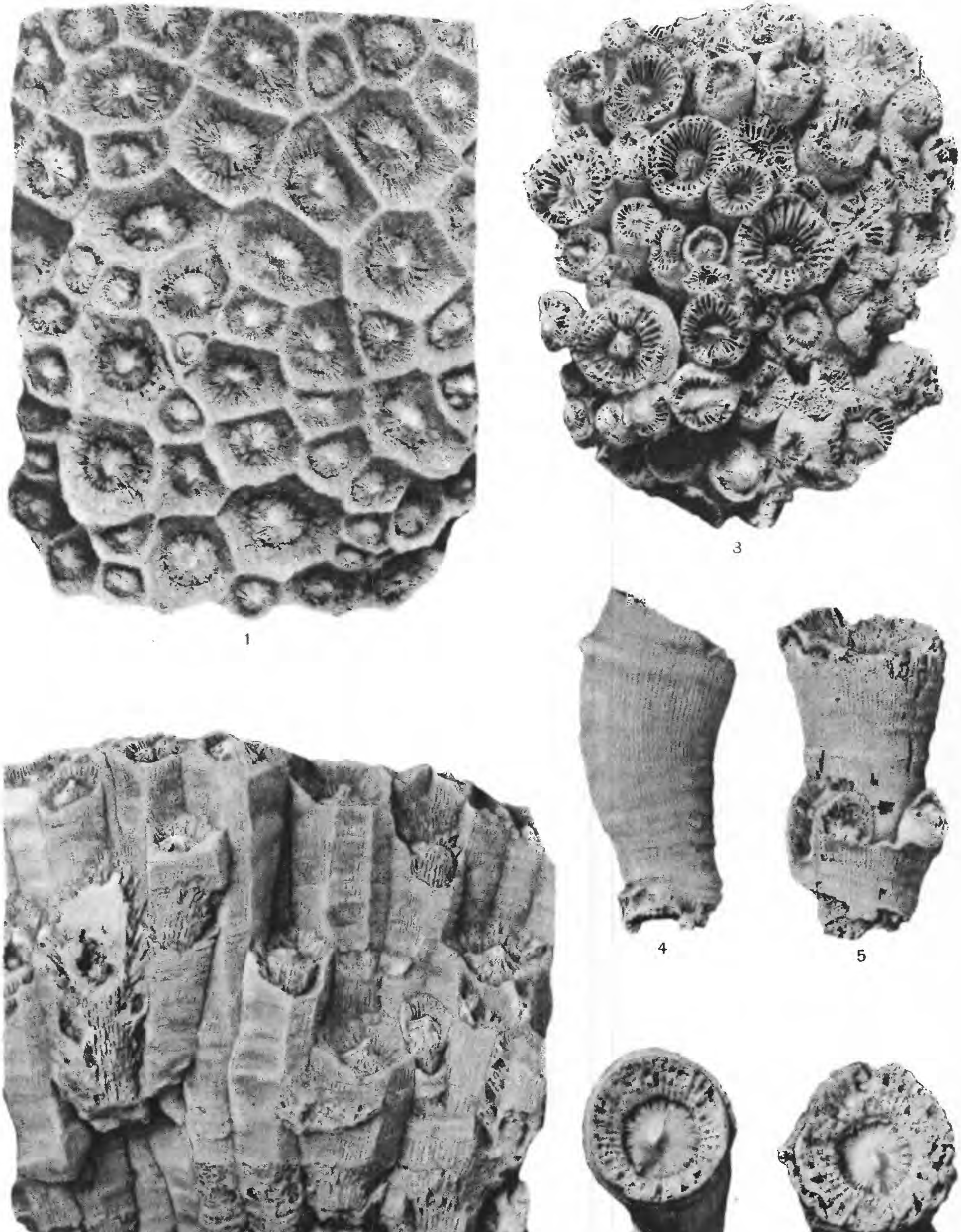
FOSSIL CORALS OF THE ST. LOUIS LIMESTONE.[a]

FIGS. 1 and 2. Views showing parts of the top and side of a mass of *Lithostrotion? canadense*, the most characteristic fossil of the St. Louis limestone.

FIGS. 3 to 7. Views of three specimens of *Lithostrotion? proliferum* Hall. Fig. 3 represents an unusually well preserved example of a variety of this species, characterized by the great prominence and twisted character of the columellar boss that rises from the floor of the calyx, and also by the relatively small size of the corallites. The specimen is from Clarksville, Tenn. Figs. 4 and 5 show the sides and figs. 6 and 7 the calices of large parent corallites, found at Eddyville, Ky. Fig. 5 shows a ring of young corallites budding from the lower part of the parent.

These two corals have been for many years referred to the genus *Lithostrotion*, yet the columella is not styliform, but is produced by the central elevation and intertwining of the tabulæ, and the species can not, therefore, belong to this genus. The structure of these corals is much nearer that of *Lonsdaleia*, but in the almost chaotic state of our knowledge of Paleozoic corals the writer hesitates to make a change in generic names.

[a] All the fossils illustrated in this report are contained in the "Ulrich collection," which now belongs to the United States National Museum.



FOSSIL CORALS OF THE ST. LOUIS LIMESTONE

frequency of caverns and underground channels,[a] the surfaces of even these less rugged areas are often diversified by "sink holes." Along the major streams, particularly the Cumberland River, bluffs 100 feet or more in height are common.

Paleontology.—Taken as a whole, the St. Louis limestone is the least fossiliferous of the limestone formations in this region, except the Tullahoma. Yet certain parts contain organic remains in great abundance and considerable variety, while one or both of two species or varieties of a large composite coral—*Lithostrotion? canadense* and *L.? proliferum*—may be found nearly everywhere in St. Louis areas. In *L.? proliferum* (see Pl. III) the hemispheric coral mass is made up of separate cylindrical corallites, usually one-half to three-fourths of an inch in diameter. In *L.? canadense* (see Pl. III) the corallites are in contact and polygonal, and together form a solid mass. The former species apparently occurs alone in the oolitic limestones of the Spergen formation, and possibly also in the basal part of the St. Louis, while *L.? canadense* occurs alone in the upper third or half of the St. Louis limestone. They are thus, when not found together in the same bed, characteristic of their respective horizons. Both species, however, seem to be about equally common in the lower half of the St. Louis. (See Pl. IV.)

The fossil horizons in the lower 200 feet contain only a few rare individuals of the Mollusca of the Spergen Hill fauna, but most of the Brachiopoda and Bryozoa are present, besides others of these classes not known in that fauna. The plates of species of Melonites (see Pl. IV), which genus seems confined to this formation, are the principal element of the new fauna. Bryozoa also are very abundant, especially when the beds are shaly. Out of a total of over 50 species the following list contains the commonest and probably also the most characteristic forms. The latter are distinguished by an asterisk (*). Figures of some of the species will be found on the accompanying Plates III, IV, and VI.

Characteristic fossils of the St. Louis limestone.

*Syringopora, sp.
Monilopora (near crassa).
*Lithostrotion (? Lonsdaleia) canadense Castleman.
Lithostrotion (? Lonsdaleia) proliferum Hall.
*Zaphrentis calcariformis Hall.
Palæacis cuneiformis Edwards & Haime.
Pentremites conoideus Hall.
*Pentremites cavus Ulrich.
*Melonites multiporus Owen & Norwood.
*Melonites crassus Hambach.
*Archæocidaris wortheni Hall.
*Dichocrinus simplex Shumard.
Fenestella serratula Ulrich.
Hemitrypa proutana Ulrich.
Fenestralia st. ludovici Prout.
Polypora varsoviensis Prout.
Polypora biseriata Ulrich.
*Cystodictya major Ulrich.
Rhynchonella mutata Hall.
Dielasma formosum Hall.
Dielasma turgida Hall.
Spirifer keokuk littoni Swallow.
Reticularia setigera.
Eumetria verneuilana Hall.
Productus punctatus?
*Myalina sancti-ludovici Worthen.
Bellerophon gibsoni White.
*Euomphalus, sp. undet.
*Naticopsis, sp. undet.
*Spirorbis imbricatus Ulrich.

[a] This limestone is sometimes called the "Cavernous limestone." The most notable examples of its caverns are the Mammoth Cave, in Kentucky, and the Wyandotte Cave, in southern Indiana. The latter has been explored for 23 miles and contains a room 240 feet high.

EXPLANATION OF PLATE IV.

BRYOZOA AND OTHER FOSSILS OF THE ST. LOUIS AND BIRDSVILLE LIMESTONES.

FIG. 1. Small slab of lower St. Louis limestone, showing the noncelluliferous side of a frond of *Fenestralia st. ludovici* Prout, 4 miles northwest of Princeton, Ky.

FIG. 2. Another slab from same horizon and locality as the preceding, showing (*a*) celluliferous sides of two fronds of *Fenestralia st. ludovici* Prout, (*b*) the noncelluliferous side of a frond of *Polypora varsoviensis* Prout, (*c*) the noncelluliferous side of a small piece of *Hemitrypa proutana* Ulrich, (*d*) an imperfect frond of *Fenestella tenax* Ulrich, and in the lower left-hand corner the coiled shell of an undescribed tubicolous annelid, for which the name *Spirorbis imbricatus* is here proposed (see also fig. 10).

FIG. 3. The celluliferous face of one of the two fronds of *Fenestralia st. ludovici* shown in fig. 2, magnified 3 diameters.

FIG. 4. Two specimens of the solid axis of an undescribed species of *Archimedes*, for which the name *Archimedes lativolvis* is proposed. This species differs from all others known in the unusual width of the spiral flange. Not uncommon in shaly limestone belonging to the middle part of the Birdsville formation at Champion Hill, about 2 miles west of Salem, Ky.

FIG. 5. Two axes, one wound to the right, the other to the left, of *Archimedes swallovanus* Hall. This is a common and highly characteristic fossil in the calcareous beds of the lower and middle parts of the Birdsville formation.

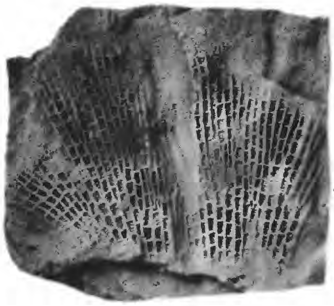
FIGS. 6, 7, and 8. *Archimedes confertus*, n. sp.; fig. 6, the hollow mold of a specimen from a calcareous sandstone bed near the base of the Birdsville formation, at Scottsburg, Ky. Fig. 7 is the greater part of a specimen consisting chiefly of the central axis only, from an equivalent horizon near the mouth of the Okaw River in Randolph County, Ill. Fig. 8 is a specimen from the same locality in Illinois that preserves the fenestrated network which extends more or less obliquely outward from the edge of the spiral flange in Bryozoa of this genus. *A. confertus* is related to and has been confused with *A. compactus* Ulrich, but a careful comparison with the types of that species shows that the flange and fenestrated network stand at nearly a right angle to the vertical axis in the older species, while in *A. confertus* they are directed upward so as to appear invaginated in a lateral view. In the new species the axis is also much longer and thicker, but proportionately more slender.

FIG. 9, *a–e*. Five examples of the axis of *Archimedes meekanus* Hall, showing extremes in thickness of shaft so far observed. This species begins as a rare fossil in the Ste. Genevieve limestone, and ranges almost or quite to the top of the Birdsville formation. The five specimens shown in the figure were found in shaly limestone near the top of the formation at Claxton in Caldwell County.

FIG. 10. The specimen of *Spirorbis imbricatus* Ulrich attached to the frond of *Polypora varsoviensis* shown in fig. 2, magnified 3 diameters. This *Spirorbis* is distinguished from other Mississippian species of the genus by its strongly lamellar, imbricating surface markings.

FIG. 11. A plate of *Archæocidaris wortheni* Hall. The separated plates and spines of this echinid are often very abundant in the lower part of the St. Louis limestone.

FIG. 12 *a–c*. Interambulacral plates of *Melonites multiporus?* O. & N., *a* and *b* show the upper surfaces of fragments consisting of a number of plates; *c*, *d*, and *e* represent side views of loose plates and show their great thickness. Plates like these and the preceding found with *Lithostrotion? proliferum* and *Pentremites cavus* are always to be accepted as reliable indications of the lower half of the St. Louis limestone.



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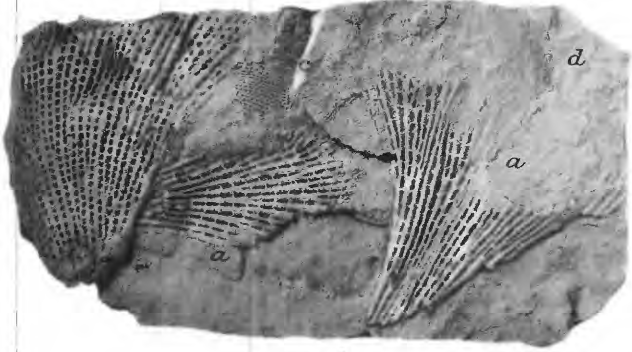

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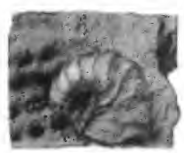

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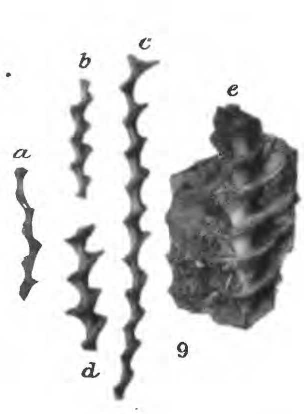

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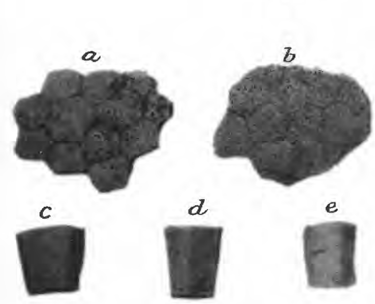


12

BRYOZOA AND OTHER FOSSILS OF THE ST. LOUIS AND BIRDSVILLE LIMESTONES

Fossils do not appear to be generally distributed through the upper 150 feet of the formation, but the cherts resulting from the decay of certain unplaced layers are often crowded with Bryozoa (chiefly *Fenestellidæ*), and Brachiopoda, apparently all of species that occour also in the lower beds of the formation. *Melonites* and *Archeocidaris*, the plates of which are common in the lower beds, have not been observed in this part of the formation. *Lithostrotion? proliferum* also seems wanting but *L.? canadense* is not uncommon.

Distribution.—Over nearly the whole of Lyon County and the adjoining greater part of the southern half of Livingston County the St. Louis limestone is the surface rock. This limestone area extends eastward several miles into southwestern Caldwell County and, northeastward, between converging fault lines, as a triangular tongue terminating on Flinns Fork, about 3 miles northeast of Princeton. The northern boundary of this main area lies in Crittenden County, where it is cut off, east of Clay Lick, by the Tabb fault and its subsidiary fractures, while west of that stream it is limited by the Crittenden fault. Farther west it sends up other fault-bounded projections, the largest being rhomboidal in outline and extending to a point about 3 miles northeast of the mouth of Sandy Creek. On the north and east, except for 6 or 7 miles in southern Caldwell County, the boundary is everywhere defined by faults; on the southwest by the Tennessee River, beyond which it is covered by Cretaceous and Tertiary deposits. Southeastward the area continues around the western Kentucky coal field and farther south into Tennessee.

Another large area borders the Ohio River and embraces the greater part of the northwestern angle of Crittenden County. Northward it extends across the river into Illinois. On the west it is bounded by the Deer Creek fault; on the south and east by the Lerue, Corn, and other faults. On account of the abundance of cross faults and subsidiary fractures, this border is very irregular, especially in the region west of Sheridan, which also contains several triangular downthrown blocks terminating superficially with rocks of later date.

The irregularity of the fault-defined boundaries of these large areas is greater than can be shown with the scale to which the accompanying maps have been drawn. It is especially evident where the downthrow is sufficient to bring the formations of the Chester group to the level of the St. Louis limestone. In one set of cases it is due to the disruption of the stratified crust along comparatively short lines arranged en echelon and paralleling each other but crossing the average strike of the fault; in the other, to the step-like arrangement of the strata by faults subsidiary to and paralleling a main fracture. The former type is well exhibited by portions of the Tabb fault, the latter by the northern end of the Larue fault. The faults of the district are discussed and described in detail in Chapter III, which is devoted to the structure of the region.

Besides the large areas above defined, there are three much smaller ones, all of which lie within a few miles of the boundary line between Crittenden and Livingston counties. The largest of these is traversed by Clay Lick and lies southwest of View, between the Marion fault on the northwest and the Crittenden and Hodge faults on the southeast. The second forms a narrow strip between the Marion and Woods faults and extends southwestward from Pucketts Branch of Clay Lick to the Cumberland River. The third, situated about 2 miles southeast of Salem, is a small triangle between converging faults.

Nomenclature and correlation.—The St. Louis limestone derives its name from St. Louis, Mo., where it was first studied and described by Engelmann in 1847, and, more correctly and in greater detail, by B. F. Shumard in 1855.[a] According to Shumard's definition the formation is limited to beds above the oolitic limestones for which the name Spergen formation is here adopted. This is clear from his description, in which no important bed of oolitic limestone, as is now known to occur in St. Louis County, is mentioned. The upper limit is defined by the base of his Ste. Genevieve limestone. The last formation, however, is wanting, as are also the succeeding formations of the Chester group at St. Louis, where this limestone is succeeded unconformably by shales of Pennsylvanian age. Although it contains on the whole more chert in western Kentucky than at the type locality, there is no doubt that the limestone here described as St. Louis is strictly the same formation as that exposed in the numerous quarries at St. Louis and in the bluffs along the river below that city.

CHESTER GROUP.

CHARACTER AND SUBDIVISIONS.

This group of rocks consists of a variable series of limestones, sandstones, and shales, which, for the sake of convenience in classification and reference, is separated into four main divisions. These should take the rank of formations, discriminated chiefly by lithologic differences. Considering their respective faunal aspects only, there would be less reason for their separation. Still, the four formations, of which two were distinguished and named years ago and two are now discriminated for the first time, are not by any means devoid of fossils that so far appear to be characteristic of each.

Except for a few plant remains most of the sandstones are unfossiliferous—the massive ones nearly always so—yet certain of the more argillaceous and calcareous sandstones of the uppermost or Birdsville formation are often crowded with remains of marine invertebrates. The limestones and interstratified calcareous shales, however, always contain fossils, and consequently are of the first importance in determining special horizons.

[a] Geol. Survey Missouri, First and Second Ann. Repts., pt. 2, pp. 139, 170, and 181.

On account of the extensive and abundant faulting to which this region has been subjected, it proved extremely difficult to construct a satisfactory section of the rocks. The difficulties were especially trying in the case of this group of strata, because the sandstones, which offer greater resistance to decomposition than most other sedimentary rocks, are more commonly at the surface than the intercalated limestones and shales. Sandstones, of whatever age, look much alike, and also are subject to very similar variations. It is therefore no easy matter to determine offhand and positively the stratigraphic position of any given outcrop of that rock. But it was necessary to do so in many instances in this field, and the result has shown that one may become sufficiently familiar with the local lithologic and other peculiarities of sandstones even to make reasonably accurate determinations without the aid of fossils.

In describing the various formations of the group an attempt will be made to point out their respective characteristics, though it is recommended that the lithologic determinations be verified as far as possible by paleontologic evidence. Indeed, it is very doubtful whether one could acquire a clear and accurate conception of the stratigraphy and structure of this region, and more especially of its Chester and Mansfield areas, without considerable training in paleontology.

In the course of the writer's work in the district in 1889 and 1890 every exposure that might be believed to throw light upon the succession of the various beds of the group was carefully studied and noted. The best, because least interrupted, sections were obtained along the east-west line of the Illinois Central Railway between Princeton and Claxton. The Ste. Genevieve limestone is very well shown at Princeton, and the Cypress sandstone caps the hills inclosing the valley on the north and east. The upper part of the Tribune limestone also is shown in cuts along this railroad about 2 miles east of Scottsburg, while as satisfactory outcrops of the Birdsville formation as can be seen in this field occur between these cuts and Claxton. The lower third, as well as the uppermost beds of the section of the Birdsville, however, had to be compiled from exposures found in disconnected areas.

The top of the group varies greatly in different sections, whole beds being absent in some that are present in others. The two lower formations, the Ste. Genevieve limestone and the Cypress sandstone, also vary considerably in character and thickness, but in these cases the variations in volume are due chiefly to overlap and nondeposition, while in the case of the top of the Birdsville it is caused principally by early Pottsville erosion.

GENERALIZED SECTION.

The succession of the beds of the Chester group, so far as known at present, is about as follows:

Generalized section of the Chester group in the Kentucky-Illinois district.

Mansfield sandstone, of late Pottsville age.

Formation	Description	Feet.
Birdsville formation.	Flinty limestone at the top	0– 20
	Arenaceous shales above, hard, dark limestone and soft clayey shales below	0–105
	Dark shale above and sandstone in two beds alternating with two beds of limestone below	116–220
	An extremely variable series of shales, sandstones, and limestones, the last usually aggregating but a small part of the whole	225–350
	Total thickness of Birdsville formation	400–680
Tribune limestone.	A heavy body of light-gray or blue, mainly crystalline, limestone, interbedded with thinner beds of calcareous shale and rarely sandstone. Many of the limestones form massive beds, and some of them are semi-oolitic in structure. At least 100 to 150 feet thick here and possibly reaching 200 feet locally.	
	Maximum thickness of Tribune limestone about	200
Cypress sandstone.	Quartzose sandstone, generally massive, but sometimes partly made up of oblique flags	60– 80
	Bluish or gray, cherty limestone, usually affording an abundance of silicified *Pentremites godoni*	0– 10
	Massive quartzose sandstone	0– 50
	Total thickness of Cypress sandstone	60-135
Ste. Genevieve limestone.	Shales, shaly limestone, and various kinds of purer limestones, most of them fine-grained, the proportion of shale and limestone varying greatly in different sections=Ohara limestone member	30–107
	Highly calcareous sandstone=Rosiclare sandstone member	1– 25
	Mainly oolitic limestones, white and light blue, interbedded with crinoidal, crystalline and fine-grained limestones.=Fredonia oolitic limestone member. Base not seen	113
	Total observed thickness of Ste. Genevieve limestone	144–245
	Total maximum thickness of Chester group	1,260

All the maximum thicknesses at one place would give a total of 1,250 feet or more for the whole group, but according to the evidence in hand, which shows that some of the beds vary in thickness for no other reason than unequal deposition, it does not seem likely that the total thickness will exceed 1,100 feet at any point within the counties of Crittenden and Caldwell. A hundred feet less would probably be nearer the average for these counties, while in Livingston County 800 to 900 feet is regarded as a reasonable estimate. The thickness of most of the beds seems to decrease toward the southwest from the edge of the western Kentucky coal field. On the east side of the coal field the total thickness of the Chester is much less, as it is also in Indiana. The reduction in this direction is due to overlap, the two lower formations and, locally, a part of the Tribune limestone, being absent.

The more general characters of the group having been described, the four divisions will now be considered separately and in detail.

STE. GENEVIEVE LIMESTONE (PRINCETON LIMESTONE).

General features.—In certain respects this is the most important limestone formation in the district. In the first place it gives rise to the best upland soils in this part of the State. Next, valuable or promising ore bodies are oftener associated with it than any of the other formations. Finally, it represents, together with the following Cypress sandstone, an interval in geologic history that has scarcely been appreciated heretofore. So far as known, the interval has only in a few areas east of the Mississippi River left a stratified record. The Batesville sandstone of northern Arkansas is probably a contemporaneous deposit, but the true sequence of the strata and faunas can be determined only in the more complete record preserved in this part of the Mississippi Valley.

The Ste. Genevieve limestone rests on the St. Louis limestone, but as an actual contact between them has not been observed in this area it is impossible to describe the local characters of either the top of the one or the base of the other. For the present it is assumed that the St. Louis ends with the last of the highly cherty, fine-grained limestones and that the Ste. Genevieve begins with the first of the oolitic limestones making up the greater part of the basal member of the latter formation. The assumption accords with facts observed in the corresponding part of the section at Ste. Genevieve, Mo., where this formation was first studied and from which it derives the name given it by Shumard. In the typical exposures south of Ste. Genevieve the relations of the two formations are clearly shown, the lithologic distinctions between the two being no less obvious than in this district. The contact of the Ste. Genevieve with the underlying St. Louis, moreover, is distinctly unconformable.

Subdivisions.—The Ste. Genevieve limestone is divisible into three members that are clearly distinguishable wherever the formation has been observed. The lowest of these consists principally of oolitic limestones. An appropriate name for this member is the Fredonia oolitic limestone, since good exposures occur in the immediate vicinity of the village of Fredonia, in Caldwell County. The member also forms the floor of the well-known Fredonia Valley. The middle member, a well-marked datum horizon in the district, is a calcareous sandstone, for which the name Rosiclare sandstone is suggested. Above this comes a variable member containing more or less shale. Being well developed and perhaps better exposed in the quarries at Ohara, near Princeton, than at any other locality, this may be called the Ohara limestone.

So far as observed, the Ste. Genevieve limestone has a maximum thickness in this region of at least 250 feet. Possibly a full section would add as much as 50 feet more to the base. So great a thickness as this—that is, 300 feet—probably could occur only at localities where the Ohara member is present in full force, as east of Princeton in Caldwell County, and at Rosiclare, on the north side of the Ohio. Toward the western border of the district, where the Ohara member is much thinner, the total thickness of the formation is likely to be correspondingly less.

Fredonia oolitic member.—In two continuous sections, both in Crittenden County, one at View, the other between Bethel Church and Crittenden Springs, at least 115 feet of beds belonging to this member were observed. The base was not seen, but at top the exposure includes the Rosiclare sandstone and a part of the Ohara limestone member. These 115 feet of rocks consist chiefly of white oolitic limestone, interbedded with blue oolite and generally thin bands of subcrystalline and crinoidal limestones. Here and there a seam of green clay shale occurs, and occasionally a bed of fine-grained argillaceous limestone. A single layer of such limestone, frequently several feet in thickness, may be observed, in most sections, about 60 feet beneath the top of the member. The white oolites usually occur in massive beds and locally at least these strata should afford an excellent building stone.

Since the base of the member has not been observed in the district it is impossible now to give the total thickness. More detailed work in the field may possibly result in the discovery of a locality where the contact with the underlying St. Louis limestone may be seen. If not, then the point may be decided by a study of the walls of some of the mines. In the meantime it is perhaps safe to place it at about 150 feet.

Rosiclare sandstone member.—This is a bed of calcareous, laminated sandstone, usually 3 or 4 feet thick on the Kentucky side of the river, but varying here from 1 to 10 feet. North of the river, in Hardin County, Ill., it is heavier, the increase in that county being from about 12 feet in the bluff at Rosiclare to 20 or 25 feet along a line connecting Cave in Rock, Lead Hill, and Hicks. Under cover, or when freshly exposed as in a quarry, it appears as a light greenish-gray, very finely arenaceous, usually massive limestone. In natural exposures, however, most or all of the lime is leached out, and in this condition it generally forms bare, light-red or reddish-brown ledges of more or less laminated, soft, porous sandstone. Very commonly the laminæ are oblique and separated by open spaces.

In its weathered condition the rock resists decomposition very well and often retains its integrity even after the limestones above and just beneath it have been completely removed. Frequently the underlying limestone is locally decomposed and carried away by percolating waters, leaving a cavern beneath the sandstone. In such cases the roof may fall in, causing the sandstone ledges to become inclined and to assume relations to the adjacent undisturbed limestone ledges that sometimes very closely simulate the surface indications of a strong fault. One who has become familiar with this bed, in either the leached or the unleached condition, can not confuse it with any other sandstone in the district. A layer of greenish, marl-like, and wholly unfossiliferous shale, ranging from a few inches to 2 feet in thickness, occurs so generally just beneath the Rosiclare sandstone that it is an important aid in the recognition of the latter.

Ohara limestone member.—This member of the Ste. Genevieve formation is more variable, both in thickness and lithologic character, than the lower member. Its limestone layers are generally thinner and most of them are fine-grained and earthy. They are also interbedded to a considerable but variable extent with soft, greenish, calcareous, and clayey shales and so-called "marls." Sometimes these shales occur in beds from 2 to 6 feet thick. Among the limestones certain layers may be shaly; others, especially those in the first 20 feet above the Rosiclare sandstone, may be oolitic, while an occasional layer higher up is more or less clearly brecciated.

On the whole, the Ohara member contains more shaly matter and, possibly in consequence, is slightly thicker in corresponding portions in Caldwell County than in Crittenden and Livingston counties. Yet in the Rosiclare section (p. 43), which shows a somewhat greater development of the Ohara than was observed at any other point, it appears to consist almost entirely of limestone.

Sections of Ste. Genevieve limestone.—The variations suggested in the two preceding paragraphs will be better appreciated after a comparison of the following three sections. The first of these sections is shown in the hill at the railroad quarries (Ohara post-office) about 2½ miles east of Princeton, Ky. Here practically every foot of the upper 160 feet of the Ste. Genevieve formation is exposed to view, the lower half of the section in the quarry and near-by sink holes, the upper part in good natural exposures above the quarry to the top of the hill, which is capped by the Cypress sandstone.

SEC. I.—*Section of Ste. Genevieve limestone 2½ miles east of Princeton, Ky.*

	Feet.
Massive Cypress sandstone, capping hill	20
6. Impure and shaly limestone, mostly gray in color, massive at top, with a 4-foot, highly fossiliferous, subcrystalline layer just beneath the middle, and a similarly fossiliferous brownish limestone at the base. *Productus cestriensis* and *Productus* sp. (near *P. cora* and *tenuicostus*) very abundant in fossiliferous bands	30
5. Dark-gray or drab, impure limestone, interbedded with shales and shaly limestone; the more argillaceous layers full of fossils, particularly a slender ramose fucoid (*? Buthotrephis*) and species of *Productus* and *Spiriferina transversa*	27

	Feet.
4. Light-gray, impure, more or less shaly limestone, its upper part full of fenestellid Bryozoa; at base a layer of purer limestone, 1 foot or more in thickness, filled with *Productus cestriensis* and *P. tenuicostus?*	13
3. Mostly shaly limestone of light and dark shades of gray, containing very few fossils. Lower part includes a bed of oolite about 5 feet thick, while the upper part contains a brecciated layer or layers reaching a thickness of 4 feet. Under the weather the brecciated layers break up into pebbles	30
Total thickness of the Ohara member	100
2. Calcareous sandstone (Rosiclare sandstone), solid and greenish in unleached condition, reddish brown and porous when weathered	2
1. Mainly oolitic limestones, white, yellowish, or blue, interbedded with impure blue cherty limestone; 10 feet below top a coarse oolite is full of *Pentremites florealis*, *Platycrinus huntsvillæ*, and other fossils; 20 to 30 feet beneath top is another very fossiliferous bed containing the highly characteristic corals—*Lithostrotion harmodites*, *Cystelasma quinqueseptatum*, *C. rugosum*, and *Michelinia subramosa*—figured on Pl. V. Fredonia oolite to base of exposure, about	60
Total thickness exposed here of Ste. Genevieve limestone	162

The second section is made up of disconnected parts, observed mainly in the vicinity of Bethel Church and Crittenden Springs, 4 to 5 miles west of Marion, Ky. The region is about 24 miles northwest of the first section.

SEC. II.—*Section of Ste. Genevieve limestone in Crittenden County, Ky., between Marion and Crittenden Springs.*

	Feet.
Cypress sandstone, massive except the basal 10 to 20 feet, which may be flaggy	40–100
6. Light-gray, generally massive limestone	0– 10
5. Greenish soft shales and thin-bedded limestone, extremely fossiliferous; *Amplexus geniculatus* and *Spiriferina transversa* very characteristic	8– 12
4. Massive, impure, gray limestone, breaking up into blocks under the weather; fossils very few, chiefly *Productus cestriensis*	40
3. Covered, probably limestone	10
Total thickness of Ohara member	58– 72
2. Rosiclare calcareous sandstone	3
1. Mainly oolitic limestones, white and light blue, varying from thin-bedded to massive; interbedded with crinoidal, crystalline, and fine-grained limestones, the last generally yellowish or brown; near the middle a flaggy, deep-blue, semicrystalline limestone. Fredonia oolitic limestone to base of exposure, about	113
	175–188

The third section is a continuous one, exposed in the bluff on the Illinois side of the Ohio River below Rosiclare. The locality is 12 to 14 miles northwest of the second section and 38 to 40 miles from the first.

SEC. III.—*Section of Ste. Genevieve limestone in bluff on Ohio River below Rosiclare, Ill.*

	Feet.
Cypress sandstone, massive and quartzose, capping the hill	35
6. Brown and gray, argillaceous limestone, apparently interbedded with thin seams of shale, about	45
5. Shale and thin seams of limestone, extremely fossiliferous	10
4 and 3. Interbedded, impure, and semioolitic limestones, mostly heavy, though somewhat irregularly bedded	52
Total thickness of Ohara member	107
2. Laminated, calcareous sandstone, thin-bedded, and reddish when weathered. Rosiclare sandstone	8– 12
1. Fredonia oolitic member, gray, massive limestones, largely oolitic; to level of Ohio River, about	50
Total exposed thickness of Ste. Genevieve limestone	165–169

In these and most other sections of the formation containing the horizons three beds are easily distinguished from the rest, the first and third by their fossils, the second by its lithologic character. The first, occurring usually from 20 to 30 feet beneath the top ot the Fredonia oolite, is characterized, as stated in the description of Sec. I, by several well-marked corals (*Lithostrotion harmodites, Cystelasma quinqueseptatum*, and *Michelinia subramosa*—see Pl. V). The second is the peculiar Rosiclare sandstone, which intervenes between the Fredonia oolitic limestone and the Ohara limestone member. The third is bed 5 of the above sections. It may always be recognized in this district by its more than usually shaly character and the great abundance of its fossil remains. The bed usually contains many thin plates of limestone, consisting principally of organic remains. Nearly all the fossils noted as occurring in the Ohara member in the tabular list on a succeeding page are from this bed. It is to be noted, further, that the fossils increase in abundance and variety as the argillaceous character of the bed grows more pronounced.

By comparing the three sections it may be seen that bed 5 is proportionally less different in its lithologic features from the overlying and underlying beds in the Caldwell County section than in the Crittenden County and Rosiclare sections. In the first section the argillaceous material is more evenly distributed through the whole of the upper member, while in the second and third sections it is concentrated in bed 5, the preceding and succeeding beds of the formation being made up of comparatively pure limestone.

In common with all the limestone formations of this district, the Ohara member grows thicker in a northerly and northeasterly direction from the southwestern border of the district. In the case under consideration it appears that the increase in thickness is by the addition of layers at the top. In the vicinity of Crittenden

Springs bed 6 may be wanting entirely, while it has not been observed here to exceed 10 feet in thickness. North of the Ohio River, in the southern part of Hardin County, Ill., it attains its greatest observed thickness, from 40 to 50 feet. In the northwest corner of Hardin County, however, unless the apparent difference is due to faulting, the Ohara member as a whole is much thinner than at Rosiclare. Traced southwestward from Crittenden Springs to Salem and Puckett Spring, not only bed 6, but bed 5 as well, is at least locally absent. Here the total thickness of the Ohara member has not been observed to exceed 50 feet, bed 4 of the section being succeeded by the Cypress sandstone. The same appears true of the section exposed in the hills inclosing Clements Valley (View post-office), 4 to 5 miles southwest of Marion, though here the top of the section is not well exposed and the succession of the upper beds, moreover, is obscured by faulting.

In the Ste. Genevieve areas that lie farthest southwest, of which the area containing Bissels Bluff and the outcrops near the Royal and Pittsburg mines affords the best exposures, only the Fredonia member of the formation has been satisfactorily identified; but on account of lack of time and opportunity for exact observations on the point, it is not yet possible to say definitely that the Ohara member fails entirely in that direction.

On tracing the formation through the southwestern half of Caldwell County, from the vicinity of Fredonia to Princeton, and thence to the southeastern border of the county, it was seen that the upper member maintains a nearly uniform thickness, with bed 6 only varying in thickness from about 18 feet to 30 feet. Farther southeast, however, as at Hopkinsville, Ky., where the Rosiclare sandstone was observed and where the Fredonia member is very well exposed, the Ohara member seems to be greatly reduced in thickness. From all the facts in hand that bear in one way or another upon the point there seems to be no reason to doubt that the Ste. Genevieve was deposited in a mere remnant of the broad area covered by the submergence that prevailed in the St. Louis age, immediately preceding the Ste. Genevieve age.

Topography of Ste. Genevieve limestone areas.—Wherever this formation is at the surface it forms valleys, and, except the bottom lands along the main streams, the lands in these valleys are by far the best in the district for agricultural purposes. Sink holes occur frequently, especially in the narrower valleys, in which little more than the upper member of the formation is exposed. They are particularly common along lines of fracture, and often serve to locate these. Where the lower member is the surface rock—and this member usually, if not always, forms the floor of the larger valleys—sink holes are less abundant, but they are generally of larger size and frequently contain ponds.

Paleontology of the Ste. Genevieve limestone.—Unfortunately the fauna of this little-known geologic horizon has never been described. Its most characteristic species are nearly all new to science and, being unnamed, are difficult to refer to in an intelligible manner. A few of the more striking forms are illustrated on the accompanying plates (Pls. V and VI), and the new species among these are briefly characterized on the sheets explaining the plates. As to the other fossils, they are mostly of long-known species. Some of these the formation holds in common with the underlying St. Louis limestone; others, especially of the Bryozoa, indicate an earlier appearance of species generally considered as characterizing the overlying Chester formations; while a considerable number, among them the most common brachiopods, range without interruption and with little modification, from the base of the Spergen Hill limestone of the Meramec group to the Tribune limestone or even the Birdsville formation of the Chester. A partial list of the last class includes the following species: *Fenestella tenax*, *F. serratula*, *Stenopora tuberculata*, *Productus semireticulatus*, *Spirifer keokuk leidyi*, *Spiriferina norwoodi*, *Dielasma formosum*, *D. turgidum*, *Reticularia setigera*, *Seminula trinuclea*, and *Cleiothyris sublamellosa hirsuta*.

The foregoing list does not take into account the characteristic elements of the fauna commonly known as the Spergen Hill or Warsaw fauna, which reappears in the oolitic Fredonia member and is less fully represented also in the shales of the Ohara member. The Ste. Genevieve representatives of this fauna have been determined only in part, much of the material collected remaining yet to be prepared for study. The species so far known are included in the following incomplete list of Ste. Genevieve fossils and are distinguished by notation in a column devoted to the Spergen fauna. In some cases the particular form is indicated by a number instead of a specific name. This mode of reference, however, is employed only when the species, which in these cases is notable because of its occurrence elsewhere in higher or lower rocks, could not be satisfactorily identified with described species. When the Ste. Genevieve form of a species is distinguishable as a variety from the typical form of the species occurring only in the earlier Spergen and St. Louis or later Tribune and Birdsville formations, or when for other reasons the identification is doubtful, the fact is indicated in the columns showing vertical range by a question mark. This mode of notation, however, is not employed when the same variety is believed to occur with the typical form in the other formations.

EXPLANATION OF PLATE V.

CORALS OF THE STE. GENEVIEVE LIMESTONE.

FIGS. 1–10. *Michelinia subramosa* n. sp.

Fig. 1, under side of a slender corallum; figs. 2 and 3, upper and lower sides of a large example consisting of six partly intergrown colonies; fig. 4, specimen consisting of three well-defined colonies; figs. 5 and 6, opposite views of a corallum consisting of numerous irregularly grown colonies; figs. 7, 9, and 10, three young coralla; fig. 8, under side of a corallum in which the development of the colonies has resulted in a more distinctly ramose appearance than usual.

This species is closely related to *Michelinia eugeneæ* White, described as from the Coal Measures of Indiana and as forming small, rounded masses attached by a relatively broad base to foreign bodies. *M. subramosa,* as may be seen from these figures, has a small basal attachment and by the successive development of colonies, or clusters of tubes, finally produces more or less distinctly ramose coralla.

This coral is sometimes very abundant in western Kentucky, and so far as known its presence always indicates the upper part of the Fredonia member of the Ste. Genevieve limestone. The illustrated examples were etched from blocks of impure limestone found 2 miles east of Princeton, Ky.

FIG. 11. One of several examples of a small "massive" species of *Michelinia* found at Princeton, Ky., lower in the Fredonia member than the specimens of *M. subramosa.* It is distinguished from the latter by its larger corallites and mode of growth, and in both of these respects closely resembles one of White's figures of his *M. eugeneæ* (Thirteenth Rept. Geol. Indiana, 1884, p. 119). Provisionally the Ste. Genevieve form may be referred to as *M. eugeneæ* var. *princetonensis.*

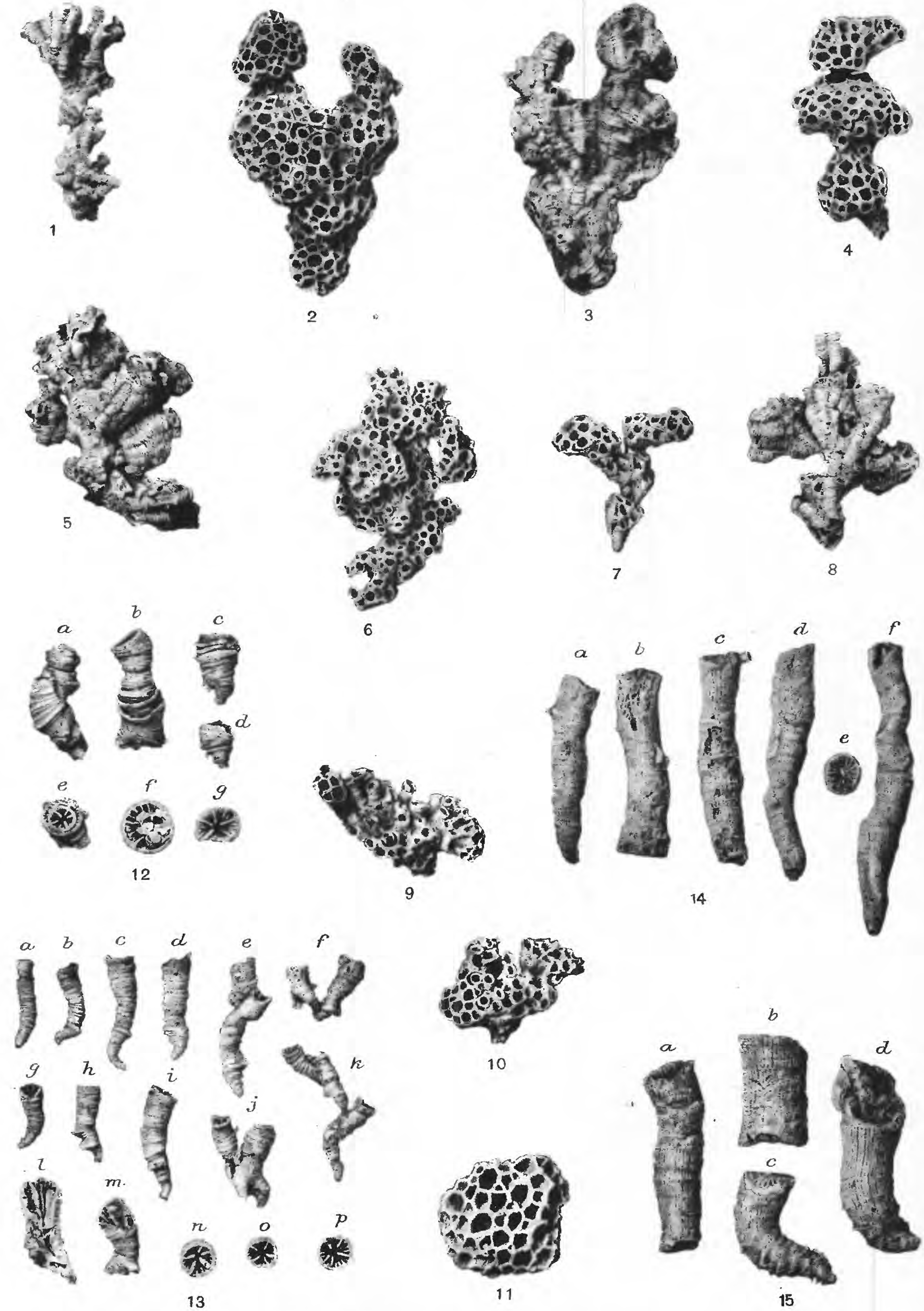
FIG. 12, *a–g.* A group of specimens of *Cystelasma rugosum* n. sp. or var., from the Fredonia member of the Ste. Genevieve limestone in the vicinity of Princeton, Ky. This form may perhaps be merely a strongly marked variety of the next species, *C. quinqueseptatum,* but so far the two forms are readily distinguished by the differences shown in the illustrations. In *C. rugosum,* which is represented in the material before the writer by no less than 25 specimens, the corallum is always proportionally wider and much more strongly wrinkled transversely.

FIG. 13, *a–p.* A group of 16 etched specimens of *Cystelasma quinqueseptatum* n. sp., from the upper part of the Fredonia member of the Ste. Genevieve limestone about 2 miles east of Princeton, Ky. This species is characterized by its slender and finely wrinkled corallum.

In describing *Cystelasma* Miller states that septa are wanting. As a rule this *appears* to be true of the species upon which he founded his genus (*C. lanesvillense* Miller, Spergen limestone, Indiana), and average examples of the type species therefore look very different from the two species here referred to *Cystelasma.* However, other examples of *C. lanesvillense* in the Ulrich collection, from the original locality, do show septa. In some these are mere rudiments, but in a few evenly grown examples they are sufficiently developed to show that normally the type species also has five principal septa like the west Kentucky species here figured. In the latter the septa are always present and are generally as strongly developed as shown in these figures.

FIG. 14, *a–f.* Lateral views of five separated corallites and the calyx of another example of *Lithostrotion harmodites* Edwards and Haime. Originally these corallites formed part of a loosely connected, bushy mass, 3 inches or more in height and width. The main septa, 16 to 18 in number, reach the small styliform columella at the center of each corallite. This is a true *Lithostrotion.* So far as known the species is limited to the upper part of the Fredonia member of the Ste. Genevieve limestone, at which horizon its bushy colonies have been seen in the massive limestone at many localities in this district. The figured examples are from Princeton.

FIG. 15, *a–d.* Four large examples of *Amplexus geniculatus* Worthen, one of the most characteristic fossils of the Ohara member of the Ste. Genevieve limestone. In other coralla of this species the average diameter is less than 5 mm. The figured specimens are from Downeys Bluff, at Rosiclare, Ill.



CORALS OF THE ST. GENEVIEVE LIMESTONE

Partial list of fossils occurring in the Ste. Genevieve limestone, with columns indicating occurrences in lower and upper members, and in other formations.

Species.	Fredonia member.	Ohara member.	Spergen fauna.	St. Louis.	Tribune or Birdsville.
1. Lithostrotion harmodites Ed. & H.	×				
2. Amplexus geniculatus Worthen		×			
3. Zaphrentis pellænsis Worthen	×	×		×	
4. Cystelasma quinqueseptatum n. sp. [a]	×				
5. Cystelasma rugosum n. sp.	×				
6. Michelinia subramosa n. sp.	×				
7. Michelinia eugeneæ princetonensis n. var.	×				
8. Pentremites florealis Schlotheim	×	×	?		×
9. Pentremites godoni? De France		×			
10. Pentremites conoideus? Hall	×		?	?	
11. Mesoblastus glaber M. & W.		×			?
12. Platycrinus huntsvillæ (Troost?) W. and S.	×				
13. Batocrinus irregularis Casseday?	×	×	×	×	
14. Fistulipora n. sp.		×			
15. Stenopora tuberculata Prout	×	×	×	×	×
16. Stenopora rudis Ulrich		×			×
17. Anisotrypa solida Ulrich		×			×
18. Lioclema araneum Ulrich		×			×
19. Cœloconus rhombicus? Ulrich		×		×	
20. Streblotrypa nicklesi Ulr. var.		×			?
21. Cystodictya n. sp.		×			?
22. Glyptopora punctipora Ulrich		×			×
23. Fenestella tenax Ulrich	×	×	×	×	×
24. Fenestella serratula Ulrich	×	×	×	×	×
25. Fenestella elevatipora Ulr. var.		×			×
26. Fenestella flexuosa Ulr. var.		×			×
27. Fenestella cestriensis Ulr. var.		×			×
28. Polypora cestriensis Ulr. var.		×			×
29. Polypora corticosa Ulr. var.		×			×
30. Septopora cestriensis Prout		×			×
31. Septopora subquadrans Ulrich		×			×
32. Archimedes meekanus Hall	×				×
33. Sphragiopora parasitica Ulr.		×			×
34. Rhipidomella dubia Hall	×		×	×	×
35. Orthotetes kaskaskiensis McChesney		×			?
36. Productus cestriensis Worthen		×			×
37. Productus sp. 2 (near P. cora)		×			×
38. Productus sp. 3 (near P. punctatus)		×		×	×
39. Productus semireticulatus?	×			×	×
40. Pugnax grosvenori Hall	×		×	×	

[a] For figures of the new species named in this list see Pl. V.

Partial list of fossils occurring in the Ste. Genevieve limestone, etc.—Continued.

Species.	Fredonia member.	Ohara member.	Spergen fauna.	St. Louis.	Tribune or Birdsville.
41. Pugnax mutata Hall	×	----------	×	×	----------
42. Dielasma formosum Hall	×	×	×	×	×
43. Dielasma turgidum Hall	×	×	×	×	×
44. Spirifer near increbescens Hall	----------	×	----------	----------	×
45. Spirifer leidyi N. and P	×	×	----------	×	×
46. Spirifer bifurcatus Hall? (small, subquadrate form of S. leidyi?)	×	×	×	×	×
47. Reticularia setigera	----------	×	----------	×	×
48. Spiriferina norwoodi	×	×	×	----------	×
49. Spiriferina transversa McChesney	----------	×	----------	----------	×
50. Cleiothyris hirsuta Hall	×	×	×	----------	----------
51. Cleiothyris sublamellosa Hall	×	×	----------	----------	×
52. Seminula trinuclea Hall	×	----------	×	----------	----------
53. Seminula subquadrata Hall	×	×	----------	----------	×
54. Eumetria marcyi verneuilana	×	×	×	----------	×
55. Eumetria marcyi vera	----------	×	----------	----------	×
56. Aviculopecten sp. 1	×	----------	×	----------	×
57. Aviculopecten sp. 2	×	----------	?	----------	×
58. Pteronites sp. 1	----------	×	----------	----------	?
59. Nucula shumardana illinoisensis, W	×	----------	×	----------	×
60. Nuculana nasuta Hall	×	----------	×	----------	×
61. Modiola illinoisensis Worthen	×	----------	×	----------	×
62. Pleurophorus minima Worthen	×	----------	×	----------	×
63. Pleurophorus sp. 2	×	----------	×	----------	×
64. Macrodon sp. 1	×	----------	×	----------	×
65. Cypricardella oblonga Hall	×	----------	×	----------	×
66. Cypricardinia indianensis Hall	×	----------	×	----------	×
67. Schizodus compressus Worthen	×	----------	×	----------	×
68. Bellerophon sublævis Hall	×	----------	×	----------	?
69. Bucanopsis textilis Hall	×	----------	×	----------	?
70. Pleurotomaria elegantula Hall?	×	----------	?	----------	×
71. Straparollus spergenensis	×	----------	×	----------	?
72. Loxonema sp. 1	×	----------	×	----------	?
73. Naticopsis sp. 1	×	----------	×	----------	?
74. Orthonychia acutirostre Hall	×	----------	×	----------	×
75. Leperditia carbonaria Hall	×	----------	×	----------	×
	47	43	35	17	58

The writer does not contend that it is impossible or even undesirable to distinguish many of the Ste. Genevieve and Chester representatives of the Spergen fauna. In most cases where these forms reappear they are characterized by differences which under close biologic and stratigraphic study it may be desirable to recognize by giving the mutations subordinate designations. The writer does maintain, however, that the forms thus reappearing are members of a single slowly modifying and largely pelagic fauna that existed continuously elsewhere and entered this epicontinental basin only when conditions were favorable. One of these conditions involved the deposition of oolitic limestones. Another probably was the subsidence or modification of barriers, allowing communication with seas more permanently inhabited by the invading fauna.

When the 35 species of the Spergen fauna are eliminated from the above list, it will be seen that the remaining species show close affinities with later Chester faunas, especially the Tribune limestone fauna. This relationship is particularly evident in the Ohara member, but is also well expressed in the Fredonia member, and is strong indeed when the Spergen fauna is included in the comparison. The strong Chester element in the Ste. Genevieve fauna, coupled with the fact that this formation and the overlying Cypress sandstone were the first deposits following the great restriction of the preceding St. Louis sea, has induced the writer to extend the lower limit of the Chester group to the base of the Ste. Genevieve.

As originally defined and used by Worthen and Engelmann in southern Illinois[a] the Chester group included the Rosiclare sandstone and Ohara limestone members of the Ste. Genevieve limestone, but the lower or Fredonia member was referred to the St. Louis. Their reasons for placing the lower member of the Ste. Genevieve with the underlying formation, in which they were followed in Kentucky by Norwood,[b] is not now apparent, unless they regarded the "Spergen Hill" fauna in it as evidence that it belonged to the great body of limestone of which the St. Louis is the upper division. Upon reading over their descriptions of the Mississippian limestones occurring beneath the Rosiclare sandstone in southern Illinois it becomes evident that Worthen and Engelmann had but an imperfect conception of the stratigraphic relations of the various formations into which the limestones are divisible. Of unconformities between them they knew nothing, nor do they seem to have had knowledge of the Ste. Genevieve limestone, described several years before in Missouri by Shumard. When both these facts are known, as well as the no less important fact that the Spergen Hill fauna reappears not only in the Ste. Genevieve but again in the Tribune limestone, the resulting classification of the Mississippian series becomes simpler, more strictly coordinate in its subdivisions, and more natural.

As a final result of the analysis of the above list we have a few species remaining that may be considered as strictly characteristic of the formation (see Pls. V and VI). The five corals found in the lower member have been already mentioned. Another, *Amplexus geniculatus*, seems to be equally characteristic of the main shaly bed of

[a] Geol. Survey Illinois, vol. 1, 1866, p. 356.

[b] Geol. Survey Kentucky, n. ser., vol. 1, 1876, pp. 362-366.

the Ohara member. This horizon (bed 5 of sections discussed on preceding pages) is extremely fossiliferous; but its fauna consists chiefly of Brachiopoda and Bryozoa, and seems entirely devoid of Mollusca. The characteristic pentremite of the formation (Pl. VI, fig. 18) a form apparently too near *P. florealis* to be distinguished from it—is abundant in both the Fredonia and Ohara members. One of the commonest fossils of the oolitic limestones of the formation—and one that for this region at least is highly characteristic of it—is the crinoid identified provisionally with Troost's *Platycrinus huntsvillæ*. Its basal plates form a shallow cup, one-half inch or less in diameter, marked on the outer side with three radially arranged prominent keels or ribs, and generally with intermediate granulations and striations. Its column is flattened and twisted, and the dismembered segments elliptical in outline and spiniferous (Pl. VI, fig. 27).

Distribution of Ste. Genevieve limestone.—The largest outcrops of this limestone in the district occur in the southeastern half of Caldwell County. Of these the one farthest south extends northward from Christian and Trigg counties to McGowan station, on the Hopkinsville branch of the Illinois Central Railway. Its western outline is generalized on the map, exposures of the rock being infrequent in that direction and no satisfactory contact with the underlying St. Louis limestone, which occupies the country west of it, having been seen at any point. In drawing the line dependence was placed chiefly upon the relative abundance and the character of the chert found in the residual mantle. The soil of the Ste. Genevieve, besides having less chert, is also of a darker shade of red than that resulting from the decay of the St. Louis limestone. The eastern outline is defined by the normal contact with the overlying Cypress sandstone, which caps the first hills of the higher country lying to the east of the area.

Between this and the second large area are two small, fault-bounded areas, the first a very narrow, triangular strip, extending a mile and a half westward from McGowan, the second a block of rhombic shape lying just south of Eddy Creek.

The second large area in Caldwell County is triangular in outline, with Saratoga, in the adjoining edge of Lyon County, at its apex, and the town of Princeton near the middle of the wide northeast side. The latter boundary is irregular and formed by contact with the Cypress sandstone on the slopes of the hills east of Princeton. Near the town there are also several small outliers of that sandstone. The southern boundary is formed by the Eddy Creek fault, the northwestern one by the Saratoga fault, and the northern side by the Princeton fault. A narrow, faulted triangle joins this large area on the north and forms the southeast slope of the Chester sandstone hill 2 miles west of Princeton.

The third large area in this county includes the village and valley of Fredonia in its northwestern part, and Crider in its southern part. From Crider it sends an arm northeastward among the Cypress sandstone hills to one of the upper branches of Dollarson Creek, where it is cut off by the Stone fault. Between this fault and the Fredonia fault, which forms the northern boundary of the quadrilateral area, a considerable remnant of Cypress sandstone is included. The Skin Frame fault limits the area on the south, while the Livingston fault forms the western boundary.

In Crittenden and Livingston counties there are but four large outcrops of Ste. Genevieve limestone that are distinguished from the surrounding country by topographic and agricultural features comparable to those marking the large Ste. Genevieve areas of Caldwell County. Except where erosion has not removed the whole of the overlying Cypress sandstone these areas are all bounded by faults. The largest forms the well-known Salem Valley, which extends southwest of that village to the bend of Sandy Creek. Northeastward from Salem the valley expands to a width of 4 miles; but beyond New Salem Church the Ste. Genevieve, which thenceforth exposes little more than the upper or Ohara member, forms the floor of a comparatively narrow, meandering valley that continues to the Marion and Lola road. Beyond this road the expanding region lying between the Columbia and Stevens faults, as far as the Marion and Fords Ferry road, continues to expose Ste. Genevieve limestone areas, most of which are clearly the result of underground drainage and subsequent breaking in of caverns. Bethel Church is located near the center of the largest and geologically most excavated of these areas. Sink holes are very common here, especially along fracture lines and where the cover of Cypress sandstone is thin.

A similar but agriculturally more important Ste. Genevieve area is in the View or Clements Valley, beginning about 5 miles south of Marion. Except on its northern side it is entirely bounded by faults, the Crittenden fault on the south side separating the Ste. Genevieve limestone from the Birdsville formation, while on the northwest side the Hodge and a probably unimportant north-south fault divide it from St. Louis limestone outcrops.

Another important Ste. Genevieve area occurs in Livingston County just south of the Salem Valley. It is of triangular shape and lies between the converging southwestern extensions of the Columbia and Marion faults.

The Lola and Deer Creek valleys embrace the last of the Ste. Genevieve limestone areas that have considerable agricultural importance. This area lies between the Deer Creek fault, which divides it from the St. Louis limestone of the region to the east, and another nearly parallel fault a mile or more to the west that generally brings the lower part of the Birdsville formation to the level of the Ste. Genevieve limestone. The southern part of the valley exposes the Fredonia member of the formation. This, as usual, forms a nearly level country, but the northern extensions consist mainly of small, irregular valleys and limestone slopes, riddled with sink holes, in the rather rough country formed by the remnants of Cypress sandstone.

Ste. Genevieve limestone forms the base of the Ohio River bluff below the mouth of Deer Creek. This, probably, is part of the Princeton area that is exposed in the bluff on the north side of the river above and below Rosiclare, Ill.

A large but straggling and rough exposure of Ste. Genevieve limestone occurs near the mouth of the Cumberland River. It extends about 4 miles up Bissels Creek, forms Bissels Bluff on the north side of the great bend of Cumberland River as far down as the Royal mine on the Latrobe fault, and then turns northward again from that fault up Cypress Creek to Dyers Hill Church. The latter part is a triangle bounded by faults on the east and northwest and by the alluvial bottom on the southwest. The northern boundary of the remainder of the area is formed by normal contact with the Cypress sandstone. The southeastern boundary is formed by the Latrobe fault.

Finally, there seems to be a triangular, fault-bounded Ste. Genevieve outcrop about 2 miles south of Smithland. This area was so identified by the writer in 1890, but, on account of lack of time, the identifications could not be verified in the course of the more recent investigations.

The floors of nearly all of these Ste. Genevieve limestone valleys are formed by the Fredonia oolitic member. The Ohara member in these cases occurs in the slopes of the hills and escarpments bounding the valleys, except on those sides of the areas that are limited by fault planes.

Derivation of name and synonymy.—This limestone formation was named by B. F. Shumard from exposures about 2 miles south of Ste. Genevieve, Mo.[a] These were recently visited by the writer and found to be of the same formation that he had named *Princeton limestone.*[b] In the vicinity of Ste. Genevieve the formation was found to rest unconformably upon typical St. Louis limestone. As will be remembered, the contact between these two formations was not observed in western Kentucky. The typical section at Ste. Genevieve is therefore important in adding discordance of stratification to the differences in lithologic and faunal characters previously relied upon to distinguish the two formations. The Ste. Genevieve limestone has been either ignored or overlooked by all writers of the geology of the Mississippi Valley except Shumard, who distinguished and named the formation, and Keyes,[c] who adopted the name and ranked the formation as the upper member or division of his St. Louis stage. The present writer refers the Ste. Genevieve to the Chester group, being impelled to this course chiefly by the strong Chester affili-

[a] Trans. St Louis Acad Sci., vol. 1, 1860, p. 406; Geol. Survey Missouri, Rept. 1855-1871, 1873, p. 293.

[b] Geol. and Min. Res. Crittenden County, Kentucky: "Crittenden Press," Dec., 1890. Bull. U. S. Geol. Survey No. 213, 1903, p. 207.

[c] Geol. Survey Missouri, vol. 4, 1894, pp. 30, 76. Idem, vol. 6, 1894, pt. ii, p. 390.

ation of its fauna, and secondarily by the fact that the two upper members were included by Worthen and Engelmann in their definition of the group in southern Illinois. The lower member, as has been already stated, was referred to the St. Louis limestone by the last authors.

CYPRESS SANDSTONE.

Lithologic characters.—In its usual development this formation consists of massive, generally fine to medium grained, rarely coarse, quartzose sandstone. Sometimes masses of it are soft and friable, but usually the grains are well cemented. Not infrequently portions are thin-bedded and slightly argillaceous, but these seem to occur chiefly, if not solely, in the upper member, the lower one, so far as observed, being apparently always massive. Occasionally a large part of the upper member is flaggy, and in such cases cross-bedding is common. The sandstone varies in color, but, being as a rule somewhat ferruginous, is commonly of a light brown. Sometimes, however, it is nearly white or colorless, and in such cases is composed almost entirely of quartz.

In the most complete development of the formation it is divisible into three members or beds. Of these the upper one is always present in this district, but in areas where the Ohara member of the underlying Ste. Genevieve limestone is incompletely developed (see p. 44) one or both of the lower beds may be absent. The middle bed lies from 60 to 80 feet or more beneath the top of the formation. It is a highly fossiliferous, cherty, blue, fine-grained limestone, rarely more than 4 or 5 feet thick. Sometimes, even where the thickness of the formation indicates that its horizon is present, the limestone is either absent or so thin that it may be overlooked. In natural outcrops its horizon may generally be recognized by the rather small chert fragments—commonly not over an inch or two in diameter—in the red clayey soil that results from its decomposition, and contrasts very well with the friable brown sandy soils derived from the sandstone on either side of it. This bed has been observed at a number of points in Caldwell and Crittenden counties, and also near Rosiclare and Shetlerville in Hardin County, Ill. Perhaps the most accessible of the localities where it may be seen and its fossils collected is in the hills a mile or so northeast of View. Here it occurs usually less than 10 feet above the top of the Ste. Genevieve limestone.

The lower sandstone bed may be, as already stated, absent altogether. At its maximum it probably does not exceed 50 feet in thickness, and when the thin limestone bed above it is absent or can not be located it may not be possible to distinguish it from the upper bed.

Topography.—The Cypress sandstone nearly always forms rough and wooded country. It is especially rough when contiguous to fault lines, being, apparently, unusually susceptible to silicification. Where erosion has reduced its thickness to 30 feet or less the normal unevenness of its surface is likely to be increased by abundant sink holes that penetrate to underground drainage channels and caverns in the Ste. Genevieve limestone. Generally the surface is strewn with sandstone bowlders.

Paleontology.—So far as known, the marine fossils of the Cypress formation are restricted to the thin bed of limestone that often intervenes between the lower and upper sandstone. As weathered out the fossils are always silicified and consist principally of *Pentremites godoni*, which, however, often occurs in great abundance. Among the associated fossils a small form of *Zaphrentis spinulosa* ranks next in abundance, while the calyces of a species of *Talarocrinus* and the brachiopod *Cleiothyris sublamellosa* are less frequently found. The absence of Bryozoa and the rarity of Brachiopoda, particularly of *Productus*, constitute a striking peculiarity of the fauna of the bed. On the whole, however, both the fossils and their mode of occurrence remind one strongly of certain parts of the Tribune limestone, the formation next above.

Distribution.—Where the sequence of the strata has not been disturbed by faulting the Cypress sandstone forms the capping of the hills inclosing the Ste. Genevieve limestone areas already described. It is well shown along the greater part of the eastern borders of the Ste. Genevieve areas in Caldwell County; also on the northern and eastern borders of the View or Clements Valley and on many of the hills surrounding or included in the Ste. Genevieve areas northeast of Salem. Again,it is found in characteristic development capping the first hills west of Deer Creek and also at the top of Bissels Bluff on the Cumberland River.

Nomenclature.—The sandstone which is found in the Mississippi Valley immediately above and apparently always in association with the Ste. Genevieve limestone, and which is correlated with the Cypress sandstone of this district, was originally called the "Ferruginous sandstone" by Swallow and Shumard.[a] In 1868 Henry Engelmann, who, as a member of the Illinois Geological Survey, had made extensive investigations of the Mississippian rocks in southern Illinois, proposed the name here adopted.[b] The type locality is on Cypress Creek, in Johnson County, Ill., where, according to Engelmann's description just cited and in his report on Johnson County,[c] it is of the usual character and has a thickness of 150 feet or more (? 250 feet).

The publication of Engelmann's name for this sandstone in 1868[d] seems to have been overlooked by later workers on the Mississippi section, so that one and probably two synonyms have crept into literature. Thus, in 1876, Norwood[e] applied the name "Big Clifty" sandstone to a formation in western Kentucky that, if it is not

[a] Geol. Survey Missouri, First and Second Ann. Repts., pt. 2, 1855, pp. 91, 174, 181, 193.
[b] Trans. St. Louis Acad. Sci., vol. 2, p. 189. (Paper read Nov. 3, 1862.)
[c] Geol. Survey Illinois, vol. 1, 1866, pp. 383 and 397.
[d] Trans. St. Louis Acad. Sci., vol. 2, p. 189.
[e] Geol. Survey Kentucky, n. ser., vol. 1, p. 369.

strictly equivalent to the Cypress sandstone, at least agrees closely with it in lithologic character and seems to occupy the same stratigraphic position. In 1892 Keyes,[a] who overlooked not only the name proposed by Engelmann, but Norwood's designation as well, proposed the name "Aux Vases" sandstone, to take the place of "Ferruginous sandstone." The type localities for the formations to which these three names—first Cypress sandstone, then Big Clifty sandstone, and finally Aux Vases sandstone—were applied are all contained within an area less than 200 miles across. They are, moreover, unquestionably in one and the same geologic basin and are practically identical in lithologic character. Finally, as the formations in each case were assigned to precisely the same stratigraphic position, i. e., next below the Kaskaskia limestone, there can be no reasonable doubt of their synonymy.

TRIBUNE LIMESTONE.

Lithologic characters.—As developed in this region, the Tribune limestone consists of thin-bedded and heavier-bedded, generally light-gray, limestones, more or less abundantly interbedded with thin seams of calcareous, clayey shale and occasional thin beds of sandstone. The limestones vary in texture, some being fine grained, others slightly crystalline, while many layers vary from granocrystalline to distinctly oolitic. The proportion of shale varies in different exposures, being least near and north of the Ohio River and greatest along the southern and eastern parts of the border of the western Kentucky coal field. In the latter areas the proportion of shale to the whole mass of the formation is probably greater in the lower third than in the succeeding parts. Nearly everywhere, however, limestone is the predominating constituent of the formation. So far as observed in Caldwell County, none of the beds of shale exceeds 6 feet, or possibly 8 feet, in thickness. Both the limestones and shales are fossiliferous, and often highly so.

The Kentucky-Illinois district presents no complete section of this formation and, so far as known, no exposures from which a complete section can be constructed. On account of the general uniformity in lithologic and faunal character displayed in most of its parts by the formation and the extremely limited number and area of its outcrops, few positive data tending to show its total thickness could be procured. According to the evidence at hand, its maximum thickness in Caldwell County is probably not less than 100 feet. In Crittenden County it appears to be from 20 to 50 feet thicker and contains much less shale. Across the river, in Hardin County, Ill., it appears to consist almost entirely of limestone, and here the thickness, as a rule, probably exceeds 150 feet. At the Fairview mine, near Rosiclare, the top of this limestone outcrops at the shaft and forms the east wall of the vein. No change from limestone to sandstone was observed in this wall from

[a] Bull. Geol. Soc. Am., vol. 3, p. 296.

the mouth of the shaft to the 200-foot level. It appears, therefore, that in this vicinity the Tribune formation may exceed even 200 feet in thickness.

Topography.—Outcrops of the Tribune limestone are too infrequent in western Kentucky to exert much influence on the general topography of the country. In less disturbed regions the areas in which it is the surface rock are comparatively level strips, bordered, especially on the side of the Cypress sandstone, by rougher country. On the opposite side these strips run out into usually narrow valleys lying between hills that are composed of the more resistant arenaceous deposits of the succeeding Birdsville formation.

Paleontology.—The fauna of the Tribune limestone embraces a large proportion of the species that are characteristic of the Chester group. With the exception of *Spiriferina transversa*, which has not been here observed in the Tribune limestone, all the species noted on pages 47 and 48 as common to the Ste. Genevieve limestone and later divisions of the Chester group occur in this formation. Some, perhaps many, of these reappearing 58 species, when subjected to a final study, will doubtless receive subordinate designations, but for present purposes their affinities are too apparent to justify a greater separation than is indicated by the use of the question mark. The majority of these reappearing species, again, are of the Spergen fauna. As in the Spergen and Ste. Genevieve formations, this mostly diminutive fauna occurs also in the Tribune limestone in oolitic strata.

In addition to these species of the Spergen fauna listed among the fossils of the Ste. Genevieve limestone (ante, pp. 47–48), the Tribune limestone of this district has afforded very slightly modified representatives of the following Gasteropoda of the same fauna, as described by Hall and Whitfield:

Bulimorpha bulimiformis.
Bulimorpha elongata.
Holopea proutana.
Eotrochus concavus.
Murchisonia attenuata.
Murchisonia turritella.
Pleurotomaria subglobosa.
Pleurotomaria meekana.
Straparollus quadrivolvis.
Straparollus planorbiformis.
Naticopsis carleyana.

The Gasteropoda and Pelecypoda of the Tribune fauna, which embrace also the more distinctive elements of the Spergen fauna, are almost entirely restricted to the oolitic limestones. The general aspect of the fossil contents of these, therefore, impresses the observer as quite different from what is ordinarily considered as a Chester fauna. In the shales and other limestones, particularly the former, these two classes of fossil shells are comparatively rare, the faunas of these being composed chiefly of bryozoans, brachiopods, corals, and echinoderms. Since the common and more characteristic fossils of the Chester group belong as a whole to the Echinodermata, it is evident that the age of the Chester shales and the nonoolitic calcareous

EXPLANATION OF PLATE VI.

BLASTOIDS AND CRINOIDS OF THE LIMESTONES OF THE ST. LOUIS, STE. GENEVIEVE, TRIBUNE, AND BIRDSVILLE FORMATIONS.

FIGS. 1–6. *Pentremites conoideus* Hall, Spergen and St. Louis limestones. Figs. 1–5, group of five specimens from shaly lower St. Louis beds, 4 miles northwest of Princeton, Ky.; fig. 6, original of fig. 3 magnified 3 diameters.

FIGS. 7 and 8. *Pentremites cavus* n. sp. Lateral views of two specimens found with others in association with *P. conoideus, Lithostrotion? proliferum* and plates of *Melonites* and *Archæocidaris* in lower St. Louis limestone, 4 miles northwest of Princeton, Ky. This species differs from its associate and nearest congener, *P. conoideus,* in its greater size, concave base, more depressed interambulacral areas and more rounded outline in a lateral view. In the surface sculpture of the plates and in the markings of the ambulacral areas, especially in the elevation of the median parts of the latter, the two species are essentially the same.

FIGS. 9–12. Views of four silicified specimens of *Pentremites pyriformis* Say, showing variations in form. Tribune limestone, 2 miles east of Scottsburg, Ky.

FIGS. 13–17. *Mesoblastus glaber?* Meek and Worthen. Ohara member of the Ste. Genevieve limestone. Fig. 13, lateral view of a rather young example, magnified 3 times, showing coarse markings of upper part of interambulacral plates; fig. 14, lateral view of an old example, magnified 3 times, showing, among other features, the elevation of the posterior deltoid plate that incloses the outer side of the anal opening; figs. 15 and 16, similarly magnified views of the two lower specimens shown in fig. 17; fig. 17, group of six specimens, of natural size, four showing variations in lateral views incident to age, and two mature examples, one showing the base, the other the summit. In part collected by Mr. F. J. Fohs, on Crooked Creek, less than 2 miles northwest of Marion.

Fig. 18, *a–f*. In part *Pentremites florealis* Schlotheim. A series of specimens from the Ohara member of the Ste. Genevieve limestone; *a, b, c,* and *f*, from the vicinity of Crittenden Springs, in Crittenden County, Ky., *d* and *f* from Rosiclare, Ill. This series illustrates the extreme range of variation observed in over 100 examples from this formation and the tendency exhibited by a few examples, like *e* and *f*, to take on the peculiarities of *P. godoni* which, however, did not attain its typical form until later. By far the most of the Ste. Genevieve specimens agree better with *P. florealis* (Sch.) Hambach than with *P. godoni*. They constitute a species or variety (represented by figures 18 *a, b, c,* and *d*) that for the present may very well be referred to *P. florealis*, differing as they should from *P. godoni* in the relatively small size of the deltoids, the greater height of the base, and the very slight concavity of the interambulacral spaces.

Fig 19, *a–d*. *Pentremites godoni* De France. *a* and *b*, two silicified examples of the earlier form of this species, from the Tribune limestone, 2 miles east of Scottsburg, Ky.; *c* and *d*, two specimens of the typical form of the species from the Birdsville formation in Meade County, Ky. In the earlier form, which occurs also in the Cypress sandstone, the ambulacral areas are more depressed than in the later and most typical variety of the species.

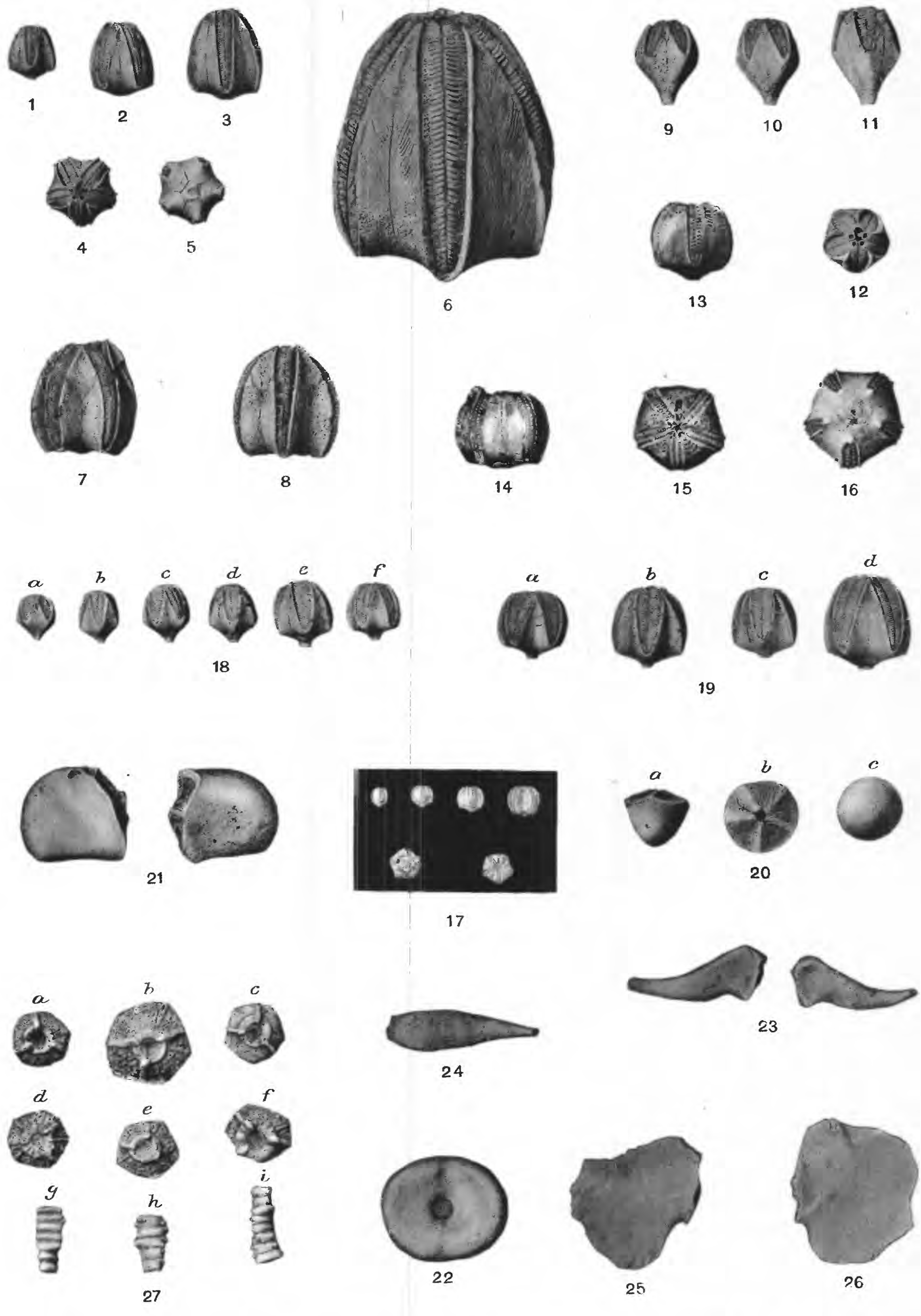
Fig. 20, *a–c*. Different views of three specimens of the ancylosed basal plates of *Agassizocrinus conicus* Owen and Shumard, from Sloans Valley, Ky. This is one of the most characteristic and abundant fossils of the Chester group above the Cypress sandstone.

Figs. 21 and 22. *Pterotocrinus capitalis* Lyon, a common fossil of the Birdsville formation at Champion Hill and other localities in western Kentucky. Fig. 21, two of the five lobes that form the summit of the vault of this crinoid; fig. 22, anchylosed basal plates, showing cicatrix for the attachment of the column. While the "wings" or summit lobes of this and other species of *Pterotocrinus* are abundant enough, entire examples of these crinoids are very rare.

Figs. 23 and 24. Lateral and top views of three of the spine-like "wings" of *Pterotocrinus acutus* Wetherby. Birdsville formation, Sloans Valley, Ky.

Figs. 25 and 26. Lateral views of two of the broad "wings" of *Pterotocrinus depressus* Lyon and Casseday. Birdsville formation, Sloans Valley, Ky.

Fig. 27, *a–i*. Six specimens of the basal ring of plates and three fragments of the twisted column of the Ste. Genevieve limestone crinoid referred to in the text under the name of *Platycrinus huntsvillæ*. Fragments like these are very common in this formation, especially in the oolitic limestones of the Fredonia member.



BLASTOIDS AND CRINOIDS OF THE LIMESTONES OF THE ST. LOUIS, ST. GENEVIEVE, TRIBUNE AND BIRDSVILLE FORMATIONS

beds is generally apparent at a glance. Even in the case of the oolites, a brief search usually results in the discovery of species that clearly enough indicate the Tribune instead of the Ste. Genevieve or Spergen age of this third appearance of the Spergen fauna. Associated with the latter, most hand specimens of Tribune oolite will contain specimens of strictly middle and upper Chester species of *Archimedes*, like *A. compactus*, *A. intermedius*, *A. proutanus*, and *A. sublaxus*, or of *Pentremites* like *P. pyriformis*.

Aside from the Spergen fauna, which is not known to occur in rocks younger than the Tribune, and which thus distinguishes this division from the overlying Birdsville formation, the rocks of this formation contain many species that pass over into the next formation and a much smaller number that seem to be confined to it. As to the last, however, since practically all of its bryozoans and brachiopods, and in a less degree, perhaps, of its corals and crinoids, range beyond its limits, it is no easy matter to compile even a brief list of species which shall contain nothing that is not strictly characteristic of the Tribune formation. Such a list, if prepared, would be made up principally of undetermined and undescribed species, and it is deemed inadvisable to attempt its compilation at this time.

The beds containing the Spergen fauna are, of course, readily distinguished from limestones of the succeeding formation of the group. Concerning the beds of the Tribune in which this fauna is not present, even these are not so difficult to recognize as the foregoing paragraph may lead one to believe. In the first place, the fossils that pass on into the succeeding Birdsville formation are mostly rare and delicate as compared with their successors in the calcareous and shaly beds of the later formation. These fossils, of which *Zaphrentis spinulifera*, *Pterotocrinus* (summit wing plates), *Polypora cestriensis*, *Spirifer increbescens*, and *Spiriferina spinosa* are among the most important and conspicuous, are not, therefore, such predominant factors of the Tribune fauna as they become in the Birdsville formation. Next, these species are associated in the latter division of the group with many other fossils that do not occur in the Tribune, so that the general aspects of these two faunas are quite different. Finally, ordinary Chester shales and limestones interbedded or exposed in close stratigraphic association with oolitic limestone containing representations of the Spergen fauna can, according to the present state of our knowledge, be confidently regarded as members of the Tribune limestone.

Distribution.—The Tribune limestone rarely comes to the surface in the region under discussion. Indeed, it has been certainly recognized at only six localities in the district and at only five points in the area covered by the maps accompanying this report. The first is in the vicinity of Tribune, a small post-office about 6 miles east of Marion; the second in and about, particularly south of, Lamb's cut, on the Illinois Central Railway, about 2 miles east of Scottsburg. The third and perhaps best exposure occurs along the Princeton and Hopkinsville road, partly in Christian County and partly in Caldwell County. The fourth exposure occurs a mile or less east of Joy, in the northern part of Livingston County. The fifth is at the Fairview mine, near Rosiclare, Ill., where a block of it outcrops and forms the foot wall of the vein for a short distance. A small sixth outcrop occurs in the bluff on the west side of Puckett Branch. There are three other outcrops of what may be this limestone, one occurring about midway between Marion and View, another lying between 1 and 2 miles north of Mount Zion Church, and the third, which is more likely to be Ste. Genevieve limestone, forming the southern wall of the Senator mine, near Princeton.

Nomenclature and correlation.—This formation is named from Tribune, a small settlement and post-office 6 or 7 miles east of Marion, where the most satisfactory exposures of this limestone seen in the district occur. The formation is shown in bluffs a short distance east of the post-office, and outcrops along the Marion road on the slope of the hill a mile west.

The Tribune limestone is the main and more persistent lower body of limestone contained in the typical Kaskaskia division of the Chester group. In the remaining part of the Kaskaskia, here distinguished as the Birdsville formation, there are several beds of limestone intercalated between generally much heavier beds of sandstone and shale. As a rule the Birdsville limestones are thin, shaly, irregularly developed, and unimportant as compared with the Tribune limestone.

In the Mississippi and lower Ohio valleys the two divisions of the Kaskaskia—Tribune and Birdsville—are readily distinguished, but the lower formation is much more limited in its geographic distribution. It is absent, beneath the overlapping Birdsville, in the northern part of the Chester area and on the east side of the Indiana-Kentucky coal field. The horizon is present in the southern Appalachian region, but on account of the unusually calcareous nature of the beds corresponding to the Birdsville formation the twofold division of the Kaskaskia here made is not practicable there. As mapped in publications of the United States Geological Survey, the Kaskaskia, together with the St. Louis and probably the Spergen limestone, is there embraced in the Bangor limestone.

BIRDSVILLE FORMATION.

Lithologic characters.—This is an extremely variable series of sandstones, shales, and limestones. As a rule, the sandstones, which vary from nearly pure quartzites to highly argillaceous or calcareous sandstones, constitute fully one-half of the total thickness, while the shales and limestones make up about equal parts of the remaining half. The limestones vary in color from various shades of gray to light or darker blues, in texture from subcrystalline to fine-grained and more or less earthy types, and in structure from thin plates in shales to massive beds several feet thick. The shales are commonly arenaceous and then quite unfossiliferous, but in other cases, confined almost entirely, however, to the upper half, they are calcareous and contain an abundance of fossils. More rarely a bed or two of shale may be encountered that is highly argillaceous and perhaps bituminous, the color in one case being almost black. The color of the shales varies from light green to various shales of yellow, purple, or gray.

Generalized section.—An idea of the lithologic composition and succession of the beds included in the Birdsville formation may perhaps best be gained through a descriptive section. The following section is compiled from many more or less complete exposures observed in Caldwell, Crittenden, and Livingston counties. In using this section the reader should bear in mind that the lithology and thickness of the beds varies so greatly and so rapidly that no two exposures more than a mile or two apart will agree sufficiently to permit satisfactory correlations. Sandstones are liable to replace shales, or they may be interpolated in, or even replace, the thinner limestone beds with disconcerting frequency.

Generalized section of the Birdsville formation in western Kentucky between Tradewater River and the mouth of Cumberland River.

[Mansfield sandstone of late Pottsville age at top.]

	Feet.
12. Cherty limestone, chert in thick plates	0– 20
11. Arenaceous shales or shaly sandstones, occasionally containing Pelecypoda and fucoids	0– 60
10. Hard, heavy-bedded, mostly dark-gray or blue limestone, with a smaller proportion of light-blue or drab limestone. Contains large forms of *Bellerophon*, *Nautilus*, *Seminula subquadrata*, *Spirifer increbescens* and an unusually large, undescribed species of *Archimedes*	0– 30
9. Yellowish, green, and purple calcareous clay shales, with generally thin, highly fossiliferous limestone plates	0– 15
8. Dark-gray, greenish, or purple, unfossiliferous, soft shale	10– 30
7. Sandstone, sometimes nearly white	30– 60
6. Gray fossiliferous limestone, often highly argillaceous, with thin interbedded seams of clay shale	36– 50
5. Sandstone, usually absent	0– 15
4. Mostly thin, highly fossiliferous limestone, interbedded with green and blue, clay shales	40– 50
3. Variegated shales, with purple and green colors predominating; occasionally soft and friable and slightly phosphatic ("Litchfield marls"), at other points harder and more or less arenaceous. Apparently quite unfossiliferous, about	50
2. Contains some sandstone, often calcareous, and more yellow to blue shales, interbedded with from a few to many layers of earthy and compact and subcrystalline limestone, with sometimes a layer or two highly ferruginous; includes occasionally also a thin seam of coal. The calcareous layers are always fossiliferous. This is the main horizon for *Pentremites sulcatus* and for the other species of this genus figured on Pl. VII; also for species of *Pterotocrinus* (Pl. VI)	75–100
1. Mostly shaly and generally thin and even-bedded, occasionally flaggy, sandstones, all unfossiliferous except a calcareo-ferruginous, thin-bedded sandstone near the base, which is sometimes crowded with fossil remains. Among these *Archimedes confertus* n. sp. (Pl. IV) is highly characteristic and perhaps the most abundant and striking. Toward the southeastern edge of the district some of the sandstones are nearly pure and more massive, and contain a small amount of asphaltum ("tar sandstone")	150–200
Total thickness of Birdsville formation	400–680

Largely on account of its greater thickness, but also because of its more homogeneous composition, bed 1 of the above section outcrops over a greater area than any other two beds of the formation. It occurs over most of the area traversed by the Marion and Fredonia road, its middle and upper parts being well exposed just north of the Fredonia fault At Crayneville it is the upper part; likewise west of Marion, along the road to Crittenden Springs. East of Marion, along the road to the Tribune limestone outcrop, most of the exposures seem to be of the lower part. Good exposures occur in several railroad cuts about 2 miles west of Claxton, where the rocks dip rather steeply and are repeated by step-faulting. The heavy-bedded and somewhat asphaltic sandstone phase may be seen in the southwest angle of Caldwell County, between Curry and the Princeton and Hopkinsville road. Large areas of bed 1 occur also in Livingston County, particularly at and north of Hampton.

Bed 2 was observed at many points within the district. Among the most accessible localities are the bluff at Birdsville, where it is well shown; on Champion Hill, 4 miles west of Salem; in the railroad cut at Marion, where the lower beds are exposed; on the east slope of Pickering Hill, in Crittenden County; at Carrsville and Smithland, in Livingston County, and in the hill just north of Golconda, in Pope County, Ill.

The ten beds above these are much less frequently seen. Most of them are unimportant, and the four at the top may be wanting entirely. Beds 3 to 10 and a part of 11 were noted in a number of fairly good exposures lying to the west and south of Claxton. Beds 4 and 6 are well exposed in a bluff about 2 miles southeast of Birdsville, on the road to Smithland. Bed 10 is easily recognized. It was formerly quarried at Claxton, in Caldwell County, and at Giles quarry, near Gladstone, in Crittenden County, and outcrops a few feet beneath the Mansfield sandstone on the Marion road, about 2 miles east of Sheridan. It occurs in most sections that contain the upper beds of the formation, but the upper part of bed 11 and all of bed 12 are perhaps as often absent as present. Bed 11 is well developed northeast of Creswell, in Caldwell County. Bed 12, with its often heavy layers of flinty chert, when present, is always a conspicuous stratum. It is well developed in the southern end of the Mansfield sandstone ridge, in the northwestern part of Livingston County, and frequently caps the highlands 2 miles west of Salem and at other localities along Sandy Creek to Cedar Grove Church. It usually forms the top of the formation in the northern part of Caldwell County and the eastern part of Crittenden County, and it has been observed also in Hardin and Pope counties on the north side of the Ohio.

Topography.—Where the lowest bed of the Birdsville formation is the surface rock the topography is generally not very hilly and sometimes the undulations are very moderate. Near the western border of the Coal Measures and the isolated knobs and ridges capped by the Mansfield sandstone the country becomes much rougher. This change is due, first, to the rapid variation in lithologic character exhibited by the beds and their unequal resistance to erosive agencies; and, second, to the protection against removal afforded to the highlands by the overlying Mansfield sandstone and the consequent steepness of the declivities.

Paleontology.—The fauna of the Birdsville formation is the one that, in consequence of its abundance at the typical and long-studied localities along the Mississippi River, has gradually become the type of the Chester or Kaskaskia fauna. Though distinguishable faunas occur in the earlier divisions of the Chester group, it is after all but right that the Birdsville fauna should stand as the most typical.[a] The genera and species that most prominently characterize the Chester fauna as a whole are not only all present in the Birdsville, but most of them occur here in better development and greater abundance than before. Besides, many species, constituting a great host, are met here for the first time. The writer has collected over 150 species from horizons of the Birdsville in western Kentucky. About two-thirds of this number occur, so far as known, only in this formation. As a full list of the fossils would be essentially the Chester fauna of literature, it is unnecessary to give it here. However, with a view to assist in discriminating between different parts of the formation a few of the more characteristic species of each part may be mentioned.

Aside from an occasional mold of a land plant, bed 1 of the section on page 61 is practically unfossiliferous. Still, fossils may occur sometimes, as in the vicinity of Scottsburg, where a few, thin, slightly calcareous strata near the base of the bed are crowded with organic remains. Most of these are of ordinary Chester fossils, but among them, and abundant, is the well-marked *Archimedes confertus* Ulrich. (See Pl. IV.) This species holds about the same horizon in Randolph County, Ill., and elsewhere. Bed 2 contains most of the peculiar Chester crinoids, particularly *Pterotocrinus*, of which the summit processes or "wings" of several species are common. (See Pl. VI.) Also the large *Pentremites obesus* Lyon, and another almost equaling it in size, for which the new name *Pentremites fohsi* is proposed. (See Pl. VII.) This is, furthermore, the principal horizon for *Archimedes*, at least five species (*A. swallovanus, A. intermedius, A. terebriformis, A. lativolvis*, and *A. proutanus*) being restricted to it, and for *Lyropora, Meekopora, Prismopora serrulata*, and many other Bryozoa. Finally, a considerable number of undescribed Pelecypoda are found only in this bed. These occur mainly in shales toward the base of the bed.

[a] When full lists of the faunas of the Ste. Genevieve and Tribune formations are compared with the Birdsville fauna, apparently a wide difference is observed; but when this difference is analyzed it proves to consist mainly of the Spergen fauna, which is present in the two earlier formations and so far absent in the Birdsville. If that periodically invading fauna be disregarded, the aspect of the remainder in both the Ste. Genevieve and Tribune is eminently "Chester."

EXPLANATION OF PLATE VII.

PENTREMITES OF THE BIRDSVILLE FORMATION.

Figs. 1–4. *Pentremites obesus* Lyon. Fig. 1. Lateral view of a fine example of this species which, like most of the specimens seen from western Kentucky, differs from Lyon's figured type of *P. obesus* in being proportionately narrower and in having longer basal plates; fig. 2, lateral view of another and shorter specimen in which the lower part is constricted so as to cause it to appear somewhat pedunculate; fig. 3, summit view of a third specimen which, except that the basal plates are wanting, is in a better state of preservation than usual; fig. 4, portion of one of the ambulacral areas of another example, magnified 3 diameters.

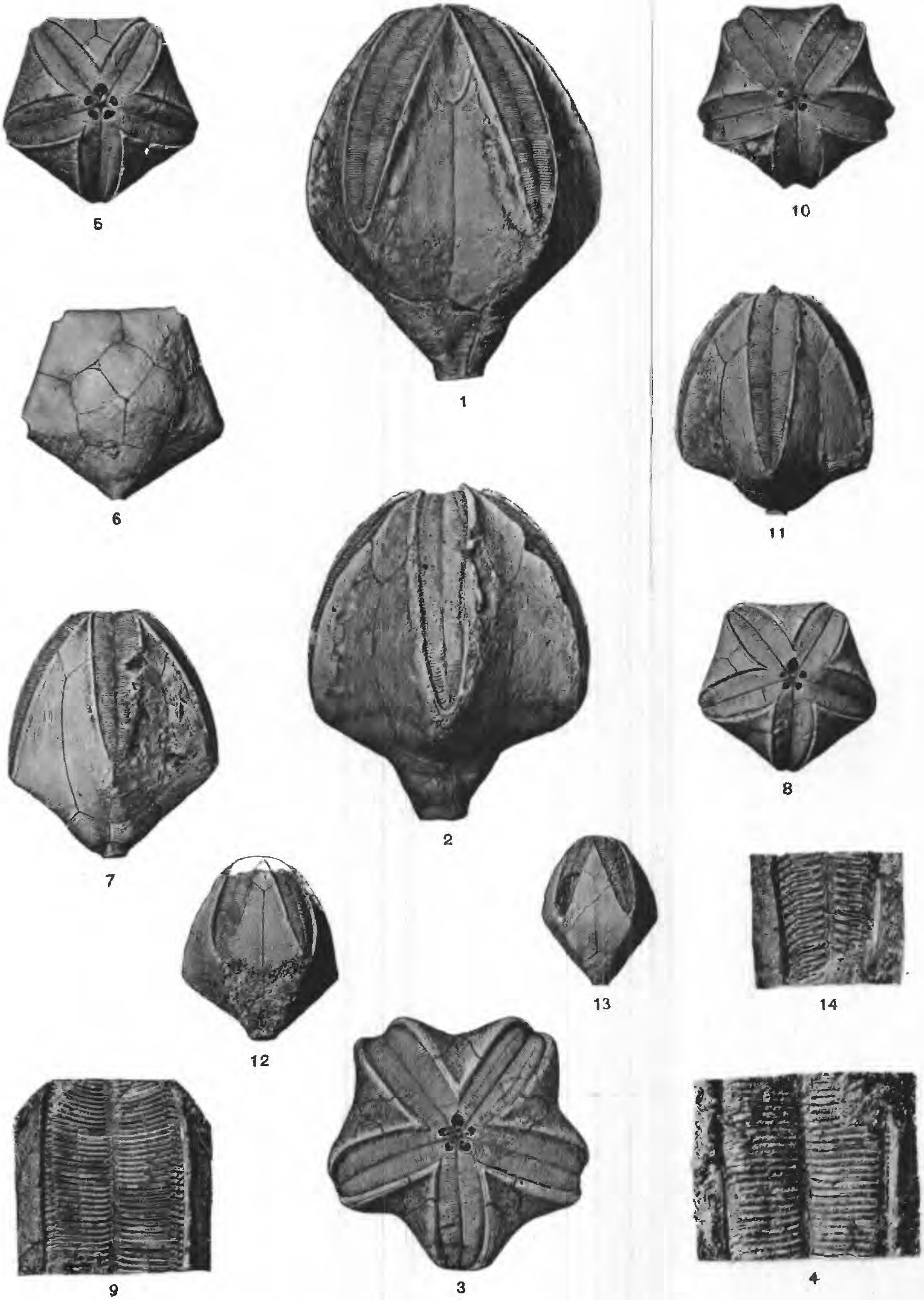
In this species the ambulacral areas are strongly biconvex in transverse section, the median groove being rather deeply depressed. The specimens figured were collected by Mr. F. J. Fohs in Crittenden County and presented to the writer for illustration.

Figs. 5–9. *Pentremites fohsi* n. sp. Figs. 5 and 6, summit and basal views of an adult example, in which the base is somewhat weathered and shows besides the usual three sutures faint evidence of two additional sutures across the two large basals; fig. 7, lateral view of the largest and in some respects the best-preserved example seen, regarded as the type of the species, which, with the preceding specimen, was found near the "Belleville Spring," about 8 miles northwest of Princeton, Ky.; fig. 8, summit view of another specimen collected in the railroad cut near Marion by Mr. F. J. Fohs, after whom the species is named; fig. 9, upper part of one of the ambulacral areas of figure 7, magnified 3 times.

P. fohsi seems to be related to *P. chesterensis* Hambach, but is a larger species and has a longer and more conical base. The side plates or "poral pieces" also appear to be narrower, 27 to 29 of these occurring in 10 mm., whereas Hambach's species is said to have only about 24 in this space ("6 to 0.1 of an inch"). The features relied on in distinguishing *P. fohsi* from all of the large species of the genus lie, first, in the general form; second, in the flatness of the interambulacral spaces; and, third, in the depth of the central part of the ambulacral areas coupled with the very slight convexity of the slopes on either side between the median and marginal grooves.

Figs. 10 and 11. *Pentremites fohsi* var. *marionensis* n. var. Summit and lateral views of an unique and finely-preserved example found by Mr. Fohs in the railroad cut near Marion, Ky. The basal part is more depressed and the interambulacral spaces less flat than in the typical form of the species. In both of these respects the variety is nearer *P. chesterensis* Hambach, but judging from the figure and description of the latter in Volume IV of the Transactions of the St. Louis Academy, this specimen can not belong to *P. chesterensis,* since it has about 30 side plates in 10 mm. and relatively wider ambulacral areas.

Figs. 12–14. *Pentremites pyramidatus* n. sp. Fig. 12, a specimen of medium size, imperfect at the summit but showing the pentangular pyramidal form of the base and the convex ambulacral areas which together characterize the species; fig. 13, a smaller but more complete example, differing from figure 12, like all other young specimens of the species, in being proportionately narrower; fig. 14, portion of an excellently preserved ambulacral area, magnified 3 times. This figure is taken from an incomplete specimen that originally exceeded fig. 12 in size. As shown in this and the other specimens referred to this species, the ambulacral areas are convex and constructed very much as in *P. conoideus.* The affinities of *P. pyramidatus,* therefore, are believed to lie with that species and its allies rather than with the group typified by *P. obesus* or with the other group of which *P. fohsi* is a good example. Much of the uncertainty prevailing among paleontologists endeavoring to identify species of *Pentremites* is due to the fact that in describing and classifying the species authors have paid more attention to the comparatively unimportant variations in the general form of the theca than to the more constant structural features displayed on the surface of the ambulacral areas.



PENTREMITES OF THE BIRDSVILLE FORMATION

Beds 4, 6, and 9 contain a good and abundant Chester fauna, that is distinguished from the fauna immediately preceding it chiefly by the absence of its more striking elements. It consists almost entirely of Bryozoa and Brachiopoda, the other classes being much less conspicuous than in bed 2.

Bed 10 contains a number of peculiar fossils, but, unlike those found in the other beds, they are so firmly embedded in hard limestone that it is always difficult to procure good specimens.

Distribution.—The Birdsville formation is exposed over nearly one-third of the combined area of the three counties of Caldwell, Crittenden, and Livingston. In Caldwell its upper limit is usually defined by normal contact with the overlying Mansfield sandstone. This is true also in the outliers of the sandstone. As represented on the map this boundary is everywhere more or less generalized, as is also the undisturbed contact with the underlying Tribune limestone. With the poor maps and short time at disposal it was impossible to delineate details. Where the boundary is marked by a fault the mapping, it is believed, is a nearer approximation to the truth.

The second largest area occupies the greater part of Livingston County north of the Cumberland River. The largest continuous outcrop embraces nearly a third of the area of Crittenden County and extends southeastward into Caldwell. On the northeast side it is bounded mainly by the Tradewater fault; on the west by the Columbia, Stevens, and several other shorter faults; on the south by the Tabb, Fredonia, Stone, and Bodard faults. The irregular area in the southwestern part of Caldwell, containing Scottsburg, Curry, McGowan, and Friendship, probably is bounded on all sides by faults. There are numerous smaller areas and projections from the larger ones, all inclosed by fault planes. Smithland is located on one, Vicksburg on another, a third occurs at the convergences of the Woods and Crittenden faults, while a fourth forms the sandstone hill west of Princeton

Nomenclature and correlation.—This formation is named from the village of Birdsville, situated on the Ohio River, in the western part of Livingston County. The middle beds of the formation are well displayed in the bluffs at this locality, while higher beds, and possibly the top, may be seen in the bluffs along the first 4 miles of the road to Smithland.

The Birdsville comprises the more arenaceous and shaly upper and greater part of the Kaskaskia division of the Chester group. This portion of the group is present wherever the Chester is represented. It overlaps all the preceding formations of the Chester, so that as a rule it forms the outer border of areas exposing rocks of this group. Consequently the geographic distribution of the Birdsville is greater than that of the underlying Tribune, Cypress, and Ste. Genevieve formations, and corresponds in extent with that of the Chester group as a whole.

The exact equivalent of the Birdsville in Indiana has recently been named the Huron formation,[a] but as this name has been twice preoccupied[b] it can not be used in the sense proposed by Ashley. Under the circumstances a new name for the formation was required. Birdsville, the name here proposed, should hereafter be substituted in Indiana for Ashley's Huron.

POTTSVILLE GROUP.

MANSFIELD SANDSTONE.

Lithologic characters.—This formation consists of a variable series of sandstones, conglomerates, and shales. In some places, as in the vicinity of Claxton, it consists, apparently, of only a single bed, generally forming bluffs 50 to over 100 feet in height, of more or less coarse, yellow or brown sandstone, in which irregular bands containing quartz pebbles stand out conspicuously in weathering. This sandstone constitutes the chief member of the formation in this area, but farther inward from the edge of the coal basin, and also in some of the outliers, other beds referable to the same formation come in over it. At or near the top of the main sandstone a ferruginous layer has been frequently observed, but it seems never to contain sufficient iron to justify its being called an ore.

Occasionally a bed of shale, including a thin, pockety bed of coal and a band of highly ferruginous lenticular masses, occurs beneath the main sandstone. This lowest bed may be seen about 1 mile north of Flat Rock Church, in the northwestern part of Caldwell County, where the coal was mined many years ago to supply a local demand. Here the bed has a maximum thickness of nearly 35 feet, with about 10 feet of shaly sandstone, containing specks of carbonaceous matter at the base and resting on the eroded top of a late limestone of the Birdsville formation. The remainder of the bed consists of soft, greenish to dark-gray, argillaceous shale, with coal and ferruginous beds in the lower part. The same bed of coal apparently is worked occasionally even now about 4 miles north of Princeton.

Above the coarse-grained main sandstone one, or more rarely two, distinguishable beds that are referred to the Mansfield sandstone have been observed. In Hardins Knob, an outlier in the western part of Crittenden County, the coarse sandstone has a thickness of about 135 feet. Above this, to the top of the knob, come 110 feet of, first, finer-grained conglomeratic and quartzose sandstone filled with plant remains, and then very fine-grained sandstone or quartzites. Some of the latter doubtless would furnish a fair quality of whetstone. In other sections, as in the vicinity of Enon and Ruth, in Caldwell County, and along the eastern border of Crittenden County, this bed is somewhat shaly and the sandstone layers

[a] Ashley, Twenty-seventh Ann. Rept. Dept. Geol. and Nat. Res. Indiana, 1902, pp. 71–77.

[b] Logan, W. E., Huron formation: Am. Jour. Sci., 2d ser., vol. 14, 1852, pp. 224–229. Winchell, Alexander, Huron group: Geol. Survey Michigan, First Bien. Rept. Prog., 1861, pp. 71, 139.

are thin and uneven and in parts nodular. As a rule it contains impressions of *Lepidodendron* and other land plants in abundance. The bed of coal included in it in the northeastern part of Crittenden County seems to be, considering the horizon, unusually persistent in thickness and character.

The coal bed that was worked for many years at several points west of Carrsville, notably at the old Union or Trabue mines, also appears to be included in this bed. Here, however, there is another conglomerate above the coal. The coal occurs in argillaceous shale immediately beneath the "slabby" whetstone sandstone. Here, beneath the lower conglomerate, which is the bed that is generally distributed through the district, there is sometimes, as at Flat Rock Church, in Caldwell, a variable bed of shales with coal streaks, and beneath this a thin-bedded sandstone resting unconformably upon upper Birdsville limestone. The upper conglomerate varies in a short distance from a few feet to about 50 feet in thickness, the increase in volume being westward from Carrsville. The lower conglomerate, on the contrary, decreases in that direction. As the bed between the two conglomerates observed in the northwestern part of Livingston County is much thinner than the fine-grained sandstone described as forming the top of Hardins Knob, it is regarded as probable that the upper conglomerate at Carrsville is merely a coarse local facies of its upper part. Whether this belief proves true or not, it can not be denied that the beds of the Mansfield are extremely variable in thickness and to a great extent in lithologic character. The deposits evidently vary according to local conditions, and much detailed work will be required to correlate them satisfactorily with presumably contemporaneous beds in Indiana, or even from point to point within the area under consideration.

According to the evidence now available it appears probable that the lower conglomerate is approximately the same bed that Kindle,[a] in a section of the Mansfield and Kaskaskia formations in Orange County, Ind., designates by the number 6, and to which he gives a thickness of 100 feet. Above this bed his section distinguishes (7) a bed of coal 14 inches thick; (8) the Hindostan whetstone, 20 feet; (9) coarse sandstone, 35 feet; (10) coal, 1 foot; and (11) coarse sandstone, 14 feet. The lower of the two coals—i. e., bed 7—may be correlated with the bed of coal often found above the lower conglomerate in this district, and the whetstone probably occupies nearly the same horizon in both areas. The sandstone above the whetstone in Kindle's section may then represent the upper conglomerate at Carrsville. Further, if the coal of Kindle's bed 7 is, as there seems little reason to doubt, the equivalent of Ashley's coal I,[b] which he describes as at or near the base of the Mansfield in the area north of Orange County, then it would appear that the lower conglomerate wedges out by overlap northward

[a] Twentieth Ann. Rept. Indiana Dept. Geol. and Nat. Res., p. 346, 1896.
[b] Twenty-third Ann. Rept. Indiana Dept. Geol. and Nat. Res., 1899.

in Indiana, where deposits are preserved that were laid down nearer shore than were those found in the more eroded area along the Ohio River. It is to be understood that the overlap referred to is here eastward rather than northward.

When the quartz pebbles are wanting the heavy-bedded Mansfield sandstone looks much like the Cypress sandstone. The thin-bedded sandstones of the Mansfield, however, resemble much more closely certain sandstones of the Birdsville formation, particularly one near the top and another at the base of that formation. In the faulted condition of the district it sometimes happens that sandstone outcrops occur whose stratigraphic position is not indicated by their relations to some more easily recognized bed, but must be determined solely by the lithologic peculiarities of the outcrops in question. It is therefore probably worth while to point out the criteria here chiefly relied on to discriminate between Mansfield and Chester sandstones. The most important of these is the universal presence of small flakes of muscovite mica in the Mansfield sandstones and the comparative rarity and generally entire absence of mica in both the Cypress and Birdsville sandstones. Mica flakes have been observed in the upper sandstones of the Birdsville formation, but in no case that comes to mind at this moment was its presence noted in any of the lower sandstones. Carbonaceous specks also are rare in the Birdsville and rather common in the Mansfield.

The discovery in a massive sandstone of even a few small quartz pebbles was accepted as positive evidence that it is Mansfield and not Cypress or some other Chester sandstone. Where the beds were thin and shaly the presence of plant remains in considerable quantity was regarded as equally conclusive evidence in favor of Mansfield. Where these could not be found, the mica test was supplemented by the fact that whereas the surface of the thin-bedded Birdsville sandstones is nearly always even, it is commonly hummocky or nodular in the Mansfield.

Topography.—Where the lower half of the Mansfield sandstone is the surface rock, the country is always extremely rough. The surface is strewn with great bowlders and masses of conglomeratic sandstone, while bluffs and bare walls 50 to over 100 feet in height abound. Where the areas retain a considerable part of the thinner bedded upper half, the topography is less rugged, and sometimes may even take on the character of a table-land. This change in topography is very well illustrated in passing northward across the large outlier of Mansfield sandstone that occupies the northwestern part of Livingston County.

Paleontology.—Impressions of land plants are the only fossil remains so far found in the Mansfield sandstone in western Kentucky. These occur in greater or less abundance and generally in a fair state of preservation in nearly every exposure of the middle portion of the formation. They are less common and not so well preserved also in the other beds. Plant remains were collected at only one locality, viz, in Caldwell County, between Enon and Ruth. These were submitted to Mr. David White of the Survey, who has kindly determined and listed the following species:

Fossils from Mansfield sandstone, collected in Caldwell County, Ky.

Eremopteris macilenta (Lx.) D. W.
Danæites macrophyllus (Newb.) Lx.
Neuropteris cfr. Schlehani Stur.
Calamites cistii Brongn.
C. Roemeri Goepp.
Lepidodendron clypeatum Lx.
Lepidostrobus pennsylvanicus D. W.
Lepidophloios cfr. laricinus Sternb.
Lepidocystis vesicularis Lx.
Halonia sp. undet.
Triletes (megaspores.)
Sigillaria, sp. indet.
Artisia transversa Lx.?
Cardiocarpon bicuspidatum (Sternb.) Lx.
C. elongatum Newb.
C. ovale Lx.
C. crassum Lx.
Trigonocarpum ampullæforme Lx.
T. dawsonianum D. W.

Distribution.—The Mansfield sandstone outcrops as a continuous band from 2 to 10 miles wide along the eastern borders of Caldwell and Crittenden counties. Beyond the Tradewater River, which forms the eastern boundary of the counties named, the formation soon dips under later deposits. Most of the western boundary of this area is sinuous, being formed by normal contact with the underlying Birdsville formation. In Crittenden County a part of the boundary is straightened by the Tradewater fault. West of this area 11 outliers have been determined, all of them being conspicuous in the topography of the district. Reckoning from east to west, the first of these is at Iron Hill, in Crittenden County. This is a high flat-topped hill in the angle of convergence of the Tradewater and Crittenden faults. Geologically higher strata occur at lower levels on the other sides of these faults. The second outlier covers a considerable area in the northwestern part of Caldwell County and owes its preservation to downthrow in faulting. The third area occurs as the capping of a high hill less than 2 miles south of Weston. The fourth is an elongated area, averaging rather less than 1½ miles in width by about 10 miles in length, that has been thrown down between the Columbia and Lerue faults. It is cut into two parts by the Hurricane fault, the downthrow in the portion northeast of this fault being greater than in the portion southwest of it. The fifth area is a small, angular one, bounded by fault-planes and known as the sand hill, situated just west of Sheridan. The sixth forms an elongate triangular area, with the prominent Hardins Knob at its north end. It is bounded on the east side by the southern prolongation of the Glendale fault and on the western side by the Miller fault. The area forms a rough ridge divided about half and half between the counties of Crittenden and Livingston. Between 2 and 3 miles south of the acuminate extremity of this area is another that forms, as usual, a patch of very rough country. The eighth outlier lies just north of the Cumberland River and a short distance west of the mouth of Sandy Creek. The ninth is provisionally indicated on the map as an ovoid area about 3 miles east of Hampton and nearly the same distance south of Lola. The tenth is a triangular, fault-bounded area south of the Cumberland River between Smithland and Livingston chapel. The eleventh is the largest outlier in the district. It lies in the northwestern part of Livingston County and covers most of the area lying between the Ohio River and the Fairview fault, which crosses the county in a southwesterly direction from Carrsville to Bayou. The strata dip on the whole gently northward, allowing the upper limestones of the underlying Birdsville formation to outcrop in the slopes inclosing the southern half of the area. This part contains little more than the main sandstone of the formation and affords much rougher topography than the portion north of the Golconda road.

Nomenclature and correlation.—The name of this formation is adopted from the reports of geologists of the Indiana Survey.[a] Previous to 1896 the formation was generally referred to as the "Carboniferous conglomerate." The latter is commonly, and no doubt correctly, correlated with the Pottsville group of Pennsylvania; but the basal beds of the Pennsylvanian series in Indiana, southern Illinois, and western Kentucky, above described under the name Mansfield sandstone, probably represent only the upper members of the (Pottsville) group.

ALLUVIAL DEPOSITS.

The term alluvial deposits includes only such recent deposits as those forming the bottom lands adjacent to the large rivers. Where these are broad they have been distinguished in a generalized manner on the maps. In the absence of a topographic base it was thought better to do this approximately than to continue the patterns of the Paleozoic formations across the bottoms. The latter have, of course, considerable agricultural value, but the mineral veins and faults which cross them can no longer be traced superficially, and if worked under the bottoms at all it must be by underground drifting from shafts much farther inland.

Other and older alluvial deposits occur as beds of chert gravel well up on the hills bordering the Cumberland and Tennessee rivers. These deposits were not studied, but they are probably worthy of careful investigation, since some of them at least may afford valuable road metal.

[a] Hopkins, T. C., Mansfield sandstone: Dept. Geol. and Nat. Res. Indiana, Twentieth Ann. Rept. for 1895 (1896), pp. 186, 195, 196, 199.

CHAPTER III.

GEOLOGIC STRUCTURE.

GENERAL FEATURES.

In a broad way the Kentucky-Illinois fluorite district represents two truncated stratigraphic domes. The northern one of the domes centers in Hardin County, Ill., and is the sharper and more complete of the two. The southern dome is so badly broken up and eroded that its center can not now be definitely fixed. It was probably somewhere along the Tennessee River and not far from the town of Grand Rivers. Both domes are irregularly circled to the north and east by an escarpment formed by the Mansfield sandstone, which is here the basal formation of the Coal Measures of the Pennsylvanian series.

On the southwest the district is bounded by the remains of an ancient and often submerged anticlinal fold, against and over which deposits were piled from both sides.[a] The southwestern limb of this fold evidently has with time grown the steeper of the two, and leads down into the much deeper basin of the Mississippi embayment. It is an elevation on this anticlinal fold that is supposed to be the center of the southern dome, for it is here that the lowest rocks in the Kentucky portion of the district are most commonly found. Between this place and the Mansfield escarpment the Mississippian formations occur in successive but very much interrupted bands. To the southwest the Cretaceous and Tertiary clays overlap the slope to, and in places across, the Tennessee River. Most, if not all of the Mississippian formations are believed to have extended, in part at least, over the anticlinal fold into the embayment.

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[a] In his report on the Jackson Purchase Region, pp. 321-326. published by the Ceological Survey of Kentucky in 1888, R. H. Loughridge discusses the evidence afforded by a deep well at Paducah and reaches the conclusion that an immense east-west fault passes through the Paleozoic rocks beneath the Tertiary clays at or just north of Paducah. According to his interpretation of the beds passed through by the well boring the region south of the Ohio River sank "to a depth of more than 1,300 feet." As interpreted by the present writer, the evidence afforded by the well tends to show that if there is any fault at all beneath Paducah, the displacement can not exceed 400 feet. Indeed, it is thought possible that instead of being the result of faulting the difference in altitude of certain stratigraphic horizons on opposite sides of the Ohio River in the immediate vicinity of Paducah, upon which Loughridge's theory of a buried fault is based, is really due to mere anticlinal folding. However, the embayment proper is most probably paralleled on the northeast by a great fault that passes a few miles south instead of north of Paducah.

FAULTS.

GENERAL CHARACTER OF FAULTS.

The fluorite district contains a very large number of faults, no less than 35, with a maximum displacement ranging from 300 to perhaps over 1,400 feet, being known on the Kentucky side of the Ohio alone; and it appears that the northern half of the district will not fall far short in this respect. Since many of these are connected with series of subsidiary fractures and faults, whose displacement rarely exceeds 200 feet, and is usually considerably less than that, they may be distinguished as the main faults. Of the subsidiary fissures, there are probably hundreds.

The faults, apparently in all cases, are normal, and strike in many directions. Their planes divide the area into a large number of very unequal, but always sharp-sided polygons. As a rule the lines of faulting are practically straight, apparent slight deflections in the course being generally due to the dip of the fault planes (which is usually considerable) upon the line of outcrop over an undulating surface. Often, however, as in the case of the Tabb fault, the faults are broken up into series arranged en échelon. Each plane of such a series is straight, but the strike of the individual planes is not quite parallel, and generally crosses the average strike of the *zone* in which the faulting has taken place. Again, when one of the main faults is accompanied by, or is split up into, subsidiary fractures, as in the case of the Columbia, it often happens that the major displacement occurs along first one and then another of the subparallel fractures, and oftener it is transferred back again to the main line. In these cases the main line may as a rule be traced through, but the degree of faulting along it is periodically subsidiary. In other cases, finally, the subsidiary faults are arranged step-like on one or both sides of the main line, as in the case of the Larue, between Hurricane and Crooked creeks. The determination of any of these conditions in this and most other fissured districts depends very largely upon the results brought out in abundant prospecting and subsequent development of the veins. Of course, the detailed work required to bring them out clearly enough to delineate them on a map was possible in only a few cases in this district. In the other cases it is not to be doubted that future investigations will often, if not always, necessitate similar modifications of the long straight lines by which the faults are now represented on the accompanying maps. In the meantime they should be viewed as representing the average courses of zones rather than individual fault-planes.

TRACING OF FAULTS.

When the displacement of the strata is sufficient to bring two lithologically distinct formations into juxtaposition, as, for instance, when the sandstones of the Mansfield formation and of the Chester group are thrown down to the level of the normally underlying limestone formations, there is little difficulty in tracing the fault; but where the displacement is insufficient to produce this result, or where the opposing formations are lithologically similar, very close stratigraphic or paleontologic comparisons are required to establish its presence. Indeed the difficulties seemed almost insurmountable in the cases where the faults extended into the deeply weathered areas occupied by the St. Louis and lower limestones. Still, fortuitous discoveries along their lines of strike will, it is believed, result in the extension of many of the faults into such areas, and particularly into the large one that embraces nearly the whole of Lyon County and smaller portions of the adjoining counties. In the cases where different parts of any of the formations of the Chester group are on the two opposite sides of the fault-plane the difficulties are usually not so great, since the different members of these formations may be distinguished without much trouble. Besides, they are as a rule not deeply weathered, while in the arenaceous formations the course of the fault is very commonly marked by protruding dike-like masses of silicified sandstone.

DIVISION OF FAULTS INTO SYSTEMS.

Taken as a whole, the fractures fall into at least two well-defined systems, one trending northeast to east, the other north to northwest. In Kentucky the northeasterly system is the more prominent and its fractures are perhaps more generally mineralized than those of the other systems. The faults in this system have also resulted in a much greater average displacement of the strata than prevails in the northwest system. The faulting in the latter rarely amounts to 400 feet, while in the former it commonly exceeds that amount, and sometimes reaches the maximum of 1,400 feet observed in the district.

The division of the faults into systems varies according to the criteria employed in classifying them. If they are classified solely according to direction of strike, they fall into two main systems—one northeast, the other northwest—and a third more subordinate system trending nearly due east. If, however, other factors, such as arrangement with respect to centers, direction of diminution of throw, and localization of development are also considered, the resulting classification, though similar on the whole, is still somewhat different in detail. Thus, while the subordinate system of easterly fractures, which has its main development in Caldwell County, is the same in both classifications, the northeast system in the first includes several northeast faults in the northwestern quarter of Livingston County that in the second classification are referred to the otherwise northwesterly trending system. As to the respective merits of the two classifications, convenience alone is consulted in the first, while in the second supposed natural relations are the controlling factors.

When plotted on a map (see Pl. II, opposite p. 22) the northeast faults, excluding the Fairview and Rosiclare faults, constitute an obviously natural and geographically distinct system. This presents an obscure fan-shaped arrangement, radiating and diverging eastwardly from the region between Pinckneyville and Smithland in Livingston County. The ribs of the fan pass through or into Crittenden County, and its successive lines run more and more easterly as we approach the southern boundary of that county and enter Caldwell, where they pass over into the subordinate system in which the fractures strike from a little north of east to a few degrees south. As a rule, the faulting grows less and finally dies out entirely in an easterly direction. Considered geographically, this system is eminently Kentuckian.

In a comprehensive view, the faults in the northern parts of Livingston and Crittenden counties, which strike toward the Ohio River, appear to belong to a similarly though less compactly arranged system, radiating and diverging southward from the western part of Hardin County, Ill. The course of the most western of this clearly Illinois system of faults is about S. 30° W.; that of the Tradewater fault on the opposite side of the district S. 56° E. Except the dikes, which probably form systems of their own, all of the northwest fractures in west Kentucky may be referred to this Illinois system.

This irregularly radial arrangement of the fractures has, so far as known, no relation to the igneous deposits of the district. Indeed, no igneous rocks of any sort have yet been found either in Livingston County, the southern half of which contains the imaginary converging point of one of the systems, nor in the part of Hardin County in which the Illinois system centers. Moreover, with one or possibly two exceptions, the trend of all of the dikes is essentially at right angles to the more prominent system, being northwest instead of northeast.

The fractures, whether mineralized or not, frequently serve as channels for descending waters, as is shown by the corrosion of the walls, some of the apparently unmineralized fractures forming either open fissures or crevices filled with red clay. Sometimes, though perhaps only where the Birdsville formation occurs in one of the walls, the crevice is largely occupied by dragged-in shales and dark, secondarily deposited clays. Sink holes are common along some of the fractures, and to a certain extent these may be used as guides in locating the fissures. They are, however, likely to prove unreliable and misleading, since very often they lead to nothing better than merely enlarged joints and caverns in the limestone formations. The limestone beds contained in the faulted blocks are of course abundantly traversed by such joints. These often parallel the fault-planes, but as a rule there seems to be no definite relation between them. At any rate the relations are not obvious.

DATE OF FAULTING.

The axes of the two primary domes contained within the limits of the Kentucky-Illinois fluorite district doubtless were in existence long before the fracturing began. Aside from these axes, the structural phenomena observed in the region are seemingly due almost entirely to vertical uplift and gravitational adjustments following or incident to the process of fracturing. During the later stage of this process some oblique lateral stresses doubtless came into play to modify the effects of the purely vertical movements. As to when these movements and the consequent fracturing and faulting occurred it is difficult to secure definite data. It must have been subsequent to the close of the Carboniferous, since beds of that age are involved in the faulting, and it is perhaps equally certain, though more difficult to prove, that it took place before the close of the Tertiary. A full discussion of the matter would require more space than is warranted by its relatively small importance. It must therefore suffice for the present to merely state the writer's opinion that the greater part of the movements occurred during the later half of the Cretaceous period, and that the faulting then established continued, with periodic accentuations and additions of fractures of minor import, almost to the present time. Also that the origin of the dikes and of most of the main faults was nearly contemporaneous, the former probably having a brief priority over the latter.

DETAILED DESCRIPTION OF FAULTS.

To facilitate the location of the faults they are divided, somewhat arbitrarily, into four sets, (1) those trending northeast to southwest, (2) those trending nearly east and west, (3) those extending from northwest to southeast, and (4) a set of unimportant faults, mainly in Caldwell County, trending nearly north and south. Those in each set are considered in the order of their occurrence, beginning with the first of the northeast set in the northwestern angle of the maps (Pl. II, p. 22, and Pl. VIII, p. 116) and passing southwesterly across it. The east-west set is almost confined to Caldwell County. Each fault of this set is considered in the same order, beginning with the Fredonia and ending with the McGowan. The description of the northwest set begins with the Tradewater fault and, proceeding southwesterly across the area, ends with the Deer Creek faults. Finally, following brief remarks on the fourth set of faults, the peridotite dikes are considered in a similar order, beginning with the Flanary, which has a northeast trend, and ending with the most westerly one of the northwest dikes.

LIST OF FAULTS AND DIKES.

The following list shows the order in which the faults and dikes are considered. Those with a maximum displacement of less than 300 feet are distinguished by italics. Following the name the average course of each is given according to the magnetic north, which in 1902 varied in the district from 4 to 5 degrees east of true north. In the description following the list, however, the error of the magnetic needle has been corrected as much as possible, but it is to be understood that the direction given is in all cases only approximate, and applies to the *zone* of faulting, and not, as a rule, to the individual and local fault planes.

List of faults and dikes in western Kentucky.

Northeast-southwest faults (N. 12°–72° E.):
- Undetermined fault (N. 26°–31° E.).
- Fairview fault (N. 24° E.).
- Rosiclare fault (N. 8° E.).
- Lola fault (N. 37° E.).
- Faulted blocks at and west of Sheridan.
- Corn fault (N. 61° E.).
- Dyers Hill fault (N. 36° E.).
- *Latrobe fault* (N. 44° E.).
- Pittsburg fault (N. 19° E.).
- Fault 2½ miles east of Smithland (N. 32° E.).
- Miller fault (N. 27° E.).
- Larue fault (N. 29° E.).
- Glendale fault (N. 36° E.).
- Sandy Creek fault (N. 19° E.).
- *Minor fractures in vicinity of Salem.*
- Evening Star fault (N. 37° E.).
- Columbia fault (N. 23° E.).
- *Memphis group of fractures* (N. 30°–33° E.).
- Stevens fault (N. 34° E.).
- Marion fault (N. 39° E.).
- Woods fault (N. 39° E.).
- Hodge fault (N. 41° E.).
- Crittenden fault (N. 52° E.).
- *Yandell fault* (N. 36° E.).
- Bibb group of fractures (N. 52°–56° E.).
- Tabb fault (N. 72° E.).
- Faults bordering large sandstone hill west of Princeton.
- Princeton fault (N. 63° E.).
- *Saratoga fault* (N. 40° E.).

Northeast-southwest faults, etc.—Continued.
- *Two small faults south of Princeton.*
- Friendship fault (N. 50° E.).

East-west faults (N. 74°–94° E.):
- Fredonia fault (N. 94° E.).
- *Lowery and Marble fissures.*
- Matthews fault (N. 86° E.).
- Clay Lick fault (N. 83° E.).
- Skinframe fault (N. 86° E.).
- Eddy Creek fault (N. 74° E.).
- McGowan fault (N. 92° E.).

Northwest-southeast faults (N. 15°–68° W.):
- Tradewater fault (N. 60° W.).
- Bodard fault (N. 68° W.).
- Dollarson faults (N. 56°+W.).
- Livingston Creek fault (N. 26° W.).
- *Hurricane fault* (N. 17° W.).
- Tolu fault (N. 34° W.).
- Holly faults (N. 31° W.).
- Puckett Branch fault (N. 34° W.).
- Deer Creek faults (N. 15°–17° W.).
- Other small and generally unimportant faults.

Dikes:
- Flanary dike (N. 44° E.).
- Hard dike (N. 38° W.).
- Walker dike (N. 39° W.).
- Old Jim dike (N. 36° W.).
- Carden dike (N. 33° W.).
- View dike (N. 34° W.).
- Caldwell Spring dike.

NORTHEAST-SOUTHWEST FAULTS.

Undetermined fault (N. 30°–35° E.).—On entering the Kentucky part of the fluorite district at its northwestern corner and passing southwesterly across it, the first fracture encountered is a fault of small displacement that is believed to cross the river in a southwesterly direction from Hardin County, Ill. Evidences of faulting were observed about 2 miles west of Carrsville, but as no special interest seemed to attach to it, no attempt was made to trace and locate it on the map. Possibly it is due to this fault that the upper limestone of the Birdsville formation outcrops so suddenly about 1 mile south of Berry Ferry. If so, the course of the fault would be N. 30°–35° E.

Fairview fault (*N. 29° E.*).—This is a well-marked fracture with a displacement varying in Kentucky from somewhat over 200 feet to about 400 feet. It is shown, with the fault plane slightly mineralized, on the river bank just below Carrsville. The outcrop is marked by a dike-like mass of quartzite. On the west side of the fault here the slopes of the hills expose upper limestones shales and sandstones of the Birdsville formation, and above these to the tops of the hills mostly heavy-bedded Mansfield sandstone. The nearest exposures on the east side of the fault indicate beds occurring at least 200 feet lower in the Birdsville. Similar conditions prevail for about 2 miles southwest along the fault before the general increase in altitude of the country on the east side buries the contact between the top of the Birdsville and the Mansfield. Passing over the divide and down the north or Sugar Camp fork of Bayou Creek the upper beds of the Birdsville soon show again on the west side and continue thence with gradually deepening exposures to the Ohio River bottom near the mouth of the creek. Throughout the course of the Fairview fault in Livingston County the downthrow remains on the west side of the fault.

Besides the slightly mineralized outcrop in the river bank at Carrsville, only one other prospect is known in Kentucky on this fault. This is the Wright shaft, situated about three-fourths of a mile south of Carrsville on the west of the Joy road. This is one of the few good prospects of those having Birdsville rocks in both walls. It is being developed by the Ohio Valley Mining Company.

There seem to be no reasonable grounds for doubt that this is an extension of the fault upon which the Fairview mine in Hardin County, Ill., is located. At that mine the country rock on the west of the fault was determined as Mansfield sandstone, and on the east side, at the shaft, as Tribune limestone. A short distance south of the main shaft another shaft was sunk in thin-bedded lower Birdsville sandstone and shale, indicating that between the two shafts there is a cross fault. South of this cross fault the rocks on the two sides of the main fault would appear to be about the same as above described in Livingston County, the only difference being that the throw is somewhat greater on the Illinois side of the river.

The Fairview fault and vein is sometimes spoken of as a continuation of the Rosiclare vein. In part this is doubtless a fact, yet it seems to the writer that the deflected part of the vein now chiefly worked at the Rosiclare mine is really not the same vein as the one that can be traced from the old workings to the Fairview shaft. Instead of a bend in the vein, which is only one of the necessary assumptions in the opposite view, it seems more likely that there are two intersecting faults at the Rosiclare mine, or that the Rosiclare vein forks, one branch being the Fairview vein, while the other, or true Rosiclare, continues with a more southerly course through the "well prospect" on the Fairview company's property and thence across the river into Kentucky. The difference in the formations on the east side of the Rosiclare and Fairview mines is accounted for in this view but not in the other.

Rosiclare fault (N. 12.5° E.).—In passing over the east and west roads crossing the northern half of Livingston County indications of faulting in Birdsville rocks, with a general northeast-southwest trend and comparatively small displacement, were observed at three points. The first is near the forks of the road rather less than a mile southeast of Carrsville; the second occurs a mile or so east of Joy, on the Lola and Golconda road; the third point lies about 2 miles northwest of Hampton. A line connecting the three points corresponds very nearly with the course here ascribed to the Rosiclare fault. It is most probably not a continuous fault plane, but rather a zone of faulting in which a number of planes are arranged en échelon. Possibly the obscure fault mapped as extending from Dyers Hill Church to and beyond Smithland represents a continuation of the same zone. As no mineral prospects were reported along this line and as mineralization of fractures in Birdsville rocks is rare and with the possible exception of the Ohio Valley Mining Company's prospect on the Fairview fault near Carrsville, is, in no case observed, of permanent value, the indications were passed without careful examination.

Lola fault (N. 41° E.).—As this fault resulted in only a small amount of displacement and, moreover, as it passes chiefly through areas unfavorable for exact determinations, it is not well known. It is indicated in the village of Lola by an outcrop of fluorspar in the road and again, 2 miles southwest, in the Bonanza mine. The throw at Lola seems to be on the north side, but at the Bonanza mine it appears to be on the opposite side. The fracture probably continues northeastward across Deer Creek into the St. Louis limestone area, in which it seems to be indicated by the northeast vein in the Mann mine, but, on account of the small throw and depth of weathering of the limestone, its course is very difficult to follow.

Faulted blocks at and west of Sheridan.—There are three fault-bounded sandstone areas almost entirely surrounded by St. Louis limestone, one at Sheridan, the other two several miles west of that place. The latter appear to consist of Chester sandstone, but whether of Cypress or Birdsville age was not positively determined. Their boundaries also are conjectural, time in the field having been too limited to plot them accurately. Provisionally they are mapped as Cypress. The block at Sheridan, however, is of Mansfield sandstone and bounded on four unequal sides by faults. With undoubted St. Louis limestone on three sides, and apparently Cypress sandstone on the southwest, the maximum throw of this block can not be less than 1,000 feet and may exceed 1,200 feet. If these blocks, especially the last, are, as is believed, wedge-shaped vertically, with the smaller dimensions beneath, then there should be some very wide fissures in the limestones beyond their superficial angles. In 1890 the writer observed fragments of igneous rock just beyond the northeast extremity of the Mansfield sandstone block, and it is possible that the conjectured fissure is here filled by a great dike. Such a dike might very well occur here as an extension of the Flanary dike, the supposed course of which corresponds with that of the fault forming the southeast boundary of the block.

Corn fault (N. 65° E.).—This fault has been traced westward from a point on the Miller fault about one-half mile east of Pleasant Grove Church to the Deer Creek fault, which it meets and possibly crosses about 1½ miles southeast of Lola. Especially in the eastern half of its length the Corn fault is broken up into, or is accompanied by, several subsidiary planes arranged en échelon. Throughout its length the northern side of the fault exposes residual clays and chert of the St. Louis limestone. The greatest displacement occurs in the mile farthest east, where it forms the northern boundary of the long strip of Birdsville formation country included between the Dyers Hill and Miller faults. In the next mile west the St. Louis limestone abuts against Cypress sandstone and upper beds of the Ste. Genevieve limestone. In the next mile a Chester sandstone, provisionally referred to the Birdsville formation, is on the south side, while in the last mile, after crossing a northwest fault, it passes with slight faulting through St. Louis limestone.

Although several interrupted planes in the eastern half of the Corn zone of faulting lie from 100 to perhaps 600 feet south of a straight line connecting the western half of the fault with the Pleasant Grove Church, the Madrid prospect and certain surface indications tend to show that fracturing of the St. Louis limestone occurred all along this line. The major throw of the fault, however, may occur along the shorter planes, as at the Ben Belt mine. There are several of these subsidiary planes, the Corn or Givens mine being on a second and the Bebout prospect apparently on a third. They seem to diverge rather uniformly from the direct line in a westerly direction.

Dyers Hill fault (N. 41° E.).—The southwestern end of this fault in Livingston County is easily recognized by the abnormal and rectilinear juxtaposition of the Ste. Genevieve limestone, which occurs on the south side, and the Birdsville formation, here usually sandstone, on the north side. Northeast of Dyers Hill Church, however, it is much more difficult to follow the fracture, since for a distance of nearly 9 miles sandstone prevails on both sides of the fault. Over about one-half of this distance the country on the south side of the fault exposes mainly Cypress sandstone, but the block may also contain higher Chester formations. Similarly, the block south of Lola, now on the north side of a fault that is believed to be a continuation of the Dyers Hill fault, is provisionally mapped as Cypress. With such similar sandstone formations more time in the field than was available would be required to determine their respective areal distributions.

The J. O. Belt prospect, near Pleasant Grove Church, is believed to be on an extension of the Dyers Hill fault. Here the narrow block between the Ben Belt plane of the Corn zone of faulting and this fault consists of upper Ste. Genevieve limestone capped by Cypress sandstone. The rocks on the south side of the fault at the J. O. Belt shaft were determined as Birdsville. There is some evidence indicating that the Dyers Hill zone of faulting continues northwardly beyond the Corn fault, but the indications are soon lost in the deeply weathered St. Louis area. Besides, there are so many intersecting northeast faults in this region that it is extremeiy difficult to determine their relations exactly.

Latrobe fault (*N. 49° E.*).—This fault may be traced very satisfactorily across the hills in the point of land between the Ohio and the great bend of the Cumberland River. It is clearly shown in the bluff at the Royal mine. In the bend on the other side of the Cumberland it is again recognizable, but not so easily. On the north side of the river it passes up Bissels Creek and intersects the Pittsburg fault at the Benard or Klondyke mine. Farther east it passes through the Coker (formerly Donake) mine and finally is lost in the sandstone hills beyond. Possibly it forms the southern boundary of the high Birdsville and Mansfield sandstone area between Mullikin and Sandy Creek.

West of the Pittsburg fault the Latrobe fault forms the southern boundary of a Ste. Genevieve limestone area capped farther back from the river by Cypress sandstone. On the opposite side the Cypress occurs in the outcrops observed in the triangle between the diverging Latrobe and Pittsburg faults. East of the latter both sides of the Latrobe fracture expose only Birdsville rocks. The throw along the Latrobe fault seems to be everywhere on the south side, but is always small, the maximum, so far as observed, being probably less than 100 feet.

Pittsburg fault (*N. 24° E.*).—This fault zone was definitely located at several points along the line drawn on the accompanying maps. It forms a sharp boundary between the Birdsville area at Smithland and the small, downthrown block of Mansfield sandstone 1 mile east of that town. From the Cumberland River northward to and beyond the Klondike mine its course is very sharply defined by great sheeted masses of quartzite. For 4 or 5 miles north of Mullikin faulting occurs in this zone, but as two other faults, the Miller and Glendale, converge toward or into the same zone, it is difficult to distinguish one from the other. After an interval of 3 or 4 miles more of Birdsville rocks, in which no observations were made, the Pittsburg trend is again taken up by a fault forming the eastern limit of a small, downthrown block of Birdsville sandstone situated about midway between Lola and Pleasant Grove Church. Elsewhere the throw is apparently always on the east side, varying, in the instances observed, from about 200 feet to perhaps 400 or 500 feet.

Fault 2½ miles east of Smithland (N. 32° E.).—A strong fault forms the eastern boundary of the Mansfield sandstone block about 1¼ miles west of Livingston Chapel. A triangular projection of Spergen limestone from the large Meramec area to the south lies on the east side of the fault. The displacement, accordingly, is one of the greatest in the district, being no less than 1,200 feet. The Spergen limestone, which is here largely oolitic, is very well exposed in the slope of the hill just north of the chapel. It is also shown, with its characteristic fossils, in the dump of a prospect on the fault a short distance north of the forks of the road. Traced northward the fault is either cut off entirely or greatly reduced in throw by an east-west fault before reaching the first creek. North of the east-west fault the surface of the whole block between the Pittsburg and Sandy Creek faults exposes, as far as observed, only Birdsville rocks.

Miller fault (N. 31° E.).—The Miller fault may be traced with unusual facility from the west side of the Mansfield sandstone block at Sheridan to a point a short distance east of the crossroads near Pleasant Grove Church. Here the line is somewhat disturbed by the Corn zone of faulting, but it is soon taken up again, and may be followed without serious interruption or difficulty along the west side of a Mansfield-sandstone ridge that extends to within a mile of Old Salem Church. Beyond this point it enters into a tumbled region containing the Pittsburg fault zone in which the separate lines are not readily distinguished.

North of the Corn fault, near Pleasant Grove Church, the St. Louis limestone lines the west side of the Miller fault. Four mines or prospects are located on the fault plane, which is here more or less mineralized; they are the Miller, Milligan, Clement, and Jones prospects. Between Pleasant Grove and Old Salem churches the fault passes almost entirely between sandstone formations and, so far as known, this stretch of the fault plane or planes contains no deposits of valuable minerals.

Larue fault (N. 33° E.).—Under this name the writer refers to a zone of faulting that can be traced from the Larue mine on Coefield Creek (east branch of Deer Creek) to the Ohio River at Fords Ferry. From the latter point to Hurricane Creek the main fault plane, as a rule, separates Mansfield sandstone on the east from St. Louis limestone on the west, giving a displacement of from 1,000 to 1,400 feet. On the west side and running parallel with this plane several subsidiary planes are indicated by mineralized fissures, which separate very narrow strips of Chester sandstone and Ste. Genevieve limestone. Between Hurricane Creek and

Glendale Church the St. Louis of the west side is in juxtaposition with an elongate block of apparently Birdsville shale and sandstone, bounded on the east side by an extension of the Glendale fault. South of Glendale Church to the Larue mine, the throw of the Larue fault is greatly reduced, St. Louis limestone occurring on both sides of it.

Besides the Larue mine, the Franks prospect, near Glendale Church, is on the main plane of this fault. Some calcite veins opened in the valley of Crooked Creek are in Spergen limestone, and only a short distance west of the main fault.

Glendale fault (*N. 40° E.*).—This fault seems to be in part a continuation of the Larue, and might be merely another plane in the same zone. But as it maintains its own direction for some miles northeast of the Larue mine, near which the two fault planes seem to join, it is more convenient to refer to them under distinct names.

The Glendale fault apparently begins at the Hurricane fault and extends southwest between Birdsville sandstone on the west and Mansfield sandstone on the east, to a point a short distance south of Glendale Church. From here to the Holly fault, a distance of about 3 miles, the course of the fault is much more easily followed, the east side consisting of various beds of the Birdsville formation, while the west side is of St. Louis limestone, as may be recognized at once by the characteristically abundant chert of that formation. Southwest of the Holly the Glendale fault again becomes difficult to trace, the rocks displaced by it being highest Birdsville and Mansfield sandstone on the west and middle and lower Birdsville on the east. North of the Holly the throw is on the east side, while south of that fault it is on the west side.

The Moore, Clark, and Haywood prospects occur on or close to this fault plane between the Larue mine and the Marion and Sheridan road. Some prospecting has also been done farther north on the same line.

Sandy Creek fault (*N. 24° E.*).—This, probably, like many other cases in the district, is a zone of faulting rather than a single continuous fault plane extending from the east side of Hardins Knob in Crittenden County to Livingston Chapel on the south side of the Cumberland River. For nearly 4 miles it separates the Ste. Genevieve limestone area, in which the town of Salem is situated, from the Birdsville rocks to the west of it. The fault is sharply defined and marked by a vein of barite at the forks of the road 1 mile west of Salem. It is again plainly shown in the sheeted quartzite just across the bridge over Sandy Creek on the Salem and Vicksburg road. Also near the mouth of this creek, where it forms the boundary between a block of St. Louis limestone on the east and lower Mansfield and upper Birdsville on the west. Birdsville and St. Louis are similarly opposed on the south side of the Cumberland to a point less than a mile east of Livingston Chapel. Apparently all along the line the throw is on the west side. It is greatest near the mouth of Sandy Creek, being here probably not less than 1,000 feet.

Little prospecting has been done along this fault, although, considering that limestone formations occur on the east side through a large part of its course, the ground appears encouraging. The Guill mine, northwest of Salem, though close to the line of this fault, is on a more easterly fracture that intersects and locally disturbs the course of the Sandy Creek fault near the mine. However, the Butler prospect and a barite prospect, respectively less than a mile northwest and west of Salem, seem to be strictly in the latter zone of faulting.

Minor fractures between the Sandy Creek and Columbia faults in the vicinity of Salem.—Near the northern end of the Salem–Ste. Genevieve limestone area there is a fracture with very little faulting having a course of about N. 54° E. The Guill mine and the Morse, Tom Babb, and Ramon Babb prospects are on this fracture. A similar fissure, with about the same direction and slight faulting, occurs about 3½ miles southwest of Salem. It is shown in the Hudson mine and in the Pierce prospects. Two other northeast faults of small displacement are shown southwest of Salem. These are nearly parallel with the Sandy Creek and Columbia faults. One is shown at the south Ramage prospect, near the bridge over Sandy Creek; the other crosses the road about half a mile east of the first, and strikes toward the town of Salem. Possibly this same fissure continues northward to the Crosson prospects.

Evening Star fault (N. 35–42° E.).—By this name the writer designates a zone of faulting extending in the direction given, from the Cumberland River near Vicksburg to and perhaps beyond the Salem and View road. It consists of numerous, apparently irregularly arranged planes, trending on the whole more westerly near the river than in the vicinity of, and north of, the Evening Star and other mines located on them. North of the Evening Star mine the Birdsville formation occurs on the east side of the main plane, with Ohara limestone and often highly silicified and crushed Cypress sandstone on the west side in the narrow angle between this and the Stevens fault. South of the Evening Star mine the rocks on the two sides of the fault are quite different, the Fredonia member of the Ste. Genevieve limestone being on the southeast side and St. Louis chert and limestone on the northwest. After crossing the Columbia fault zone the rocks are again changed, the Ste. Genevieve limestone of the Salem valley and, farther down, remnants of Cypress sandstone being on the northwest, and apparently a higher Chester sandstone on the southeast. West of the Sandy Creek fault middle and upper Birdsville occur on the north side and lower Mansfield on the south. A fluorspar prospect a few hundred yards west of Vicksburg, in the line of strike, possibly indicates that the fracture crosses the river. Throughout this distance the throw is on the southeast side. The maximum displacement is attained in the vicinity of the Stevens clay mine, where it may amount to about 400 feet.

The occurrence of the Ohara member of the Ste. Genevieve limestone in the banks of Crooked Creek just east of Freedom Church, and of Cypress sandstone between this point and the Stevens fault, probably indicates that the Evening Star zone of faulting extends many miles northeast of the Salem-View road. This extension was not suspected while in the field, but the presence of the fault in the area of Chester sandstones east of the Stevens fault could very easily have been overlooked.

The mines and prospects in this zone of faulting are nearly all located just within the east boundary of Livingston County. Of these the Evening Star, Morning Star, and Nancy Hanks mines are well known.

Columbia fault (*N. 27° E.*).—This is one of the best-marked fault zones in the district. It is also one of the longest, fracturing with more or less faulting occurring along this line from the Ohio River near Weston to the Cumberland River, a distance of over 22 miles. Except in the last 2 or 3 miles, near the Cumberland, where the relations are reversed, the throw is always on the west side. It is greatest in the part from 1 to 2 miles north of Crittenden Springs, being no less than 900 feet in this region. Farther north the throw grows rapidly less, being probably not more than 400 feet where the road passes over Pickering Hill. From Crittenden Springs to Levias the throw seems nowhere to exceed 750 feet. In the vicinity of the Columbia mines the aggregate displacement between the Ste. Genevieve on the east of the main fault and the Birdsville on the west is about 700 feet. In the vicinity of Levias it is estimated at 500 feet or less.

In the Salem Valley the displacement is insufficient to bring different formations into juxtaposition until the fault reaches the county line, beyond which the St. Louis limestone is exposed on the west side for 2 miles or more. After crossing the Evening Star fault this cherty limestone gives place to Ste. Genevieve limestone. The latter continues on the east side, except in a series of narrow Cypress sandstone hills, and forms a broad, level valley extending to the Cumberland River. The western border of the lower part of this Ste. Genevieve limestone valley is lined for about 2 miles by the Cypress sandstone hills just mentioned. Immediately west of these hills lies an extremely hilly and cherty block of St. Louis limestone, indicating that in this southern extension of the fault the throw is on the east side instead of the west.

Though numerous mines and prospects have been located on the fault planes of this zone, they are almost all confined to territory limited by a distance of less than 2 miles north and south from the Crittenden Springs Hotel. The more important of these are the Columbia, Watkins, New Jim, Major Clemens, and Struck-it-rich mines. No reason is known why this and other faults passing through important limestone formations are not more generally mineralized, unless it is that large bodies of fluorite and other valuable minerals occur only in areas where the main faults are accompanied by numerous subsidiary fractures, either crossing or paralleling the major plane and serving to promote free circulation of waters carrying minerals in solution.

Memphis group of fractures.—In the area lying east of the Columbia fault and north of the Old Jim mine there are a number of minor faults. Most of these run nearly parallel with the average course of the Columbia fault, but several have a more easterly direction. In all of them the maximum displacement is less than 100 feet, and as a rule it is much less. In the Memphis fault and in the similar fault next east the throw is on the west side, but in the Klondike fracture it is on the east side. On account of this reverse in throw a narrow strip of Ste. Genevieve limestone extends all the way from the Klondike mine to the larger area of this limestone surrounding Bethel Church. All of the sandstone outcrops in this area are of the Cypress formation. Along the Fords Ferry road, however, a few miles north of the Memphis and Klondike mines, apparently all the observed outcrops are of the Birdsville formation. It is not known whether this change is due to simple dip of the strata in that direction or to a cross fault, though it is suspected that the latter will prove the truer explanation.

Stevens fault (sink-hole break) (N. 38° E.).—This fault extends in an almost unbroken and generally easily recognized line from the east border of Livingston County at the Stevens clay mine, where it has St. Louis limestone on the north and Cypress sandstone on the south, to and perhaps beyond a point about 4 miles due north of Marion. In these 12 miles the throw is always on the southeast side. It decreases in amount in a northeasterly direction, being about 350 feet at the Stevens mine and 150 feet or less northeast of Levias. So far as known nothing higher than Cypress sandstone occurs on the southeast side of the fault, though it must be admitted that in the middle third of the plotted length of the fault the rocks on this side remind one strongly of Birdsville. Possibly the Eaton fracture, near Levias, causes faulting between this fault and the Evening Star fault zone, and that another cross fault occurs between Freedom Church and the Marion and Crittenden Springs road. In that case the Birdsville probably stretches northwestward from the Marion fault to the Stevens fault in the area between the two cross faults. Provisionally the doubtful strip is mapped as undifferentiated Chester.

The only notable mining prospect that has so far been discovered on the Stevens fault is a large deposit of highly siliceous clay which is being worked by tunneling at the Stevens mine. This clay is evidently a residual product of decomposed Cypress quartzite and to a less extent of St. Louis chert.

Marion fault (N. 43°–44° E.).—The Marion fault is a well-marked structural feature extending from a point on the Cumberland River, a little over a mile west of Pinckneyville, to Marion. It passes on through the eastern edge of this town, where it crosses the railroad, and finally dies out in the third or fourth mile farther northeast. The throw is everywhere on the northwest side, but it is not uniform, and, as usual, the rocks on either side vary greatly from point to point.

From the Cumberland to near Amis Church, Ste. Genevieve limestone occurs in the broad valley on the northwest side of the fault. At the church and thence to the southern end of Rings Bluff, Cypress sandstone, in bluffy elevations, is on the northwest side. Rings Bluff itself seems also to be of Cypress sandstone, but back of it, beyond the line of the Marion fault, the formation is lower Birdsville. Rocks of the latter formation continue on this side of the fault to the Mansfield sandstone on the north of the Tradewater fault.

On the southeast side of the Marion fault a narrow strip of St. Louis limestone, limited on the opposite side by the Woods fault, stretches from the Cumberland to Puckett Spring. For about 2 miles northeast of this spring a sandstone occupies more or less of the space between the Marion and Woods faults. For a part of the distance between Amis Church and the Ebby Hodge mine, two smaller cross faults, one nearly north and south, the other east and west (Clay Lick fault), bring the St. Louis limestone again to the Marion fault plane. Beginning at the intersection with the Clay Lick fault, near which the Ebby Hodge mine is situated, Cypress sandstone now occurs on the southeast instead of the northwest side of the Marion fault, and continues to form this wall for at least 3 miles in a northeasterly direction from the mine mentioned. A Chester limestone, whether Tribune or Birdsville was not determined, comes next, but soon gives way to more sandstone; and this sandstone apparently continues to Marion. It resembles the Cypress sandstone, but is probably one of the lower beds of the Birdsville formation. Should it prove to be the former, then more faults will be required to explain the known areal distribution of Chester formations east of Marion.

Two mines, besides a few more or less doubtful prospects, have been located on the Marion fault. The Ebby Hodge mine, at the southern end of Rings Bluff, has already been mentioned. The Lucile mine is located at Marion, just east of the railroad.

Woods fault (N. 43° E.).—This fault parallels the southern half of the Marion fault and the two might justly be considered as unusually well-defined planes of a single zone of fracturing. Southwest of Puckett Spring Branch the two faults are separated by a narrow strip of St. Louis limestone. Opposite this chert and limestone strip, and immediately on the southeast side of the Woods fault, is a rough, eastwardly expanding ridge of sandstone, indicating a throw of at least 400 feet.

As the strata in this ridge evidently are much disturbed, some of this sandstone may be of the Cypress formation, but the greater part doubtless belongs to the Birdsville. At the eastern end of the ridge, where it is abruptly broken off by the Puckett Branch fault, the lower half of the bluff exposes a considerable bed of partly oolitic limestone that is provisionally referred to the Tribune limestone.

Northeast of this cross fault the relations of the geologic formations on the two sides of the Woods fault are reversed. At the Riley mine various beds of the Birdsville formation are exposed in the bluff on the northwest side of the fault, while St. Louis limestone occurs on the southeast side. The throw, probably amounting to not less than 500 feet, is here on the west side. A quarter of a mile northeast of the Riley mine the main displacement is taken up by certain subsidiary planes between the Woods and Marion faults. A short distance farther on it returns to the line of the Woods fault, but soon thereafter, beginning at the bridge near Amis Church, the St. Louis area again expands and this time reaches the Marion fault-plane. Northeast of the Clay Lick fault the St. Louis area is again restricted to the east side of the Woods fault, Rings Bluff, believed to consist of Cypress sandstone, being on the west side. North of the View-Salem road the Woods fault is soon lost in the Cypress sandstone hills lying east of the Marion fault.

Two mines, the Woods and Riley, have been located on this fault. The main shaft of the former lies a short distance west, the latter just east, of Puckett Spring Branch. Several prospects occur southwest of the Woods mine, while another, the Butler prospect, shown in two shallow shafts, occurs in the St. Louis limestone forming the east bluff of Clay Lick about a mile above Amis Church.

Hodge fault and associated fractures (N. 45° E.).—The Hodge fault runs nearly parallel with the Woods and Marion faults and about a mile south of the former. From a point about half a mile southwest of Whitehall Church, which it should pass a little to the north, the southwestward course of the Hodge fault is easily recognized by the difference in the two limestone formations outcropping on opposite sides of the fault and in the soils and topography characterizing the respective formations. Rough, chert-covered St. Louis limestone hills occur on the northwest side, while sharply opposed to these is the valley-forming Ste. Genevieve limestone. The throw is here on the south side and ranges in amount from 200 to 400 feet. Northeast of the point mentioned the throw is usually too little to effect the juxtaposition of different formations. In the first 2 miles Ste. Genevieve limestone occurs on both sides, in consequence of which the fracture is very difficult to locate. Where the fault passes out of the valley and where one might expect to observe the effect of faulting in the outline of the limestone area the determination is again obscured by a small cross fault. Northeast of this cross fault, especially in the rocks of the Chester group, 1½ to 3 miles southeast of Marion, abundant evidence of faulting having the general trend of the Hodge fault was observed. This evidence was nowhere quite satisfactory, but, as the questions involved seemed not to be of immediate economic importance, it was not thought worth while to follow it up sufficiently to show its exact relation to the Hodge fault. At present it appears likely that northeast of Clements Valley this fault will be found split up into, or represented by, several subparallel fractures in a broad zone of faulting.

Probably the Hodge fault should be viewed as one of a group of long fractures comparable with the Memphis group. As a glance at the accompanying maps will show, the relations also of the Memphis group to the Columbia fault on the one side and the Stevens fault on the other are rather closely simulated by the relations of the Hodge group to the Crittenden and Marion faults.

Two mines, the Hodge and Brown, and several promising fluorspar prospects are located on or near this fault. Some of the prospects in the vicinity of these mines are on parallel subsidiary fractures that lie entirely in St. Louis limestone, a hundred feet or more north of the Hodge fault. In the Lovelace and Dan Riley shafts, which are on one of these subsidiary fractures, one of the walls consists apparently of the oolitic Spergen limestone. Some prospecting has been done southeast of Marion in the Chester area above mentioned, on the supposition that it may contain an extension of the Hodge zone of fracturing. As usual in sandstone areas far removed from outcrops of St. Louis and Ste. Genevieve limestones, the efforts of the prospectors have so far not met with encouraging results.

Crittenden fault (*N. 56° E.*).—More or less distinct faulting occurs in this zone from the Tradewater River to the Ohio at Smithland. Though probably not strictly a continuous fault plane, the line of faulting is nevertheless continuous and straight enough to make it appear so in mapping. For 7 miles west of its intersection with the Tradewater fault it produces an abrupt division line between the Mansfield sandstone on the south side and various members of the Birdsville formation on the north side. In the next 6 miles, which bring us to the eastern extremity of Clements Valley, its course is mainly through Chester sandstones, the throw being still on the south side. Though less sharply defined in this part, the evidences of faulting are yet quite plain on all the roads crossing the fault. The Birdsville formation and the throw remain on the south side to the point where the fault crosses Clay Lick and is itself crossed by the Puckett Branch fault. On the north side of this section of the fault there occur in succession, first, the Ste. Genevieve limestone of the Clements Valley; then the Ohara member of this limestone, with remnants of Cypress sandstone capping it, in the vicinity of the Hodge and Brown mines; and, finally, St. Louis limestone. Southwest of the Puckett Branch fault to Pinckneyville, on the Cumberland River, the throw is on the north side of the Crittenden fault, with the acutely triangular high ridge of Birdsville rocks, consisting chiefly of sandstone and already mentioned in the description of Woods fault, on this side, and chert hills underlain by St. Louis limestone on the south side. The throw of the fault north of the Cumberland River probably attains its maximum amount in this part, being something like 750 feet. Northeast of the Puckett Branch fault it varies from about 700 feet to probably less than 200 feet.

On the south side of the Cumberland the Crittenden fault passes chiefly through St. Louis and Spergen limestones. It is clearly indicated at only two points, viz, just south of the river and about 2 miles west of Tiline by an outcrop of quartzite with an associated mining prospect, and again 1 to 2 miles west of Smithland, where it forms the southern boundary of a fault-bounded area of Mansfield sandstone. At the last point the throw can not amount to much less than 1,400 feet. With the possible exception of the prospect near Tiline, nothing of value has been found in this fault plane. Whether this is due to lack of prospecting or to actual absence of mineral deposits is unknown.

Yandell fault (*N. 40° E.*).—Though of considerable economic importance, this fault is, so far as known, less than half a mile in length. Possibly it extends northeastward beyond the cross fracture on which the Matthews shaft has been sunk. In that case a slight deflection of the course might bring it into the Bibb group of fractures, observed a few miles northeast of the Yandell mine. At this mine the fault forms the western boundary of a small triangular block of Cypress sandstone. On the west side of this there is a narrow valley with outcrops of Ste. Genevieve limestone. The maximum throw of the fault probably does not exceed 50 feet.

Bibb group of fractures (*N. 56–60° E.*).—Two or three subparallel fractures near Cookseyville Church, about a mile northwest of Mexico, have occasioned more prospecting probably than they are worth. At the King prospects, which are located on the hill immediately behind the church, Birdsville shale and limestone, dipping strongly to the south, form the hanging or southern wall of one of the fractures. On the north side is a heavy-bedded sandstone, apparently of the Cypress formation. The Bibb and Davenport prospects are located a half mile southwest of the King prospects and are evidently on a different fracture. The relations of these fractures were not carefully determined, but it is believed that the latter fissure forms the northern boundary of the narrow strip of Cypress sandstone observed at the King prospects.

Tabb fault (*N. 72° E.*).—Though consisting of a number of planes arranged somewhat irregularly en échelon, this fault in its central part is one of the sharpest and most easily recognized fractures in the district. For 4 miles eastward from Pinckneyville it passes through St. Louis rocks only, and in this part its course is most difficult to locate. East of Mexico it is confined to Birdsville rocks, in which, as usual, the course of the planes, which, moreover, are wider apart here than farther west, is readily determined only in exceptionally good exposures. From the Livingston fault westward to the Asbridge mine Birdsville rocks occur on the north and St. Louis limestone on the south side. West of the Asbridge mine the fault first forms the base of a small northerly projecting triangle of St. Louis, and beyond this to the intersection with the Puckett Branch fault divides low Cypress sandstone hills from the broad St. Louis area on the south side of the fault. The displacement of the fault is greatest in the vicinity of the Tabb mine, where it can not be less than 700 feet.

Several good producers of fluorspar, notably the Tabb and Asbridge mines, besides a number of prospects, are located on one or another of the subparallel planes in the zone of faulting commonly referred to under the name Tabb fault. All of these mines and prospects, however, are confined to the 4 miles east of the Pogue mine. A number of holes have been dug on or near the fractures east of Mexico, but so far nothing of consequence has been found there.

Faults bordering large sandstone hill west of Princeton (*N. 53° and 57° E.*).—Between the Fredonia Valley on the north and the Princeton Valley on the southeast there is a large body of rough, chert-covered country that extends westward from the central part of Caldwell to the Cumberland River. Included in and forming the northeast extremity of this hilly area is an elongated block of Chester sandstone, trending northeast and bounded on four sides by faults, with St. Louis and probably older rocks on the southwest, north, and northeast, and mostly Ste. Genevieve limestone on the southeast side. This block is skirted on the north by the Princeton and Henderson branch of the Illinois Central Railroad and is crossed about midway of its length by the old State road from Princeton to Fredonia. It has not been positively determined whether this sandstone is Cypress or Birdsville, but as some of the exposures contain more shale than is believed to occur in the former, the writer is strongly inclined to refer it to the Birdsville formation. Along the borders of the block, especially in the northern third, the sandstone is largely altered to quartzite. Locally it is also brecciated.

Princeton fault (*N. 67° E.*).—This fault limits the triangular eastern extremity of the St. Louis area, mentioned in the preceding paragraph, on the south and separates it from the Ste. Genevieve limestone and Cypress sandstone areas just north of Princeton. It is readily located for a distance of nearly 4 miles from a point near the middle of the east side of the sandstone block just described to Flinns Fork, where it is either cut off entirely by the Bodard fault or continues down this stream with a greatly diminished throw.

Saratoga fault (*N. 44° E.*).—This fracture extends from the western extremity of the Princeton fault, where it is shown in the road at the foot of the large sandstone hill, to Saratoga in the edge of Lyon County. The throw is nowhere large, the maximum amount probably not exceeding 200 feet. It is on the southeast side, except opposite the northern half of the sandstone ridge, where a narrow triangle of St. Louis limestone is wedged in between this and the Princeton fault. On the ground the exact location of the fault is not easily determined, but here and there along the line the abrupt transition from Ste. Genevieve soils to the more cherty soils of the St. Louis limestone is plainly indicated. No outcrops of the rocks themselves showing faulting were observed.

Two small faults south of Princeton (N. 30° and 34° E.).—Two short northeast faults form the east and west boundaries of a rhomboidal block of Ste. Genevieve limestone situated about 2 miles directly south of Princeton. This block is limited on the north by the Eddy Creek fault, on the south by the most western of the planes included in the McGowan zone of faulting. The displacement effected by these two northeast faults probably does not exceed 200 feet for the one on the west side, but can not be less than 300 feet for the one on the east side. The latter has brought undoubted Birdsville shaly sandstone down to the level of the top of the Ste. Genevieve limestone. In both cases the throw is on the east side.

Friendship fault (N. 54° E.).—The course of this fault is occasionally distinguishable in the Birdsville area between Friendship and Curry, but where it is not indicated by structural features it requires considerable knowledge of the succession of beds embraced in the Birdsville formation to recognize the fact that faulting has occurred. Beyond the point where it crosses the McGowan fault the course of the southwest fracture becomes more readily apparent. It is best defined about a mile east of Otter Pond, where for a short distance Birdsville shale and sandstone on the north side of the fault lie in juxtaposition with Ste. Genevieve limestone.

EAST-WEST FAULTS.

Fredonia fault (N. 98° E.).—This fault consists of a number of planes arranged mostly en échelon, the course of the individual planes being as a rule more nearly due east than the average trend of the whole series. For nearly 4 miles eastward from Livingston Creek the fault, with one or another of its planes, causes a sharp division between the rocks of the Birdsville formation on the north and the valley forming Ste. Genevieve limestone on the south. In the next 3 miles eastward along this fault, to its intersection with the Dollarson zone of faulting, Cypress sandstone instead of the limestone is opposed to the Birdsville formation, which lies on the north side of the line. Over a considerable part of these 3 miles the course of the fault is marked by more or less rectilinear, generally sheeted, and often brecciated masses of quartzite. A good example of such quartzite may be seen on the hillside where the east road from Fredonia leaves the valley. It has not been determined whether the Fredonia fault continues eastward beyond the intersection with the Dollarson faults. If it does then the displacement has been so greatly reduced that it can no longer be followed with certainty.

Practically no prospecting has been done on this fault. At a few points the quartzite, which often lines the fault plane and is generally regarded as a favorable indication for prospecting, contains fluorspar in small amounts.

Lowery and Marble fissures.—These are fractures in the Ste. Genevieve limestone and Cypress sandstone, trending nearly due east at distances south of the Fredonia fault varying from a few hundred yards to nearly a mile. Two similar fissures occur within the next mile and a half south of the Marble vein. These fractures are accompanied by very slight faulting and, judging from the information now available concerning them, are to be explained as adjustment planes formed subsequent to the major faulting of the district. They seem further to have resulted from obliquely opposed lateral movements, and are probably similar in origin to the Memphis and Hodge group of fractures. In each of these cases fractures of minor displacement occur in a space bounded by diverging faults of major throw. In each case again they are more nearly parallel with one of the major faults than with the other. It is a curious and perhaps significant fact that the minor fractures are geographically farther from the main fault with which they are parallel than from the other boundary of the space containing them. Another fact is that in at least two of the cases, the Lowery-Marble group and the Memphis group, the minor fractures are nearer that one of the two main faults that produced the greater displacement. From facts like these we may argue that the original movements here were of local elevation and resulted in diverging fractures, while the subsequent adjustment movements tended to break the triangular blocks into parallelograms.

Matthews fault (about N. 90° E.).—The exact course of this rather unimportant fault is still somewhat in question, but it can not vary many degrees from due east and west. It may represent a westward extension of one of the Fredonia fault planes, but it will be almost impossible to establish the connection across the St. Louis area intervening between the Asbridge mine and the most western point at which the Fredonia faults were observed.

Beginning on the line of the Tabb fault, apparently very near the Asbridge mine, the Matthews fault extends west to Clay Lick, a distance of 3 miles. On the north side lies the southern extremity of the large Birdsville area that stretches far eastward between the Crittenden and Tabb faults. On the south side Cypress sandstone capping Ste. Genevieve limestone occurs in the 2 miles or more west of the Matthews shaft, while east of this shaft a small triangular block of St. Louis, recognized solely by its chert, is wedged in between the Birdsville rocks on the north and another triangle of Cypress sandstone on the southwest. The latter is limited on the south by the Tabb fault and on the west by the Yandell vein.

Clay Lick fault (about N. 87° E.).—This is another of the numerous small faults that are known to exist, but that could not be accurately plotted in the time allotted to work in the field. The part east of the Marion fault is based on observations, and may be accepted as apparently correct. The portion extending westward from that fault toward the Evening Star mine, however, is based upon a theoretic solution of the occurrence of nearly horizontal beds of the Birdsville formation in the northern part and of Cypress sandstone in the southern part of the area lying between Amis Church and the Evening Star fault.

Skinframe fault (N. 90° E.).—Beginning at the line of the Bodard fault, 200 or 300 yards northwest of the point where that fault crosses Flinns Fork, the Skinframe fault extends due west to the edge of Lyon County, in which, perhaps, it can not be traced with certainty. The middle part of this course lies in the valley of Skinframe Creek. For over 4 miles westward from the Bodard fault the course of the fault is sharply defined between the Cypress sandstone on the north and the more or less cherty St. Louis and probably older limestones on the south side. In the remainder of the distance to the county line erosion has removed the Cypress sandstone and brought to the surface the underlying Ste. Genevieve limestone that forms the floor of the Fredonia Valley. Although limestones now occur on both sides of the fault, the latter is still easily located by the topography and other superficial characteristics that distinguish the two formations. As a rule the valley ceases abruptly at the base of the chert-covered hills that bound the fault on the south side.

The line of the Skinframe fault continues across Lyon and Livingston counties, strikes very near an east-west fault that passes a short distance north of Livingston Chapel, and separates a Birdsville area on the north from a Spergen limestone area on the south of the fault. Although evidences of faulting were observed along the projected line, as, for instance, at a point about 1 mile south of Dycusburg, it seems improbable that the Livingston Chapel fault can be a direct continuation of the Skinframe fault. Whether a fact or not, it will prove a very difficult task to connect them across the intervening 16 miles of almost uniformly chert-covered country.

Eddy Creek fault (N. 78° E.).—This fault adheres, with little variation, to the average direction given from the Caldwell-Lyon county line near Saratoga eastward to Scottsburg. Beyond this point, chiefly because of the greater difficulties experienced in discriminating between different parts of the formations passed through, it is not so easily located. Also, in the western third of the length indicated on the general map, the course of the fault may often seem obscure. Outcrops of bedded rocks are comparatively rare here, but as a rule the observer should not find it unusually difficult to distinguish the soil derived from the Ste. Genevieve limestone on the north side of the fault from that of the St. Louis limestone on the south side. The fault is more readily located in the part extending a little over 2 miles west from Scottsburg, in which the Ste. Genevieve limestone on the north is opposed to more or less shaly sandstone of the Birdsville formation on the south side. East of Scottsburg the location of the fault is further complicated by numerous cross faults. Except in a small area shown in Lambs cut, where the Tribune limestone comes to the surface on the south side of the fault, and another short stretch southeast of Claxton, where a remnant of Mansfield sandstone occurs on the north side, all the exposures on either side of this part of the fault fall within the limits of the Birdsville formation.

A single prospect has been located on this fault. Several shafts have been sunk on a vein of fluorspar and barite discovered near Eddy Creek on the Satterfield farm, a little over 3 miles south-southwest of Princeton. In these shafts the Fredonia member of the Ste. Genevieve limestone forms the north walls, but the south wall appears to be of St. Louis limestone. Therefore the vein is believed to be in the fault plane itself, and not in a subsidiary fracture.

McGowan fault (N. 96° E.).—Immediately south of McGowan station a fault crosses the railroad. Faulting shows then along the bluff of a sandstone ridge to a point about a mile west of the station, where the ridge is cut off by a northeast fault. In the slope of the ridge there is a narrow wedge of Ste. Genevieve limestone; and south of this the fields contain undoubted St. Louis chert. East of McGowan the fault is indicated at intervals for 2 miles between Cypress sandstone hills on the south and lower hills made up of Birdsville rocks on the north. After an interval of about 2 miles, in which Birdsville rocks seem to occur on both sides of the projected line, faulting was again observed in the branch just south of Friendship. The strike of the fault appears to be nearly the same as at McGowan, and here, as there, massive Cypress sandstone occurs on the south side of the fault. Though the fault was not traced over a half mile beyond Friendship, it is known that Cypress sandstone continues along the Hopkinsville road to the county line, where a considerable outcrop of Tribune limestone sets in. A mile or so north of this outcrop Birdsville rocks, referred to a position well up in this formation, were observed. On account of these facts it is believed that the McGowan fault extends eastward at least to the county line.

An outcrop of gravel fluorspar lies several hundred yards south of the crossroads at Friendship. Masses of slightly silicified Cypress sandstone occur just south of the fluorspar, while the nearest outcrop of bedded rocks to the north is of Birdsville shale and sandstone. Some prospecting has been done west of McGowan, but the shafts, which were sunk on mere seams of calcite in Ste. Genevieve limestone, have not shown anything of value.

NORTHWEST-SOUTHEAST FAULTS.

Tradewater fault (N. 56° W.).—This fault extends nearly or quite across the northeastern part of Crittenden County. It is obscure and perhaps does not extend west of the point where the Stevens fault would strike it. However, there is reason to believe that the zone continues into Illinois with a parallel line passing close to Weston. Southeast of the Crittenden fault it is also difficult to recognize, but this obscurity may be due to the more uniform lithologic character of the Pennsylvanian rocks here displaced rather than to absence. Between the Stevens and Crittenden faults, however, the Tradewater fault is readily located by the rectilinear boundary between the downthrown Mansfield sandstone on the northeast side and various beds of the Birdsville formation on the southeast. Where the railroad crosses the fault, upper beds of the Birdsville occur north of the fault, but soon pass out of sight beneath the Mansfield. Possibly Birdsville rocks are similarly exposed in the valleys of Pigeonroost and Piney creeks. These two streams were not visited recently, but as the notes on the writer's earlier work in the district mention Chester rocks on the Mansfield side of the fault only at the railroad, it is assumed that farther east the throw is sufficient to keep the top of the Birdsville beneath the beds of the streams.

Bodard fault (N. 64° W.).—The Bodard fault and vein is named for the old French settler on whose land the vein was first discovered. These prospects, one of which is now known as the Senator mine, are located near the northwest end of the Bodard fault line and within a mile of the point where it is believed to join one of the planes of the Dollarson zone of faulting. From the Senator mine the fault has been traced eastward to Flinns Fork, and in this stretch it maintains an average course of E. 26° S. On projecting this course across the map to the county line, it was found to connect several points on roads leading east from Princeton at which faulting having approximately the same trend had been observed by the writer in 1889 and 1890.

West, and also at points about 2 and 4 miles east, of Flinns Fork, Birdsville rocks, representing horizons from about the middle to near the top of the formation, occur on the north side of the Bodard fault. The rocks on the south side are in part still undetermined. This is true more especially of the stretch between Flinns Fork and the junction with the Dollarson fault. At the Senator mine the south wall consists of a limestone that is either Tribune or Ste. Genevieve. If the former, then most of the stretch should probably be mapped as lower Birdsville. If the latter, then it should be Cypress sandstone instead of Birdsville. In the former case the most southerly of the Dollarson fault planes may continue to the Skinframe fault, and may perhaps account for most of the displacement between the Cypress sandstone on the southwest of it and the upper Birdsville on the north of the Bodard fault. In the latter case the top of the Ste. Genevieve limestone in the undetermined triangle between the converging Bodard and Dollarson faults would be slightly higher than in the similar areas on the southwest side of the Dollarson fault, while the throw occasioned by the faulting in this region would be entirely on the north side of the Bodard fault. Though the latter view is the one favored by the writer, it has been decided to map the area in question as undifferentiated Chester. The region just north of the Senator mine is likewise mapped as undetermined, because Cypress sandstone and Tribune limestone are believed to outcrop on Canadas Run.

Dollarson faults.—A strip of Chester sandstone country, 1 to 2 miles in width, extending from the headwaters of Flinns Fork, in Caldwell County, in a northwesterly direction past Ruth and Enon into Crittenden County, presents apparently a number of fault planes that were not definitely located. Between Canadas Run and Farmersville the outcrops are of unquestionable Birdsville rocks. South of that stream, however, there are practically horizontal sandstones that greatly resemble the Cypress formation. Just east of the Stone and Dodds shafts of the Union Central Mining Company the same sandstone is found, while a mile farther east the outcrops are of the Birdsville formation. West of Enon, again, the Mansfield sandstone gives way abruptly to Birdsville rocks, while farther north, in the vicinity of Piney Church, small faults having the same general direction were observed. In none of these cases can the areal distribution of the beds be accounted for by either dip of strata or difference in altitude, so that faulting must be assumed. As the strip in question is drained by the head branches of Dollarson Creek, the fractures may be provisionally called the Dollarson faults.

The line represented on the accompanying maps under this name joins the most western points at which faulting of this zone was observed. It is very doubtful, however, whether all these points are on a single plane, since at most of them the apparent strike of the faulting is more nearly westward than N. 52° W., which is the course of the line as drawn. The faulting noticed near the mouth of Canadas Run likewise seems to trend more nearly westward, being nearly parallel with the Bodard fault. Probably the zone contains a series of overlapping planes like those shown in the Tabb zone of faults. It may prove also that the Dollarson faults extend well into and perhaps through Crittenden County. Certain it is that some yet unknown northwest faults in this county are necessary to explain the observed distribution of particular beds in the undifferentiated Chester areas.

Prospecting has been carried on to a limited extent in this zone, but so far without success. None of the prospect holes seen by the writer were on the planes of the fractures, but several afforded small specks of galena and sphalerite, possibly indicating larger deposits in the near-by fissures.

Livingston Creek fault (about N. 22° W.).—Of this fault only the part lying in Crittenden and Caldwell counties has been observed. Even this part was not very accurately located, though the course as mapped is doubtless not far wrong. St. Louis limestone occurs on the west side. Except about a mile of country that lies between the Tabb and Fredonia faults, and that contains rocks of the Birdsville formation, the surface just across the fault plane exposes, so far as known, only Ste. Genevieve limestone.

Hurricane fault (N. 13° W.).—With approximately the course given, this fault follows the valley of Hurricane Creek across the Mansfield sandstone area included between the Columbia and Larue faults. West of the Hurricane fault the base of this sandstone occurs well up in the high hills opposite the Crittenden Springs Hotel. East of the fault its base lies some distance beneath the level of the creek. North of the Larue fault the creek flows through one of the large areas of St. Louis limestone, in which, on account of the rarity of outcrops and the great depth of the residual clays, it is always difficult to trace a fault. However, at two points on this part of the creek, one at the edge of the Ohio River bottom, opposite Cave in Rock, the other nearly 3 miles farther up the creek, vein matter, indicating fracturing if not much faulting, was observed fifteen years ago by the writer. Projected northward the line of the Hurricane fault passes either through or very near these points.

Tolu fault (about N. 30° W.).—Very little is known about this fault. Some indications of faulting were noticed near the mouth of Caney Fork. The approximate course given was obtained by bringing this point in line with another on the Marion road, about 1½ miles southeast of Tolu, where a small and quite isolated outcrop of Chester sandstone was accepted as unquestionable evidence of faulting. This sandstone doubtless indicates still another fault in this region, in this case one trending probably northeastward, since it could not very well have been dropped into an otherwise St. Louis area without being bounded on at least two sides by fault planes. Unfortunately satisfactory outcrops of bedded rocks are so rare in the valleys of Caney Fork and Hurricane Creek that neither of the faults could be definitely located. Possibly the faults cross the Ohio, in which case more satisfactory data might be secured on the north side of the river.

Holly faults (N. 27° W.).—Two fault planes, including between them a narrow strip of Ste. Genevieve limestone, are referred to under this name. Both planes show mineralized outcrops on the old Holly farm, and the various shafts and open cuts on them are collectively known as the Holly mines. The Ste. Genevieve limestone strip is limited on the west side by upper Birdsville rocks, on the east by St. Louis limestone. At some unknown but probably considerable depth, it is believed the two Holly planes will converge and form one.

According to the evidence now available at least one of the Holly planes, and with it the Ste. Genevieve limestone, is cut off on the north by the Flanary dike and fault. The other seems to form the southwest boundary of the small block of Mansfield sandstone just north of the dike. No attempt was made to trace either plane in the St. Louis area beyond the Miller fault.

It is not positively known that either of the Holly faults extends southward across the Chester area between the Larue and Columbia faults, though they are provisionally mapped as so extending. Some faulting is required to explain the partial and locally complete absence of Tribune limestone between the exposures of the Cypress and Birdsville formations in this area, and the Holly fault is the only fracture now known whose extension will serve the purpose.

Puckett Branch fault (about N. 30° W.).—This fault is necessary to explain the occurrence of horizontal St. Louis limestone on the east and upper Chester formations on the west side of Puckett Branch south of the Woods fault, and the same formations in reversed relations north of that fault in the narrow strip between the Woods and Marion faults. South of the Crittenden fault a continuation of the Puckett Branch fault is indicated by the abnormal juxtaposition of Cypress sandstone and upper Ste. Genevieve limestone on one side and St. Louis limestone on the other. A prospect has been located, apparently on this continuation, about a half mile southeast of the mouth of Puckett Branch.

Deer Creek faults (N. 12° W.).—This fault follows the general course of Deer Creek from the head of its west branch, 2 or 3 miles southeast of Lola, to the Ohio River bottom, where the creek bends sharply west toward Carrsville. Through nearly the whole of this distance St. Louis limestone lies on the east side of the fault and Ste. Genevieve limestone on the west side. The throw, which is on the west side, is comparatively uniform, the minimum and maximum amounts being, respectively, about 200 feet and 350 or possibly 400 feet.

The fault extends northward across the Ohio and continues to divide St. Louis limestone from Ste. Genevieve limestone exposures as far north at least as the bridge over Big Creek, 2 miles northwest of Elizabethtown.

Generally a little less than 1½ miles west of the Deer Creek fault there is another that is nearly parallel with it and has mostly Birdsville rocks west of it and either Ste. Genevieve limestone or the overlying Cypress sandstone on the east side. This second fault, which is complicated north of Lola by the development of cross faults and of parallel accessory fractures, can not be properly plotted and described without further field work.

As it looks at present these Deer Creek faults belong to a series of five or six faults that traverse the northern part of Livingston County in a southerly direction and together constitute a good example of step faulting. Beginning with the Deer

Creek fault and ending with the last fracture mapped in the northwestern part of the county, the St. Louis limestone is dropped from 150 to 350 feet lower with each of the successive faults.

Other small and generally unimportant faults.—The general map shows, besides those considered on the preceding pages, a number of apparently unimportant faults. These have various directions, but in the majority the trend is nearly north and south. Most of the latter occur in Caldwell County, crossing the Illinois Central Railroad between Scottsburg and Claxton. The one passing through the western edge of Scottsburg, after crossing to the north of the Eddy Creek fault, causes a throw to the east of several hundred feet. A similar throw is indicated also for the southern part of the fault a mile or more east of Scottsburg. The short faults west of Claxton are step faults, with strong westerly dips, well shown in cuts along the railroad.

Of remaining Crittenden County fractures, aside from the dikes, only one deserves mention. This is the Eaton fissure, near Levias, on which several promising fluorspar mines and prospects have been located. The fracture is accompanied by very little faulting in the Ste. Genevieve limestone area north of the Stevens fault, but the displacement seems to be greater south of that fault.

FOLDING.

Very little folding occurs in this district. Where any has been observed it could always be explained as due either to mere drag or to other adjustments incident to faulting. Generally the strata along the borders of the downthrown blocks are strongly bent upward—that is, they dip away from the fault-planes—while the opposite is the case on the other side of the planes. In a few instances also a slight "buckling" of the strata was observed in the zones immediately beyond the dragged edges. This buckled zone usually varied in width from about 50 to 200 feet, its width, and apparently its presence at all, depending upon the character of the beds involved, being narrowest, and the buckle at the same time most pronounced, where the strata were thinnest.

DIKES.

Igneous rocks, occurring in vertical dikes and horizontal sheets, are, so far as known, confined to Crittenden County on the south side of the Ohio River and to Pope and Hardin counties on the Illinois side. The material forming these igneous intrusives consists generally, if not always, of the dark-colored, holocrystalline variety of peridotite to which J. S. Diller[a] has applied the special designation mica-peridotite. Most of the dikes have a northwest trend. The fractures containing them, which range from 2 to 25 feet in width, appear to be very nearly straight and

[a] Am. Jour. Sci., vol. 44, 3d ser., 1892, p. 288.

probably have great length. They do not, however, form continuous vertical planes or fissures through all parts of the stratified crust, continuity of the fractures apparently being possible only in the heavier limestone formations. When formations containing considerable beds of shale were encountered the fractures seem not as a rule to have passed through them, the intruded igneous matter in these cases being forced to spread laterally between the bedding planes of the stratified rocks.

For the reason just stated, it is not believed that the dikes can generally be traced by continuous outcrop across areas of Birdsville rocks. If they did pass through the variable rocks of this formation as commonly as through the Ste. Genevieve and St. Louis limestones their outcrop should be discovered more readily and frequently in the sandstone and shale areas of the Birdsville than where the large limestone formations are at the surface. The reason for this is that the Birdsville rocks usually occupy high ground and are covered by shallower soils. But field experience in discovering outcrops of dikes shows that the opposite is true. So far in Crittenden County only one dike, the Walker, is known to outcrop in Birdsville rocks, all the other discoveries of dikes, except the one in St. Louis limestone near Caldwell Spring Church, being in Ste. Genevieve limestone areas. Even in limestone regions conditions may be so unfavorable that the chances for finding dikes are very small. In the St. Louis limestone areas, for instance, the task of discovering new dikes, or of tracing by surficial indications those already known, is rendered almost hopeless by the extraordinary depth to which this limestone is decomposed and the equal readiness with which the peridotite turns to soil.

Most of the outcrops of dikes so far discovered occur in or adjacent to stream beds. In these the dike rock may be solid to the surface. But when it is uncovered on a more level and older surface the decomposed peridotite may be extracted without the use of explosives to a depth of from 20 to 40 feet. In these cases the soil immediately over the dike may be distinguished from that on either side by its slightly different color and smoother feel. A few feet down these differences quickly become more pronounced. The dike matter now is granular and commonly of a light-grayish color, to which a faint greenish tinge is often added. Frequently it reminds of wood ashes. With increasing depth the color grows gradually darker and the mass more solid, until, finally, it passes into the hard and tough and dark greenish-gray to black rock described by Mr. Diller. As a rule the final transition is more abrupt than those preceding it. Although harder than any of the bedded rocks in the district, the peridotite is probably still harder at greater depth, since none of the rock yet seen is entirely fresh.

The intrusion of these dikes and sheets of igneous matter produced only very slight metamorphism of the inclosing rocks. Where the latter consisted of pure limestone the contact was locally altered to a white marble. This altered zone, however, is very narrow, rarely extending more than a few inches from the surface of the dike. The shales and sandstones as a rule exhibit no appreciable effects, but in one case they were darkened for a distance of from 6 to 9 inches from the contact. In another case that is probably to be attributed to a near-by dike a layer of fine-grained sandstone 6 to 8 inches thick, included in thinner bedded, shaly sandstone, was neatly divided into five- and six-sided vertical columns, varying in diameter from 1 to 3 inches.

As already stated, the dikes were probably formed prior to the extensive faulting of the region. This conclusion is accepted for two reasons. The first is that when a strong fault has been observed to cross one of the dikes or sills the latter is cut through or off. Unfortunately there are few opportunities for observation along this line, but only a single unquestionable occurrence of this condition—as, for instance, the sill in Downey's Bluff—suffices, in connection with the second reason, to impart high plausibility to the view. The second reason is that if the region had been faulted prior to the formation of the dikes the igneous matter would have been injected between the already existing fault planes instead of breaking new paths for itself. Even if new fissures were necessary to relieve the subterranean accumulation, it is inconceivable that the greater part of the flow was not through fissures already at hand. As a matter of fact, however, no igneous rock of any sort has yet been found in any of the hundreds of openings on the mineralized faults. The only possible exception known to this statement is the Flanary dike, which, as originally mapped by the writer, appears to have a northeast instead of a northwest trend, the latter being the course of all the other dikes. Whatever its direction, the Flanary is not known to occupy a previously existing fault plane, and even if it should prove to do so it may still represent a later flow than the northwest dikes.

Flanary dike.—A shaft sunk between forty and fifty years ago on an outcrop of this dike located about 1 mile southwest of Sheridan was long known as the "Flanary silver mine." Recognizing the igneous character of the weathered rock on the dump of the old shaft, the writer engaged men to cross-cut from the bottom of the shaft. The object of this work was twofold—first to procure the fresher material that was subsequently sent for determination and description to Mr. J. S. Diller, and, second, to obtain more definite data concerning the width and trend of the dike. The latter object was not entirely satisfied, but enough was learned to prove a width of 15 feet or more. The direction given to the dike on the map published in the Crittenden Press in 1890 was determined as much by the location of the shaft with respect to a point near Sheridan, where fragments of similar igneous rock were found, as by the observations in the immediate vicinity of the shaft. Although the writer was afterwards inclined to doubt that the Flanary dike trends northeastward, recent developments in the vicinity of the old shaft have induced Mr. F. Julius Fohs to declare positively that it strikes as originally mapped by the writer, i. e., N. 48° E.

The Flanary dike therefore appears to differ in its strike from all the other well-known dikes in the district, the course of the others being northwest instead of northeast, and varying but a few degrees either way from N. 33° W. Another point in which it seems to differ from the others is found in the reported occurrence of a fluorspar vein "just northwest of the dike." Possibly this fluorite occurs in a northerly continuation of the Holly vein, which is believed to have either crossed or been crossed by the dike. However, after admitting that the course is as originally mapped, the most important peculiarity of the Flanary dike is that it is associated with a fault of great displacement. As estimated by the writer, the throw of the block of Mansfield sandstone on the north of the dike can not be less than 1,000 feet. The faulting accompanying the other dikes is almost nothing when compared with this great throw.

As usual in this district, the intrusion of even this the largest of the dikes has produced only a very limited amount of metamorphism of the walls. The change in the walls where they consist of shale and sandstone or of shaly limestone is scarcely notable, but where the limestone is nearly pure it is, at least locally, altered for a few inches to a white marble. Sometimes the marble has a distinct greenish tinge.

Hard dike.—This dike is known from a single exposure on the Hard farm, 2 miles northwest of Marion. Here, in the bank of a branch of Crooked Creek a fissure, 4 to 5 feet wide, in the Ohara member of the Ste. Genevieve limestone is filled with mica-peridotite. As near as can be determined from the limited exposure the course of the dike is about N. 34° W. The limestone walls are not appreciably or only very slightly metamorphosed at the contact with the dike.

Walker dike.—This dike joins the Old Jim dike at some point between the mine and the sink-hole pond a fourth of a mile south of the mine. Just north of the pond both dikes are distinguishable, but are close together and exhibit indications of transverse connections. On the south side of the pond they are farther apart, the rate of divergence thence being about 3°. On following the trend of the dike southeastward it is next seen in an old shaft on the Deboe place, nearly a fourth of a mile from the pond. South of the Marion and Salem road it is again seen in the Walker shaft and in the bed of a small stream about 100 yards beyond the shaft. Finally, it outcrops on the south side of the Marion-View road just south of the home of Greene Jacobs. When these five outcrops are connected on the map the result is an almost perfectly straight line trending about N. 36°–37° W. The average thickness of the dike seems to be about 7 feet.

Old Jim dike.—This dike is well shown in the Old Jim mine, where it separates the zinc ores which have replaced the Ste. Genevieve limestone that originally formed the walls of the dike. North of the mine the dike is shown in the "pyrite shaft," and farther on it outcrops in a small tributary of Hurricane Creek. South of the mine it is shown in a number of prospect holes and cuts, the last being near the crossing of the Stevens fault. The average trend as shown in these exposures is about N. 33°–34° W.

As the Old Jim dike has not been detected south of the Stevens fault it seems probable that its fissure is, in part at least, limited to the limestones underlying the less brittle sandstones and shales of the Chester group. The latter failing to break cleanly must have made room for the intruded peridotite between the bedding planes.[a] Such horizontal sheets are very well shown in gullies on Ace Belt's place, situated on the north side of Clay Lick, about 3½ miles southwest of Marion. The locality is about midway between the two points where the Walker and Old Jim dikes should cross the creek. A clean exposure afforded the following section of rocks of the Birdsville formation with two peridotite sills.

Section on Clay Lick, 3½ miles southwest of Marion showing sills of mica-peridotite.

	Ft.	In.
Soil and loose sand rock at top.		
Fine-grained, thin-bedded, argillaceous sandstone not appreciably metamorphosed	6	0
Decomposed mica-peridotite	1	4
Shaly sandstone, apparently unaltered	0	9
Mica-peridotite, less decomposed than sheet above, with a few inches of dark-red clay at top	5	0
Slaty sandstone, normally grayish-blue, upper 9 inches blackened	2	0

Carden dike.—Judging from two outcrops, one on the Carden place near the head of the little stream about a mile north of View, the other about two-thirds of a mile northwest of the first, the course of this dike is about N. 30° W. The width of the dike is only about 2 feet, but the character of the material filling the fissure is practically the same as in the other dikes in Crittenden County. The Ste. Genevieve limestone forming the walls of the dike at the first outcrop is not appreciably metamorphosed.

View dike.—This dike crosses the Salem road a short distance west of the post-office at View. In the field on the north side of the road, W. L. Lowery sank a shaft, nearly 50 feet in depth, in the decomposed peridotite. Having an unquestionable dike and the same kind of wall rocks as at the Old Jim mine, the miners felt confident of striking a body of zinc ore, but, so far as known, not a sign of either carbonate or blende was discovered. Both in the road and in the shaft the dike is at least 12 feet thick. The trend between the two points is very nearly

[a] Since the above was written the writer has received from Mr. F. Julius Fohs notes on and specimens of a sill in Birdsville rocks passed through by a prospect shaft near Glendale Church. Both the Old Jim and the Flanary dike strike toward this church and the sill encountered in the shaft may be connected with either one of these dikes.

N. 30° W. Plotting this course on the map, it was found to strike directly for an outcrop of mica-peridotite about 1 mile southeast of Levias. The latter having previously been determined as trending toward View, it was assumed that the two outcrops were on the same dike.

Caldwell Spring dike.—This dike is known only from an outcrop on the east side of Caldwell Spring Branch, a short distance south of the church. It is evidently a large dike, but the exposure, when visited, gave no clue as to its course.

Notes on samples of dike rocks.—The following notes on samples of the peridotite from some of the dikes of the Kentucky-Illinois fluorite district are by Doctor Smith:

"The rock from the Flanary dike is dark greenish gray and moderately fine grained. As seen with a lens, it consists mainly of abundant small or minute, dull, blackish grains in a pale to moderately dark-greenish matrix. The rock contains a considerable though variable amount of a dark mica with silvery luster, which occurs in scattered minute flakes, and also in larger, ragged, pœcilitic flakes having a maximum noted diameter of about 4.5 mm. The rock contains occasional threads and narrow seams of some carbonate, probably mainly calcite.

"This rock has been fully described by Mr. Diller,[a] who proposes for it the name mica-peridotite.

"One slide of this rock, more altered than usual, contains among its secondary products pyrrhotite, considerable titanite, and a good deal of chlorite.

"The rocks from the other dikes are also mica-peridotite, similar in general character to that from the Flanary dike, though some differ from this, to some extent, in structure and the relative proportions of the different minerals. Most of the specimens collected are very much weathered, the Golconda rock being the freshest of them all. In this, not only is there considerable olivine only partially altered to serpentine, but also a good deal of a nearly colorless augite, which is one of the essential constituents of the rock. This mineral probably occurred originally in all the dikes, though this is the only one in which either augite or olivine was found.

"Macroscopically the rock from the different dikes scarcely varies more than different samples from any one dike. It is always dark greenish gray, sometimes approaching black. It sometimes contains minute, dark-reddish grains of iron oxide, due to the alteration of magnetite or other contained iron ores. While the biotite occurs in some of the dikes in broad, pœcilitic flakes, in others the flakes are minute, and though common are not abundant. This is the case with the Hard dike and the View dike. At the Old Jim mine, mica was noted in small flakes in the peridotite, though at the Pyrite shaft, on the same dike, it is found in coarser form.

"Under the microscope the rock always shows considerable alteration, even that from Golconda. When first altered it contains abundant serpentine and little carbonates. On further alteration carbonates develop, and some of the specimens are very largely composed of these, probably mainly calcite, though this is doubtless associated with more or less magnesian carbonates. In one of the specimens from

[a] Am. Jour. Sci., vol. 44, 3d ser., 1892, pp. 286–289.

the Hard dike, on Crooked Creek, the rock was so altered that even the biotite had almost wholly disappeared. Seams of serpentine, calcite, or other carbonates, sometimes associated with quartz, are common in the altered rocks. Pyrite was noted in small quantity in several of the dikes. Where the rocks are considerably altered secondary mica and what is apparently talc may occur among the products of weathering, as was noted in the peridotite of the Hard dike.

"The amount of mica varies considerably, as do also the relative proportions of magnetite (?) and the mineral determined as perofskite. The latter is usually deep reddish brown, though in one of the specimens from the Hard dike it was a rather bright yellow. It is usually, though not always, bordered with a narrow black rim having the general appearance of magnetite. The cloudy, whitish, secondary product so common in most of the slides is apparently derived from the perofskite or some other titanium-bearing mineral in the rock, and is probably leucoxene.

"In the Hard and View dikes the biotite is found as abundant small laths instead of in the large pœcilitic flakes in which it usually occurs."

LEAD, ZINC, AND FLUORSPAR DEPOSITS OF WESTERN KENTUCKY.

Part II.—ORE DEPOSITS AND MINES.

By W. S. TANGIER SMITH.

ILLUSTRATIONS IN PART II.

PART II.—ORE DEPOSITS AND MINES.

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CHAPTER I.

MINING IN THE DISTRICT.

The area including the lead and zinc deposits of western Kentucky, together with those of southern Illinois, forms one of the subsidiary lead and zinc districts of the Mississippi Valley. This district differs from the others in several respects: (1) In the presence of dikes of basic igneous rock in the same vicinity; (2) in the almost constant association of the lead and zinc ores with fluorite, the latter occurring in well-defined fissure veins; (3) in the common occurrence of sphalerite in fine grains, largely as a metasomatic replacement of the limestone in or adjacent to the fissure veins.

HISTORY OF MINING OPERATIONS.

Lead ores were known in this district to the early settlers from about 1812. The first attempt to mine the deposits was made in 1835 by a company headed by President Andrew Jackson. The operations of this company were carried on in Crittenden County, Ky., its shaft being sunk on the Eureka vein within 100 yards of the present main shaft of the Columbia mine. Between that time and the civil war other scarcely less primitive attempts were made to mine the deposits, notably at the Royal mines in Livingston County, near Smithland. About 1850 the impression prevailed that the galena of the district contained a considerable amount of silver, and it was for this mineral rather than for the lead that the Royal, Columbia, and other mines were first worked.

In the seventies, incited by the successful operations at Rosiclare, on the Illinois side of the Ohio River, prospecting and mining were somewhat generally resumed in western Kentucky. Considerable activity, indeed, was displayed in the development of mines in Crittenden County. For several years the Columbia mines were worked for lead, apparently with profit. In 1878, however, these and most other mines in the district were shut down, because, with the lack of adequate transportation facilities and the depreciation in the market value of lead which set in about that time, mining operations became unprofitable.

The first shipments of fluorspar from the Kentucky side of the district came from the Yandell mine in 1873. The ore was hauled to Dycusburg, on the Cumberland, and shipped thence by boat. In the following year the Memphis mines were opened, the fluorspar being hauled to the Ohio River. These two mines remained in operation for several years, but the long wagon hauls over bad roads finally caused them to succumb to the competition of the more fortunately situated Rosiclare mines. In the last six years interest in the district has been renewed, the rise in the price of zinc being perhaps the principal of the factors causing the revival. As a result of the search for this mineral the district, for the first time in its history, is being thoroughly and more or less systematically prospected. Over forty companies have been organized since 1899 and are now working in the district. Although but few of these have so far succeeded in discovering important bodies of zinc and lead, the efforts of most of them have not been wholly fruitless, since they have uncovered large deposits of fluorspar which, after all, is the main ore of the district. Further details of the past and present operations at some of the more important mines are given in Chapter III of Part II of this report.

PRODUCTION.

There are no data for determining the production of galena from this district prior to 1880, but it must have amounted to at least 1,000 tons. For over twenty years production ceased entirely. Even since the revival of interest in the mines of this district a few years ago the production of lead has been insignificant, only a few tons having been shipped. Early in the past year the Kentucky Fluorspar Company, at Marion, installed machinery and is now prepared to separate the small amounts of galena contained in the fluorspar ground by them. Later in the year the Columbia Mining Company erected a mill for the separation of their ores, and a small plant was erected by Messrs. Blue & Nunn at the New Jim mine, on the Columbia vein. This vein generally carries some galena. The Riley mine, which is, so far as known, the only mine in the southern part of the district having no sphalerite with the galena, is likewise being equipped with a mill. Under the circumstances it is expected that the district will this year begin to assume rank as a small but regular producer of galena.

The production of zinc has hitherto been confined almost entirely to one mine—the "Old Jim." In 1901 this mine shipped 3,154,151 pounds of carbonate (smithsonite), and in 1902, up to September 1, 5,036,390 pounds of the same ore, al at an average value of $13.90 per ton f. o. b. at Marion. In 1903 a considerable proportion of the output from the Old Jim was of sphalerite. In 1904 little was done on this property, the Columbia and New Jim being then the main zinc producers. Other but comparatively small producers of carbonate in these years were the Mann, McDowell, and Miller mines. In 1900 the Lanham mine produced about 25 tons of sphalerite. Of recent years the zinc output of the district has been from 1,500 to 2,500 tons. As sphalerite is the most important of the elements of the ores of some of the mines in the Columbia fault zone, a number of which are being actively developed, the production of this mineral may be increased materially in the immediate future.

The output of fluorspar in the district prior to 1882 can not now be determined exactly, but it doubtless amounted to many thousands of tons. From that date to the close of 1903 the production reached a total of about 250,000 tons, valued approximately at $1,562,500. Before 1899 considerably more than half of the annual output came from the north side of the Ohio, but since that date the production has been about equal on the two sides of the river. An effort was made to determine the output of the mines in each of the two States separately, but the data secured for most of the years were insufficient to serve the purpose. The statistics for 1899 and later years, however, appear to be more detailed and definite, so that the following table of amounts of spar shipped from the various mines in Kentucky from January 1, 1899, to September 1, 1902, may be accepted as approximately correct.

Fluorspar shipped from mines in Kentucky from January 1, 1899, to September 1, 1902.

	Pounds.
Hodge	14,801,076
Memphis	15,756,435
Klondike	3,213,630
Yandell	26,694,820
Brown	1,437,490
Ebby Hodge	569,490
Kentucky No. 4	459,860
Panther Hollow	886,875
Holly	635,465
Blue Land	24,045
Tabb	3,641,871
Blue and Marble	3,352,338
Wheeler	823,960
Lanham	92,620
Mary Belle	1,051,695
Evening Star	156,000
Tabor	160,000
Asbridge	4,644,000
Sam Matthews	28,000
Lovelace	88,000
Babb	850,000
J. K. P. Hudson	92,000
Austen Guill	144,000
Dan Riley	20,000
Archie Crosson	30,000
Lucile	882,130
Marble	1,945,950

During this period 700,000 pounds of fluorspar were ground by the mill of the Eagle Fluorspar Company, near Salem, and 10,493,395 pounds by that of the Kentucky Fluorspar Company, at Marion.

The production of fluorspar by the mines in western Kentucky in 1903 amounted to 29,168 tons. Of this output 21,549 tons, valued at $93,800, were shipped in the crude state, and 3,336 tons, valued at $33,360, were ground. Nearly the whole of this production came from Crittenden County.

Six grades of fluorite are recognized in the American market: (1) American lump No. 1, (2) American lump No. 2, (3) gravel, (4) crushed, (5) ground fine, (6) ground extra fine.

The first three of these are recognized in mining, the fluorite being graded according to size and purity. White or colorless and transparent or nearly transparent fluorite belongs to the first grade, or No. 1; clear blue ore, especially when very pale in color, comes under the same head. To No. 2 belong the dark-colored fluorites and those admixed with impurities, such as calcite and fragments of limestone. The fluorite is further graded, as to size, into lump and gravel, the former consisting of the ordinary massive, granular fluorite, in fragments and blocks, and the latter of the same material after the grains have become separated by weathering.

USES OF FLUORSPAR.

Fluorspar is used chiefly as a flux in the manufacture of steel and pig iron, and to a minor extent in the reduction of lead. It is claimed to be of advantage also in the smelting of copper and nickel. In addition it is employed in the enameling trades, and comparatively small amounts are used in the manufacture of hydrofluoric acid and of opalescent glass. For these last purposes only the best quality of fluorite is used, the second and third grades being sold for fluxing.

MINING METHODS.

For the purposes of prospecting or mining land supposed or known to be ore bearing is as a rule either leased or purchased. In some cases only the mineral right in the land is obtainable, while rarely the right to mine one mineral, as fluorite, is sold or leased to one individual or company, while the right to other minerals occurring in the same vein (as lead and zinc ores) is sold or leased to others. Occasionally the lessee does not work the property himselt, but subleases it. There are no fixed royalties, the leasing rates for fluorite ranging from 10 cents to $1.25 per ton of cleaned ore, and from 25 cents to $2 or possibly $2.50 for separated lead and zinc ores.

There are few fully equipped plants in the district and mining is carried on for the most part by simple methods. Many of the mines or prospects consist of open cuts, more of shallow shafts, and both are worked by windlass. With increase in depth of the shaft the windlass is exchanged for the whim, operated by horse power. This is probably the most commonly used method of hoisting in the district, being depended on by some of the more important mines. The better equipped mines use steam power or gasoline engines for hoisting, pumping, and other purposes, and a few are furnished with such accessories as compressed air drills and electric lights.

A. GRAVITY FLUORSPAR WASHER AT TABB MINE.

B. GRAVITY FLUORSPAR WASHER AT MARY BELLE MINE.

As most of the mines are above permanent water level, more or less timbering is necessary in the drifts. Usually this is of the simplest possible kind, though in a few instances the timbering is excellent. Some of the drifts, especially those below water level, have little or no timbering. The open cuts as a rule are not timbered, that at the Old Jim mine being an exception. The character of the timbering here is well shown in Pl. XV, *A* and *B*.

The mills of the district are of two classes, those for grinding fluorspar and those for concentrating the ores. Of the former there are two, one belonging to the Kentucky Fluorspar Company, at Marion, the other belonging to the Eagle Fluorspar Company, at the Evening Star mine, southeast of Salem. Only the best fluorite, a clean first-grade ore, is used for grinding. The ore is first heated in a kiln to free it from moisture, after which it is coarsely crushed and finally ground to a flour and bolted through cloth. After being ground it is barreled and shipped to glassworks and acid manufacturers. Lumps or fragments of ore containing galena are culled and saved for the lead. There is shipped from the district for fluxing purposes much fluorite which would make good grinding spar if it could be separated from the associated galena and calcite.

The mill at Marion has been in operation since about 1898, and the Eagle Fluorspar Company's rolls were installed at about the same time. The Kentucky Fluorspar Company's mill has one coarse and two fine rolls, with a capacity of 80 barrels a day. The mill works intermittently, and both the company's and purchased ores are ground. The Eagle Fluorspar Company's rolls were installed for their own ores and for custom work. They were not in operation when the district was visited.

At the present writing there are three concentration plants in operation in the district, one at the Marble mine, one of about 30 tons' capacity at the Columbia mine, and the third, of the same capacity, at the Evening Star mine. That at the Columbia is intended primarily for the concentration of sphalerite and galena, the others for the separation of galena, sphalerite, and fluorite from each other and from rock fragments and calcite. At all of the mills the general method is the same, the ores being crushed, rolled, sized, and finally concentrated; but at the Columbia and Marble mines the concentrating medium is water, while at the Evening Star mine it is air, the ores being treated dry by the Hooper pneumatic system. At the Columbia and Marble mines the method employed is that in common use in the Joplin district, in southwestern Missouri, and their plants consist of the usual crusher, three rolls, screens, and jigs. The Columbia has three jigs, and the Marble four of the American Concentrator Company's jigs of three compartments each. Where this method is used only for the separation of sphalerite and galena, as at the Columbia, it is of course satisfactory. At the Marble mine the separation of the galena is satisfactory, but that of the fluorite from the other minerals and rock is not. Even where sphalerite is not present, this mode of separating the fluorite is far from satisfactory, but where sphalerite must be separated as well the difficulties are increased many fold. The sphalerite usually occurs in fine grains disseminated in limestone and to a less extent in fluorite, thus necessitating much finer material for concentration, and rendering separation by the wet methods much more difficult.

The plant at the Evening Star mine was being installed when the district was visited by the writer. It was to consist of a crusher, three sets of straight-face rolls, nine groups of sizes (the finest screen being of 180-mesh silk bolting cloth), and 12 Hooper pneumatic concentrators. This method of separating the ores of this district, to judge from practical results so far as they can be learned, is scarcely more satisfactory thus far than separation by jigging. It seems probable, however, that sooner or later some method will be devised by which the Kentucky ores may be properly concentrated.

The fluorite above water level usually occurs in a more or less granular form known as gravel spar, mixed with a varying proportion of clay, and much of it must be cleaned before it can be shipped, although many of the mines are not equipped with any washing apparatus. There are two methods in use for cleaning the ore, one known as the gravity washer, the other the log washer, commonly used for washing the oxidized ores in the Wisconsin lead and zinc district.

The gravity washer consists of one or two ore pens at the top of a trough, which is inclined at an angle of 10° or 12°, and has one or more openings toward its lower end. The ore is usually sized to a greater or less extent at the same time, one or more screens being placed just beneath the openings of the trough, as shown in Pl. IX, *A* and *B*. A strong stream of water turned on the ore in the pens carries it into the trough and down the incline, at the same time washing it from any admixed or adhering clay. The water with the fine ore and suspended clays passes off at the first screen. At the Tabb mine settling troughs are used, in addition, for collecting this fine fluorite.

The log washer is shown in Pl. X, *B*. It is slightly inclined, ore being introduced at the lower end and water at the upper. By the revolution of the "log," the ore is gradually worked toward the upper end, and finally out, while the water with its suspended clays passes out at the lower end. At the Brown mine two such washers are used, the ore being subjected to a double washing by passing from the first into the second. Besides being used for fluorite, the log washer is used at the Old Jim mine for cleaning the smithsonite.

The cleaner ores, especially those from the unweathered portions of the veins, are shipped directly, without washing, the coarser impurities, such as calcite and limestone, being culled from them by hand.

A. HODGE MINE.

General view, showing location of washer.

B. LOG WASHER AT HODGE MINE.

CHAPTER II.

ORE DEPOSITS OF THE DISTRICT.

MINERALS OF THE ORE DEPOSITS.

The minerals forming the ore deposits and associated with them in this district are the following: Galena, cerussite, pyromorphite, sulphur, sphalerite, smithsonite, hydrozincite, calamine, greenockite, pyrite, marcasite, limonite, chalcopyrite, malachite, fluorite, barite, calcite, quartz, kaolinite, and ankerite. In addition to these, small quantities of some of the hydrocarbon compounds are occasionally found in the veins. Of all these minerals, only fluorite, barite, galena, sphalerite, and smithsonite are known to be of economic importance within the district.

DESCRIPTIONS OF THE MINERALS.

Galena or galenite, lead sulphide (*PbS*).—Galena or galenite, characterized by its lead-gray color, its cubic cleavage, and its high specific gravity (7.4–7.6), is generally found in irregularly shaped grains, up to 1 inch or more in diameter, in and with fluorite. It occurs usually in individuals, but sometimes in aggregates. Occasional aggregates 6 inches or more in diameter are reported from several of the mines of the district, though none of such size were seen by the writer. Well-developed crystals are not common, but it is sometimes found in cubes, especially where it occurs in vugs. Less often it is cubo-octahedral. In addition to its occurrence with fluorite it is occasionally found disseminated in small grains in limestone and also in coarser form as a cement to breccia. The cleavage surfaces are sometimes more or less curved. It is occasionally found in elongated forms with fine granular or columnar structure, due to post-mineral movements in the vein; also, rarely, in very fine-grained aggregates.

The galena of western Kentucky is practically nonargentiferous, as is generally the case with this mineral in the sedimentary rocks throughout the Mississippi Valley. So far as has been determined by analysis, the silver content of these ores appears to be no greater than that of the ores from the various lead districts of Missouri[a] on the whole. On the other hand, the ores from southern Illinois contain somewhat more silver than those from Kentucky, if we may judge from the reports

[a] Winslow, Arthur, Geol. Survey Missouri, vol. 7, 1894, p. 455.

of previous writers,[a] which indicate a proportion of silver ranging from 2 or 3 ounces to 32 ounces per ton.

Peter,[b] commenting on a specimen of galena from Owen County, Ky., in which he found "no ponderable quantity" of silver, remarks that "this has been the usual result of the analyses of the galenas of this region. They all appear to be remarkably poor in silver."

Three specimens of galena from the western Kentucky district assayed by Dr. E. T. Allen, of the United States Geological Survey, yielded the following amounts of silver in troy ounces per ton:

Silver in galena from western Kentucky.

[Troy oz. per ton.]

Drescher open cut	1.63
Lovelace mine	0.25
J. N. Riley mine	No silver.

Cerussite, lead carbonate ($PbCO_3$).—This is sometimes found colorless and translucent, with vitreous or adamantine luster, although it occurs usually in impure form as a dark-gray to nearly black, fine-grained aggregate, sometimes compact, though generally earthy and dull. It is common, coating galena or filling cavities once occupied by galena within the zone of oxidation above the level of ground water. It is by far the most common oxidation product of galena.

No lead sulphate (anglesite) was identified. A number of specimens tested for this mineral gave only reactions for lead carbonate.

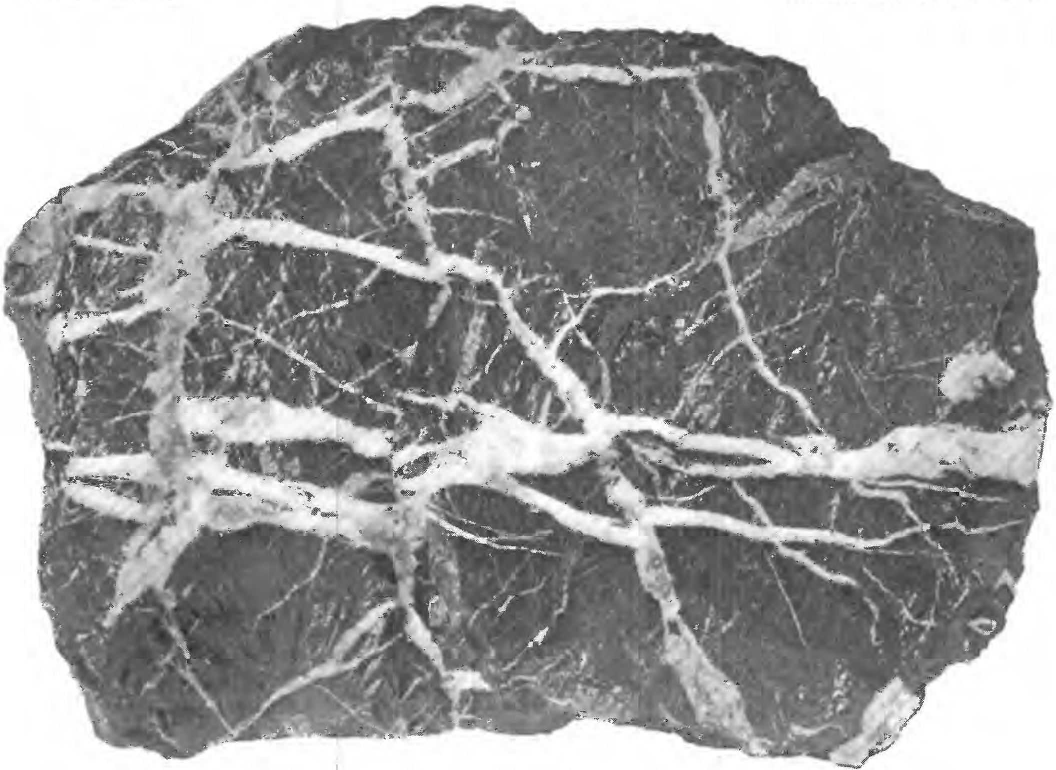
Pyromorphite, orthophosphate of lead with chloride of lead ($(PbCl)Pb_4(PO_4)_3$).—This occurs in minute or microscopic green translucent crystals, as individuals or small aggregates. It is comparatively rare, but was noted in small amount on fluorite at the Tabor and Wheeler mines and in druses in a cavity in fluorite once occupied by galena at the Kentucky No. 4 shaft. It is an oxidation product of galena and is found only in the zone of oxidation.

Sulphur (S).—Sulphur is comparatively rare. It was noted in only two localities, at the Brown mine and at the Kentucky No. 4 shaft, occurring at both places as minute yellow crystals in partially oxidized galena. It is one of the products of weathering of galena, and is found, therefore, only in the zone of oxidation.

Sphalerite or "blende," zinc sulphide (ZnS).—This occurs usually in small or minute crystals or grains, of a yellowish or brownish, occasionally nearly black, color, disseminated in limestone, less often in fluorite. It is also sometimes associated with calcite. Occasionally it occurs in vugs or as a cement to breccia, and it is then somewhat more coarsely crystallized and more or less aggregated. It is a

[a] Owen, D. D., Geol. Survey Kentucky, vol. 1, p. 88 1856. Whitney, J. D., Report of a Geological Survey of the Upper Mississippi Lead Region, Albany, 1862, p. 199. Norwood, J. G., Geol. Survey Illinois, vol. 1, p. 372, 1866. Emmons, S. F., Fluorspar deposits of southern Illinois: Trans. Am. Inst. Min. Eng., vol. 21, p. 33, 1893.

[b] Geol. Survey Kentucky, part 1, vol. 4, 2d series, 1877, p. 134.



A. TYPICAL SPECIMEN OF SEAMED LIMESTONE.

B. HYDROZINCITE AND SMITHSONITE FROM OLD JIM MINE.

common mineral in the veins, but is found in more than ordinary abundance at a few localities, as at the Columbia mine, as part of the cement of a limestone breccia, and at the Old Jim mine, where it replaces limestone.

A red[a] and a white[b] oxide of zinc are reported as occurring in the district, the former at the Columbia mine and the latter at the Old Jim. Samples of the former (the so-called zincite) seen by the writer proved to be only a variety of sphalerite (ruby blende), while the supposed white oxide is the basic zinc carbonate, hydrozincite, described below.

Smithsonite, zinc carbonate ($ZnCO_3$).—This is found both crystallized and massive. The crystals are generally light colored and translucent; they are always small, are found singly or in aggregates on the walls of cavities, and are usually short rhombohedral, with curved rough faces. They also occur doubly terminated, spindle shaped, or with club-shaped terminals, frequently aggregated in masses. Reniform, botryoidal, and stalactitic aggregates are common in cavities in the more massive granular varieties (Pl. XI, *B*). A large part of the smithsonite occurs replacing limestone, and is massive, granular, and moderately dark gray in color. Only rarely it is found white and fine grained. Occasionally small amounts of greenockite (noted especially at the Old Jim mine) are included in the smithsonite, coloring it yellow and forming the variety "turkey-fat." Smithsonite is the commonest of the oxidation products of sphalerite. It has a somewhat greater specific gravity than limestone, which is sometimes mistaken for it by the miners, and it does not effervesce so readily with acid.

Hydrozincite, basic zinc carbonate, perhaps $ZnCO_3.2Zn(OH)_2$.—This was noted in small amount at the Drescher open cut and locally in considerable quantity at the Old Jim mine, incrusting cavities in deposits of smithsonite. Usually laminated and associated with laminæ of smithsonite (Pl. XI, *B*), its surface forms are like those of smithsonite. In places it shows a fibrous structure at right angles to the lamination. It is white, dull, and chalky in color, and rather soft (hardness, 2–2.5). It sometimes appears to be mixed with some smithsonite and is then a little harder. It is found just above the level of ground water at the Old Jim mine. This mineral is apparently an alteration product of smithsonite.

Calamine, basic silicate of zinc ($H_2Zn_2SiO_5$).—This is seen in very small amount at the Hodge and Evening Star mines and at the Clement shaft, occurring in small hemispherical or sheaf-like aggregates in cavities in ore or rock, having rough surfaces formed by the projecting ends of the minute, white, translucent crystals. Calamine is an oxidation product of sphalerite.

Greenockite, cadmium sulphide (CdS).—This occurs in greenish yellow or orange-yellow films coating the walls of cracks in ore and rocks near and usually above ground-water level. These films, where of appreciable thickness, very much

[a] The Mineral Industry for 1900, vol. 9, 1901, p. 294.

[b] Mining and Eng. Jour., vol. 74, 1902, pp. 413-414.

resemble the precipitated and dried cadmium sulphide of the laboratory. As already noted, greenockite also occurs in small amounts coloring smithsonite crystals. It is common in small quantities throughout the district wherever sphalerite occurs as one of the products of weathering.

Pyrite and marcasite, iron disulphide (FeS_2).—Both of these minerals are found, the pyrite occurring apparently in the greater quantity of the two. They are not common except locally, and are then occasionally abundant, as at the Old Jim mine, where they occur replacing in large part a 6 to 12 inch bed of limestone close to the Old Jim dike. This is the common mode of occurrence of the minerals, replacing limestone, though they have been occasionally noted in Chester shale and also (at the Old Jim dike) in partially weathered peridotite. Both minerals occur in crystals and grains, usually of microscopic size.

Limonite, hydrated sesquioxide of iron ($2Fe_2O_3.3H_2O$).—This is common as an oxidation product. In addition to its occurrence as a constituent of clays and among the residual products of some of the minerals, as of sphalerite, it is occasionally found more or less aggregated, usually forming moderately hard, compact, dark-brownish masses in clay adjacent to the veins. It sometimes occurs also in stalactitic forms.

Chalcopyrite, sulphide of copper and iron ($CuFeS_2$).—This is characterized by its moderate hardness (H 3.5–4), its metallic luster, brass-yellow color, and, when crystallized, by its crystal form. This mineral has been noted in small amounts at several localities. It was found as numerous minute sphenoids disseminated in fluorite in zones or bands parallel to the cubic faces of some of the individuals in an aggregate from the Holly mine. A very small amount in minute grains was also noted in fluorite at the Marble mine and in silicified limestone at the Nancy Hanks shaft; also in greater amount disseminated in limestone at the Wilson copper shaft.

Malachite, basic cupric carbonate ($CuCO_3.Cu(OH)_2$).—This is a bright-green mineral usually of dull, earthy character. It effervesces freely with dilute hydrochloric acid. It was noted at the Wilson copper shaft above ground-water level as an oxidation product of chalcopyrite.

Fluorite, calcium fluoride (CaF_2).—Fluorite is the principal vein-forming mineral of the district. It is sometimes found in cubic crystals coating the walls of cavities in the vein or in the country rock adjacent to the vein, but is more often massive, occurring then as a nearly uniform granular aggregate. It is usually medium grained, though sometimes finer or coarser, crystals and grains having been noted with a diameter of as much as 5 inches. The crystals are always cubes, their faces generally somewhat rough, owing to irregularities of development. Although the fluorite usually has a perfect octahedral cleavage it is sometimes indistinct, owing in some cases to movements in the veins since the mineral was deposited. The mineral has a vitreous luster, and is translucent or, rarely, transparent. Where granular it is usually white, though often purplish. In individual grains and crystals it is generally colorless, sometimes blue or purplish, and occasionally almost black. In one instance, at the Tabor mine, amber-yellow crystals were noted. Green fluorite is reported from one of the Illinois mines, but none was seen in Kentucky. No fluorescence has been noted in the Kentucky fluorite, and most of the specimens that were tested gave no observable phosphorescence. The mineral does not effervesce with dilute hydrocloric acid.

The source of the color of fluorite has not yet been conclusively determined, although Wyrouboff's[a] experiments, in his view, showed it to be due to the contained hydrocarbons rather than to the metallic oxides. To the present writer, however, the results of these experiments appear to have proved rather the presence of hydrocarbon compounds in the mineral than the connection of these compounds with the color; although certain facts (particularly the decolorization of the mineral on moderate heating) would seem to make the correctness of Wyrouboff's conclusions as to the source of the color reasonably sure.

Wyrouboff noted that in the violet-colored fluorite from Welsendorf both color and odor were variable, and that the specimens with the strongest odor were also darkest in color. This first led him to the supposition that the cause of the color and odor were the same. In the course of his experiments he found that all of the fluorite specimens that possessed odor contained hydrocarbons; that white fluorite from Cumberland had no odor and contained no hydrocarbons; that the quantities of metallic oxides present were totally inadequate to explain the color, besides being the same for different colors; and that small pieces of the Welsendorf fluorite with pronounced odor, treated with ether for twenty-four hours, completely lost their odor, showing it to be due, in this case, to hydrocarbons infiltrated in the fractures of the mineral. He found, also, that the colored varieties lose their color when heated, that from Welsendorf becoming decolorized at 370° C., which, he remarks, is a higher temperature than that required for the decolorization of most fluorites. He tested fluorite of different colors, including violet, dichroic, yellow, green, blue, and white varieties, and his conclusion from all his experiments is that the coloring matters are various compounds of hydrogen and carbon, probably arising from bituminous limestone, and also that phosphorescence on heating is due to the decomposition of the coloring matter.

In the Kentucky district the fluorite is mainly white, and the principal colored variety is purplish in different shades. Yellow fluorite is rare. No thorough investigation of the cause of the color of the Kentucky fluorite was made, but some facts

[a] Wyrouboff, M. G.: Bull. Soc. Chim. de Paris, 1866, n. s., vol. 5, pp. 334–347.

have been brought out by field observations and a few experiments. There can be no question that the odor obtained when the mineral is struck or broken is due to contained hydrocarbons. As regards the relation of the odor to color, the present writer's observations, contrary to those of Wyrouboff, show that the purplish varieties have, in general, no stronger odor than the white or colorless, the odor of the latter being frequently very pronounced. The strongest odor is found in the brownish variety, which contains an unusually large amount of hydrocarbons. In this case the color appears to be due merely to mechanical admixture with the hydrocarbons, the fluorite itself being white or colorless. On heating, the yellow fluorite from the Tabor mine, the purple and the brownish fluorite are all decolorized considerably below red heat, the purple specimens showing slight phosphorescence at the time of the loss of color. Coarsely powdered, dark-purple fluorite treated for several weeks with ether did not lose color, nor was the ether colored; but small fragments of brownish fluorite gave up a considerable part of their color within 24 hours, turning the ether yellow. Metallic oxides, if present, occur only in extremely minute quantities; beads of borax and of sodium carbonate showed no color with the colored fluorites. Manganese is not uncommon in the clays adjacent to some of the veins, and it is probably present also in small amounts in sphalerite, althougn the writer has nowhere noted any such relation of purple fluorite to the occurrence of sphalerite as that given by Burk.[a]

From the writer's observations it seems probable that the white or so-called colorless varieties of fluorite contain no less coloring matter than do the colored varieties, the differences in color being accounted for by differences in the chemical condition of the coloring agent. Wherever purple fluorite was seen it was always associated with white, colorless, or even yellow fluorite in such a way as to make it seem probable that the purple color is due to oxidation, and is not original with the fluorite. In the mines the purple color first appears in those places first reached by oxidation, that is, along the contacts between the grains of fluorite, especially near the vein walls or along some fracture in the vein. It also forms on crystal surfaces in vugs, and is especially common in the oxidized portions of the vein. In the belt of weathering, fluorite is most often purple, where found in thin seams and particularly where occurring as a cement to brecciated chert or quartzite, these conditions being more favorable to oxidation. Only a small proportion of the fluorite in the belt of weathering is purple, as a rule, most of it still retaining its white or colorless character, except in some cases where it occurs in thin seams cementing breccia. In the case of dark-purple fluorite occurring in vugs, the color, where noted by the writer, is not uniformly distributed through the mineral, but is found in bands parallel to the surface of the vug, and in some instances the bands com-

[a] Burk, W. E., The fluorspar mines of western Kentucky and southern Illinois: The Mineral Industry for 1900, vol. 9 1901, pp. 293-295.

pletely encircled the cavity, passing from crystal to crystal and following all the surface irregularities.

These observations strongly suggest, though they do not prove, that the purplish fluorite, at least in western Kentucky, is derived from fluorite of other colors by oxidation of the contained coloring matter.

Decrepitation of the fluorite is apparently closely connected with the amount of contained hydrocarbons. Some specimens, as the yellow variety from the Tabor mine, decrepitate only slightly, but most of them show considerable decrepitation, while the brownish fluorite from the Lucile mine decrepitated violently, being reduced in the process to a fine sand. Microscopic liquid inclusions are very common in the fluorite, occasionally with moving bubbles. They were especially abundant in some of the specimens having pronounced odor, and it is probably to them that the decrepitation is largely due.

Barite, barium sulphate ($BaSO_4$).—This is common as a vein-forming mineral, and is usually found massive in fine-grained aggregates, though it is occasionally noted as crystals, especially in small cavities in the partially weathered, more massive forms. The individuals of the massive barite are generally thin and platy and are frequently grouped in arborescent forms, best seen on somewhat weathered specimens, which, however, usually show a more or less reticulated structure. Aggregates of unusually large barite crystals were noted at Crosson Cave, the individuals having a maximum length of half an inch. The barite crystals wherever seen had the same habit, a combination of unit prism and basal pinacoid, the crystals flattened parallel to the latter. The massive barite may usually be readily distinguished by its white or nearly white color when fresh, its fine-grained crystalline character, its specific gravity (about 4.5), and its noneffervescence with acid.

Calcite, calcium carbonate ($CaCO_3$).—Calcite is a common vein mineral and is also found in limestone adjacent to the veins. Although sometimes found in crystals in vugs, it usually occurs in irregularly shaped grains or in granular aggregates. The size of the calcite grains is very variable. The vein calcite, though sometimes fine grained, is generally quite coarse, the grains having a maximum diameter of 6 inches or even more. It is generally white, and is translucent only in thin fragments. It has a well-defined rhombohedral cleavage. The crystals occurring in vugs are usually small or of moderate size, and subtransparent and colorless, or nearly so. The forms of the crystals are sometimes complex, although as a rule they are simple, consisting generally of a single rhombohedron ($-2R$) or less often of this combined with a scalenohedron (R^3).

Quartz, silica (SiO_2).—Quartz in hexagonal crystals, usually minute or microscopic, is frequently found in druses coating the walls of small fractures, especially on siliceous surfaces. Its chief occurrence, however (aside from that in chert and Chester sandstone and quartzite), is in and replacing limestone, sometimes as scattered, doubly terminated microscopic crystals, sometimes largely or wholly replacing the rock and forming jasperoid. (See p. 140.)

Kaolinite, basic silicate of aluminum ($H_4Al_2Si_2O_9$).—This occurs as a white or cream-colored, very fine-grained aggregate, sometimes with a tinge of red. It is earthy and dull, or has a slight waxy luster, is soft (easily scratched with the finger nail), unctuous, adheres strongly to the tongue, and when placed in water readily slacks. It is found in patches in clay adjacent to the fluorite veins at the Asbridge mine and at shaft No. 6 of the Blue and Marble mines. It was chiefly noted, however, in the open cut at the Givens prospects—here also in residual clays and sands. In addition to these occurrences it was seen in minute particles in red clay at a number of the mines.

Wad.—Wad, an impure mixture of hydrated oxides of manganese, is found as a product of weathering, usually in minute dark-gray or blackish specks scattered in clay. It was noted also in barite. It occurs in the kaolinite just described, especially in that of the Givens open cut, where it is sometimes so abundant as to give the kaolinite a gray color. In some of the kaolinite the wad is largely segregated, in places making up the mass of the rock, though always containing a greater or less admixture of kaolin. This segregated wad occurs in minutely botryoidal forms. Wad from the Givens mine at Pleasant Grove Church, according to analyses by Mr. W. George Waring, contains from 2 to 17 per cent of cobalt and nickel.

Ankerite, carbonate of calcium, magnesium, and iron (*with some manganese* ($CaCO_3(Mg,Fe,Mn)CO_3$).—This was noted at the Old Jim mine, at the margin of the Old Jim dike, where it occurs as a product of the alteration of peridotite, associated with calcite and sphalerite. It occurs as a medium granular, crystalline aggregate, nearly white with a pink tinge, and with curved rhombohedral cleavage faces.

Hydrocarbon compounds.—These, although not homogeneous substances and therefore not mineral species, are considered here for convenience. Much of the limestone of the district, when fractured by a blow, gives off an odor resembling that of crude petroleum. A similar odor is given off when the limestone is dissolved in hydrochloric acid, and a brownish scum forms on the solution. Some dark-colored limestones also give off a decided bituminous odor when heated. These effects are due to the presence in the limestone of a very small amount of contained organic matter, probably largely in the form of petroleum. A similar odor is obtained sometimes from coarse white-veined calcite; also from most fluorite when it is broken, and it is frequently much stronger in the fluorite than in limestone. Sometimes the amount of contained hydrocarbons is so great as to make the fluorite somewhat brownish or even blackish. This coloring matter appears to be concentrated along the cracks and between the grains of granular fluorite and gives a bituminous odor when heated. Rarely the cleavage surfaces of the fluorite have the appearance of being moistened with a film of oil, and at the Bonanza mine occasional pockets of oil are reported as occurring with the ore. Finally, small films of asphalt are sometimes, though not often, seen on the fluorite. The amount of hydrocarbons contained in the limestone and fluorite is so small that even where the odor is strongest they can seldom be determined quantitatively with the amount of material ordinarily used in chemical analysis.

MODES OF OCCURRENCE OF THE ORE DEPOSITS.

The ores of this district may be most conveniently described under three heads: (1) Fissure veins; (2) ores cementing breccias; (3) metasomatic replacements. The first class includes the deposits filling fissures due to faulting. The second class consists mainly of deposits cementing breccias of country rock which has been thoroughly shattered by differential movements, but in which as a rule there is no simple, clean-cut fault. Under the third head are treated those deposits which occur as replacements (in some cases not adjacent to any fissure vein) mainly of the country rock or of rock fragments in deposits of the other two classes. The three types are frequently associated, and the first two classes may grade into each other; nevertheless, in typical cases in this field, the distinctions between all of them are so clear that the division seems warranted for purposes of description.

Fluorite, barite, some galena, and some sphalerite are found in fissure veins, which are by far the most important occurrence, taking the district as a whole. The same ores occur as a cement to breccias; while those found as metasomatic replacements include mainly sphalerite below the influence of surface oxidation, and smithsonite within that zone.

FISSURE VEINS.

GENERAL FEATURES OF THE VEINS.

All the forms of deposits just described occur along or in the vicinity of well-defined fractures or faults, and in particular the well-defined veins of the district, probably without exception, fill fissures due to faulting. While the veins follow all the systems of faulting which have been described by Mr. Ulrich in Part I of this paper—filling both northwesterly and northeasterly fissures, and at the Marble mine a practically east-west fissure—many more of the northeasterly veins have been discovered and developed than of those trending in other directions. Although it is not to be understood from this statement that such veins as do occur in other directions are not so well defined or so important economically as the northeasterly ones, still the present chief producers are the northeasterly veins.

Ore-bearing fractures belonging to one system are occasionally noted intersecting those of another system. The northwesterly Eureka fault, for example, intersects the northeasterly Columbia fault at the Columbia mine (figs. 6 and 7). So far as known, ore has been found only southeast of the Columbia fault, and judging from Norwood's description[a] it seems probable that this fault is cut off by the Columbia fault, although it was noted intersecting the shales that formed the northwest wall of the drift at the 80-foot level of the Columbia mine. Another instance of intersecting fissures was noted at the Crosson cave prospect, where a fault with a trend of N. 37° E. is cut off by another fault striking north and south. Both fissures contained ore. This occurrence is described in more detail in a later section of the paper.

Approximately parallel veins may have an opposite arrangement or may be arranged en échelon. The arrangement of the veins at the Asbridge, Tabor, and Wheeler mines (fig. 11) is a good example of the latter. The relation of the Eureka vein to that at the Lanham shaft (fig. 6) is probably similar. Two ore deposits along fractures belonging to the same system, but not entirely parallel, occur at the Ebby Hodge mine (fig. 24).

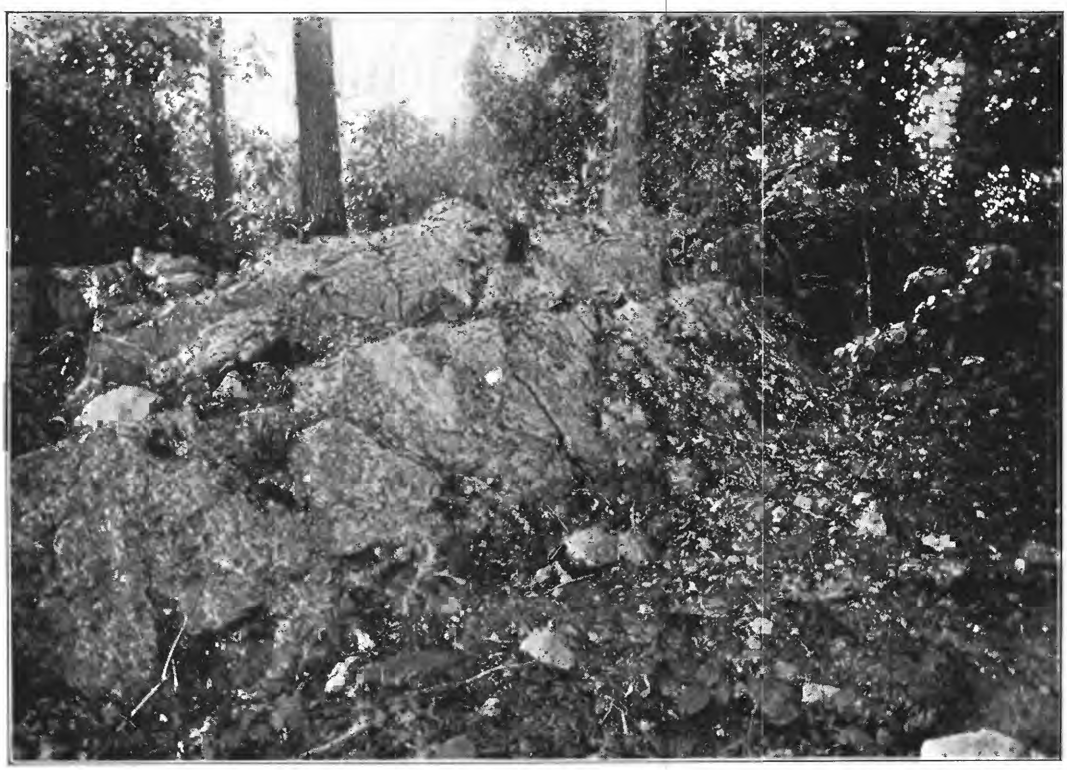
While veins may and do occur along minor fault planes parallel to and not far from a main fault, it is probable that the chief ore deposits have in the majority of instances been formed along the main fault.

The veins occur, so far as known, only in the formations of the Chester and Meramec groups, either in one or more often between two of them, where they have been faulted into juxtaposition. A vein may thus have both walls mainly of sandstone (or quartzite) and shale, as at the Lucile mine near Marion; or one wall may be of quartzite and shale and the other of limestone, as at the Riley mine southeast of Salem; or finally both walls may be of limestone. The third and most common occurrence is illustrated by the Memphis mine northeast of Crittenden Springs.

The walls of the veins are usually, though not always, well defined, and are frequently marked by pronounced slickensiding, which occurs as a fine grooving or as coarse, open corrugations. Where the walls are of limestone they are often fractured and frequently much seamed with minute veins, usually of calcite, though sometimes of fluorite, together with some galena and sphalerite, and, less often, barite. The limestones of the different formations are differently affected in this respect, as shown at the open cut of the Tabb mine (No. 11, fig. 12), where a part of the northern wall (of Birdsville limestone) is considerably seamed, while the southern (of St. Louis) shows only a few fine veinings of calcite. This seaming (see Pl. XI, *A*) also accompanies ordinary fracturing of the limestone where no

[a] Norwood, C. J., Report of a reconnoissance in the lead region of Livingston, Crittenden, and Caldwell counties: Geol. Survey Kentucky, vol. 1, pt. 7, sec. ser., pp. 480-482.

A. OUTCROP OF SHEETED CHESTER QUARTZITE AT BENARD MINE.



B. OUTCROP OF QUARTZITE AT MAYES AND WILSON PROSPECT, CLOSE TO COLUMBIA FAULT.

vein is known to occur. When Chester quartzite forms the wall it is sometimes brecciated and the breccia is more or less cemented with fluorite.

Most of the veins show distinct evidence of movement by the displacement of the beds or of the formation on the opposite sides of the fissure, by the slickensiding of the walls, or by sheeting parallel to the walls of the vein with or without slickensiding. This sheeting occurs both in the vein itself, especially near the walls, and in the country rock, most often in Chester quartzite and shale, where it may extend 50 feet or more from the vein. In places subsidiary veins are formed between the sheets, bands of ore alternating with partings of rock. Chester shale dragged in along the fault plane frequently forms a body at times a foot or more in thickness between the vein and one of its walls (fig. 25).

The Chester sandstone, where it occurs close to the faults, is usually more or less silicified to a quartzite. This quartzite passes gradually into sandstone on the side away from the fissure, the width of the silicified zone being from perhaps 30 to about 100 feet. The quartzite is more resistant to weathering and erosion than the other rocks of the district, and therefore often stands a few feet above the general level, forming at intervals along its course dike-like outcrops frequently 20 to 30 feet wide (see Pl. XII, *A* and *B*, and fig. 12), by which the fault may be readily followed. For the same reason the faults having quartzite for one wall frequently follow ridges. Although the quartzite not uncommonly forms a vein wall, these surface outcrops, where noted, were generally not at the main fault, but from 15 to 80 feet to one side of it. The outcropping masses usually show sheeting parallel to the near-by main fault, as illustrated in Pl. XII, *A*. In Pl. XII, *B*, there is similar sheeting, the partings being 3 or 4 feet apart. The silicification of the sandstone is merely a more thorough cementation of the rock by silica carried in solution by waters probably circulating along these minor fault planes.

The width of the veins varies considerably. In the case of well-defined simple veins, as at the Hodge mine, the maximum width thus far recorded is 19 feet. Several veins have a maximum width of 12 or 15 feet, but most of the important ones do not exceed 6 or 8 feet in width. On the other hand, many of the veins pinch out completely for short distances. Fig. 23, *C*, shows the variations in width of the vein at the lowest level of the Hodge mine.

The veins are not perfectly straight, either horizontally or vertically, both dip and strike changing from point to point, usually in accordance with local variations in the dip and strike of the fault plane. The variable course of some of the fissures is well illustrated in figs. 1 and 18. The dip of the vein is always at a high angle, usually 60 degrees or more; and local changes in dip are not great as a rule, those shown in fig. 25, illustrating reversal of dip at the Riley mine, being unusual.

Veins are occasionally reported as being overturned and lying flat, close to the surface, though none of this character were seen by the writer. Norwood in his report[a] has figured such a vein at the Henry Woods shaft. This phenomenon is evidently due to the creep of surface material in the direction of the slope.

The shafts and cuts by which the veins have been opened are irregularly distributed along the fissures, and although ore has been found at intervals for as great a distance as 2 miles along a single fissure, the veins have been too little exploited to make it possible to state with any degree of certainty that the individual ore bodies are continuous for more than an eighth of that distance. In some instances it seems probable that the ore occurs in comparatively short, lenticular bodies at intervals along a given fissure. This may be the case along the Columbia fault, the ore variations here being such as to suggest it. The same seems to be true of the Tabb fault. In the latter instance some of the ore deposits at the Tabb and the Blue and Marble mines apparently occur not along the main Tabb fault but along near-by parallel faults. The longest continuously mined vein known to the writer is the Memphis, which, as shown in fig. 1, has been followed at the Memphis mine for about 800 feet. Although the Yandell vein has been mined only at intervals, it is evident that the ore body at the Yandell mine (fig. 18) is practically continuous for more than 1,000 feet. While, therefore, the evidence as to the horizontal extent of the single ore bodies is far from satisfactory, it is apparent that some of them are at least a quarter of a mile long.

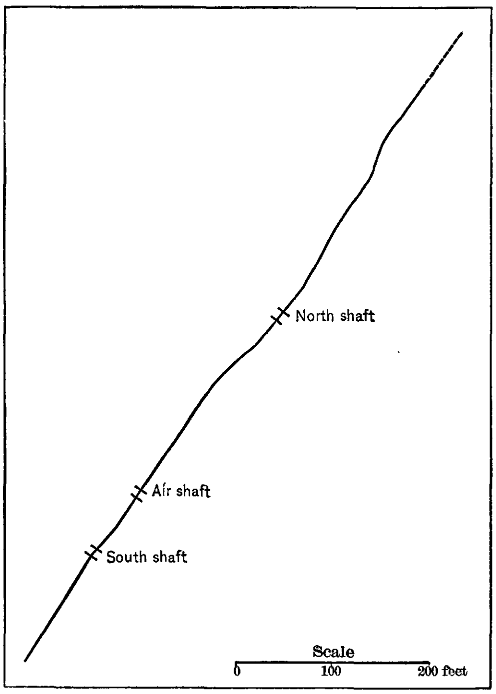


FIG. 1.—General course of the vein, Memphis mine, at a depth of about 100 feet.

There is, without doubt, as has been observed by others, some general though not very exact relation between the two dimensions of a fault—vertical and horizontal—a relation sometimes actually seen in the case of small fractures. What is true of the smaller faults is probably true in a general way of the larger ones, allowance being made for the effect of increasing pressure and of changes in the character of the rocks with increased depth. Where, therefore, faults have great

[a] Op. cit., pl. 3, fig. 2.

horizontal extent, a correspondingly great depth must be postulated, and if the length of a fault is measured by miles, it must extend or must have originally extended to a depth of several thousand feet at least. It must be remembered, however, that in this district we are dealing with truncated faults, the tops of which have been worn off by erosion at the surface, so that their present vertical extent is not the same as their original depth. Further, in the case of faults limited in length by intersection with other faults, the actual length of the surface, of course, is not necessarily a criterion of their vertical extent.

The relation between the throw of a fault and its vertical range affords another criterion for judging the latter. In general, a fault with a displacement measured in inches will have a vertical extent measured by feet or yards at least. Where the throw is measured by hundreds of feet, as is the case with many of the faults of this district, it is probable that the fissure extends to a depth of thousands of feet. The maximum displacement is given by Mr. Ulrich as 14,00 feet.

The occurrence of igneous dikes in itself indicates that some of the fissures extend below the base of the sedimentary rocks. All things considered, therefore, it is believed that the more important faults of the district extend to great depths.

While this is true of the fissures, it does not necessarily follow that the veins which fill them extend to an equal depth; in most cases they probably do not. As with the fault itself, so with the vein—the length may be taken roughly as an indication of the depth. Changes in the physical and chemical characters of the rocks in depth, in the source of the ores, and in the direction of circulation of the ore-bearing solutions, will all affect the vertical extent of the deposit. A known length in two instances of from 800 to 1,100 feet, and in a number of cases a known depth of at least 150 feet (at which depth, as noted by Emmons [a] in the southern Illinois deposits, the veins are of undiminished strength), would indicate a probable continuation of some if not most of the veins to at least the base of the St. Louis limestone, and probably well down toward the base of the sedimentary rocks, the conditions beneath the St. Louis depending somewhat on the factors already mentioned as affecting the depths of the deposits.

Emmons has suggested [b] a possible variation in the mineral contents of the veins with the character of the inclosing beds, believing that these may be expected to diminish very much, if not to be entirely cut off, when the vein walls are formed by more siliceous and less readily soluble rocks. The mineral contents do without doubt vary to a greater or less extent with changes in the character of the rocks, although in the rocks at or near the surface fluorite, barite, and galena are all found in both sandstone and limestone. As noted elsewhere in this paper, however, variation of vein width, due to differences in the character of the inclosing

[a] Emmons, S. F., Fluorspar deposits of southern Illinois: Trans. Am. Inst. Min. Eng., vol. 21, 1893, p. 51. [b] Loc. cit.

rock, appears in the Kentucky district to result more from the different effects of faulting on the various rocks than from difference of solubility, although this also is doubtless effective to some extent. One effect of varying solubility which may be mentioned here is that while the limestone in and adjacent to the veins is frequently more or less replaced by sphalerite, the sandstone is not so affected.

COMPOSITION AND STRUCTURE OF THE FISSURE VEINS.

The vein in its simplest form consists wholly of evenly granular fluorite, unmarked, from wall to wall, by fractures or other structural features. This condition is seen in comparatively few cases, as, for example, here and there along the course of the Memphis vein. Usually, however, the vein includes other minerals or dragged-in country rock, and it is frequently broken by banding or other structural features.

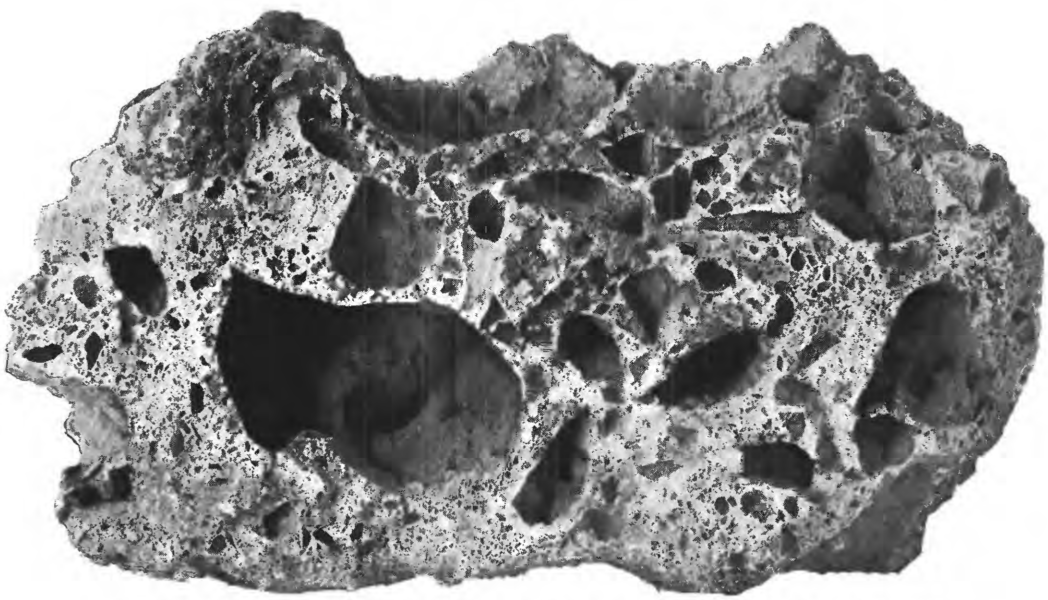
Angular inclusions of country rock are common, tending, as a rule, to concentrate near the margins of the vein. Occasionally scattered blocks occur as far out as the center of even the wider veins. Sometimes the contact of vein and wall is sharp, even where the former contains numerous rock inclusions. At other times, apparently less often, the vein grades into a cemented breccia of country rock with no well-defined wall. The contact of vein and inclusion is usually, though not always, sharply defined in the case of fluorite (see Pl. XIII, *A* and *B*), less often so in the case of calcite. The rock fragments vary considerably in size, and frequently, where of limestone, they contain more or less disseminated sphalerite; also at times scattered pyrite in minute grains, or small amounts of fluorite, galena, or calcite. Secondary silicification of the included limestone fragments is common. Rarely in well-defined veins the rock fragments are so numerous as to make mining unprofitable.

In addition to its occurrence in fragments of country rock included in the vein, sphalerite is found at times disseminated in patches or streaks in the wall rock where this is limestone. It is met farther in very small amounts disseminated in the fluorite of the vein, and it also sometimes occurs in the rock fragments of the vein, not disseminated but forming a thin layer over their surfaces.

Galena occurs in many of the fluorite veins, sometimes in quantities large enough to make it profitable as a by-product, though in most cases it is insignificant in amount. It is occasionally somewhat uniformly distributed through the vein, but usually it is found in varying abundance in different parts. It frequently occurs concentrated close to the walls or in narrow bands parallel to them.

Calcite, next to fluorite, is the most abundant vein mineral, and locally may form the entire vein content from wall to wall. It also occurs in grains or patches in and replacing the country rock close to the vein, or filling the narrow seams of the veined limestone. It is coarse grained as a rule, though sometimes it is

A. FLUORITE CONTAINING INCLUSIONS OF COUNTRY ROCK.



B. CAVERNOUS FLUORITE FORMED BY LEACHING OUT OF COUNTRY ROCK INCLUSIONS.

fine grained, replacing to a greater or less extent the limestone fragments in the veins. It occurs massive or in aggregates intergrown with fluorite; also in individuals of irregular shape scattered in the fluorite. Fig. 5 illustrates some of these modes of occurrence. In banded veins some portions may consist wholly of calcite, while others may contain none whatever. (See figs. 19, 25, and 27.) Occasionally the calcite is associated with barite. Crystals of calcite are sometimes found coating the walls of fractures in the veins parallel to the vein walls. Such a fracture completely filled with calcite showing comb structure was noted at the Hodge mine, the only well-defined example of this structure seen in the district.

Barite is common in some of the veins, although in many if not most of them it is not found at all. Taking the district as a whole, however, it is probably next in abundance to calcite as a vein mineral. In many cases where it occurs it forms only a small proportion of the vein, although occasionally it is the chief constituent, as at the Lowery mine, at one of the Myers prospects, and at the Bateman prospect. Seams in brecciated rocks and narrow veins sometimes consist wholly of this mineral.

Barite occurs in all of the rocks in which fluorite is found—in Chester quartzite and in both Ste. Genevieve and St. Louis limestone. Where seen only in small amounts it was, as a rule, along the margin of the vein (see fig. 14) and never distributed through it. When occurring with fluorite in seams, it sometimes shows symmetrical banding.

The only vein of this mineral which has been developed to any extent is that on which the Ray and Lowery shafts are situated. Here the vein has a width of several feet near the surface, pinching to from 6 inches to a foot at a depth of 30 or 35 feet. It consists almost entirely of barite, with a very small proportion of fluorite and calcite. It is more or less banded, and locally one of the central bands, from a fraction of an inch to 2 inches in width, contains a considerable amount of medium-grained sphalerite.

The most pronounced structural feature of the veins is the banding shown to a greater or less extent by most of them, at least below the level of ground water. The vein may be divided into a few broad bands (figs. 5, 20, and 28) or into many narrower ones (Pl. XIV) or both (fig. 20). The bands may not differ in mineralogic composition, the structure being brought out merely by partings throughout the vein or in some particular portion of it (as shown in fig. 20, near the southeastern wall), the planes of parting sometimes showing slickensiding. In most instances, however, the different bands show more or less pronounced mineralogic differences, and the structure may be due to this alone, as where fluorite and calcite occur intergrown along the margin of a vein of fluorite. Any of the vein minerals just described may predominate in a given band, though the occurrence of sphalerite or galena as the principal mineral of a band is rare. As a rule, either fluorite or calcite is dominant. The figures just referred to show some of the variations seen in the different bands of some of the veins.

As already noted, banding may sometimes occur where rock and vein matter alternate, as in sheeted rocks where deposition has taken place along the planes between the thin rock sheets. In one instance observed the thin bands of rock, in this case averaging only a quarter of an inch in thickness, had been completely replaced by fluorite (much of it in minute cubes) and by quartz, these bands alternating with bands of fluorite containing scattered grains of galena and no quartz.

Another structural feature, noted only at the Klondike mine, is a series of horizontal fractures (shown in fig. 5), believed to be due to the persistence of bedding planes where ore occurs as a replacement of bedded limestone. They have the spacing characteristic of bedded limestone and run across the fluorite and its included limestone without break, both limestone and fluorite separating easily along the partings. They were noted at both upper and lower levels through an interval of about 25 feet. For these reasons it is believed that they are not due to postmineral horizontal movements in the vein. It could not be determined with any degree of certainty whether these partings were continuous from the vein into the wall or not.

ORES CEMENTING BRECCIAS.

Ores that cement breccias occur along or near the main planes of faulting, and, with increase in the relative amount of the cement, they grade into true fissure veins with included rock fragments. The breccia deposits may have more or less the form of a fissure vein, one or both walls being well defined, or—and this is the typical form on which this division of the deposits is based—they may be entirely without definite walls, the differential movements having resulted in a general brecciation of the country rock within a narrow zone along the course of the fault, usually accompanied by more or less irregular sheeting. Breccias of this type are largely confined to the more siliceous rocks, occurring sometimes in siliceous limestone, but more often in sandstone, especially that of the Birdsville formation. Where this formation is found on both sides of a fault, sheeting and brecciation usually take the place of a single fault plane, the ores forming the cement of the breccia. Where, however, the amount of faulting is sufficient to bring the Birdsville and one of the lower formations into juxtaposition, there is usually a well-defined fault plane between the two, along which most of the ore is deposited as a simple fissure vein, though in such cases the Birdsville rocks may be brecciated and cemented for some distance from the fissure, as at the Royal mines.

Usually the brecciation or sheeting of these rocks is not open, and the seams of ore are thin. Rarely, however, they may have a width of a foot or more. Such breccias have never furnished ore in paying quantities, so far as known. The cement of the breccia is similar to the filling of the fissures, consisting chiefly of fluorite, with small amounts of galena and sphalerite. Barite also occurs occasionally as a cement, having been noted, however, only in thin seams. The cementation is often only partial, leaving open fractures lined with fluorite crystals or with drusy quartz.

Although limestone seamed with calcite is common in connection with the ore deposits, definite breccias of the calcareous rocks cemented with ore are comparatively rare. One instance of cemented limestone breccia, which differs from those already mentioned in that only an insignificant proportion of the cement is fluorite, and which has not as yet been shown to be connected with a vein of fluorite, is at the Columbia mine, where siliceous Ste. Genevieve limestone has been somewhat openly brecciated and cemented, mainly with calcite, galena, and sphalerite. In places the cement is largely of galena and sphalerite, and, as usual where these minerals occur in this manner, they are coarser grained than where they are disseminated.

As there is no known occurrence in the district of unsilicified limestone openly brecciated, it seems probable that in this case the silicification took place prior to the brecciation, the latter being due to the brittle character of the silicified rock. If this is true, it is most likely that the rock was silicified after some faulting had taken place, later movements along the fault plane producing the brecciation. That the movements along this plane did not all occur at one time is indicated by a brecciation and cementation of some of the calcite which forms the cement of the brecciated limestone. As stated elsewhere in this paper, these breccias are believed to be of somewhat limited extent, both vertically and horizontally.

The ores at the Watkins and Drescher open cuts are suggestive of deposits of similar character, oxidized and brought near the surface by erosion.

METASOMATIC REPLACEMENT.

BELOW THE BELT OF WEATHERING.

Replacement by sphalerite.—Below the level of ground water, sphalerite is the principal ore that occurs as a metasomatic replacement, though occasionally small amounts of galena or fluorite are also seen replacing limestone. This is the chief mode of occurrence of sphalerite throughout the district. It is found in fine grains, usually less than 1 millimeter in diameter, disseminated in limestone, both in the walls adjacent to the fluorite veins and in the fragments of limestone found within the vein itself. While the grains are frequently distributed through the rock, they often tend to concentrate along or near the margin of the fragments included in the vein, or along the edges of some of the seams in the wall rock. There are all degrees of replacement, from a few scattered grains to rock which to the eye consists wholly of sphalerite, but which under the microscope always shows, in the specimens examined, a considerable proportion of other minerals. The average and maximum size of the grains varies somewhat in different deposits, though in all observed cases of replaced limestone the mineral is fine grained. The sphalerite, as far as can be judged, attains a size independent of the grain of the limestone which it replaces. Selective replacement of particular portions of the limestone has been noted, although it is by no means common. In some of the oolite occurring at the Klondike mine, northeast of Crittenden Springs, the oolitic grains are the first portions of the rock replaced, a single grain of sphalerite taking the place of one of oolite, though not conforming to it in size or shape. The sphalerite grains seldom if ever show well-developed crystal forms, though partial forms are not uncommon.

Some limestones appear to be more favorable for replacement by sphalerite than others, owing no doubt to slight chemical and physical differences. An example of this is seen at the open cut of the Tabb mine (No. 11, fig. 12) where the southern wall (St. Louis limestone) contains no ore, while a part of the northern wall (Birdsville limestone) contains more or less, fine-grained, disseminated sphalerite, occurring in patches and streaks in the limestone. Of the different limestones of the district, the Ste. Genevieve appears to be especially liable to replacement by sphalerite as well as by other minerals, as quartz, pyrite, and fluorite; and of this formation perhaps certain beds are more susceptible than others.

In addition to the occurrence of sphalerite as a replacement in rock fragments in the vein and here and there in one or both walls close to the vein, more extensive deposits are occasionally found where the conditions for the lateral spread of circulating waters were especially favorable, as at the Old Jim mine, where single beds of limestone have been largely replaced by sphalerite in places for a distance of 20 feet or more from the peridotite dike, adjacent to which the ores have been deposited. Some of the limestone beds here contain little or no sphalerite, while others are partly or largely replaced by iron sulphide (pyrite or marcasite), or by iron sulphide and sphalerite, the extent of the replacement of a given bed varying considerably from point to point. The contact of the dike and country rock has here formed a trunk channel for the circulation of the ore-bearing solutions, which have spread widely into the adjoining limestones. The dike itself contains no ore.

Metasomatic replacement by other minerals.—It may be fitting in this connection to speak of rock replacements by minerals other than sphalerite, which, while they do not in general form ore deposits, are still of importance in a study of the ores with which they are usually associated. The occurrence of pyrite or marcasite formed by replacement of limestone at the Old Jim mine has been mentioned. These are the most extensive deposits of iron sulphide known in the district. At some of the mines (e. g. at the Klondike) it is associated with sphalerite as one of the minerals replacing the limestone in or adjacent to the fluorite veins, and like the sphalerite it always occurs in small or minute grains or crystals, generally much smaller than those of the sphalerite. Other minerals found in connection with the vein deposits and under conditions similar to those under which pyrite and sphalerite occur are fluorite, galena, and quartz. Of these quartz is by far the most important, limestone completely replaced by it being of common occurrence. Galena is not common, being found occasionally in disseminated grains of moderate size. Fluorite is also of occasional occurrence, being usually found in moderately coarse grains with other metasomatic minerals in the altered limestone. It also occurs fine grained, the only instance noted being at the Columbia mine. In this case the replaced limestone was seen as a fragment in a matrix of moderately coarse calcite. A part of the limestone had been replaced mainly by sphalerite, the rest mainly by fine-grained fluorite, associated with very little sphalerite. The fluorite in thin section still shows outlines of some of the microscopic fossils originally contained in the limestone.

The mode of occurrence of quartz differs in no respect from that of the minerals already described. All stages in the process of silicification are found, quartz first appearing in the limestone as a few scattered, very minute, frequently microscopic, doubly terminated crystals. These gradually increase in number till the entire rock has been replaced, the final result being an aggregate of microscopic grains, still giving some indication of crystal form though seldom showing good crystal boundaries. Any or all of the other minerals described in this section may occur with the quartz. This silicification of the limestone is most often noticed in the rock fragments found in the fissure veins, although it occurs in the country rock adjacent to the vein. Masses of this secondary rock outcropping at the surface have been noted near the Morning Star mine, southwest of Salem, and at the New Jim mine, on the Columbia fault, associated at the former place with fluorite and at the latter with smithsonite. The silicification of the rock fragments in the veins does not as a rule change their general appearance, as they still retain the gray color characteristic of the limestone, and their greater hardness is the chief difference apparent in the hand specimen. The outcrops near the Morning Star mine, however, have the aspect of Birdsville quartzite. Rarely chert occurs altered to a rock like that just described.

This silicification of limestone by quartz is believed to be related to the process of fissure filling, and not to be a common characteristic of the limestones of the district, although a slight degree of replacement by quartz is commonly found in the limestone. Several fragments of limestone, obtained from localities where no veins are known to occur, were dissolved in acid. A comparatively small residue was obtained from all, consisting mainly of minute, irregular quartz grains with a few stocky crystals of the same mineral. The replacement of limestone by quartz is common in fissure veins in general, and is therefore not believed to have any specific relation to the deposition of the fluorite in this district. To similar rocks from Aspen, Colo., Spurr has given the name jasperoid,[a] which he defines as follows: "A rock consisting essentially of cryptocrystalline, chalcedonic, or phenocrystalline silica, which has formed by the replacement of some other material, ordinarily calcite or dolomite." The figures of these Colorado rocks given by Lindgren[b] might almost equally well represent the Kentucky jasperoids.

Metasomatic replacement is not limited to limestone, but occasionally occurs in other rocks of the district as well. What is apparently silicified calcareous shale is found at Major Clemens shaft, near Crittenden Springs, and 125 feet west of the Columbia fault. This rock will be described later. At the westernmost opening of the Tabb mine a mass of fluorite occurs as a replacement of quartzite (fig. 13), which it simulates in general appearance and structural features.

METASOMATIC REPLACEMENT IN THE BELT OF WEATHERING.

Smithsonite.—Zinc sulphate, the first product of the oxidation of sphalerite, taken into solution by the waters of the belt of weathering, reacts with the adjacent limestones as follows:

$$ZnSO_4+CaCO_3=ZnCO_3+CaSO_4$$

The calcium sulphate formed is taken into solution and carried downward, but only a small proportion of the zinc carbonate is thus removed, the greater part forming a metasomatic replacement of the limestone. Almost any partially weathered piece of the massive granular smithsonite shows here and there on the weathered surfaces rude remnants of some of the fossils, such as shells and fragments of crinoid stems, which were contained in the limestone. Other features of the limestone reproduced by the smithsonite are occasional bedded structure with interbedded chert or scattered chert nodules. In one specimen containing chert nodules the smithsonite was analyzed qualitatively, showing it to consist mainly of zinc carbonate (probably as much as 95 per cent) with less than 1 per cent of lime and a small proportion of other substances, chiefly silica. Unreplaced blocks of limestone occur here and there in the smithsonite.

The metasomatic replacement of limestone by smithsonite is by no means rare either in this or other countries; on the contrary, it is without doubt the method by which considerable bodies of smithsonite are most often formed. Numerous European examples of the replacement of limestone by "calamine" (chiefly zinc

[a] Spurr, J. E., Geology of the Aspen mining district, Colorado: Mon. U. S. Geol. Survey, vol. 31, 1898, pp. 219–220.
[b] Lindgren, W., Metasomatic processes in fissure veins: Trans. Am. Inst. Min. Eng., vol. 30, 1901, p. 628. Also, The Genesis of Ore Deposits (reprinted from Transactions of the American Institute of Mining Engineers), 2d ed., 1902, p. 548.

carbonate) are cited in the text-books of Phillips and Louis, Fuchs and De Launay, Beck, etc.[a] In this country similar replacements have been noted by the writer in the Joplin district, Missouri, and if evidence bearing on this point were sought, the same thing would probably be found to be true in the other zinc districts of the Mississippi Valley.

In the Kentucky replacements, it is believed that the reaction with limestone takes place soon after the sphalerite is taken into solution, and that therefore the smithsonite deposits are formed in the immediate vicinity of the original as well as the present sulphide deposits. Where sphalerite has been deposited in considerable amount, smithsonite will be found in correspondingly large quantity, as at the Old Jim mine. Here there is no definite fissure vein, the abundant sphalerite occurring in limestone and free from galena or fluorite. Above ground-water level, massive deposits of zinc carbonate are found, following the general line of the sphalerite deposits.

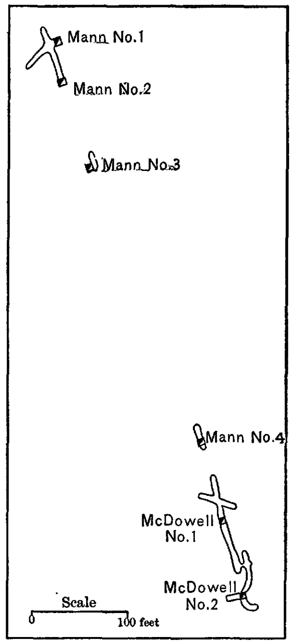


FIG. 2.—Underground workings of Mann and McDowell mines.

The smithsonite deposits, like those of the sulphide from which they are derived, tend to follow lines of fracture, partly because, as already stated, the zinc carbonate is formed in the vicinity of the original sulphide deposits, and also because such fractures furnish channels for circulation near the surface as well as at greater depths. Smithsonite occurs not only along fractures adjacent to which the sphalerite was deposited, but also along joint planes or other fractures in the limestone in the vicinity of the main fracture, especially those which intersect it. Such deposits, forming a narrow body from a few inches to a few feet in width, have been noted in apparent joints in limestone at a number of places. One of these occurrences is at the southern end of the Old Jim mine (fig. 8, p. 177). The Mann and McDowell zinc-carbonate mines (fig. 2) furnish another example of the same thing. Here the main fracture itself may be a joint in the limestone, no evidence of faulting having been noted. The deposit along this fracture is narrow (not more than a few feet wide at most), the ore-bearing solutions not having spread much beyond the fracture into the adjacent limestone. Intersecting fractures (joints) occur at the Mann No. 1 shaft and just north of the McDowell No. 1. In the latter no ore was found in that portion east of the main fracture, a small amount having been found, however, in the western division. At the face of the drift following the southwest fracture at the Mann No. 1 shaft a deposit of smithsonite was noted

[a] Cf. also Posepny, Genesis of Ore Deposits, 2d edition, 1902, pp. 133–135.

about 1 foot in width. Other joints intersecting the main fissure were seen at a number of points, but only in these two had any ore been found. The walls of these fractures at the depth reached consist of red clay, chert fragments, and masses of unaltered limestone.

In addition to replacing limestone, the smithsonite at the Old Jim mine occurs, to a limited extent, replacing chert. Occasionally chert is found wholly changed to smithsonite, forming a white, very fine-grained ore, simulating chert in general appearance and known to the miners as flint carbonate. An assay of this ore (see p. 177) gave 51.8 per cent of metallic zinc. Some of the apparently little-altered chert occurring with the smithsonite yields from 3 to 10 per cent of zinc by assay.

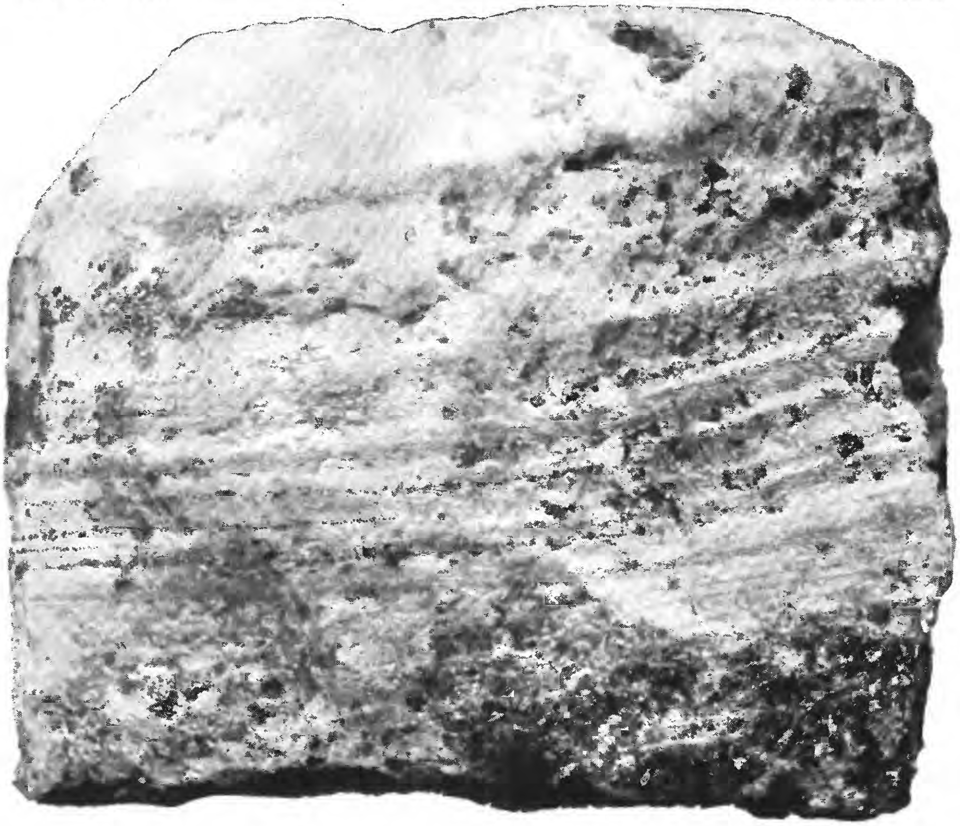
METASOMATIC REPLACEMENT IN RELATION TO THE FLUORITE DEPOSITS.

In connection with the subject of metasomatic replacement the question arises what proportion of the massive fluorite of the fissure veins, if any, has been formed by the replacement of the limestone composing the walls of the original fissure, or of sheets of rock between adjacent fissures? There is little evidence bearing on this point, and that of a negative character. From the facts determined, however, the writer is led to the conclusion that the veins have been largely formed by fissure filling, although in some cases it is probable that there has been more or less replacement of the country rock by fluorite.

In the simple veins the sharply defined and generally straight contact of wall and vein, and in typical examples the occurrence of unbroken fluorite from wall to wall; the slickensiding of one or both walls; the freedom of the adjoining country rock from fluorite as a rule; the moderate width of the veins in general—all these are suggestive of fissure filling. The fluorite itself gives little evidence that it constitutes a replacement of limestone, and contains no such impurities as would be looked for in such a case. All the limestones in which fluorite was noted were subject to replacement by quartz, but quartz was not found, except locally in very small amount, in the better defined veins; and even these occurrences can always be better explained as replacements of fragments included in the vein than as replacements of larger rock masses.

If there has been replacement of the limestone by fluorite, it has been complete. There are no indications in the vein of partially replaced limestone masses, and included fragments give no suggestion that they are residuals of such imperfect replacement, but generally show plainly their character as dragged-in material.

On the other hand, as has already been stated (p. 139) fluorite has been actually found, in limited amounts, replacing limestone and other rocks adjacent to the veins or included in them. On the dump of one of the Tyrie prospect shafts some fluorite was noted containing minute cavities representing fragments of crinoid stems. Some of the fine-grained sphalerite occurring in fluorite is associated with



A. BANDED FLUORITE WITH GALENA, FROM RILEY MINE.

B. BANDED ORE FROM TABB MINE.

more or less fine-grained quartz, and its mode of occurrence is such as to suggest the former existence of a limestone fragment containing sphalerite and quartz, and now largely replaced by fluorite.

In the more complex veins the asymmetric banding with sometimes intercalated bands of country rock, and the vertical partings, with occasional slickensiding along the parting planes, are in some cases of doubtful interpretation. Such structures may be due to the replacement of bands of limestone in a sheeted zone, or some of them may be ascribed to post-mineral movements in the vein, or they may perhaps be the result of both causes. That the fractures are, in some cases at least, due to post-mineral faulting is clear, definite evidence having been obtained in a number of instances. At the Hodge mine one of the fractures in the vein was bordered on one side by finely brecciated fluorite cemented with calcite. At the Bill Terry, or Robertson, prospect, northeast of the Memphis mine, lamellar fluorite due to sheeting was noted, accompanied by very fine granular galena drawn out roughly parallel to the fluorite lamellæ, in place of the usual coarser grains. In veins showing sheeting the fluorite frequently exhibits only imperfect cleavage, and is sometimes filled with fractures which may be grouped into one or more well-defined systems, while galena often shows warped cleavage surfaces, and is sometimes elongated or shows a fibrous or columnar structure, which in some instances has been noted parallel to one of the systems of fractures in the fluorite.

The finer banding of the veins also is believed to be due largely to movements in the vein since its deposition, thorough sheeting being sometimes sufficient in itself to produce a banded structure. The banding is made more pronounced, however, by deposition along the surfaces of fracture. This is the case in the banded ore shown in Pl. XIV, *B*, the banding being caused primarily by sheeting, which has produced more or less variation in the grain of the fluorite in the fractured portion of the vein, the whole being later cemented by galena and fluorite which have been deposited along the fractures. The galena and the variation in the grain of the fluorite, with consequent slight differences in the shade of color, serve to emphasize the banding of the ore. In some of the finely banded ore from the Riley mine the bands give good evidence of post-mineral sheeting with later filling.

PARAGENESIS OF THE MINERALS.

The evidence of the order of deposition of associated minerals in ore deposits, derived from their mutual relations, is sometimes misleading, unless the mode of formation of the deposits is known and taken into account. Where, for example, the minerals fill cavities, the order of deposition is, in general, from the walls of the cavity toward its center. Where, however, they occur replacing rock or minerals previously formed, mutual relationship is not always a safe guide, though even here the conditions of deposition may be such as to furnish the key to the problem. If the character of the ore as a replacement deposit can be made out definitely, one difficulty is eliminated, as it is largely the uncertainty of the mode of development which renders the interpretation of the observed facts doubtful. For example, sphalerite sometimes occurs disseminated in fluorite, apparently formed by metasomatic replacement of the latter mineral and therefore later. If, however, the fluorite itself is a replacement of limestone in which the sphalerite was previously disseminated, the order is reversed, the fluorite being the later mineral of the two.

Considering such doubtful cases, and also the fact that most of the minerals may have frequently developed simultaneously, any general statement as to the order of deposition of the ores of this district is difficult, if not impossible, to make, even though at times a definite sequence may be made out. Norwood in his report[a] on the lead region of Henry County, Ky., gives the probable succession of the minerals there as: (1) Lead (and pyrites); (2) zinc (and pyrites); (3) calc spar; (4) barytes; (5) calc spar. Emmons[b] doubts the existence of "any definite universal order," though he gives as the probable sequence for the southern Illinois deposits calcite, fluorite, galena, and sphalerite.

The following specific occurrences showing the sequence of the different minerals may be noted. At the Guill mine a seam of fluorite and sphalerite was seen in coarse calcite, which replaces the limestone walls of the seam, and is probably later than the fluorite. A seam in limestone from the Benard mine contained both calcite and fluorite, the former filling the body of the seam while the fluorite was found in grains, crystals, and small aggregates attached to the vein wall and occasionally showing crystal faces where in contact with the calcite. Calcite and fluorite occurring together in the fissure veins are sometimes so intergrown as to suggest simultaneous development.

No wholly satisfactory evidence as to the relations of fluorite and sphalerite was obtained. Specimens from the Lanham shaft, seen by the writer, showed coarse sphalerite apparently largely filling vugs in fluorite. At the Marble mine small crystals of ruby blende were seen on fluorite crystals lining a small cavity, but this sphalerite may have been secondary, and therefore deposited later than that usually seen.

Sharply defined cubes of galena have been found in some of the fluorite from the Mary Franklin mine. Galena has been noted in grains in fluorite at other localties, although it usually occurs between the fluorite grains. While it is probable that some of the galena is later than the fluorite, it seems likely that in most cases the two were deposited simultaneously.

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[a] Norwood, C. J., A reconnoissance report on the lead region of Henry County with some notes on Owen and Franklin counties: Geol. Survey Kentucky, vol. 2, part 7, new ser., 1875, p. 265.

[b] Emmons S. F., Fluorspar deposits of southern Illinois: Trans. Am. Inst. Min. Eng., vol. 21. 1893. p. 52.

Fluorite and barite, when occurring together, are frequently intricately intergrown. Where they have been noted in seams, the fluorite as a rule has been deposited before the barite, having formed in crystals or aggregates on the walls of the fracture, while the barite fills its central portion and is molded on the fluorite. Some barite and calcite from one of the Stone prospects showed a similar arrangement, the calcite having crystallized before the barite, and some of it showing rhombohedral outlines where in contact with the barite. In a specimen of seamed quartzite from Pope County, Ill., barite has formed here and there in aggregates on the walls of the seams, the main filling being moderately coarse-grained sphalerite.

Galena has probably, in general, been formed prior to the deposition of sphalerite. In one specimen, however, from Major Clemens shaft, galena was noted completely embedded in sphalerite, which occurred as a thin layer lining a cavity. Here the galena was evidently later than some of the sphalerite, but earlier than the remainder.

Drusy quartz has frequently been noted in cavities and on the walls of fractures, some of it of comparatively recent origin. Occasionally, as at the Columbia mine, it occurs with other recently formed minerals, all found in small quantities and in small or minute crystals. At this place drusy quartz, associated with smithsonite, not only occurs on calcite crystals, but occasionally has been deposited in corrosion cavities in calcite. These minerals are also found on sphalerite and less often on galena. Calcite, and rarely a small crystal of sphalerite, are sometimes associated with the quartz on sphalerite, and one instance was noted of minute sphalerite on the drusy quartz.

WEATHERING OF THE ORE DEPOSITS.

The different minerals vary greatly in the readiness with which they yield to weathering and solution, some of them persisting and showing only slight effects long after others have completely disappeared. While, under favorable conditions any or all of the minerals may be found unaltered at the surface, as a rule none of them reach it without showing some sign of decomposition. The probable order in which the more important minerals of the district are weathered and removed through solution, as determined by observation, is as follows, beginning with the substance most easily acted on: (1) Sphalerite; (2) calcite, either as coarse calcite or as limestone; (3) galena; (4) barite; (5) fluorite.

Sphalerite usually disappears close to underground water level, and calcite not far above this level; while all the rest of the minerals persist in a greater or less degree to near the surface.

As already stated, the first product of the weathering of sphalerite is zinc

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sulphate, which is readily soluble in water, and thus is taken into solution as formed, leaving finally only the cavit es originally occupied by the sphalerite. The fact that limestone frequently contains these small cavities, due to the removal of sphalerite, while the latter is never found as one of the residual products of the weathering of limestone, indicates the comparative readiness with which the sphalerite is oxidized and dissolved. Occasionally in a single rock fragment may be noted cavities at one end due to the oxidation and removal of the sphalerite, succeeded by a narrow zone of partially oxidized sphalerite, the other end of the fragment showing only the unaltered sulphide.

The zinc sulphate, on reacting with the adjacent limestones in the belt of weathering, gives rise, in the manner indicated in the last section, to smithsonite, which, from an economic point of view, is the most important product of the weathering of the sphalerite. In addition to its occurrence as a replacement of limestone, some zinc carbonate is also formed by the reaction of zinc sulphate with calcium bicarbonate in solution. In this way have doubtless been formed the small amounts of smithsonite that frequently occur in weathered portions of the veins, mainly as crystal aggregates or thin coatings in small cavities in the fluorite. The amount of smithsonite formed by either method varies, naturally, with that of the original sulphide, and as only small amounts of sphalerite, as a rule, occur in connection with the fissure deposits, the amount of smithsonite found in the oxidized portions of the veins is correspondingly small—insignificant in all cases known to the writer. Rarely, small amounts of zinc silicate are found as a product of the weathering of sphalerite.

Cadmium sulphide, as greenockite, is probably found wherever sphalerite is being oxidized, and has been noted as one of the minor products of its weathering at many of the mines of the district. Where sphalerite is abundant, greenockite is very common, as at the Old Jim mine. Below ground-water level the cadmium sulphide occurs in very small amounts (probably only a fraction of 1 per cent) as an impurity in sphalerite. On the oxidation of the sphalerite the cadmium sulphide is also oxidized, being taken into solution as cadmium sulphate. A good deal of this is precipitated near, and usually a little above, water level, at the expense of the unaltered sphalerite, a part of the latter passing into solution as zinc sulphate, while the cadmium is deposited as the sulphide, greenockite. The reaction is as follows:[a]

$$CdSO_4+ZnS=CdS+ZnSO_4.$$

The calcite and limestone are weathered mainly by solution. The small amounts of impurities occurring in both (especially in the latter) are largely undissolved, remaining in the form of residual clays.

[a] This reaction was first suggested to the writer by Mr. W. George Waring, who states that he has proved it many times in the laboratory.

Galena is frequently found unaltered close to the surface of the ground, and even where weathering has taken place it is often only partial, completely altered galena having been only occasionally found. Weathering usually begins on the outside, though sometimes from within, in cases where the interior is more easily reached by surface waters. Such internal alteration has been noted in some instances where galena was completely embedded in massive smithsonite. Sometimes the products of weathering are carried off in solution, leaving the galena more or less corroded; more often they are largely retained. Weathering most often results in the formation of a more or less impure lead carbonate. Very small amounts of pyromorphite and sulphur also occur as alteration products of the galena.

While according to Comey[a] the solution of barium sulphate in pure water is more difficult than is the solution of fluorite, it seems probable, from observation, that in this district barium sulphate in the form of barite is on the whole more readily weathered than fluorite, doubtless owing, in part at least, to physical differences in the two minerals and in their aggregates.

In weathering, barite is apparently merely dissolved and carried off, although it may be altered to the carbonate before its solution. No barium carbonate was noted, however, at any of the deposits in the district. At best, the solution of barite is difficult, and it is found, therefore, near the surface of the ground, frequently as float material on the surface. In weathering it first loses its slight luster, becoming duller, whiter, and more chalky in character. It then gradually softens somewhat and becomes more or less discolored with iron oxide. Small or minute cavities may develop in it, frequently lined with minute crystals of barite. The mass tends to disintegrate, but some portions of it weather more readily than others, and the less weathered portions give rise to the gravel and lump barite which forms the surface float.

Fluorite, like barite, is difficult of solution, but that it is attacked by surface waters is shown by the occasional occurrence of fluorite crystals with etched faces, or less often of massive fluorite more or less corroded. It is probably taken into solution largely as calcium fluoride, although in the process a small amount of alkaline fluorides doubtless form. Wherever the massive fluorite comes within reach of the surface waters, especially within the belt of weathering, the latter gradually percolate along the division planes between the individual grains, causing slight solution and a breaking up of the more massive form into a somewhat loose mass of grains—the gravel fluorspar of the district—usually still retained within its bounding walls, so that the form of the vein is preserved nearly to the surface of the ground. Small patches of "gravel spar" are also common in the clays adjoining

[a] Comey, A. M., Dictionary of Chemical Solubilities, 1896, pp. 73 and 419.

the veins. With the gravel fluorite are blocks of the still massive mineral—the lump fluorspar. Calcite and rock fragments occurring with the fluorite, being more readily soluble, are dissolved, frequently leaving the mineral, where it still retains the massive form, in a honeycombed or cavernous condition (Pl. XIII, *B*), usually with more or less red clay in the cavities as the residual of the dissolved substances.

The disintegration of the siliceous rocks, including sandstone and quartzite, jasperoid and siliceous limestone, results in the formation of sandy soils, some of which, as those from siliceous limestone, are composed largely of minute or microscopic but well-developed quartz crystals, as noted at the Givens mine. The residual quartzose material at this place contains scattered patches of kaolinite almost or wholly free from quartz.

RELATIONS OF THE COUNTRY ROCK TO THE CHARACTER OF THE ORE DEPOSITS.

These may be both physical and chemical, the latter being less easily determined, and, as far as indicated by the writer's observations in the field, of less importance economically.

The composition of the vein is, to a limited extent, dependent on the chemical character of the rocks forming the walls of the fissure, the most noticeable effect of differences in this respect being the greater abundance of calcite in veins where the walls are of limestone as compared with veins in sandstone. Deposits wholly confined to the latter rock are practically free from calcite, but this economic advantage is so far offset by unfavorable physical conditions as to be unimportant. It seems probable, also, that a more thorough study of the district would show greater relative abundance of calcite in the veins adjacent to certain of the calcareous formations or to certain members of a given formation. Unusual amounts of calcite have been most often noted where the Fredonia member of the Ste. Genevieve limestone forms one of the fissure walls. Whether this is generally true or not can not be stated, though it seems probable that in the observed instances it is something more than the mere irregular local variation in composition common to all veins.

No relation has been ascertained between the variation of fluorite, galena, or barite and the character of the adjacent country rock. The sphalerite occurring as a metasomatic replacement of limestone adjacent to the fissure veins varies somewhat in amount with the character of the country rock, being, so far as the writer's observations show, more abundant in the Ste. Genevieve than in the St. Louis limestone.

The width of the veins also may be more or less affected by the chemical character of the adjoining country rocks, depending on their solubility and their liability to replacement by the vein minerals. Of the rocks of the district the limestones have these characters in the highest degree, and it seems probable that the veins in these rocks, in many instances, have been more or less widened through metasomatic replacement, although, as already shown, the proportion of such increase in width can not readily be determined. The replacement of sandstone by vein minerals has been on the whole insignificant in amount.

The relations of the physical character of the country rock to the ore deposits resolve themselves largely into the effects of faulting on the rocks of the different formations penetrated by the fissures. As has already been shown, the more siliceous rocks are deformed rather by brecciation and irregular sheeting than by simple, clean-cut fractures—which are characteristic of the calcareous rocks—and the resulting ore body in the former case is mainly a cement to the breccia, while it is principally a fissure filling in the latter.

The best-defined fissure veins therefore occur where the two walls are of limestone. Such fissures may occur either in Ste. Genevieve or St. Louis limestone alone or between the two where they have been brought into juxtaposition through faulting. Well-defined veins seldom occur in Cypress and Birdsville rocks alone, mainly for the reason that these formations consist chiefly of sandstone, with subordinate shale and limestone members. Where one wall of the vein is of limestone and the other of sandstone or quartzite the vein is usually well defined and the limestone wall is generally the more sharply marked.

The differing effects of deformation on the different rocks, especially limestone and sandstone, and the consequent differences in the resulting ore deposits, are probably not confined to the rocks which outcrop at the surface within the district, but similar differences may be expected in the rocks beneath the St. Louis limestone. If, then, in depth, both walls of a fissure should change from limestone to sandstone (a purely hypothetical case), the well-developed vein in the limestone might pass into a cemented breccia in the sandstone. At still greater depths such a breccia might pass again into a well-defined fissure between limestone walls. This has a bearing even on the present condition of mining, for where a cemented breccia is found in sandstone, definite faulting having occurred, a well-defined vein may be found at a greater depth, where the fault passes from sandstone into limestone.

VARIATION IN THE RELATIVE ABUNDANCE OF THE VEIN MINERALS WITH DEPTH.

The present knowledge of the district, obtained through mining, is too incomplete to warrant a final statement as to the variation of the ores with depth, but, so far as has yet been determined, there is no definite law governing such variation except such relations as have just been shown in connection with changes in the character of the country rock. Even the differences due to this cause are probably, in some cases at least, subordinate to the general irregular local variation in vein composition. Taking the veins as a whole, fluorite is seen to be the dominant mineral, and there is at present no reason for believing that this relation changes with increase of depth—at least to the base of the St. Louis limestone.

In the deeper workings of the Memphis and Holly mines the proportion of calcite admixed with the fluorite has increased so greatly as to give rise to the fear that the fluorite may be entirely replaced at greater depths. As, however, the level at which this increase of calcite takes place corresponds in both mines to the basal part of the Ste. Genevieve limestone, it seems safe to assume that the change is due merely to the influence of the country rock on the vein composition. If this is the case, there is no apparent reason why the predominance of fluorite should not be reestablished when the St. Louis limestone is reached, since this formation, as is well known, forms one of the walls in several of the best fluorite mines in the district.

SECONDARY ENRICHMENT.

Deeper mining would be necessary before it could be determined whether any considerable secondary enrichment by waters descending from the surface has taken place. At only a few mines are the ores worked below ground water, and these have not reached a sufficient depth to justify comparison. No appreciable enrichment has been noted by the writer in any part of the district, although very small amounts of secondary sphalerite, fluorite, and barite which could be with certainty identified as such have been observed.

GENESIS OF THE ORE DEPOSITS.

The various writers[a] on the lead, zinc, fluorite, or barite deposits of western Kentucky and southern Illinois, so far as they have expressed any views as to the origin of these deposits, have been generally agreed that they were formed from solution, and that the source of the ores has been one or another of the limestone formations of the region. With these views the present writer is in accord.

The intimate association of the fluorite with other minerals known to have been deposited from solution, the fact that it is known to be somewhat soluble both in pure water[b] and in ordinary surface and underground waters[c] and to have been actually deposited from such waters, and the fact that the fluorite in the veins is generally sharply limited by the fissure walls, which, except for the effects of

[a] Norwood, C. J., Report of a reconnoissance in the lead region of Livingston, Crittenden, and Caldwell counties: Geol. Survey Kentucky, pt. 7, vol. 1, 2d series, 1876, pp. 461-464. A reconnoissance report on the lead region of Henry County: Geol. Survey Kentucky, pt. 7, vol. 2, 2d series, 1877, pp. 263-265. Shaler, N. S., On the origin of the galena deposits of the upper Cambrian rocks of Kentucky: Geol. Survey Kentucky, pt. 8, vol. 2, 2d series, 1877, pp. 279-292. Emmons, S. F., Fluorspar deposits of southern Illinois: Trans. Am. Inst. Min. Eng., vol. 21, 1893, pp. 52-53. Bain, H. F., Bull. U. S. Geol. Survey No. 225, 1904, p. 510.

[b] Wilson, George, Trans. Roy. Soc. Edinburgh, vol. 16, 1849, pp. 145-164. Edin. New Philos. Jour., vol. 49, 1850, pp. 230-233. Comey, A. M., Dictionary of Chemical Solubilities, 1896, p. 73.

[c] Bischof, Gustav, Elements of Chemical and Physical Geology. Translated by B. H. Paul, vol. 2, 1855, pp. 5-9. Translated by B. H. Paul and J. Drummond, vol. 1, 1854, p. 14.

recent surface waters, show no corrosion or other action such as might be caused by fluorine gas or molten fluorite, would seem to render it unnecessary to consider further any other mode of deposition than that from circulating underground waters. Equally strong evidence may be adduced for the deposition of the barite from solution. The only question, then, to be considered is that of the original source of the fluorite, barite, galena, and sphalerite.

While it is the writer's opinion that the fluorite was originally derived from limestone, it is not impossible that its source may have been the magma from which the peridotite dikes were derived. It is not probable, however, that the dikes themselves are the source of the fluorite, chiefly on account of the total volume of the fluorite veins as compared with that of the igneous dikes and the very small fluorine content of the peridotite. While the latter contains two possible fluorine-bearing minerals, biotite and apatite—the former usually abundant and the latter a common accessory in all the rocks—the analysis[a] of peridotite from the Flanary dike shows only a doubtful trace of fluorine. Further, the association of fluorite with galena, sphalerite, barite, and calcite, all of which were probably derived from limestone, makes it likely that the fluorite itself has the same source.

Of the sedimentary rocks, limestone is much more favorable for the original deposition of the ores with which we are dealing than either sandstone or shale. Fluorine, barium, lead, and zinc are among the many substances shown by the researches of Forchhammer and others to exist in the waters of the ocean. From these waters they are somewhat concentrated by marine animal and vegetable life. Of the substances named, the ashes of marine plants have been found to contain lead, zinc, and barium, while calcium fluoride has been found as a constituent of corals and shells, besides occurring in the bones of marine fishes and mammals. Corals, shells, and marine plants are shown by their fossil remains to have been abundant, at least locally, in the limestones of the Mississippi Valley, so that the various minerals concerned might naturally be expected to be widely disseminated in minute quantities in these rocks, though doubtless somewhat more abundant in some than in others. That lead and zinc are thus widely disseminated has been shown by actual large-quantity analyses by Winslow and Robertson[b] and by Calvin and Bain,[c] minute quantities of these metals having been found in pre-Cambrian, Silurian, and Carboniferous rocks in Missouri, and in Ordovician rocks in Iowa. No large-quantity determinations for fluorine have been made so far as known, though such analyses for both this and barium would doubtless show them to be as widespread as lead and zinc. Emmons[d] refers

[a] Am. Jour. Sci., 3d series, vol. 44, 1892, p. 288.
[b] Lead and zinc deposits: Geol. Survey Missouri, vol. 7, 1894, pp. 480–481.
[c] Geology of Dubuque County: Geol. Survey Iowa, vol. 10, 1900, p. 567.
[d] Emmons, S. F., Fluorspar deposits of southern Illinois: Trans. Am. Inst. Min. Eng., vol. 21, 1893, p. 52.

to the frequent occurrence of fluorite "segregated in small cracks and cavities in the Lower Carboniferous limestones throughout this region." He states further that "according to Kunz it is found in geodes in the limestone of the same horizon at St. Louis." A specimen of unaltered limestone collected by him at a distance from any known deposit of fluorite was found when examined chemically to contain "an appreciable quantity of fluorine." Similar samples were collected by Mr. Ulrich and the writer from the Kentucky district, and ordinary analyses of these, based on about one gram of material, were made by Mr. George Steiger in the Survey laboratory, a specimen of Lower Carboniferous limestone from southwestern Missouri being also analyzed for comparison. The results were as follows:

Analyses of oolite and limestone from Kentucky and Missouri.

	1.	2.	3.	4.
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.	Doubtful trace.	Not determined.	Doubtful trace.

1. Ste. Genevieve oolite from near View, Ky.
2. Ste. Genevieve limestone from a little less than half a mile southwest of Crider, Ky.
3. St. Louis limestone from the northern part of Crittenden County, Ky.
4. Lower Carboniferous limestone from about 5 miles southeast of Joplin, Mo.

These results show the presence of fluorine in small quantities in all except the limestone from Missouri, and of barium in only one of the specimens.

The probable wide distribution of barite in minute quantities in the limestones of the Mississippi Valley is shown by Robertson's analyses,[a] some barium sulphate having been found in all of the limestones, both Silurian and Lower Carboniferous, in which it was sought.

The widespread dissemination of the ores admits of two interpretations—either that this condition is largely original or that it is secondary and that the solutions which have concentrated the ores in favorable places have also in their general circulation through the rocks disseminated them extensively. Calvin and Bain[b] have shown the probability of the former, although the latter is also true to a greater or less extent, for as long as the solutions are ore bearing they will deposit whenever and wherever the conditions both chemical and physical are favorable for deposition, whether they follow trunk channels of circulation or slowly percolate through the country rock, the conditions being, of course, more

[a] Lead and zinc deposits: Geol. Survey Missouri, vol. 7, 1894, pp. 480–481.
[b] Geology of Dubuque County: Geol. Survey Iowa, vol. 10, 1900, pp. 569–570.

favorable for abundant deposition along and near the main channels of underground circulation.

From this widely disseminated condition in the limestones the ores have been taken into solution in minute quantities, and have been carried into the general circulation. The minerals have doubtless been taken up and reprecipitated many times before reaching the main channels of circulation, which for this district largely follow the faults and fractures. Here, the conditions being favorable for abundant precipitation, they have been concentrated, being gradually deposited in the fissures and fractures as veins, in the breccias as a cement, and in the adjacent country rock as disseminated ores.

Bain[a] has noted the common association of lead and zinc ores with dolomite or dolomitized limestone as an argument for the derivation of these ores from the Cambro-Silurian limestones. In this district, however, the limestones with which the ores are associated are, so far as known, nondolomitic, as shown by the analyses just given, nor is even any secondary dolomite, such as is found in the Joplin district, known to occur.

While no definite statement can be made at this time as to which formation has yielded the ores now concentrated in and near the fissures, it seems probable that the ore-bearing solutions came largely from the rocks below the Carboniferous formations, especially in view of the occurrence of the peridotite dikes and of the deep-seated character of many of the fissures which they indicate. Faulting in the district is complex, and the systems of underground circulation must be equally so. The general circulation in the country rocks must take place largely between the fissures, so that it is possible that all the limestones have furnished ore to some extent. A more thorough knowledge of the exact composition of the various limestones of the region would doubtless throw some light on the problem, as would deeper mining also. Emmons[b] has suggested that a change in the mineral contents of the fissure from mainly fluorite in the Carboniferous to mainly barite in the Silurian rocks would furnish "most forcible and convincing proof * * * of the derivation of the vein material from the enclosing rock, especially if it is found also that barium is more common in the lower country rocks, as fluorine is in the upper."

The occurrence of a number of igneous dikes having the same general trend as one of the systems of fissures and probably introduced at the time of the general faulting of the region, and the consequent probability that the waters circulating in the fissures at the time the ores were deposited were thermal, makes it likely that they were ascending, and that therefore the ores were in large measure derived

[a] Bain, H. F., Preliminary report on the lead and zinc deposits of the Ozark region: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 2, 1901, pp. 211-212.

[b] Op. cit., p. 53.

from limestones below the Carboniferous. Such heated waters would have been more effective in the solution of the fluorite (and of the other substances also), as diminishing temperature and relief of pressure with the ascent of the solution in the fissure may have been effective in their precipitation.

It is probable that the fluorite and barite are largely dissolved, carried in solution and precipitated as calcium fluoride and barium sulphate, respectively, although minor transformations doubtless take place in the process, some of the fluorite, for example, going into solution as an alkaline fluoride, and some of the barite as some other salt of barium than the sulphate. Galena and sphalerite may pass into solution as one of a number of salts of lead or zinc respectively—in the case of sphalerite, preferably the sulphate of zinc, or in some instances at least, a basic sulphate. It is generally believed that the lead and zinc sulphides pass into solution only after previous oxidation, which may result either from oxygen-bearing waters or by reaction with an easily reduced oxidized salt—as the oxidation of zinc sulphide, at ordinary temperatures, by ferric sulphate in solution, shown by Waring.[a] As the zinc sulphate reacts so readily with limestone it may be that below ground-water level this metal exists largely as a bicarbonate. In one of the mines of the Joplin district the writer has observed zinc carbonate being precipitated from water flowing over the floor of the mine. Where the lead and zinc exist in solution as sulphates (if they do, below water level) organic matter in the vein or adjacent country rock may act as a reducing agent for their precipitation as sulphides; or such reduction from the sulphate or other salt may be by reaction with inorganic compounds, as Van Hise[b] has shown.

FUTURE DEVELOPMENT.

CONDITIONS OF INDUSTRIAL SUCCESS.

It is essential to the successful development of the district to recognize that as a whole it is primarily dependent on the fluorite. In the majority of the veins the lead and zinc ores can be considered only as by-products, and in many cases perhaps as mere impurities in the fluorite. Most of the mines are as yet in the oxidized zone, and much of the ore from this belt must be cleaned before shipping. With depth, however, the veins will become better defined and the ores cleaner, though in some cases this may be offset by so much admixture of rock, calcite, or other impurities, as to render mining unprofitable. If a satisfactory method of separation can be devised some impure ores may be cleaned by concentration, an expensive process for fluorite alone, and perhaps only warranted by a considerable lead and zinc content.

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[a] Specification from part of Letters Patent No. 718554, dated January 13, 1903.
[b] Van Hise, C. R., Some principles controlling the deposition of ores: Trans. Am. Inst. Min. Eng., vol. 30, 1901, pp. 27-177

The output of the district will be increased by further development along the veins now mined and by better transportation and shipping facilities. More veins will, without doubt, be discovered, but it is believed that a considerable proportion of the paying veins are being already worked.

Most of the sphalerite ores of the district below ground-water level, occurring as fine grains disseminated in limestone, are of little importance. There have been several attempts to concentrate these ores by different methods, but so far without much success. Locally, where more favorable conditions have resulted in a greater abundance of these ores, they are more important. The Old Jim mine is the principal instance of this so far developed, and though similar favorable conditions may be found at other places in the district, such deposits can not be numerous in any case.

As already pointed out (p. 141), the relation of the smithsonite to the sphalerite in this district is such that the former is likely to occur only in more or less close association with the latter; and where sphalerite is not abundant, smithsonite would not be expected in paying amounts. The Old Jim deposit of zinc carbonate is exceptional, being due to the unusually favorable conditions here for the deposition of the sulphide. There are a few other promising deposits, and a few more may be found; but with this mineral, as with the sphalerite, the probability of discovering paying deposits is small.

Except in the cemented breccias along the Columbia fault, the lead ores are, for the most part, found separate from the zinc ores, the galena occurring with the fluorite and comparatively seldom in the limestone or other country rocks forming the walls of the veins. Practically all of the fluorite veins contain some galena, and in a few it occurs in sufficient quantity to warrant saving it as a by-product. It is doubtful, however, whether any mine in the district could be worked profitably for galena alone.

More important, economically, though of more limited occurrence, are the coarser lead and zinc ores, forming cementing material of breccias, such as are found at the Columbia mines. Deposits of this character are known only along the Columbia fault, where they are found at intervals for a distance of over 2 miles. The deposits of the Eureka fault, near the Columbia mine, may prove to be of the same kind, and similar cemented breccias may of course occur along other faults, although none have as yet been found.

If, as the writer believes, the breccia is closely related to the occurrence of the lower Ste. Genevieve rocks, the probability of the occurrence of similar breccias elsewhere in the district is somewhat restricted; still more is this the case if, as seems further probable, the brecciation of this rock has taken place since its silicification. More or less brecciated Ste. Genevieve jasperoid has been noted along the Evening Star vein, but the ore here is very different from that at the Columbia mine, consisting mainly of fluorite. Whether the cemented breccias along the Columbia fault are localized horizontally and of limited vertical extent—as the writer's observations would lead him to conclude—must be determined by future development.

Among the minor products of the district is barite, of which a few productive veins have been found. The deposits of this mineral, however, which are sufficiently pure and wide enough to mine profitably are rare, and barite mining can hardly be expected to be one of the more important industries of the district.

SUGGESTIONS FOR PROSPECTING.

In prospecting for ore the conditions under which it is found must first be considered. It occurs, as has been seen, along or adjacent to fractures, chiefly because these have furnished the most convenient channels for the circulation of the ore-bearing solutions. That these fractures are still used by circulating waters is indicated by sink holes along some of them. While these taken separately point only to a connection with some underground water channel, a linear series of such holes may indicate that a fracture or fault exists along this line. Such a conclusion does not necessarily follow, however, and, as as a rule, prospecting is to be discouraged when the evidence of sink holes is not confirmed by other more reliable indications.

Good evidence of faulting is given when rocks of two distinct formations, or of different horizons of the same formation, as for instance a Ste. Genevieve limestone and one of the sandstones of the Birdsville formation, outcrop on the same level and within a short distance of each other; or when a strip of "flint land" adjoins limestone or sandstone land, with the boundary line between them abrupt and approximately straight. A trench dug across this line should intersect the fault plane. In the case of the flint land, the limestone from which the flint (chert) is derived is likely to be much more deeply decomposed than the limestone or sandstone on the opposite side of the fault. Therefore, for economic reasons, the test shaft should be sunk in the red clay containing the chert, so that it will just clear or barely include the edges of the strata of the less deeply decomposed opposite wall. In most cases the latter will prove to be the hanging wall.

A reliable and common indication of a fault is the sudden bending upward or downward, near their line of contact, of lithologically different strata—as for example a sandstone and a limestone—which lie approximately horizontal farther away from this line. Where such bent strata are of similar rocks, however, prospecting is not to be advised on this evidence alone.

A linear series of outcrops of hard, silicified sandstone (quartzite), especially if sheeted and showing slickensiding, is one of the best evidences of faulting. Such outcrops usually mark the dividing line between areas of sandstone and limestone. Liberal prospecting is advised in these cases. Test shafts should be sunk as nearly as possible on the line dividing the quartzite from the limestone, or the clay resulting from its decomposition.

Seamed limestones usually accompany the well-defined veins, but they have also been found where there are no known veins, so that this indication is valuable only in connection with other confirmatory evidence.

Experience has taught that fractures showing mainly or only sandstone and shale on both sides are almost invariably unproductive. Even when one of the comparatively thin limestones of the Birdsville formation outcrops on one side of the fault, the prospect is not likely to lead to anything worth development. In the present stage of mining in the district, all prospecting in areas where one or another of the three massive limestone formations does not outcrop is to be discouraged.

In addition to the occurrences along fractures, ores may be deposited adjacent to an igneous dike, for the same reason that they have been deposited along faults—that the plane of contact between dike and rock may have been favorable to the circulation of ore-bearing solutions. It must be remembered, however, that beyond this there is no genetic relation between the dike and the ores, and that ore deposition does not necessarily occur in such places.

Since the veins are vertical or highly inclined and outcrop at the surface, the conditions are favorable for finding "float" ores along and near the line of outcrop. Since, further, no horizontal deposits of any extent are known to occur in this district, drilling for ore is of little or no value.

CHAPTER III.

DESCRIPTIONS OF THE MINES OF THE DISTRICT.[a]

DISTRIBUTION OF THE DEPOSITS BY COUNTIES.

Crittenden County.—The ore deposits thus far developed in the western Kentucky district are somewhat unevenly distributed among the three counties considered in this report. At the present time, as in the past history of mining in this region, the mines of Crittenden County include not only the largest producers in the district, but the largest number of productive veins as well. It is plain that the conditions for ore deposition have been especially favorable in this part of the district, but a further reason for the preeminence of this county is doubtless to be found in its more thorough prospecting as compared with the other two. The mines are almost entirely confined to the western part of the county, between the Tabb fault on the south and a line running northeasterly from Lola, on the north. There are few prospects within the areas of St. Louis limestone in the northwestern and southwestern parts of the county, while in the extensive area of rocks of the Cypress, Tribune, and Birdsville formations in the eastern part there are practically no mines nor prospects, with the single exception of the Lucile mine at Marion. The present eastern limit of mining is marked approximately by a southeasterly line through the Memphis and Lucile mines.

Most of the mines yield mainly fluorite. From several along the Columbia fault the ore is chiefly sphalerite (or smithsonite) and galena; while two groups yield only zinc ores—the Mann-McDowell group in the western part of the county about 1⅓ miles northeast of Lola, and the Old Jim group, including the Old Jim mine and a number of openings extending for more than half a mile to the southeast. Each of these groups is located on a northwesterly fracture, thus differing from most of the mines, which are on northeasterly fissures. Other northwesterly fractures yielding ore—in these cases mainly fluorite—are the Holly, Eureka, Lanham, Levias, and Matthews.

[a] During the month and a half spent in this district the writer was ably assisted by Mr. F. Julius Fohs, and he had also the hearty cooperation of all the mining men with whom he came in contact. He wishes to express here appreciation, on his own behalf and on that of the United States Geological Survey, for the assistance of all those who in any way aided his work for the Survey in this district.

While there are a number of barite prospects in this county, no important deposits of this mineral have as yet been discovered.

Livingston County.—Although there are a number of mines in Livingston County which have yielded fluorspar in the past, none was actually shipping when the county was visited. Comparatively few well-defined veins have as yet been found, and few, if any, of these, so far as they have been exploited, appear to be comparable to the better veins of Crittenden County. Over a large part of Livingston County north of the Cumberland River, the surface rocks belong to formations above the Ste. Genevieve, and within this area of generally unfavorable rocks there are no known mines or prospects. The latter are confined to the much faulted eastern border of the county north of the Cumberland and the central portion bordering this river, and these are by far the most promising portions of the county. Within the area of St. Louis limestone in the southern part of the county no veins are known to occur, nor were any noted by the writer north of this, bordering the Cumberland River on the south, although the geologic conditions here, between Smithland and Tiline, are by no means unfavorable to the occurrence of fluorite veins.

While fluorite is the chief constituent of most of the veins, there are a number of prospects at which barite is the principal vein mineral. At two of the prospects northeast of Hopewell Church some smithsonite is also found associated with fluorite.

Caldwell County.—The mines and prospects so far discovered in Caldwell County occur in a strip 3 or 4 miles wide extending diagonally across it from the northwest to the southeast border. In the northeast half of the county there seem to be no valuable deposits of either lead, zinc, or fluorite. Prospecting in this county has not been so extensive as in Crittenden or even Livingston County, nor has it met with the same degree of success. Since the region, especially in the strip before mentioned, is traversed by numerous well-marked fault planes separating the same geologic formations as those in which valuable deposits have been found in the other counties, and as fluorite veins have been observed as far east as Friendship, there is no apparent reason why systematic prospecting may not result in the discovery of paying deposits of this mineral in this county.

Of the present mines and prospects in this county the Marble and the Ray and Lowery are on nearly east-west fissures, the Tyrie prospects are located on a fissure with a direction a little north of east, while the Senator mine and the Stone and Dodds prospects are in a northwesterly fault zone. The Ray and Lowery barite vein has been already mentioned (p. 135); the rest yield mainly fluorite, the vein at the Senator shaft showing a considerable proportion of galena and sphalerite with the fluorite. The Marble mine is the oldest of the present mines of the county, having been worked intermittently for many years, chiefly for its lead ores, but apparently at no time with much success. The best defined fluorite vein seen in the county occurs here, with a noted width of from 2 to 7½ feet.

General conditions.—Taking this western Kentucky district as a whole (as shown on the map in Pl. II), it will be seen that there is a large unprofitable or practically barren area on the east and another on the west, composed chiefly of formations above the Ste. Genevieve. There is, in addition, a large unproductive area of St. Louis rocks on the south, and another smaller one on the north. The mines and prospects as a rule are confined to a strip, not more than 3 or 4 miles in width for the most part, lying between these larger barren areas and apparently corresponding to the belts of the most abundant and extensive faulting. The most productive mines at the present time are confined to the center of the district between the northern and southern areas of St. Louis limestone.

The groups of mines described in the following pages are not in all cases the most important of the district, but they are presented as more or less typical examples, and it is believed that the descriptions given will fairly indicate the general character as well as the individual differences of the deposits throughout the district so far as they have been developed. Other peculiarities not noted here have been discussed in an earlier part of the paper under the general character of the ore deposits. The mines and prospects are considered by groups rather than as independent units, as it is believed that this method best brings out the mutual relationships at the different localities considered.

THE MEMPHIS GROUP.

All of the mines and prospects of this group are on or near faults that are nearly parallel, with a northeasterly trend, and apparently slight throw. The Memphis mine is located on one of the two most important of these faults, while the Klondike and neighboring mines to the southwest are on or near the other. The ore from all the mines and prospects is fluorite.

Memphis mine.—The Memphis mine is one of the oldest in the district and one of the three largest producers. Its vein, so far as it has been worked, is one of the best defined and of the most uniform in width.

Work was begun on this tract in 1872, when the land was deeded by William Belt to the Memphis Lead Mining Company. Fluorite was found by the company in the Beck shaft at a depth of 15 feet. This shaft was sunk to 180 feet, but has since been partly filled in. It was soon abandoned, owing to the scarcity of galena, the fluorite not being marketable at that time.

The mine was next worked by the Cincinnati Fluorspar Company (possibly the second fluorspar company operating in the district), and the fluorite was put on the market about 1874. It was next leased by Mr. Joseph Walton, who had been the superintendent for the company, and who shipped some fluorite.

Later the property was sold by the court for the debt of the Memphis Lead Mining Company, and after changing hands several times was finally, in February, 1902, taken up by the Kentucky Fluorspar Company, of Kentucky.

The present workings of the mine consist of three shafts—the north or old Memphis shaft (see fig. 3), with a depth of 155 feet; the south or air shaft, about 100 feet deep; and the old Beck shaft, now used as an air shaft, with a present depth of 40 feet. From these shafts drifts have been run along the vein at different

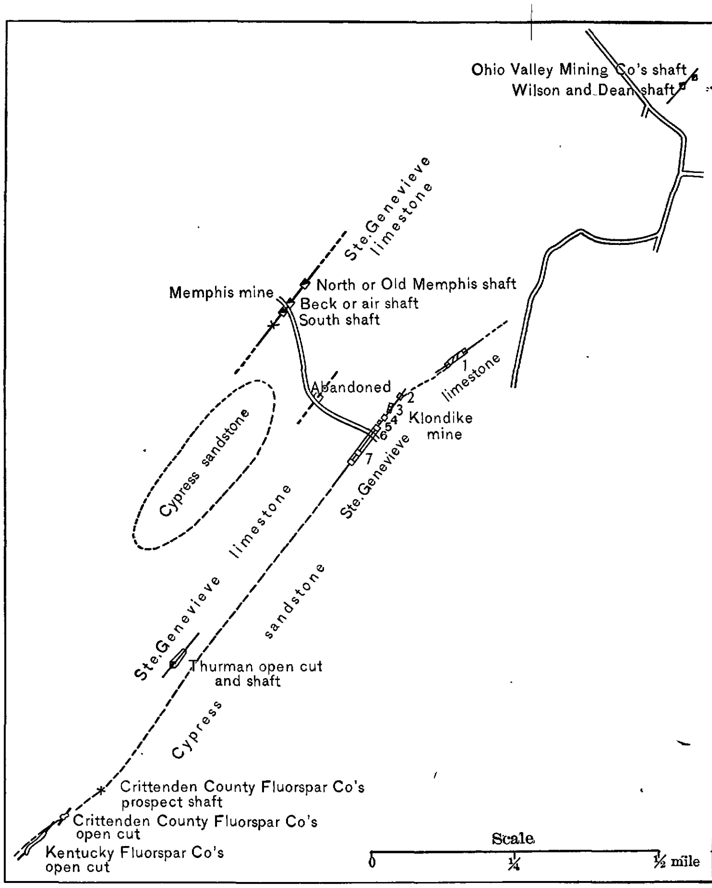

FIG. 3.—Memphis group of mines.

levels for a linear distance of about 800 feet along the course of the vein, and between these the ore has been removed to a greater or less extent by both overhand and underhand stoping. There are six levels and two overhand stopes at the north shaft, the lowest drift having been run at a depth of 140 feet. The air shaft has one underhand stope.

The vein has been formed along a fault, the throw of which does not appear to be large. Its exact amount, however, could not be determined on account of lack of suitable exposures. The Ohara member of the Ste. Genevieve limestone is found on the east, while on the west the lower part of the Cypress sandstone occurs as a surface layer. Everywhere throughout the mine the walls are of Ste. Genevieve limestone more or less seamed with calcite. They are well defined and sharply delimited from the vein material, which is easily separated from the wall, leaving smooth, clean surfaces. Except in the highest levels the vein material is in close contact with the wall, or there is only a film or thin layer of clay (selvage) between them. In general, though not at all points, the hanging or southeastern wall is the smoother, the surface of the foot wall being somewhat more knobby and uneven. Slickensiding is common on both walls throughout the mine. Southwest of the Beck shaft the slickensiding is more pronounced on the hanging wall, and in this part of the mine this wall on the whole is noticeably fluted with both coarse and fine grooves. As a rule, except where the vein is very narrow, the walls have not been cut in mining. The few exposures that were seen show limestone horizontally bedded or nearly so, except in one instance, at the face of the lowest level south of the old Memphis shaft, where the bedding planes of the foot wall dip toward the fault plane at a low angle—from 10° to 20°—for about a foot from the vein.

The strike of the vein is variable, as shown in fig. 1. Its general trend for the part mined is about N. 35° E.[a] The dip is uniformly to the southeast, at an angle ranging from about 53° to 85°, with an average of about 60°.

The average width of the vein is between 3 and 4 feet. Rarely it pinches out completely, as in the lowest drift running south from the north shaft. Here, at a distance of 145 feet from the shaft, the two walls of the fault plane, which is sharply marked, are in contact, with only a film of selvage between them. At the face of the drift to the southwest from the south shaft, the vein is from 15 to 17 inches wide. Its maximum width, so far as developed, is about 7 feet, found north of the north shaft.

In composition and structure the vein shows little variation. It consists mainly, in places wholly, of granular white fluorite, with (as is commonly the case) a minor proportion of purplish fluorite. A small amount of white calcite is frequently found, occurring intermingled with the fluorite, also in the form of thin lenticular veins or sheets between the main vein and one or both of its walls. In the latter case the calcite may be free from fluorite or may contain a variable proportion. A very little galena and still smaller amounts of sphalerite are found here and there in the mine. Structural banding (sheeting?) is common in the

[a] Throughout this portion of this report the readings are true, not magnetic, unless otherwise stated.

vein and parallel to its walls, sometimes close to one or the other, sometimes distributed through the vein. In some cases, at least, the fluorite shows slickensided surfaces along these planes of parting.

General surface oxidation has not penetrated far, and even at the 20-foot level in the Beck shaft, which is situated close to the valley bottom, the limestone is unaltered except for a few inches close to the vein along the hanging wall, and much less along the foot wall. In general below this the walls show no oxidation, though occasionally corroded through solution by underground waters. Surface waters have here and there worked down one wall or the other to the lowest levels of the mine, corroding the limestone close to the vein and forming channels locally enlarged into cavities several feet in diameter. The waters flowing down these channels carry with them in places considerable quantities of mud. Near the end of one of the lower levels running northeasterly from the north shaft a mud pocket was struck in the foot wall, the mud filling the drift and necessitating the closing of this end of it by a bulkhead.

A good deal of prospecting has been done southwesterly from the south shaft. From one of these prospects—a shaft apparently on the vein and about 140 feet S. 40° W. from the south shaft—some gravel fluorite was obtained; another at about the same distance S. 34° W. from the south shaft, though probably a short distance to the southeast of the main vein, also shows some fluorite. Farther southwest no fluorite has been found in the shallow prospect holes.

Bill Terry or Robertson shafts.—About three-fourths of a mile northeast of the Memphis mine are the Bill Terry or Robertson shafts, owned by Robertson, Conway, and Cullen, and the Wilson and Dean prospect, 150 feet southwest of this, both on a northeasterly fault or zone of faulting apparently parallel to the Memphis fault. From both prospects some fluorspar associated with a small amount of galena has been taken, though none has been shipped. The first of these prospects consists of an old shaft dug some forty or fifty years ago in search of lead. It was being reopened and retimbered when visited by the writer. While most of the fluorite seen on the dump here is of the usual granular type, some of it shows the pronounced lamellar structure referred to on page 143.

Wilson and Dean prospect.—At the Wilson and Dean prospect a drift 20 feet in length has been run at a depth of 23 feet, following a vein with a strike of S. 40° W. and a general southeasterly dip of 70°–80°.

The general character of the deposit at this place is well shown in fig. 4.

Just northeast of the road, a little less than halfway from the Klondike to the Memphis mine, is an abandoned shallow shaft worked for a short time in 1901.

A drift was run, at a depth of about 12 feet in the Ste. Genevieve limestone, following a fluorite vein said to be parallel to that of the Klondike. The location of this shaft corresponds very closely to that of the shaft described by Norwood[a] as shaft No. 3 of the Memphis mine, and it is probable that they are the same.

Klondike mine.—The Klondike mine, the property of the Kentucky Fluorspar Company, is situated 1 mile northeast of the Memphis. It consists of a number of shafts and open cuts, which form a broken line extending for a distance of about 1,700 feet along one or more well-defined veins. Of these, only shafts Nos. 4, 5, and 6 (fig. 3) were being operated at the time of the writer's visit. Some of the openings at this mine belong to the old Memphis mine, as described by Norwood, open cut No. 1, with its three old shafts, probably corresponding in position to the old "Rye Field shaft"[b] referred to by him. The general strike of the vein is N. 36° E., except at open cut No. 1, where the average trend is N. 54° E.

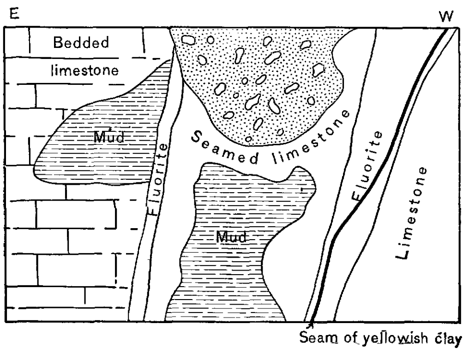

FIG. 4.—Face of drift, Wilson and Dean prospect, showing vein of fluorite with some calcite; corrosion cavities in limestone filled with mud with some fragments of chert and Rosiclare sandstone; limestone seamed with calcite; and larger vein, mainly fluorite, with some calcite and some limestone fragments, the whole cut by a thin seam of yellowish clay.

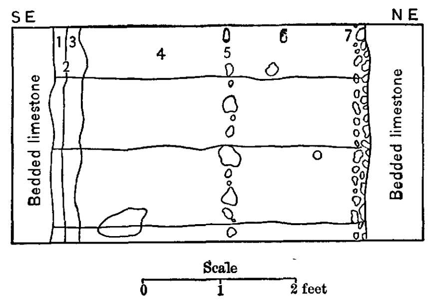

FIG. 5.—Section across the vein at the Klondike mine. 1, Calcite and purplish fluorite in varying proportions; 2, thin, broken line of fluorite, a fraction of an inch in width; 3, coarse calcite (the individuals averaging two or three inches in diameter), with more or less intermingled fluorite; 4, translucent, white, granular fluorite, almost wholly free from calcite (a block of contained limestone shown near bottom of figure); 5, broken line of calcite anhedra; 6, translucent, white, granular fluorite, with scattered calcite anhedra; 7, calcite in fluorite.

From shaft No. 5 a southwesterly drift 40 feet long had been run at a depth of about 30 feet, and above this the vein had been removed by overhand stoping. Between Nos. 4 and 5 the stope had been largely removed for about 25 feet, down to the 43-foot level.

The face of this southwesterly drift from No. 5 shows fluorite, red clay, and decomposing limestone. Alteration of the limestone does not extend far below the surface here, as at the 43-foot level the limestone is fresh and unaltered. At this level the walls are well defined and are both of bedded limestone, apparently horizontal. In places the walls are smooth, especially the southeastern, though in

[a] Report of a reconnoissance in the lead region of Livingston, Crittenden, and Caldwell counties: Geol. Survey Kentucky, pt. 7, vol. 1, 2d series, 1876, p. 486.

[b] Op. cit., p. 485.

general they are more or less rough and knobby. These irregularities appear to be due in part at least to the projection of the edges of the beds of limestone beyond the general surface of the wall. The vein in this drift is nearly vertical, with a general southeasterly dip. At the face of the stope of the 43-foot level, almost directly beneath shaft No. 5, the vein material has a width of 4 feet. A section across the vein at this point is shown in fig. 5.

From this figure it will be seen that the vein is largely of first grade fluorite. Several blocks or fragments of limestone were noted in the fluorite (one shown in 4 of the figure). The contact between vein and wall, or between the fluorite and its included limestone, is always sharp. The local abundance of calcite and fragments of limestone in the fluorite of the vein as a whole is indicated by the common occurrence of cavernous fluorite in some of the surface material (see Pl. XIII, *B*). No faulting was made out in the mine and no slickensiding was observed.

Other openings.—Southwest of the Klondike mine are four openings consisting of open cuts and shafts from a few feet to about 40 feet in depth. All are on or close to the same fissure as that on which the Klondike is located, and indicate one or more veins with a strike ranging from N. 37° E. to N. 46° E. and a general southeasterly dip. The vein width ranges from 14 inches to 5 feet. The vein walls are Ste. Genevieve limestone or Chester shale or sheeted quartzite (or their weathered products), or one wall is shale and quartzite and the other limestone.

THE COLUMBIA GROUP.

General features.—Most of the mines which are included in the Columbia group are situated on or close to the Columbia fault, a well-defined fault having a northeasterly trend and a general northwesterly dip. (See fig. 6.) Northwest of this fault the Birdsville formation is found, while the Ste. Genevieve limestone lies on the southeast. Thus all the deposits in the plane of the fault, so far as they have been mined, have Birdsville sandstone or shale for one wall and Ste. Genevieve limestone for the other.

In addition to the main fault there are several minor faults with a northwesterly trend. On one of these, the Eureka fault, are situated a part of the Columbia mine, the Drescher open cut, and the old Andrew Jackson shaft.

Some of the deposits mined in this group consist mainly of fluorite, as at the Mary Belle shaft and the Mayes and Wilson prospects; some are mainly of galena and sphalerite, or, within the belt of weathering, of smithsonite and galena. Some of the sphalerite is medium grained and occurs as a cement of a breccia or lining or filling small vugs or fractures in the rocks. In general, however, it occurs as a fine-grained deposit, disseminated in a more or less siliceous limestone.

The deposits of this group are believed to be largely localized and their variations in character and in the mode of occurrence of the ore (aside from the effects of oxidation on the ores occurring within the belt of weathering) are due partly to variation in physical conditions and partly to differences in the ore-bearing solutions.

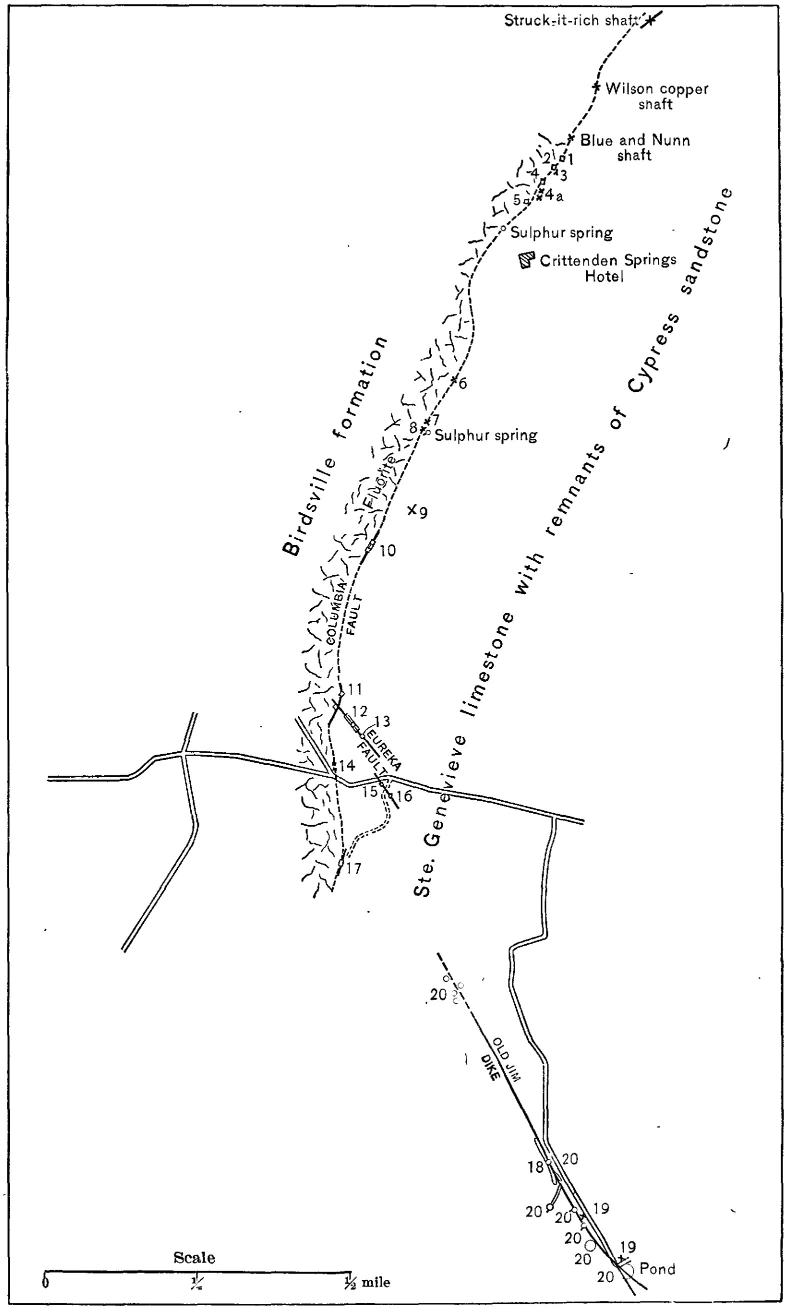

FIG. 6.—Columbia group of mines. 1–4 a, Mayes and Wilson prospects; 5, Major Clemens shaft; 6, Rochester prospect; 7–8, New Jim mine; 9, fluorite prospect; 10, Watkins open cut and shaft; 11, Columbia mine, air shaft; 12, Columbia mine, main shaft; 13, Drescher open cut; 14, Blue heirs prospect; 15, "Old Mill Shed" shaft; 16, Lanham mine; 17, Mary Belle mine; 18, Old Jim mine; 19–20, prospects along Old Jim dike.

Mayes and Wilson prospects.—North of Crittenden Springs Hotel is a small group of mines and prospects, all on or not far from the Columbia fault. The outcrop of this fault here runs up the northeastern slope of Hurricane Creek Valley, the Major Clemens shaft being situated near the foot of the slope and the Mayes and Wilson No. 1 shaft at the brow of the hill above.

The Mayes and Wilson prospects, consisting of two shafts, a short open cut and an adit, together with the somewhat older McBride shaft and a still older open cut made about 1882, are all located within a distance of about 230 feet, following a fluorite vein of very variable width, not over 5 feet wide as far as developed. This vein, which has an average strike of about N. 38° E. and a nearly vertical dip ranging from easterly to westerly, occurs along the main fault plane between the Birdsville shale and quartzite on the west and Ste. Genevieve limestone on the east. The limestone is seamed in places with calcite, and locally more or less calcite is associated with the fluorite, as is also a small amount of galena. West of the main fault plane the quartzite has been more or less sheeted and brecciated, the breccia, locally at least, as is shown in Mayes and Wilson shaft No. 1, being cemented with fluorite. Characteristic surface outcrops of quartzite are met here, one occurrence being shown in Pl. XII, *B*.

Major Clemens shaft.—The sinking of the Major Clemens shaft was begun in October, 1902, and therefore after the writer had left this field, but it was visited by both Mr. Ulrich and Mr. Fohs in November, 1902. The ore occurs in a sheeted zone in quartzite about 125 feet west of the Ste. Genevieve-Birdsville contact. The west or hanging wall in the shaft is of Birdsville shales and quartzite, the eastern or foot wall being entirely of the quartzite. Between these walls the quartzite has been brecciated, and the breccia cemented mainly with fine-grained sphalerite, a little fluorite, less galena, and a very little calcite and quartz. This cemented breccia has a width of about 5 feet and strikes approximately N. 27° E., with a northwesterly dip of about 58°.

At the time of Mr. Ulrich's visit the shaft had been sunk to a depth of 40 feet. Of about 500 cubic feet of ore taken from the shaft, it was estimated that the sphalerite constituted between 25 and 30 per cent, with a small amount of fluorite and perhaps 1 per cent of galena.[a]

In addition to its occurrence in thin seams as a cement to the more or less brecciated rock, the ore, as seen in the specimens obtained from this shaft, also occurs disseminated in small or minute grains through the rock, in the same way in which it is so frequently found in limestone at many of the mines.

[a] A new shaft, a short distance N. 4° W. from the first, is being sunk at this mine. Like the first, the new shaft is being sunk entirely in brecciated quartzite, but in the latter the rock contains much less zinc and lead sulphides This may be due to the fact that the new shaft is located about 20 feet farther west of the main fault plane than the first. A cross-cut running eastward to the Ste. Genevieve limestone is suggested.—E. O. U.

The amount of the disseminated ore varies greatly in different parts of the rock, and in some places it is so abundant that no rock can be seen even with a hand lens. It consists mainly of sphalerite with a very small proportion of galena and more or less pyrite. Such disseminated ore has not been noted elsewhere by the writer in well-defined quartzite, and a careful examination of the rock in which it occurs has led to the conclusion that it was not originally a sandstone, although it may have been somewhat arenaceous, but that it was mainly a calcareous shale, the calcareous portions having been largely replaced by quartz.

Rochester prospect.—The Rochester prospect, nearly one-fourth mile southwest of the Crittenden Springs Hotel, consists of two short east-west trenches, from one of which, on the Columbia fault, a very small amount of gravel fluorite has been taken.

New Jim mine.—At the Blue and Nunn prospect, now known as the New Jim mine, about 400 feet farther southwest, a considerable amount of smithsonite occurs in surface blocks and fragments, and the same ore has been exposed in a shallow hole dug here. Much of the ore is more or less siliceous, the smithsonite being disseminated in small aggregates in a somewhat altered jasperoid. The latter is due to the silicification of Ste. Genevieve limestone, the contained smithsonite having been derived from the oxidation of sphalerite formerly disseminated in it. There is also a small proportion of disseminated galena or its oxidation product, cerrusite.

Another shallow prospect, about 75 feet S. 52° W. of this, is on the Columbia fault, with Birdsville shale on the west and Ste. Genevieve limestone on the east, though the latter is considerably sheeted and somewhat brecciated. Seams of coarse calcite with a maximum width of 1 inch or more are common in the limestone, and with it a little galena is occasionally associated. Some galena also occurs in small seams along the sheeting planes or fills the fractures of the brecciated limestone. Some fine-grained sphalerite occurs disseminated in the limestone. In the sheeted zone on the northern wall of the hole the limestone has to some extent been replaced by zinc carbonate. These two prospects are suggestive of a zone of sheeted and brecciated Ste. Genevieve limestone not unlike that at the Columbia mine. Recent prospecting on this property has been considered sufficiently favorable to warrant the erection of a mill and extensive development[a] of the mine.

From a shallow hole one-eighth of a mile east of south of the mine just described some cavernous lump fluorite has been taken which was apparently

[a] Information received to April, 1904, confirms the suggested similarity of conditions at the New Jim mine and at the Columbia. The new shaft is 60 feet deep and the lower 20 feet passed through rich lead and zinc ores. The ore body varies from 2 to 6 feet in width and occurs apparently as a replacement of the Ste. Genevieve limestone, which forms the foot or east wall. This wall is very uneven, but the hanging wall, which is composed principally of shale of the Birdsville formation, is sharply defined.—E. O. U.

formed along a minor fissure in the Ste. Genevieve limestone parallel to the Columbia fault.

Watkins open cut.—The Watkins open cut on the Columbia fault, a little over a quarter of a mile east of north of the Columbia mine, consists of a shallow open cut about 50 feet long, to which a shaft has been added since the writer's visit. The western wall of the cut is of gray clay and shale with about 2½ feet of soil above it containing fragments of quartzite. The eastern wall as well as the main part of the cut is of red clay. Occasional bowlders of limestone occur in the cut, containing small patches and seams of purple and white fluorite, some calcite, and a little galena. The ore, mainly smithsonite, occurs in large irregular masses along the central portion of the cut, and contains a good deal of disseminated fine- to coarse-grained galena, more or less patchy, and some associated fluorite.

Some of the smithsonite noted here contained scattered, yellowish, more or less porous patches consisting of smithsonite, abundant minute quartz crystals, yellow ocher, and some wad, the patches being evidently the oxidation residuals of siliceous limestone fragments scattered through the original ore body.

Columbia mines.—The Columbia mines are the oldest and perhaps the best known in the district. The first operations at this mine were begun in 1835 by Andrew Jackson, who sank a shaft near the creek southeast of the present Columbia main shaft for silver. Dr. D. D. Owen, visiting the old workings in 1854, reported that they were from 40 to 60 feet deep. In 1863 or 1864 the mine was purchased by the Columbia Silver Mining Company, composed of J. N. Blue, sr., and others, and when, about 1873 or 1874, it was leased to Halliday and Green, of Cairo, Ill., the shaft was nearly 80 feet deep, but no drifts had been run. Halliday and Green worked the mine fifteen months, running a drift (now closed) 40 or 45 feet to the southwest at the 50-foot level. This is said to be on the vein. Henry, James, and Tom Glass then took an option on it, and retimbered the old shaft, which had caved. They also sank the shaft to a little below 80 feet and ran drifts for a short distance.

In 1876 Page & Krausse, of St. Louis, bought out the Glasses and sank the shaft deeper, running the drifts at the 80-foot level as they now are. A plant was installed which included six jigs of about 60 tons capacity, an old-fashioned two-flue boiler, a Blake crusher, and a small Scotch hearth lead smelter.

Their pig lead was hauled to the Ohio River at Fords Ferry for shipment. These operations were discontinued in 1877, owing to the decline in the value of lead. In 1899 Blue and Nunn secured from Page & Krausse a ten years' lease and option on the mine. In 1900 the lease was purchased by the Western Kentucky Mining Company, which began work on the Columbia shaft in May or June of that year. The old mine was in part retimbered and cleaned out, and some work done at the 135-foot level, but after a few months it had to be abandoned on account of water. The mine then lay idle till the Columbia Mining Company, organized in 1902, took over the Western Mining Company's lease and secured a new one from Page & Krausse. They are now sinking the shaft, which has reached a depth of 138–140 feet, and are extending the southwest drift at the 135-foot level. Buildings and machinery have also been added.

The mine was closed at the time of the writer's visit. It was examined later, in February, 1903, by Mr. F. J. Fohs, on whose observations and collections the following statements concerning the underground relations are largely based. At the time the mine was examined the main shaft had reached a depth of about 140 feet, and, as is indicated in the history of the mine, drifts ran from the shaft at the 80 and 135 foot levels. The drift at the 50-foot level was inaccessible, being filled with mud.

The Columbia mine has been developed along the course of the Columbia fault, which is here associated with minor cross faults and fractures, of which the most important is the Eureka fault. Most of the early mining here was done along the Eureka and not the Columbia fault. Nearly all of the shafts of the group described and figured by Norwood[a] are on the former, while one, the Barnett shaft, was at the junction of the two, and must therefore have been very close to the present location of the main shaft of the Columbia mine. In the Barnett shaft Ste. Genevieve limestone and Birdsville shale were found in contact, and galena occurred apparently along the Eureka fault, although but little ore has been found along this fault in the deeper parts of the Columbia mine.

Along the Columbia fault plane shale has been dragged in, and on acccount of its impervious character has doubtless aided in directing the waters circulating along the fault plane. Locally breccias have been formed along the fissure in the more or less siliceous Ste. Genevieve limestone which constitutes the eastern wall of the fissure. At other places sheeted zones have been formed. The ores and their associated minerals have been deposited here and there along both major and minor fissures and fractures, either cementing the brecciated limestone, or filling seams, or metasomatically replacing to a greater or less extent both the limestone of the breccia and that between adjacent sheeting planes. The ore is chiefly galena and sphalerite, with a minor proportion of second-grade fluorite, the best ore occurring as a cement to the siliceous limestone breccia. This breccia, though occurring at the 135-foot level, has its greatest development at the 80-foot level, where it lies south of the shaft. It appears to have an irregularly lenticular form, its longer dimensions lying in the fault plane.

[a] Norwood, C. J., Report of a reconnoissance in the lead region of Livingston, Crittenden, and Caldwell counties: Geol. Survey Kentucky, vol. 1, part 7, second series, 1876.

The strike of the fault throughout almost the entire mine is N. 26° E., its calculated dip between the 80-foot and the 135-foot levels being about 83°. Near

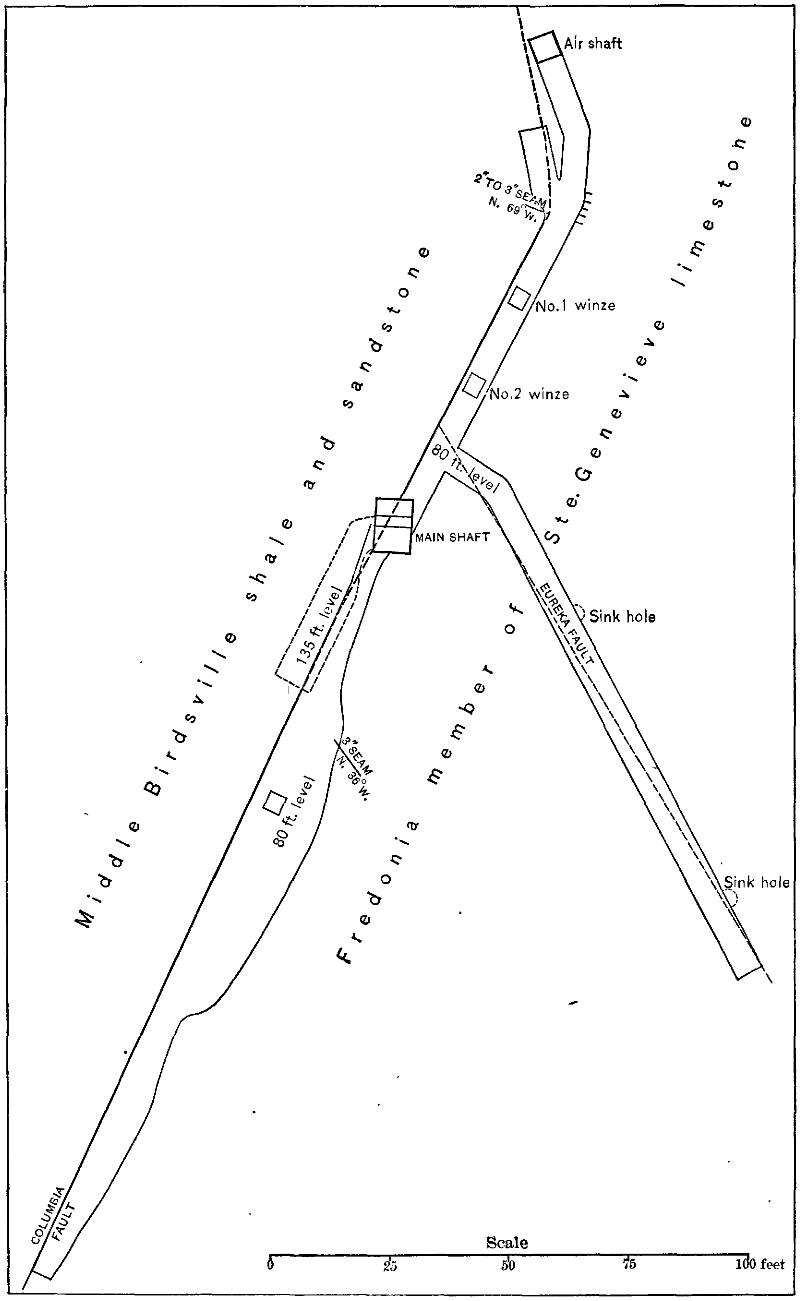

FIG. 7.—Underground workings of Columbia mine; redrawn from map by F. J. Fohs.

the northern end of the 80-foot drift there is a rapid change in the direction of the fault from northeasterly to northwesterly, as shown in fig. 6. At the point where the fault turns, a cross fracture has been developed in the shale forming the west wall, and in it a seam of galena and sphalerite three inches in width has been deposited. The opposite wall here also shows some cross fracturing. At both the 80-foot and 135-foot levels Birdsville shale and quartzite constitute the western or hanging wall, while lower Ste. Genevieve limestone forms the eastern or foot wall of the main ore body. It seems probable that some, if not all, of the shale seen at both levels has been dragged in or has worked down along the fault plane between the sandstone and the limestone, for, as seen at the face of the short drift to the northwest, near the northern end of the mine, about 3 feet of the sandstone is exposed on the west, and between it and the limestone is about one foot of shale following the fault plane. The structure of the shale generally parallels approximately in dip and strike the dip and strike of the fault plane, except at one point 20 feet north of the shaft, where the strike of the shale is toward the west, at its intersection with the Eureka fault. Slickensiding may be seen in places in the shale, and near the face of the 80-foot drift southwesterly from the main shaft some calcite and brownish fluorite have been deposited along the slickensided surfaces, although in general no ore occurs in the hanging wall. This wall is well defined and almost straight, thus differing from the eastern or foot wall, which is very irregular, especially south of the shaft where the main ore body occurs.

The eastern wall of the northeastern and southwestern drifts, and both walls of the drifts to the southeast at the 80-foot level, are of light-gray lower Ste. Genevieve limestone seamed with calcite and occurring in beds one half to one foot thick. Near the air shaft the beds are almost horizontal, while in the southeast drift they show a dip to the southwest.

The southeastern drift, cut entirely in limestone, has a trend of N. 29° W., except near its junction with the northeast drift, and has for the most part followed the Eureka fault, which has here a strike of S. 32° E., and a northeasterly dip of 72°, as seen near the fall of the drift. No ore was noted in this drift except near its mouth, although occasional patches are said to have been encountered in running the drift. Within 12 feet of its junction with the northeastern drift the southern wall, where it intersects the fissure, shows a body of ore 2 feet wide, having a trend of S. 32° E. This ore body consists almost entirely of fine-grained sphalerite disseminated in and metasomatically replacing limestone.

Two sink holes formed along or near this fissure, and shown on the map of the mine, opened into the drift just described on the northeast side and through them the mine is often flooded in storms.

In the northeast drift, except for the seam in the west wall, already mentioned, ore was noted only near the shaft. Here the ore is medium-grained sphalerite disseminated in limestone, with little or no galena. In the southwest drift, at the 80-foot level, the main ore body occurs. This body as a whole consists of an open limestone breccia cemented with calcite, sphalerite, and galena, and toward the southern end of the drift with more or less fluorite. The limestone of the breccia, and to some extent that of the eastern wall, has been replaced to a greater or less extent by quartz in microscopic crystals, and is therefore more or less siliceous in general character, little or none of the original limestone being left in some parts. These limestone fragments also contain a variable amount of fine-grained, disseminated sphalerite, which in places forms the bulk of the rock. In addition to these minerals, the limestone occasionally contains a little pyrite in fine grains, secondary calcite, a small proportion of galena in small cubes, and some fluorite. In the central, broader part of the drift the cemented breccia is sharply separated from the limestone forming the east wall, while in the southern and more constricted end of the drift the breccia grades into the limestone of the wall without noticeable break. The cement of the breccia is variable both in amount and character. Toward the southern end of the drift the amounts of sphalerite, galena, and fluorite decrease, and the cement near the face is mainly calcite with a little low-grade fluorite. North of this, but still in the narrower section of the drift, more sphalerite is found, and more fluorite of a brownish color, while a sheet of fluorite with a maximum width of 2 feet occurs in the breccia near and parallel to the western wall. The mode of occurrence of this fluorite suggests fissuring since the formation of the main ore body, with subsequent filling of the fissure by fluorite. The central broad section of the drift contains a large proportion of both galena and sphalerite, and furnishes the best ore of the mine. This part of the drift has been stoped for 30 feet above the 80-foot level. In this part of the drift a considerable amount of calcite occurs within a foot of the eastern wall. Elsewhere the cement consists mainly of sphalerite and galena. Some of the coarse white calcite from this part of the mine shows brecciation and recementation by galena, sphalerite, and clear calcite. The galena occurs in cubes, with a maximum diameter of about 2 inches. The sphalerite of the cement occurs in small or medium-sized crystals having a maximum diameter of about one-eighth inch. Where it lines cavities it is of the ruby-blende variety that is so commonly seen under such conditions.

The ore from the 135-foot level is somewhat similar to that of the 80-foot level, occurring partly cementing the broken rocks, but chiefly disseminated in and replacing limestone between planes of faulting or sheeting. At the face of this drift we have the following succession between the west and the east walls, which are here about 6½ feet apart, and dip northwesterly about 65°: (1) Shale forming west wall; (2) 2 feet of limestone with more or less disseminated fine-grained sphalerite; (3) 2 feet mainly calcite with scattered rock fragments and some galena and sphalerite; (4) 2½ feet of sphalerite and fine to rather coarse-grained galena disseminated in limestone; (5) Ste. Genevieve limestone forming the east wall. A section on the northeast side of the shaft and 2 feet above the bottom is somewhat similar: (1) Western wall of shale and quartzite; (2) 2 feet of shaly limestone; (3) 2 feet of limestone with disseminated fine-grained sphalerite and almost no galena; (4) 2½ feet of sheeted limestone seamed with calcite; (5) wall of Ste. Genevieve limestone.

Oxidation by surface waters has, to a limited extent, penetrated both the 80-foot and the 135-foot levels. This is shown in many of the specimens of ore from both levels, but is best seen in the small vugs which are common through the ore body. The calcite crystals occurring in many of these vugs are sometimes rounded on the surface; more frequently they are corroded, especially about the point of attachment. The sphalerite, both that occurring in the vugs and that disseminated in the limestone, frequently shows some oxidation, being sometimes corroded and again coated with a thin blackish film. Occasionally the galena is more or less altered to earthy cerussite. Among the secondary products which have formed, quartz and smithsonite are the most common.

All of the unoxidized deposits thus far described appear to be those of primary concentration. None of them gave any evidence of having been formed by secondary enrichment. Several instances were noted of secondary sulphides, greenockite, and sphalerite, formed in very small amounts with or after the products of oxidation already referred to.

Cemented breccias such as are found at this mine are believed to be of very limited and local development, and are perhaps to be looked for only along well-defined faults, where siliceous limestones have suffered displacement since silicification. In such breccias the coarsest and most abundant lead and zinc ore is to be found, providing deposition of such ores took place at all. Local conditions, not only at the Columbia mine, but at a number of points along the Columbia fault, appear to have been favorable for the deposition of galena and sphalerite rather than of fluorite. Depth apparently was not one of these governing conditions, and has had little or no direct influence in determining the amount of ore deposited. So far as can be ascertained there is no definite vertical relation of the ores at this mine, and there is certainly no such vertical succession as that given by W. E. Burk.[a]

With deeper mining at the Columbia, the Birdsville rocks of the western wall will be succeeded in turn by the Tribune limestone, Cypress sandstone, and Ste. Genevieve limestone, while the Ste. Genevieve of the eastern wall will be succeeded by the St. Louis limestone. With these changes in the walls there will doubtless come some change in the general character of the deposits, especially if, as appears

[a] Burk, W. E., The fluorspar mines of western Kentucky and southern Illinois: Mineral Industry for 1900, pp. 293–295.

to be the case, the St. Louis limestone is less subject to secondary silicification than the Ste. Genevieve. It is therefore by no means improbable that at greater depths, where the St. Louis forms one of the fissure walls, a well-defined vein of fluorite may be encountered.

Drescher open cut.—The Drescher open cut, a short distance southeast of the Columbia mine, was the only opening on the Eureka fault at the time of the writer's visit. The ore here consists of an irregular body of smithsonite containing a good deal of galena, both coarse and fine grained. It occurrs with red clay between walls of more or less weathered Ste. Genevieve limestone somewhat seamed with fluorite.

The Eureka vein was considerably exploited in the early mining days of this region. Norwood,[a] in his description of the Columbia mine, figures seven shafts as located on this fault, these being only a part of those that had been sunk at one time or another. From all the shafts on that portion of the vein east of the Columbia fault, galena, or galena and fluorite, had been obtained, the ore occurring between walls of Ste. Genevieve limestone.[b]

As shown at the 80-foot level of the Columbia mine, this fault intersects the west wall of the Columbia fault, though it probably extends only a short distance west of the latter into the Birdsville rocks. In this direction no ores have been found along the course of the Eureka fault, a shaft mentioned by Norwood as having been sunk 57 feet N. 37° W. of the old Barnett shaft, and finding only shale.

Mary Belle mine.—This mine, on the Columbia property, is located about a quarter of a mile south of the Columbia mine. Work was begun here in the summer of 1901, and during the nine months that the mine had been operated 525 tons of fluorite had been produced. The mine is characterized by a vein of fluorite from 2 to 6 feet wide, with an average strike of about N. 12° E. and a high westerly dip. The fluorite is associated with a considerable amount of galena, and some fine-grained sphalerite is found disseminated in the limestone walls of the unoxidized portion of the vein. At the only exposure of the vein seen by the writer both walls were of clay. That this vein must be on or within a few feet of the Columbia fault is shown, however, by surface outcrops, Birdsville sandstone being found west and Ste. Genevieve limestone east of the mine.

Norwood[c] has figured and described some old shallow pits, called by him pocket diggings, dug years before in a ravine south of the old Glass shaft, and out

[a] Norwood, C. J., Report of reconnoissance in the lead region of Livingston, Crittenden, and Caldwell counties: Geol. Surv. Kentucky, vol. 1, pt. 7, 2d ser., 1876.

[b] One wall of the Glass shaft was said to be of sandstone, but this was probably a case of mistaken observation on the part of Mr. Norwood's informant, as this was the only shaft on this fault from which sandstone was reported, and Norwood himself saw none on the surface.

[c] Op. cit., Pl. IV and p. 484.

of every one of these "lead and fluorspar were obtained in variable quantities." These appear from their location to have been close to the present Mary Belle mine.

Lanham mine.—The Lanham mine, located one-sixth of a mile southeast of the Columbia, consists of a short open cut and a shaft 20 feet deep. This shaft had not been worked for some time and was nearly filled with water. The ore consists mainly of fluorite, both white and purple, with a limited amount of associated galena and a good deal of sphalerite. The last is partly fine-grained, both associated with fluorite and disseminated in the adjacent silicified limestone. It also occurs fine to moderately coarse grained in larger patches and masses in the fluorite. The coarser grained sphalerite is dark brown, the finer grain having the usual reddish color. The fluorite, in addition to its occurrence in the usual granular condition, is found also in fine grains disseminated in jasperoid.

The ore occurs presumably as a vein here, though it is said to be not well defined. The ore body has a width of about 3 feet. Vugs lined with fluorite crystals are reported to be numerous here.

In addition to the fluorite shipped from this mine a sample shipment of 25 tons of sphalerite was made.

Near and just northwest from the Lanham shaft is an old shaft dug years ago by Mr. Henry Glass. The depth is not known. This probably corresponds to the "Old Mill Shed" of Norwood's report.[a] This mine was believed by him to be on a different crevice from the Eureka fault, as is readily seen in Pl. IX to be the case, these prospects, with the Lanham shaft, occurring apparently on a parallel fault or fracture.

Old Jim mine.—The Old Jim mine, a little more than three-quarters of a mile southeast of the Columbia mine, differs radically from the mines thus far described (1) in the absence of fluorite and calcite, the ore consisting of zinc carbonate with a minor proportion of sphalerite; and (2) in the occurrence of the ore body parallel to and in contact with a narrow but very persistent dike of peridotite. This mine has thus far been the largest producer of zinc carbonate in the district. The discovery of the body of smithsonite here took place in the fall of 1900, but no real prospecting was done until May, 1901, in the latter part of which month the first carload of ore was shipped.

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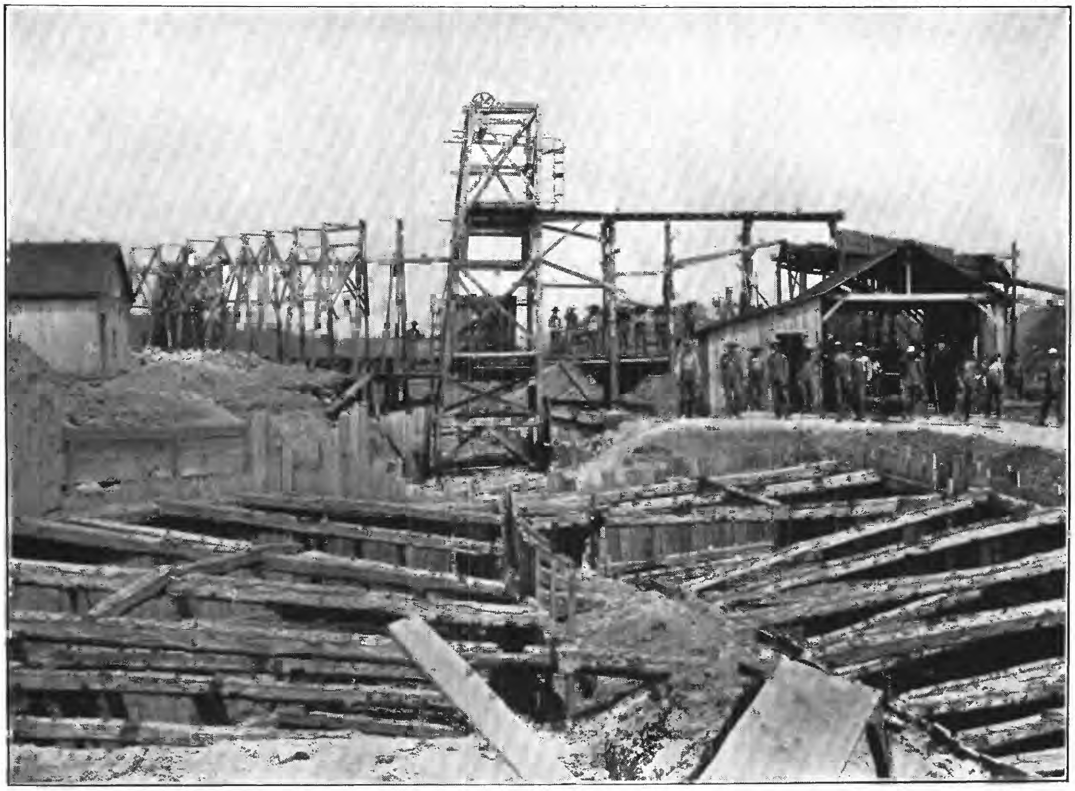
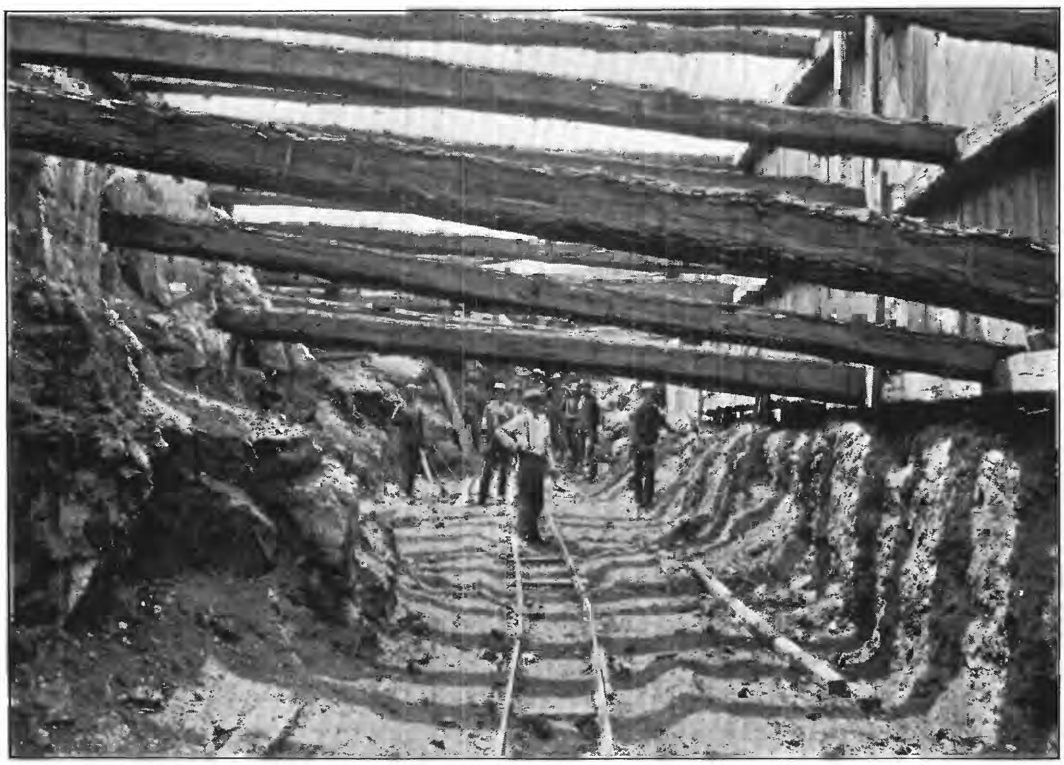
[a] Op. cit., p. 483.



A. OLD JIM MINE, SHOWING OPEN CUT.



B. OPEN CUT AT OLD JIM MINE.

Assays of samples from different parts of the mine and from the washings, etc., made by Waring & Son, of Webb City, Mo., show the following amounts of metallic zinc (pure smithsonite contains 52 per cent of metallic zinc):

Assay of samples of ore from Old Jim mine.

	Zinc.	Iron.
	Per cent.	*Per cent.*
Flint carbonate	51.80	....
Turkey fat	49.85	0.60
Pea screenings	34.80	5.20
Washed tailings	30.85	6.92
Sphalerite	60.17	1.74

The smithsonite, by the carload, averages about 46 to 47 per cent of zinc.

The mine consists of two open cuts, shown in fig. 8. Of these the northern and principal one has a length of about 400 feet and a depth of 27 feet. As seen in the figure, a dike of peridotite forms one of the walls of the cut. The dike for a part of its course is nearly straight, but near the point of its intersection by the drifts, southeast of the shaft, it shows a slight though distinct bend. Wherever noted it was much weathered, especially along the margins. Where cut through, the dike has a width of about 6 feet and a dip ranging from 81° to 90° southwesterly.

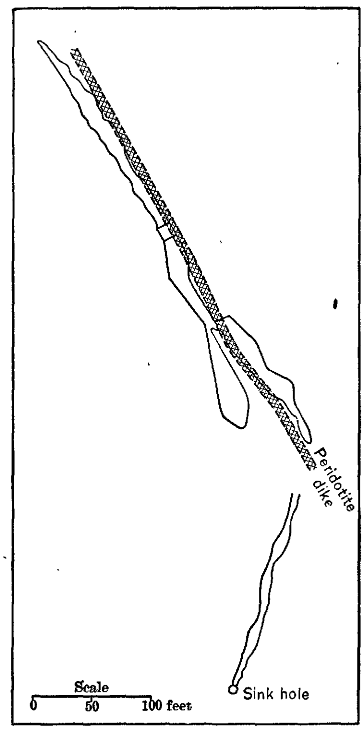


FIG. 8.—Old Jim mine.

The walls of the cut, except where formed of peridotite, are of nearly horizontally bedded Ste. Genevieve limestone, containing thin beds or lenses and scattered nodules of chert. Definite faulting was noted in only one part of the mine, at its northwestern end, where there is a displacement of between 1½ and 2 feet, with a downthrow to the northeast.

As already stated, the ore from this mine is practically all carbonate of zinc, mainly in the form of smithsonite; in addition to the simple carbonate, the basic carbonate, hydrozincite, also occurs, being found in considerable amount with the smithsonite just south of the shaft, a little above water level. More or less unoxidized sphalerite is still found at the same levels at which the smithsonite occurs. While some of that associated with and altering into the smithsonite is of medium grain, most of that seen at the mine is very fine grained, occurring disseminated in limestone.

There appears to have been no definite fissure vein corresponding to the course of the drifts, the ore body occurring mainly as a replacement of the limestone, and to a minor extent of the associated chert, along and close to the walls of the intruded peridotite dike. The ore occurs for the most part massive, cut, it is said, by the beds of chert which sometimes extend across the entire ore body to the dike. Here and there blocks of unaltered limestone occur in the smithsonite. Occasional nodules of **chert** are found in the ore, just as in the adjacent limestone. The chert of both the nodules and the beds is generally replaced in part by smithsonite. The flint carbonate in the above list of assays has already been referred to (p. 142). This was not seen in place, and so its actual relation to the main ore body is not known.

The ore-bearing solutions here have penetrated and replaced the different beds of limestone unequally at any given place, and the extent of the penetration varies also at different points along the course of the ore body. This is well shown in the varying width of the ore body in horizontal sections. At the northwestern side of the shaft the mass of smithsonite, which had a width of 8 to 10 feet at the southeastern side, pinched to less than 1 foot, widening again to the northwest, where it forms the broad northwestern drift. Again it narrowed toward the northwestern end of the drift, and pinched out about 190 feet from the shaft. Southeast of the shaft the ore pinched at a distance of about 65 feet, and in an attempt to find the continuation of the ore body, the peridotite dike which had formed its eastern wall was cut through, smithsonite being found at this point on the east side of the dike. The drift being continued to the southeast on the west side of the dike, ore was found again on this side, the two ore bodies continuing as shown in the figure—one on either side of the dike.

The sphalerite, like the smithsonite, has replaced the limestone very irregularly. In places it is very abundant, appearing to replace altogether portions of the limestone beds. While most of the sphalerite, both the coarse and the fine grained, is due to primary concentration, there has undoubtedly been some enrichment of the sulphide ores by additional deposition from descending waters.

The southern or minor open cut of the Old Jim mine is shallow, and has a length of 170 feet, with an average trend of N. 17° E. The ore, as in the main cut, is smithsonite, occurring in a narrow body between limestone walls. There had been too little development here to warrant a positive statement, but it seems probable that this deposit has been formed along a joint plane in the limestone. This open cut heads in a sink hole leading to a cave from the walls of which a considerable amount of smithsonite was secured. As shown in fig. 9, prepared from a sketch and notes by Mr. Ulrich, the walls of this cave are coated with stalagmite, behind which the ore is found in residual clay derived from the comparatively recent decomposition of the limestone.

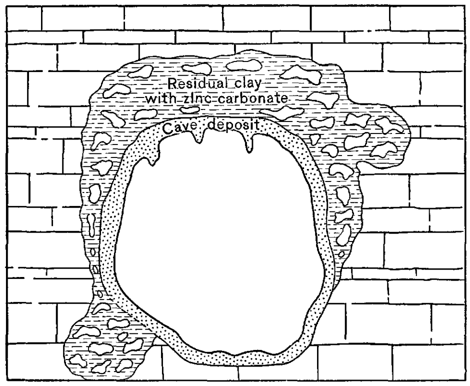


FIG. 9.—Cross section of cave at bottom of sink hole, 300 feet south of the "Old Jim" hoist. This sink hole is connected by means of an enlarged joint with the zinc deposits adjoining the Old Jim dike. The figure illustrates the occurrence of the smithsonite in the walls of the cave.

The following additional information concerning the main open cut was obtained by Mr. Fohs in 1903. The main cut was then about 37 feet deep, and a few feet below water level. Near the shaft at this depth a bed of apparently impermeable limestone had been encountered, extending across the drift and completely cutting out the ore. Just above this, in the drift south of the shaft and west of the dike, occurs a bed of limestone from 3 to 5 feet thick, largely replaced for a distance of more than 20 feet from the dike by sphalerite of fine though somewhat variable grain. Just above this is a bed of limestone from 6 to 12 inches thick, largely replaced by marcasite.

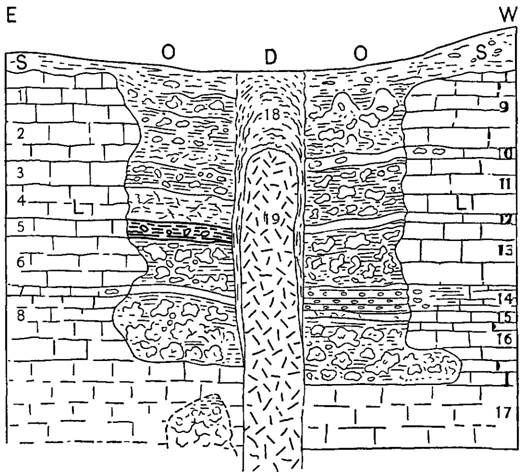


FIG. 10.—Cross section at Old Jim mine. D, Mica-peridotite dike, entirely decomposed at the surface, but growing more and more solid and fresh with depth. O, O, Ore bodies, consisting of masses of smithsonite above and of sphalerite in the basal part, the ore separated by residual clay and chert, all in irregular horizontal bands. S, Soil with variable amount of chert. L, Ste. Genevieve limestone walls of open cut. East wall: 1, Coarse-grained limestone, 4 feet; 2, fine-grained limestone, 6 feet; 3, moderately fine-grained limestone, 2.5 feet; 4, siliceous, earthy limestone, represented in the open cut, chiefly by massive chert, 3 to 3.5 feet; 5, earthy limestone, without chert, 20 inches; 6, rather coarse-grained limestone, 4 feet, the corresponding part in the ore body containing massive carbonate; 7, chert, 15 inches, more or less decomposed in open cut; 8, coarse-grained limestone, 7 feet, the corresponding part in the ore body containing large masses of smithsonite in upper half—sometimes with iron sulphide at top—and mainly sphalerite in lower half; the latter ore occurs beneath ground-water level. West wall: 9, Rather coarse-grained limestone, 7 feet; 10, chert, 15 inches, more or less decomposed in ore body but distinguishable through it to the dike; 11, coarse limestone, 6 feet, probably corresponding to bed 1 in east wall; 12, chert, 12 inches, more or less decomposed in ore body; 13, rather fine-grained limestone, about 7 feet; 14, siliceous, earthy limestone, cherty, 3 feet, probably corresponding to bed 4 in east wall; 15, earthy limestone, 12 to 15 inches, decomposed and highly pyritiferous in open cut; 16, subgranular, moderately coarse limestone, 7 feet; 17, clayey limestone extending across open cut to dike; 18, much decomposed peridotite; and, 19, solid peridotite growing harder with depth.

The accompanying sketch (fig. 10) prepared by Mr. Ulrich at the time of his last visit to the mine in November, 1902, gives a good idea of the relations of the ore bodies on each side of the dike to the limestone beds in the outer walls.

As shown in the figure, smithsonite occurs above and disseminated sphalerite below. Both kinds of ores occur in horizontal layers, for the most part continuous with the beds of limestone to which they are adjacent.

There has been a good deal of prospecting along the course of the peridotite dike, both northwest and southeast of the Old Jim mine. To the northwest the dike extends for more than a quarter of a mile from the Old Jim shaft, following a course about N. 28° W. In this direction no ore has been found.

Nearly a quarter of a mile southeast of the Old Jim shaft is a pond filling an old sink hole. Just northwest of the pond and north of the road is a prospect from which has been taken altered peridotite, a little smithsonite, and some limestone considerably seamed.

About midway between this prospect and the Old Jim mine a fissure, evidently due to solution along a joint plane, occurs in the limestone. This fissure, which is from 6 inches to 1½ feet in width, has been uncovered for a distance of about 6 feet, showing a strike of about N. 39° W. From this opening, the walls of which are considerably corroded, some small blocks of smithsonite have been taken.

TABB-YANDELL GROUP.

General features.—The Tabb mine consists of a linear series of shafts, shallow holes, and open cuts extending for a distance of about one-third of a mile along the Tabb fault. This is an extensive fault of several hundred feet throw, by which the Birdsville and other formations lying on the north of the fault have been brought into juxtaposition with the St. Louis limestone on the south of the fault. Immediately to the east of the Tabb shafts this series of mines is continued a little more than a quarter of a mile by the Blue and Marble mines and the Newkirk shaft. Still farther east, south of Mexico, are the Myers prospects, near the same fault, but between these and the Newkirk shaft there are no prospects so far as known. West of the Tabb mines the abandoned Wheeler mine occurs on the same fault, the distance from this mine to the easternmost of the Myers prospects being nearly 2 miles. Southwest of the Wheeler the Tabor mine is situated on a fault parallel to the Tabb fault, and another appears at the Asbridge mine, southwest of the Tabor, thus showing a series of faults arranged en échelon. A continuation of this condition toward the east is suggested by the sudden change in direction of the Tabb fault just west of the railroad, south of Mexico. (See fig. 11.)

At the Asbridge mine both Chester and St. Louis rocks occur, their relative positions being similar to those east of the Wheeler mine. The general relations of the formations on opposite sides of this zone of faulting shown on the maps of the district make probable an eastward connection of this fault at the Asbridge with the fault at the Tabb mines, and thus an arrangement en échelon of the Tabb fault itself.

The fault at the Tabor mine is in the St. Louis limestone, the main fault between the Chester and St. Louis probably occurring as a parallel displacement a short distance to the north.

All these parallel portions of the Tabb fault, which strike a little north of east, are probably connected by another series having a more decided northerly trend, as is suggested by the fault at the Myers prospects which has this trend, and by the southwesterly fault at the Wheeler mine, shown in fig. 11. The Tabb fault has a local and probably general northerly dip.

In addition to these, minor faults occur either parallel to or at an angle with the main fault, and ore deposits of limited extent are frequently found along these minor fractures.

As is generally the

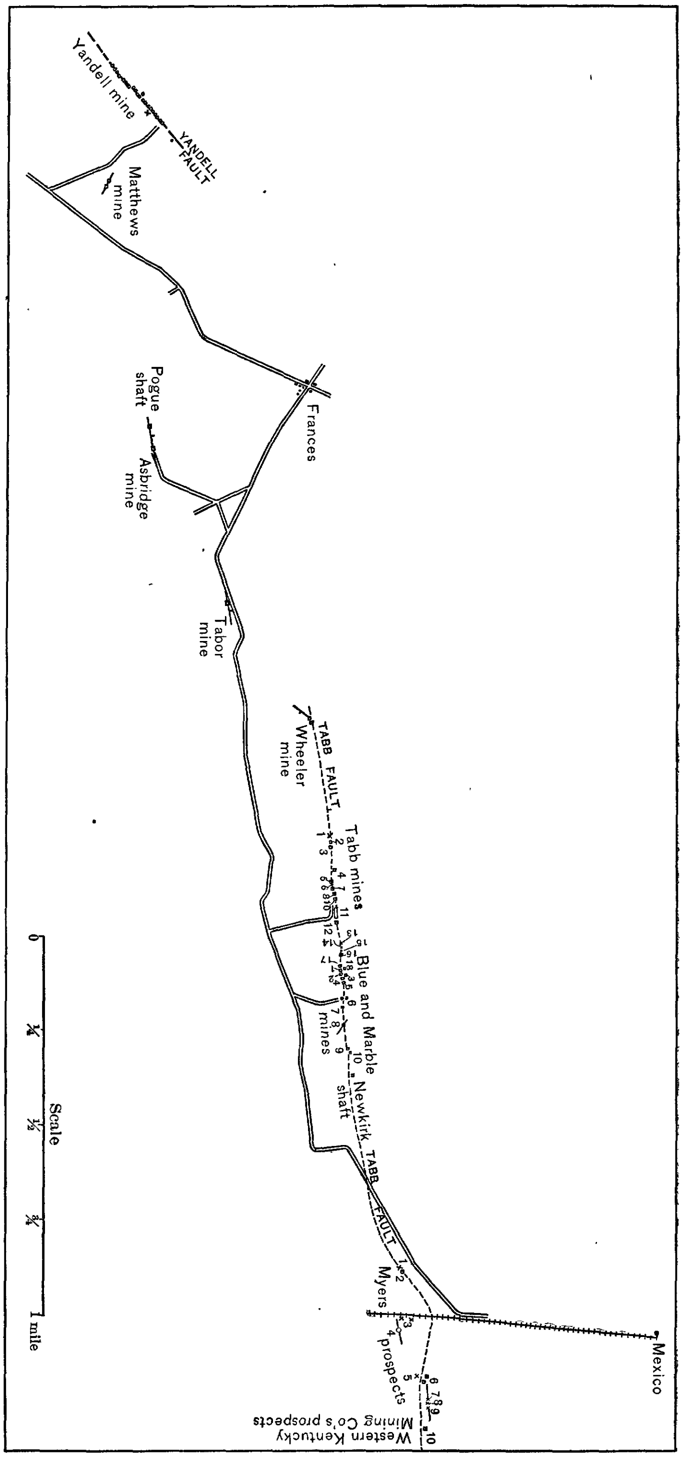


FIG. 11.—Tabb-Yandell group of mines.

case, the chief deposits have been found along or close to the main fault, though even here they are by no means continuous. The ore occurs either in simple veins or in two or more lying parallel and near together. The veins consist mainly of fluorite, accompanied at most of the mines by some galena and at the Tabb mines and eastward by more or less barite, which locally becomes dominant. In

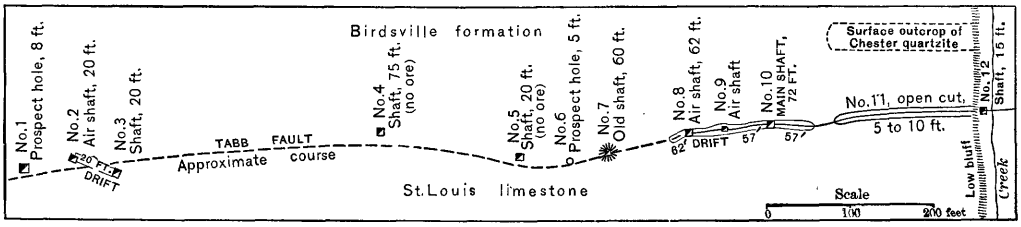


FIG. 12.—Part of the Tabb mines.

addition to these minerals fine-grained sphalerite occurs locally in small amount. Although found mainly in veins, the fluorite and barite occur here and there cementing breccias, particularly of Chester quartzite.

Tabb mines.—When these mines were visited, work was being done at three shafts—Nos. 3 and 12 and the main shaft, No. 10. Shaft No. 12 is situated on the western edge of a moderately broad, shallow valley, which divides the mines, while the prospect holes Nos. 13 and 15 are on its eastern slopes. The remaining openings of this mine on the east, together with those of the Blue and Marble mines, are along the upper edge of a slope facing an open valley on the south. Most of the openings of the Tabb mine are on or near the Tabb fault, and some ore has been found in all of those shown in fig. 12, though not in paying quantities in all cases.

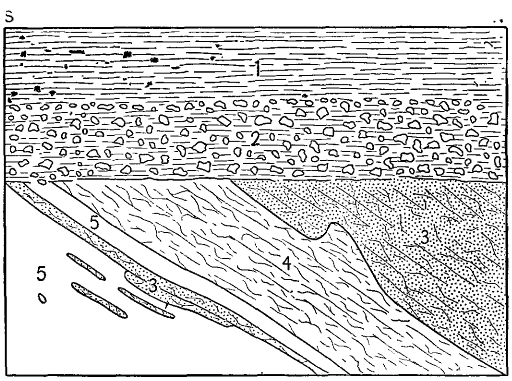


FIG. 13.—Fluorite replacing Birdsville quartzite, prospect hole No. 1, Tabb mine. 1, Yellow clay; 2, yellow clay and quartzite fragments; 3, quartzite; 4, fluorite; 5, mainly gray and yellow clay with some quartzite.

In addition to the common mode of occurrence of the ore, it has also been found replacing bedded quartzite, as at the westernmost opening of the series (see fig. 13), though this is not usual.

From the main shaft of the Tabb mine (No. 10) drifts run both east and west at a depth of 57 feet, a little above permanent water level, following an ore deposit formed along the main plane of the Tabb fault.

A general section across the deposit at this depth is as follows: First the northern wall of Birdsville limestone, the surface of which is more or less uneven. This is usually succeeded toward the south by sheeted shales dragged in along the fault plane. These shales in places contain one or more narrow veins of fluorite. Adjoining the shale is the main vein, of variable thickness and character, succeeded by between 1 and 2 feet of red clay, resulting from the decomposition of St. Louis limestone, and containing chert fragments. Last is the more or less corroded wall of St. Louis limestone. The vein has a constant northerly dip of 55° or more. In width it ranges from 0 to a maximum of about 12 feet, which is reached just east of the air shaft No. 8. The average width is between 6 and 8 feet. The vein usually shows more or less sheeting or banding. The banded ore represented in Pl. XIV B, p. 142, is from this mine.

The main ore body varies considerably through the mine, as is well shown in the accompanying figures. Fig. 14 shows the conditions at the face of the

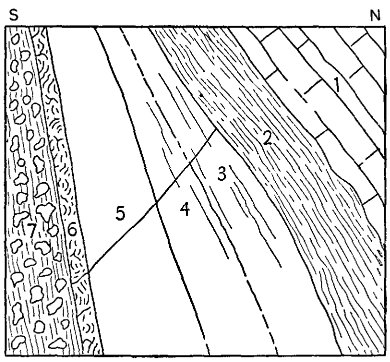


FIG. 14.—Section of vein, west face of drift at main shaft, Tabb mine. 1, Limestone; 2, mainly dark-gray shale with some mud; 3, fluorite with more or less limestone; 4, limestone—3 and 4 somewhat sheeted; 5, first grade white fluorite; 6, fluorite with barite; 7, red clay and chert fragments.

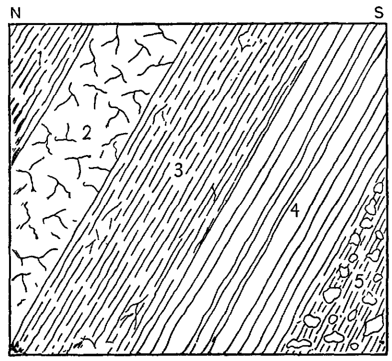


FIG. 15.—Section of vein, east face of drift at main shaft, Tabb mine. 1, Shale; 2, fluorite, 18 inches; 3, shale and red clay with some fluorite, 24 inches; 4, banded fluorite with some galena, 24 inches; 5, red clay with scattered chert fragments.

drift west of the air shaft. The limestone adjacent to the shale contains small pockets of gravel fluorite, while patches of barite, frequently with some fluorite, occur on and near its surface.

At the face of the stope, 27 feet east of the air shaft (No. 8), the full width of the vein is not exposed, but the part seen is nearly 6 feet wide. The fluorite forming the vein is roughly banded, and near the center of the vein some fine-grained sphalerite occurs in the fluorite, while toward either margin the fluorite contains scattered galena.

Near the face east of the main drift the vein shows more or less pronounced banding, as indicated in fig. 15.

A little north of the open cut (No. 11), as shown in fig. 12, is a dike-like outcrop of massive quartzite, having a width of from 10 to 20 feet. This quartzite contains occasional very thin seams of fluorite.

The three shallow prospect holes, Nos. 13, 14, and 15, have all yielded some gravel and cavernous lump fluorite. No. 13 is evidently on the main fault and No. 14 apparently a little north of it. The latter shows a 7-inch vein of fluorite containing abundant galena in small grains.

In shaft No. 17, at a depth of 15 feet, a short drift has been run in a direction N. 64° E., following an ill-defined vein of fluorite which wedges out toward the floor of the drift.

Blue and Marble mines.—These consist of numerous openings—shafts, open cuts, and prospect holes—none exceeding a depth of 50 feet and all located on or near the Tabb fault, which they have followed for a distance of about 1,100 feet. The rocks are everywhere deeply weathered, the walls in the drifts and shafts being as a rule of clay. The ore of the group is mainly fluorite, generally in lump form mixed with more or less red clay, the lump spar being frequently cavernous. Fluorite has also been noted locally cementing quartzite breccia, as at the shallow prospect No. 5; also at the abandoned Newkirk shaft of the Union Central Mining Company, northeast of the easternmost shaft of the Blue and Marble mines.

At most of the openings of these mines no well-defined vein has as yet been discovered. The Moseley shaft (No. 6) is the most important, and the only one at which there have been any extensive developments. Here a well-defined vein has been followed at the 30-foot and 50-foot levels by somewhat sinuous drifts running in a northwesterly-southeasterly direction for a distance of about a hundred feet. The vein has apparently an average width of about 5 feet, and its walls are of red, yellow, and bluish-gray clay. On the northern wall at the 50-foot level occasional patches of soft, white, muddy kaolinite occur. At the 38-foot level in this same shaft a drift has been run easterly for 12 feet, following a thin vein of fluorite a short distance north of and parallel to the vein just described and occurring in bluish-gray clay formed by the weathering of shale.

In shaft No. 8 a drift has been run southeasterly for 10 feet at the 42-foot level, following a vein in the St. Louis rocks, which has an approximate trend of S. 55° E. and a high northerly dip. This vein has probably been developed along a transverse fault in the St. Louis limestone, the main Tabb fault having here a northeasterly trend, and lying a short distance north of the shaft. Chester quartzite outcrops about 150 feet northeast of the shaft. As seen at the face of the drift, the vein is about 4 feet wide and consists chiefly of fluorite, which contains in places more or less fine-grained galena. Some rock fragments, mainly chert, were noted near both walls. Along the southern margin of the vein is a band, ranging from 2 inches to about 1 foot in width, composed mainly of somewhat cavernous barite.

Myers prospects.—East of the mines just described and near the railroad is a group of prospects characterized as a whole by the occurrence of barite. The easternmost prospect belongs to the Western Kentucky Mining Company, the rest being on the land of Mr. William Myers. These prospects comprise shallow holes and open cuts and a number of shafts, all except one caved. The relations of these openings to the Tabb fault is shown approximately in fig. 11.

In all of the prospects in the Chester rocks, including those west of the railroad, some ore is found, either barite or fluorite, or both, occurring as a rule cementing quartzite breccia.

In the St. Louis rocks the ore is mainly barite, as in the railroad cut (No. 3). In this cut barite was noted at a number of points, for a distance of 200 feet north and south. It occurs apparently as thin easterly-westerly seams and narrow veins, with an approximate maximum width of perhaps 2 feet and a nearly vertical dip. The actual conditions in the cut are somewhat obscured by the breaking down of its walls.

Prospect No. 4 consists of a broad and shallow open cut in red clay and chert, exposing an irregular vein about 3 feet wide at the western side of the cut, and nearly 5 feet wide on the eastern side, with a strike of about N. 75° E. The vein consists largely of barite, which is rudely banded parallel to the strike of the vein. This banding is due largely to seams of fluorite in the barite, most of which are less than 2 inches wide and from 1 to 3 feet in length.

Wheeler mine.—The Wheeler mine consists of two shafts, together with several prospect holes and open cuts, all more or less caved. It is located about half a mile southwesterly from the main shaft of the Tabb mine. The work at this place was done at different times during the last few years by contract for the Kentucky Fluorspar Company. Shipments were made up to the middle of 1902, but the mine was finally abandoned on account of water, as it had no pump.

The northeastern shaft, No. 1, is apparently located at the intersection of two veins, one following the Tabb fault and the other filling a southwesterly fissure in the St. Louis limestone. Short drifts were run from the shaft to the east and west along the Tabb fault, and one to the southwest on the intersecting fault. The southwesterly vein, which is said to have contained no calcite, had a width of about 1 foot at the shaft and of 2 to 2½ feet at the face of the drift. In the easterly-westerly drifts the vein is said to have been 6 feet wide at the shaft, consisting mainly of fluorite, and to have pinched in both directions toward the face of the drifts, where it was composed largely of calcite. At the surface a short open cut gives the strike of this vein as approximately N. 75° E., and its coincidence with the Tabb fault is indicated by the occurrence of both Birdsville and St. Louis rocks in the dump from this shaft.

Shaft No. 2, 70 feet southwest of shaft No. 1, is doubtless located on the same vein, which is found in the southwesterly drift from the latter shaft. Evidence of faulting is seen in an open cut a short distance southwesterly from shaft No. 2, where a body of somewhat brecciated chert cemented with purple fluorite presents a well-defined slickensided surface, having a southeasterly dip of 84°. The strike of the southwesterly vein may be given approximately as S. 39° W.

All of the fluorite at this mine is associated with some galena and a little fine-grained sphalerite, the latter also occurring disseminated in some of the limestone.

Tabor mine.—The Tabor mine, situated three-eighths of a mile southwesterly from the Wheeler, is the only one in which well-defined yellow crystals of fluorite were seen. Fluorite crystals up to about 2 inches in diameter are common on the dump at this mine, both on chert and limestone. They are as usual cubic, and their color is for the most part yellow, though a minor proportion are purplish, or yellow with surface films of purple. The yellow fluorite appears to have developed chiefly along the fractures of brecciated St. Louis chert.

The mine was not being operated when visited by the writer. The following statements are based on the notes of Mr. Fohs, who examined it later. At a depth of 60 feet an easterly drift 25 feet long and a westerly one of 30 feet have been run, following a well-defined fluorite vein. At 80 feet a cross cut of 46 feet was made toward the north, nothing but clay and chert being found, except for a little fluorite near the shaft where the vein should normally have been met.

At the 95-foot level a cross cut 6 feet long was made toward the north before the vein was encountered, drifts being then run along the vein 53 feet toward the west and 18 feet toward the east. A cross cut of 40 feet toward the north is said to have been made also, at a depth of 114 feet.

The oxidized zone is unusually deep at this mine, permanent water being found at a depth of 101 feet, above which the walls of the vein were formed entirely of red clay and chert. The vein also is considerably weathered, consisting mainly of white or purple, gravel fluorite mixed with more or less red clay. The strike of the vein is N. 79° E., with a northerly dip of 65° to 68° where noted. Its width at the 60-foot level ranged from 6 inches to 8 feet, and at the 95-foot level from half a foot to 2½ feet. In the short easterly drift at the 95-foot level the vein has a width of 1½ feet, and consists of purple fluorite in bands from half an inch to 4 inches wide, separated by thin layers of red clay. In the easterly drift of the 60-foot level also the fluorite occurs in bands alternating with red clay. Yellow fluorite is said to have been found chiefly at the 114-foot level. It was also seen at the 95-foot level, a little south of the vein, in chert and red clay.

The Asbridge mine.—The Asbridge mine, belonging to the Eagle Fluorspar Company, is located nearly half a mile southwest from the Tabor shaft. It consists of two shafts and a number of drifts, as shown in figs. 16 and 17.

The shaft was sunk for the first 30 feet by the Kentucky Fluorspar Company, but was abandoned by them before ore was found. The Eagle Fluorspar Company began operations here in July, 1900, since which time the work has been fairly continuous.

Fluorite, which forms the ore here, was first encountered in the shaft at a depth of 50 feet. Permanent water level is found at about 100 feet, and all the

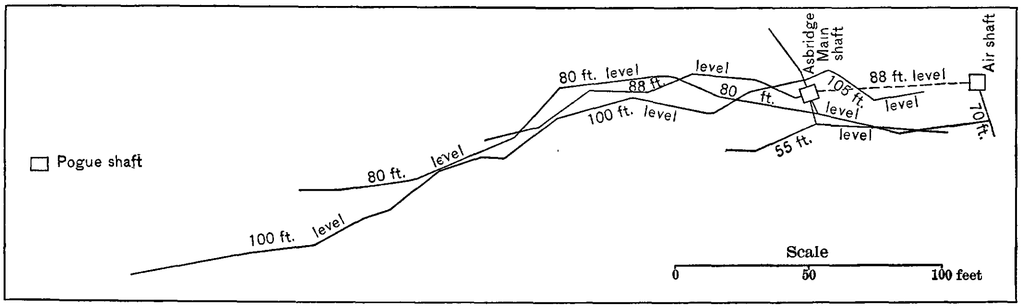


FIG. 16.—Plat of Asbridge mine, showing courses of drifts.

drifts except one have been run above this level. The rocks are therefore greatly oxidized wherever seen, and the ore consists of the gravel and lump fluorite characteristic of the zone of oxidation. The fluorite is of both first and second grade. Much "wash gravel" could be obtained here, but as there is no spar washer only the best fluorite is mined.

The fluorite occurs as a vein, from about 2 to about 10 feet wide, apparently with a high northerly dip, and following approximately the fault plane between

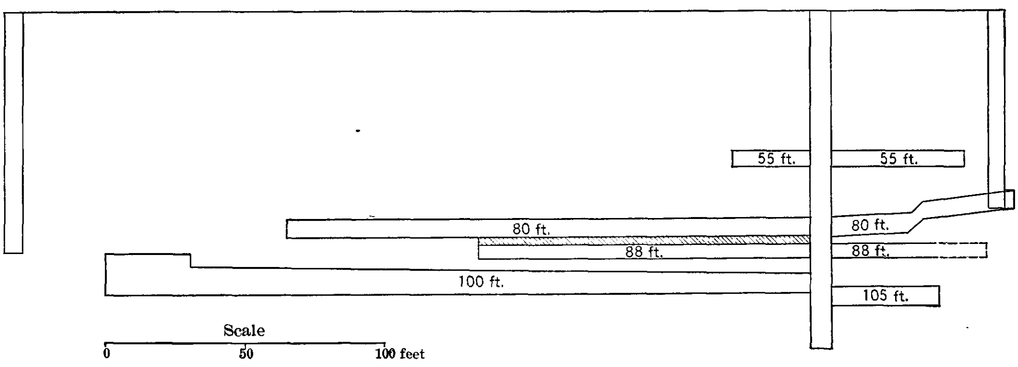


FIG. 17.—Vertical section of Asbridge mine.

the Birdsville and St. Louis formations. The Birdsville rocks form the northern wall of the vein, and their occurrence in the drifts is usually marked by yellow, sometimes sandy, clay, also by a sticky bluish clay, in addition to some red clay. Fragments and blocks of quartzite are occasionally seen.

The St. Louis limestone, forming in general the south wall of the vein, is represented by red clay and chert fragments, with occasionally a little limonite. As usual where the rocks are much weathered, scattered grains and patches of gravel fluorite occur in the clays near and on either side of the vein. At the 100-foot level, near the northern margin of the vein, and for the western 160 feet of the drift, occasional nearly white vein-like streaks occur in the gravel fluorite and red clay, having the appearance of short, thick veins, dipping toward the main fluorite vein. They average an inch or two in width, and range in length from a few inches to several feet. They are said to occur occasionally also in the central portion of the vein, or to extend from either wall toward the center. They are composed of pale cream-colored fluorite in the form of fine dust and sand, with occasional small fragments. Patches of fine fluorite sand, similar to those noted at the 100-foot level, were also seen at the 85-foot level in the south wall of the drift.

Small pockets of white or cream-colored kaolinite, containing scattered grains of fluorite, were noted in the clay north of the vein at the 100-foot level.

Pogue shaft.—The Pogue shaft,[a] the relation of which to the Asbridge mine is shown in fig. 16, has been sunk to a depth of 85 feet by the Marion Mineral Company without finding any body of fluorite, its location being apparently a short distance north of the fault noted at the Asbridge. In the bottom of the shaft (the only portion seen on account of timbering) some gravel fluorite occurs in grains and small patches scattered through shale, gray clay, and pale buff, sandy clay. The last, similar to some of the clays noted in the Asbridge mine, is seen under the microscope to consist entirely of quartz in microscopic crystals and grains.

Matthews mine.—The Matthews mine, which was closed at the time of the writer's visit, is nearly three-fourths of a mile west from the Asbridge mine and a fourth of a mile easterly from the Yandell. During the years 1900 and 1901 a shaft 80 feet deep was sunk and short drifts were run at the 45-foot and 80-foot levels. A 3-foot vein of fluorite is reported to have been found at the bottom of the shaft. Sixty feet N. 64° W. of this shaft is an older one, now caved, doubtless on the same vein as the shaft just described. A considerable amount of fluorite—mainly white, with a very little purple, and both in the form of gravel and lump spar—has been taken from both shafts, 300 tons having been shipped, it is claimed, from the older of the two.

Yandell mines.—The Yandell mines, the westernmost of those shown in fig. 11, are given in more detail in fig. 18. The first prospect hole at this place was dug forty or fifty years ago, and fluorite and some galena were taken out. It was later leased and worked for a time for lead by the Dycusburg Lead Company. Fluorspar was first shipped from the mine by Henry Glass, about 1873, and about a year later the property was taken up by the Cincinnati Fluorspar Company,

[a] A good body of fluorite has since been found at this mine, and it now ranks as a regular shipper. The production during the summer of 1903 is reported to have averaged about 800 tons per month.

who shipped hundreds of tons during the next two years. The spar was hauled 5 miles to Dycusburg and shipped by the Cumberland to the Ohio River. Since 1896 the mine has changed hands several times, being worked at present by the Kentucky Fluorspar Company.

When this mine was visited work was being done only at the main shaft, No. 16, and at shaft No. 21. The drifts which were accessible are shown in fig. 18,

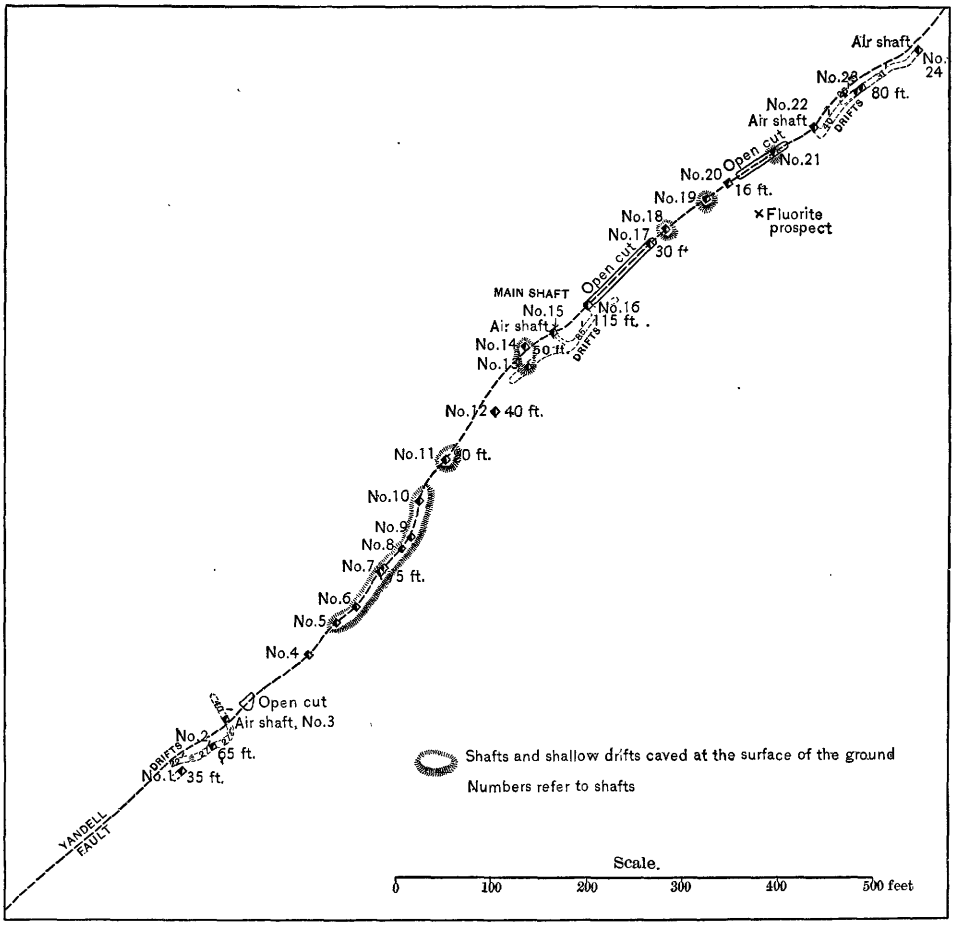


FIG. 18.—The Yandell mines.

the majority of the older drifts and shafts having caved. Mining has been carried on here at intervals for a distance of about 1,100 feet, following a fluorite deposit which occurs along a doubtless somewhat complex fault of small total displacement, with a general trend of about N. 45° E. The rocks forming the vein walls are deeply weathered, and most of the openings show mainly red clay with occasional blocks of limestone. Even in the deeper workings—at the 85-foot level from the main shaft—the walls southwest of the shaft are wholly of clay for the larger part of the drift. Where unaltered walls are exposed they consist of Ste. Genevieve limestone, some of it more or less seamed with calcite. Southwest of the main shaft a considerable amount of chert was also noted, occurring as fragments with the clay or as nodules in some of the limestone. Northeast of this shaft no chert was seen.

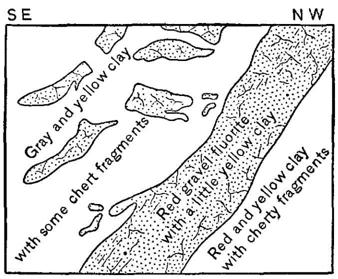


FIG. 19.—Southwest face of drift, shaft No. 2, Yandell mine. Shaded portions represent gravel fluorite; clear portions clay with fragments of chert.

As seen in the northeastern drift from the main shaft, the Yandell fault has cut sharply across the beds of limestone on either side. On the northwest wall at the 40-foot level just east of shaft No. 22, however, the limestone, which is apparently quite argillaceous, has been sheared close to the vein, as shown in fig. 21, instead of being cut sharply across.

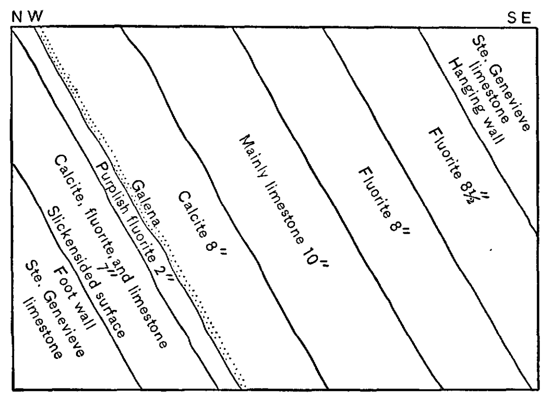


FIG. 20.—Section, northeast face, 85-foot level, Yandell mine.

Wherever noted the vein dips southerly at a high angle, ranging from 55° to 80°. Its width in the drifts from the main shaft ranges from 0 to 10 feet, the average being about 5 feet. Toward the northeastern end of the group the vein is considerably narrower, having an average width of about 3 feet, in the drifts from shaft No. 23. The vein consists of fluorite in general free from calcite where it has been mined. This is doubtless due to the removal of the calcite by solution in the weathered portions of the vein, and, judging from the only exposure seen of unoxidized vein and walls (fig. 20), calcite may be expected to be relatively abundant below ground-water level. Very little galena has been found with the fluorite at these mines, and the small amount met with usually occurs near the surface.

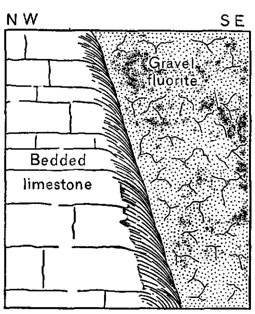


FIG. 21.—Sheared limestone adjacent to the vein, shaft No. 22, Yandell mine.

At the face of the drift southwest of shaft No. 2 numerous irregularly-shaped patches of gravel fluorite occur in the hanging wall near the vein, scattered in a matrix of gray and yellowish clays, as shown in fig. 19. These are found at a depth of about 22 feet, and are probably due to a partial breaking up of the vein near the surface and a scattering of the broken portions in the adjacent clays.

HODGE GROUP.

General features.—The mines and prospects of the Hodge Group, shown in fig. 22, are located on a number of approximately parallel fissures, of which the main one (the Hodge fault) separates the St. Louis limestone on the north from the Cypress and Ste. Genevieve formations on the south. The two most important mines of the group, the Hodge and the Brown, are situated on or very close to this fault, while the Riley and Lovelace shafts, the Redd open cut, and the Reiter

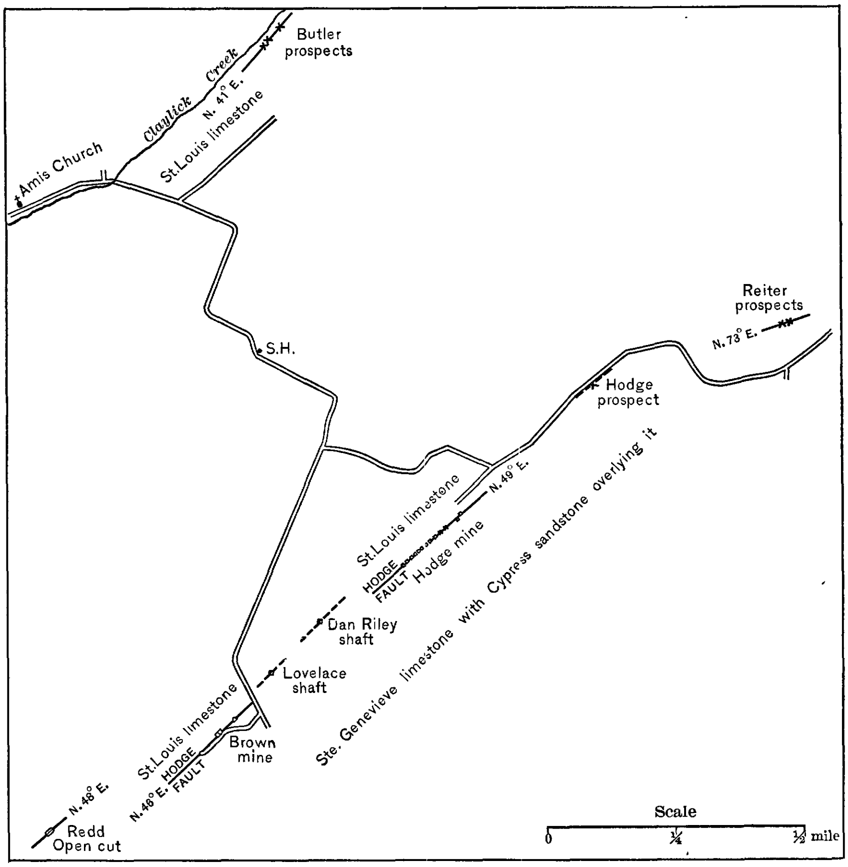


FIG. 22.—Hodge group of mines.

prospects, all in the St. Louis limestone, are probably on minor faults a short distance north of the main fault. Fluorite deposits of greater or less extent have been found at all the openings of the group, the fluorite in most of them being associated with some galena. The vein at the Hodge mine is the widest seen in the district, reaching a maximum width (so far as developed) of 19 feet.

Some distance northwest of this group are two isolated workings on fissures nearly parallel to the Hodge fault. One of these consists of several shallow holes (known as the Butler prospects) in altered St. Louis limestone, about 1 mile northwest of the Hodge mine, three of these holes being on a small and unimportant vein of fluorite with a trend of N. 41° E. The other is the Ebby Hodge mine, about half a mile a little east of north of the Butler prospects, partly in a Chester sandstone and partly on a fault between Chester and St. Louis rocks.

Hodge mine.—The Hodge mine, leased by the Kentucky Fluorspar Company, is situated about 2½ miles southwesterly from View. A plat of the mine with details of the more important workings is shown in fig. 23. The first work was done here in 1898, when operations were confined largely to the open cut at the surface

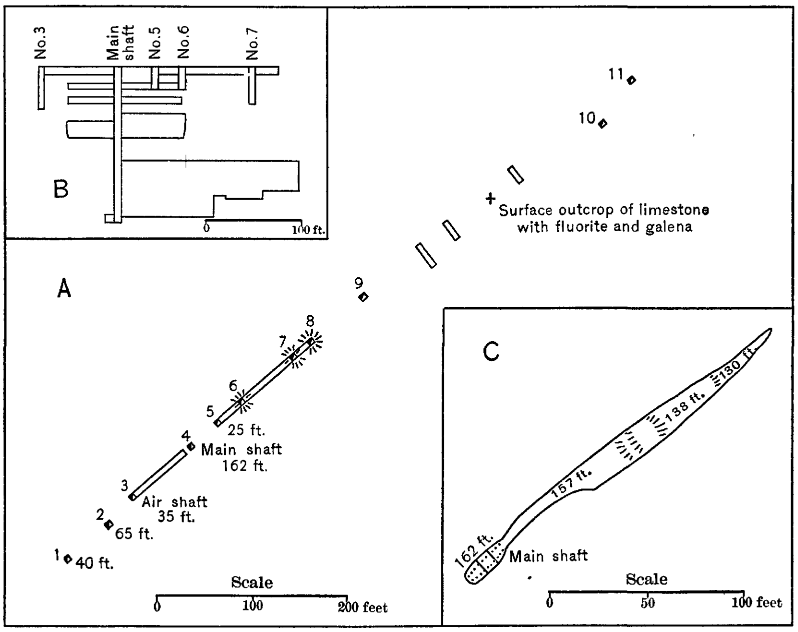


FIG. 23.—Hodge mine. A, surface features; B, vertical northeasterly section through the main shaft; C, plan of lowest level of main shaft.

(shown in fig. 23), and a considerable amount of surface fluorite was shipped at that time. These older openings have now caved for the most part.

When this mine was visited, work was being done at shafts No. 2, 3, and 4. Permanent water level is at a depth of about 100 feet, very little oxidation being noted in the lowest and only accessible drifts of the main shaft, which range in depth from about 130 feet to 162 feet. The plan and stopes of these lowest levels are shown at B and C, fig. 23. The ore from the main drift occurs as a well-defined vein of very variable width, as shown at C, fig. 23. The maximum width shown in the figure is 14 feet 9 inches, though the width of 19 feet is said to have been reached at one point in this drift. The observed dip of the vein ranges from 75° toward the southeast to 88° toward the northwest. Both walls, which are of limestone, slickensided here and there and somewhat seamed with fluorite and calcite, are well defined and sharply differentiated from the vein. The southeastern wall is somewhat more uneven than the northwestern. The vein is frequently sheeted close to one or both walls, the sheets ranging from about one-half to $1\frac{1}{2}$ inches in thickness, with slickensided surfaces. The material of the vein is largely massive, granular fluorite of variable grain. It is of first quality, translucent, and nearly all white. A small proportion of galena is associated with the fluorite here and there, and where this occurs in sufficiently large pieces, the ore is saved for crushing and jigging. Occasional pockets or seams of coarse white calcite, also fragments of limestone, occur in the fluorite, usually toward one or both walls. Besides these minerals, fine-grained sphalerite occurs disseminated in the limestone of both walls, mainly the southeastern, and also in the fragments of limestone in the fluorite. The ore as taken from the mine is fairly clean, requiring usually only a rough sorting of the lumps according to size, any fragments of rock or calcite being removed by hand.

Lovelace and Dan Riley shafts.—The Lovelace and Dan Riley shafts, between a quarter and a half mile southwest of the Hodge mine, were both sunk in 1899 and 1900, by the Eagle Fluorspar Company, on what was supposed to be the Hodge vein, but is probably a parallel fissure, or perhaps two parallel fissures, in the St. Louis, a short distance north of the Hodge fault. At the Riley there is a short tunnel just southwest of the shaft, following a vein which has here a strike of about N. 46° E., the shaft itself being a little to one side of the vein. At the Lovelace shaft no definite vein was found. From near the surface at both places, however, a considerable amount of gravel and lump fluorite was mined and shipped. The ore is similar to the surface ores obtained from the Hodge and Brown mines.

Brown mine.—The Brown mine consists of an old shallow shaft and a shallow open cut, the latter about 330 feet long. The average strike of the exposed portion of the vein is about N. 46° E. Although the vein is apparently in St. Louis limestone, no Chester rocks having been noted from the cut, it must be close to if not on the Hodge fault, since Cypress sandstone occurs 175 feet southwest of the cut. The ore is, as usual, fluorite, both gravel and lump. Some galena occurs scattered in the fluorite or in the clay.

Redd open cut.—The Redd open cut, three-eighths of a mile from the Brown mine, was dug during the summer of 1901 for the Western Kentucky Mining Company. It follows a vein having an approximate trend of N. 48° E. and filling a fissure in the St. Louis limestone parallel to the Hodge fault. Some of the best fluorite has been shipped, much wash gravel and lump fluorite still remaining on the dump. While some of the lump fluorite is free from foreign matter, most of it contains more or less impurity, mainly in the form of fragments of chert.

Ebby Hodge mine.—A typical occurrence of fluorite in faulted Chester rocks is seen at the Ebby Hodge mine, about half a mile east of north of the Butler prospects. This mine was not located accurately with reference to the Butler prospects, nor were the adjacent fault lines followed, so that their structural relations are not definitely known.

The mine consists of two series of openings, an eastern and a western, having the relations shown in fig. 24, and located on an easterly facing slope, the eastern series toward its base and the western well up on the slope..

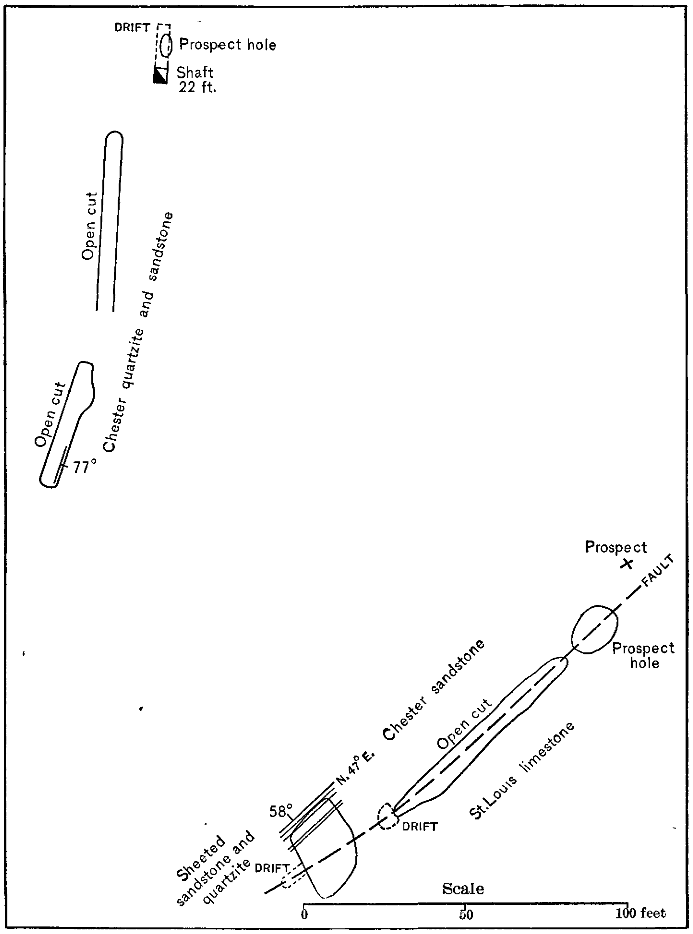


FIG. 24.—Ebby Hodge mine, showing surface and underground features.

The western group of openings has followed a belt of coarsely sheeted Chester sandstone and quartzite marking a zone of minor faulting. Some of the surfaces of parting are fluted and striated as a result of the movements along them. Their strike is variable, but where noted, near the northwestern end of the group, averages about N. 37° E., the dip ranging from 77° southeasterly to 75° northwesterly. In addition to the sheeting, the rocks are coarsely brecciated more or less thoroughly.

Fluorite has been deposited along the fault planes and also cements, more or less completely, the brecciated sandstone and quartzite. These fluorite seams are occasionally a foot or more in width.

The eastern series of openings consists of a number of prospect holes and two open cuts, the latter with short drifts at their southwestern ends. All of the openings from which ore has been obtained are located on a fault of several hundred feet throw between St. Louis and Chester rocks. A fluorite vein, with a strike of about N. 53° E. and a noted width at one point of 6 feet, follows this fault plane.

RILEY GROUP.

General features.—Norwood[a] has described three occurrences of fluorite northeast of Pinckneyville—at (1) the Tisdall shaft, 57 feet deep, and about 2 miles north of Pinckneyville; (2) the Robert Woods shaft, 35 feet deep, about half a mile northeast of the Tisdall, and (3) the Henry Woods shaft, near the last and about 3 miles northeast of Pinckneyville. All these are on what he has called the Excelsior lode, following a fault between Chester and St. Louis rocks.

Woods shaft.—Of these three old shafts only one, the Henry Woods, was seen by the writer, and this was not being worked at the time. This shaft belongs to the Riley group, shown on the map, about 3½ miles southeast of Salem and a short distance south of Puckett Spring.

The Riley mine, at present the only important member of the group, is located in Crittenden County, northeast of Puckett Creek, all the others being southwest of the creek, in Livingston County. As seen on the map, these openings are located on three nearly parallel faults.

Henry Hodge and Woods prospects.—Two hundred or three hundred yards west of the Woods shaft is a line of new and old prospect holes with a northeasterly trend, constituting the Henry Hodge and the Woods prospects. All are probably on a fault in the Chester, with a trend of approximately N. 43° E. Some ore has been found in four of these holes, either fluorite or smithsonite, or both. At one of the prospects galena is associated with the fluorite.

Riley mine.—The Riley mine, owned by the Marion Zinc Company, consists of a shaft 75 feet in depth, with a drift 26 feet long toward the northeast at a depth of 30 feet. It is located on a fluorite-bearing fissure between the St. Louis limestone on the southeast and the Birdsville formation on the northwest. The general width and dip of the vein as developed in sinking the shaft are shown approximately in fig. 25. The strike is N. 44° E. In the lower 10 feet of the shaft the vein has a width of from 3 to 3½ feet; toward the top of the shaft it apparently widens considerably.

[a] Norwood, C. J., Report of a reconnoissance in the lead region of Livingston, Crittenden, and Caldwell counties: Geol. Survey Kentucky, vol. 1, pt. 7, 2d ser., 1876, pp. 465–469.

The southeastern wall of the vein consists of red clay and chert with scattered blocks of St. Louis limestone. This limestone where seen contains practically no calcite, only an occasional thin seam parallel to the fault plane having been noted. The northwestern wall consists of quartzite and gray shale belonging to the Birdsville formation. Toward the bottom of the shaft next to the vein on the northwest, and between it and the main body of Birdsville rocks, is a strip of shale about 3 feet wide, apparently dragged in along the fault plane.

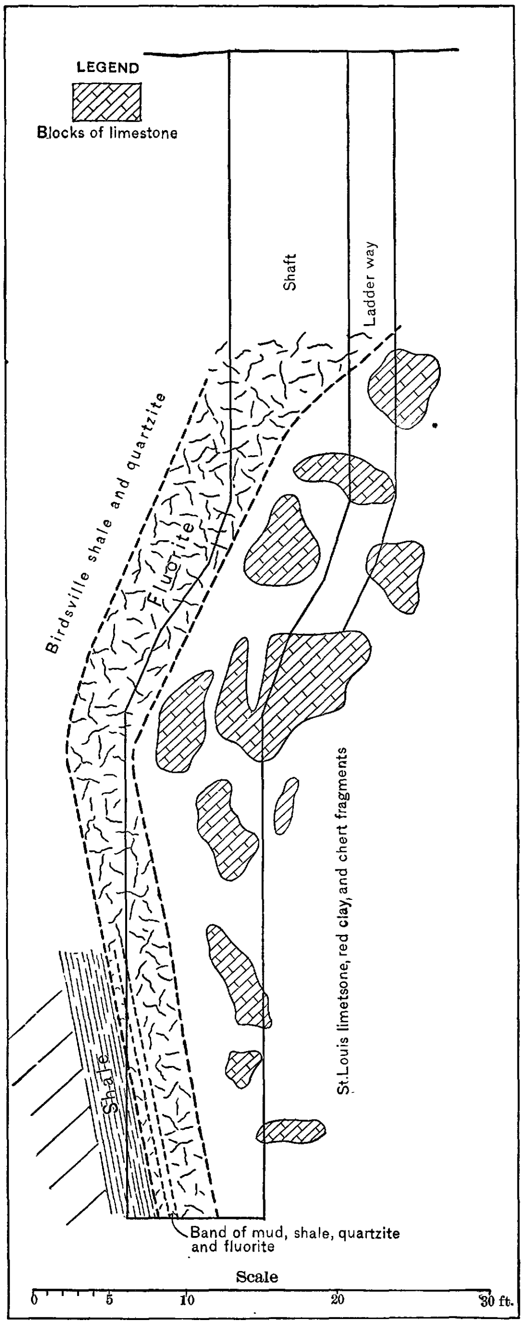


FIG. 25.—Vertical section of Riley shaft, showing cross section of fluorite vein. Barred areas are blocks of limestone.

The vein as a whole consists mainly of fluorite, and contains a variable though on the whole considerable proportion of galena—more than is commonly seen in the fluorite veins. The fluorite is locally associated with more or less coarse white calcite. This occurs in places intergrown with barite, the latter containing occasionally a little galena. Here and there, especially toward one margin or the other, scattered fragments of chert or quartzite occur in the vein. The fluorite in places shows a pronounced banding parallel to the vein walls. At the face of the drift at the 30-foot level a good section of the vein is exposed, as shown in fig. 26.

EVENING STAR GROUP.

General features.—The mines and prospects of the Evening Star group, about 1½ miles southeast of Salem, are located on one or more veins, filling fissures along or close to the Evening Star fault, which has a general southeasterly dip, with an average trend here of about N. 40 E., and lies between the Cypress and Ste. Genevieve formations on the southeast and the St. Louis limestone on the northwest. The relation of the mines of the group are shown in fig. 27.

The ore from this group is mainly fluorite, carrying a small and variable proportion of galena and usually associated with a good deal of calcite, which in places

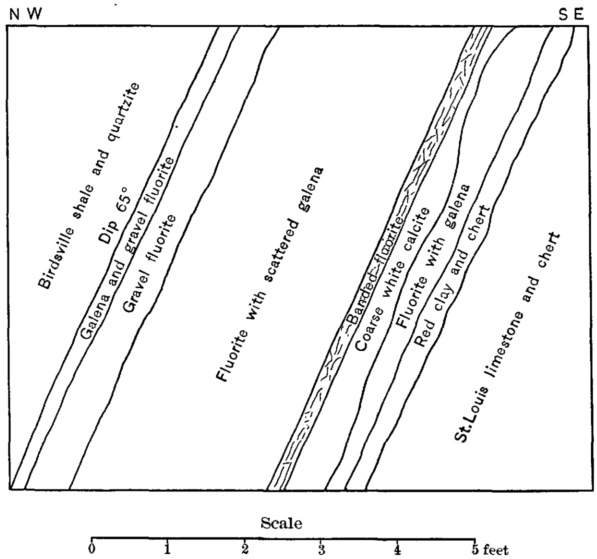


FIG. 26.—Section of vein at face of northeast drift at 30-foot level, Riley mine.

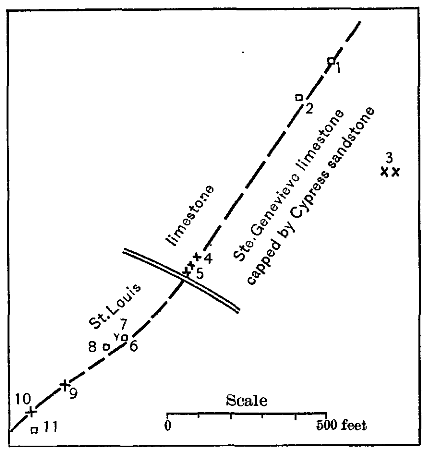


FIG. 27.—Evening Star group of mines. 1, Evening Star, main shaft; 2, Evening Star, shaft No. 2; 3, 5, and 10, fluorite prospects; 4 and 9, surface outcrops of jasperoid and fluorite; 6, Morning Star No. 2 shaft; 8, Morning Star No. 2 shaft 7, Morning Star incline; 11, Nancy Hanks shaft.

forms the bulk of the vein. Galena also occurs to a more limited extent in limestone and with calcite. Sphalerite is common and in places abundant, occurring partly in and with fluorite, but mainly replacing limestone. Limestone fragments are common in the ore, and while the vein is probably fairly well defined in general; it would seem that in places it grades into a cemented breccia of more or less silicified Ste. Genevieve limestone (jasperoid). The limestone with and adjacent to the ore body is locally replaced by coarse calcite in patches. The limestone of the breccia and the limestone fragments in the calcite or fluorite, besides being replaced to a greater or less extent by quartz, together with fine-grained sphalerite, usually contain more or less disseminated fine-grained fluorite. That some movement has taken place along the fault plane since the deposition of the ore is indicated by slight faults noted in some of it, also by the occurrence of galena with warped cleavage surfaces and occasionally drawn out to a fibrous condition.

Evening Star mine.—Of the two shafts at the Evening Star mine the southwestern or shaft No. 2 was sunk a little to one side of the vein; no ore being found. The northeastern or main shaft was sunk on the vein, following its foot wall, which is said to have been well defined, no definite hanging wall having been found. Two southwesterly drifts have been run on the vein from this shaft, one at the 50-foot level with a length of 25 feet, the other at a depth of 89 feet for a distance of 150 feet. As the mine was not open when visited no definite statement can be made as to the mode of occurrence of the ore here. The general character of the ore taken from the mine is that already indicated for the group. Some prospecting has been done at an outcrop on the south side of the creek a short distance northeast of the main shaft, where there is an exposure of ore about 12 feet in width. No definite vein was seen, the fluorite associated with some galena being irregularly distributed in a more or less weathered limestone, which contains some sphalerite. A sheeted zone, about 1 foot in width, occurs in the rocks at one point.

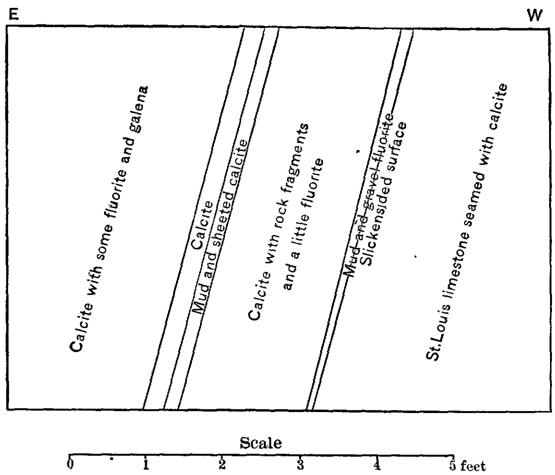


FIG 28.—Section of vein at bottom of Nancy Hanks shaft.

Work was begun at this mine in January, 1899, by the Eagle Fluorspar Company and since that time it has been worked intermittently. When visited machinery was being installed for the separation of fluorite, galena, and fine-grained sphalerite.[a]

Morning Star mine.—The Morning Star mine, belonging to the American Lead, Zinc, and Fluorspar Company, consists of two shafts and an incline. Work began here in the spring of 1900 and was continued until about the middle of 1901, when operations ceased. A good deal of fluorite was obtained, and the best, between two and three hundred tons, was sold to the Evening Star mine, the balance being marketed for fluxing purposes.

While the ore in general has the characters common to the group, a large part of the fluorite noted has the appearance of a limestone seamed with moderately coarse-grained fluorite, the limestone having been replaced with fluorite of a finer grain. Limestone breccia cemented by fluorite, and fluorite containing fragments of limestone are common, the rock in both cases more or less completely altered to jasperoid mixed with some fluorite and fine-grained sphalerite. A considerable amount of coarse white calcite occurs at this mine associated with the fluorite or replacing limestone.

[a] A new shaft is being sunk by the Eagle Fluorspar Company at this mine. When last visited by Mr. Fohs this shaft had reached a depth of 100 feet, the entire distance being through Ste. Genevieve limestone. The shaft is off the vein but near enough to intersect it at a depth of 150 feet or less. At 100 feet the proximity to the vein is indicated by a mud pocket encountered at this depth and also by the fact that the limestone is here seamed with calcite and contains occasional grains of sphalerite.—E. O. U.

Ore similar in a general way to that from this mine was obtained from prospect No. 5 (fig. 27).

Nancy Hanks shaft.—The Nancy Hanks shaft, located a few yards east of a surface outcrop of fluorite, was sunk for the first 45 feet in the summer of 1900, and when visited by the writer it had reached a depth of 85 feet. At the bottom only a part of the vein and the western wall are exposed, this portion of the vein having a width of about 5 feet. The western wall is of dark-gray limestone containing some chert and seamed with calcite, the larger seams parallel to the walls of the vein, the finer ones running in all directions. The vein (see fig. 28) has a southeasterly dip of about 75°, and is composed mainly of coarse calcite considerably banded and associated with some fluorite and galena. One of these bands contains fragments of jasperoid. Close to the western wall the vein shows a few inches of gravel fluorite.

MINES AND PROSPECTS SOUTHWEST OF SALEM.

Southwest of Salem there are comparatively few mines and prospects, and these are rather widely scattered. So far only a few veins of importance have been developed, although it is probable that other well-defined veins occur in this direction.

Royal mines.—The Royal mines, commonly spoken of as the Old Silver mines, and in the early days of their history known as the River Valley mines, are among the oldest in the district. They were situated nearly 3 miles northeast of Smithland, just west of and above the Cumberland River. When the region was visited by Norwood the mines were not in operation. He reports that one of the three shafts sunk had a depth of 175 feet, being at that time the deepest in the western Kentucky district. One of the shafts had already caved, and since that time all the rest have caved completely. As these mines were exploited only for silver, this early mining was unprofitable.

The shafts were located on an ore-bearing fissure having a strike of about N. 62° E., with Cypress sandstone on the southeast and Ste. Genevieve limestone on the northwest. As noted at the old southwestern shaft, the quartzite forming the southeastern wall was considerably brecciated and seamed with fluorite at least 6 or 8 feet out from the fault plane. The limestone forming the northwest wall is seamed with calcite. Just northwest of the central shaft the limestone which here forms a low cliff is jointed, the joints nearly vertical and approximately parallel to the main fissure. Some of them contain thin veins of calcite, in places associated with some fluorite and fine-grained sphalerite, or less often with barite. According to Norwood's description, the main vein here does not differ in composition from those most commonly found in the district, consisting mainly of fluorite together with a small and variable amount of galena.

In 1902 the Owens Cave Mining Company obtained a mineral right on this property, and a new shaft was sunk about 150 feet from one of the old shafts, to a depth of 50 or 60 feet in the quartzite wall of the vein. The quartzite in this shaft is brecciated and somewhat cemented with fluorite.

Benard or Klondike mine.—The Benard mine, 6 miles southwest of Salem, on land leased by the Pittsburg Mining and Reduction Company, consists of a number of shafts and a tunnel, shown in fig. 29, the shafts being located near the summit of a short spur running southwestward, and the tunnel having been driven into the base of the same spur near its southwestern extremity. From the mine there is a tramway to the Cumberland River, 1½ miles distant, where the ore (fluorite) is shipped. When the mine was visited operations were confined to sinking the Johns shaft.

All the openings are located in Chester (Cypress?) quartzite along a zone of faulting (the Pittsburg fault). This faulting has sheeted and brecciated the Chester sandstone, which has been silicified along the zone into a massive quartzite. Scattered outcrops of this rock are found near the crest of the ridge, and on one of these the Johns shaft is located. Patches of Chester shale or thin sheets dragged in along the fault planes occur here and there with the quartzite. At the end of the spur the quartzite forms a low cliff just above the tunnel. The sheeted structure here is shown in Pl. XII, *A*. The general strike of the fault appears to be about N. 32° E., though that of the planes of sheeting is very variable, ranging from N. 15° E. to N. 44° E. No definite vein was noted either at the Johns shaft or at the tunnel, the ore being found only in small amount at either place, occurring as thin seams in the fractured quartzite. These seams consist mainly of fluorite with some galena. A very little galena also occurs disseminated in the quartzite. At the tunnel seams of barite or of barite and fluorite are found in the quartzite, these seams having a maximum width of about 1¼ inches. To judge from the dumps at the deeper shaft, limestone somewhat seamed with calcite occurs at no great depth, and from this zone a good deal of coarse calcite is obtained. The calcite is associated with more or less fluorite, and contains here and there small angular fragments of limestone. Bowlders of seamed limestone were also noted in the tunnel northwest of the winze.[a]

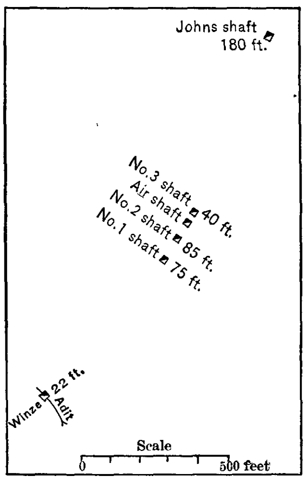


FIG. 29.—Benard mine.

[a] Recent developments at the Klondike mine, as reported by Mr. F. B. Moodie, Mr. Lorson Franklin, the foreman of the mine, and others, are as follows: The main shaft, known as the "John shaft," which is the only one now being operated, is to be sunk 300 to 400 feet. Before the close of 1903 it had reached a depth of 160 feet, when cross-cuts were driven southeast and northwest. The southeast cut is 35 feet in length and passes through the vein in the Pittsburg fault plane which

Coker shaft.—The Coker shaft, also leased by the Pittsburg Mining and Reduction Company, is an old shallow shaft sunk in part about 1878, and the rest in 1901. It is located about 1⅓ miles northeast of the Benard mine, in Chester quartzite. No vein was seen here, though some faulting has taken place, as indicated by slickensiding on some of the quartzite. Some fluorite occurs here as a cement to the somewhat brecciated quartzite, being found in druses and in seams, usually less than half an inch wide, though occasionally reaching a width of about 2 inches. A minor proportion of galena and fine-grained sphalerite is associated with the fluorite.

Hudson mine and Pierce prospect.—The Hudson mine and Pierce prospect are nearly 3½ miles southwest of Salem, and a little less than a quarter of a mile east of the road from Salem to Vicksburg. They are situated about 35 feet apart, on a vein of fluorite having a strike of approximately N. 54° E. Neither of them is being worked at present. The Pierce prospect consists of two shallow holes about 10 feet apart, while the Hudson mine, northeast of this, comprises a shaft and some open cutting at the surface, all now caved. In this shaft fluorite of excellent quality was obtained, the vein having a width of 6 inches in the upper part of the shaft, and reported to have been 4 feet wide at the bottom. Limestone, somewhat seamed with calcite, and chert fragments were the only rocks noted at these openings.

MINES AND PROSPECTS NORTH OF SALEM.

Butler prospect.—The Butler shaft, a little more than half a mile northwest of Salem, was sunk in 1899 to a depth of 30 feet in brecciated Chester quartzite more or less completely cemented with thin seams of fluorite. That some faulting has taken place here is shown by the occurrence of slickensiding on some of the blocks of quartzite.

BABB GROUP.

General features.—About a mile and a half north of Salem is a small group of openings which are located with reference to the road shown on the map, though the road itself was not traversed, so that the exact relation of the openings to each other is not known. From such location as was made, however, it is seen that all the openings are practically in a straight line, and it is probable that all of them occur on a fault with a strike of about N. 54° E., although no definite evidence of faulting was noted at any of them. The entire group is characterized by the occurrence of gravel and lump fluorite, though from only two members, the Guill and the Ramon Babb mines, has any fluorite been shipped. Calcite is common

had dipped out of the shaft. This vein when drifted in was found to contain an ore body, 3 to 9 feet in width, consisting largely of white fluorspar mixed with considerable calcite and smaller amounts of galena. The northwest cross-cut passes through Ste. Genevieve limestone and at 50 feet from the shaft struck another vein, presumably the Latrobe, which should intersect the Pittsburg fault near this point. The reports concerning this second vein are conflicting, hence no statement as to its width and character can be made here.—E. O. U.

or abundant at a number of the openings, while at several of the prospect holes, toward the northeastern end of the group some barite occurs with the fluorite. The latter is found with clay, together with one or more of the following rocks: Sandstone, quartzite, and shale, belonging to the Chester group, and limestone, probably Ste. Genevieve, seamed with calcite. At most of the openings both limestone and either quartzite or shale occur. The exact relation of the limestone to the other rocks was not seen.

Ramon Babb mine.—The Ramon Babb mine, at the northeastern end of the group, was worked by the Eagle Fluorspar Company from June, 1899, to August, 1900. It consists of two shafts and several prospects, the main shaft, 80 feet deep, being formed by the cutting together, for the upper 30 feet, of two shafts about 30 feet apart, so as to form a single, narrow shaft 40 feet in length. From this shaft a large amount of both fluxing and grinding fluorite has been obtained and shipped, about 1,500 cubic feet of screened spar still remaining at the mine. The fluorite is associated with a minor proportion of galena, and sphalerite is reported as occurring in the limestone at the bottom of the shaft. Shaft No. 2 was sunk north of the vein, to a depth of 30 feet, and only lower Chester (?) shale was found in it.

Tom Babb prospect.—This prospect consists of two holes 200 feet apart, the northeastern one being about 240 feet S. 54° W. from the Ramon Babb main shaft. From both these holes some fluorite, both gravel and lump, was obtained, associated with some barite at the northeastern hole.

Morse shaft.—The Morse prospect, consisting of a shallow shaft, now caved, is situated just west of the road from Salem to Pleasant Grove, and differs in no essential particular from the other openings of the group.

Guill mine.—At the Guill mine, at the southwestern end of the group, there are two shafts, sunk a number of years ago, from both of which a considerable amount of fluorite has been obtained and shipped. The southwestern shaft has a depth of about 60 feet, while the other, located about 190 feet N. 63° E. of this, is about 85 feet deep. A large amount of coarse white calcite has been taken from both shafts. The fluorite is associated with more or less galena, and some of it contains somewhat weathered fragments of limestone. Some sphalerite probably occurs with the ores in depth, as indicated by the small amount of smithsonite seen with the fluorite already mined. Some of the limestone noted at these mines is almost black, owing to bituminous matter contained in it.

Crosson Cave prospect.—This property, now being operated by the Crittenden Mining Company, is situated nearly 2 miles southwest of Mount Zion Church, on the road to Salem, and 200 yards southeast of the road. Some fluorspar has been shipped from a short, shallow open cut at the surface. The prospect is chiefly of interest, however, on account of the occurrence here of two intersecting veins, and of the clear exposure of their relations.

At the surface is a broad sink hole about 10 feet deep, at the bottom of which are two openings into the cave. In this, so far as explored, there are two chambers, an upper and a lower. The floor of the first is 11 feet below the entrances at the bottom of the sink, the other being about 42 feet below this floor. In the lower chamber there is a flowing stream of water. The two surface openings, 14 feet apart, have been formed on a vein with a course of N. 10° W. The single opening which joins the upper and lower chambers has formed in the obtuse angle between this vein and a second with a trend of N. 37° E.

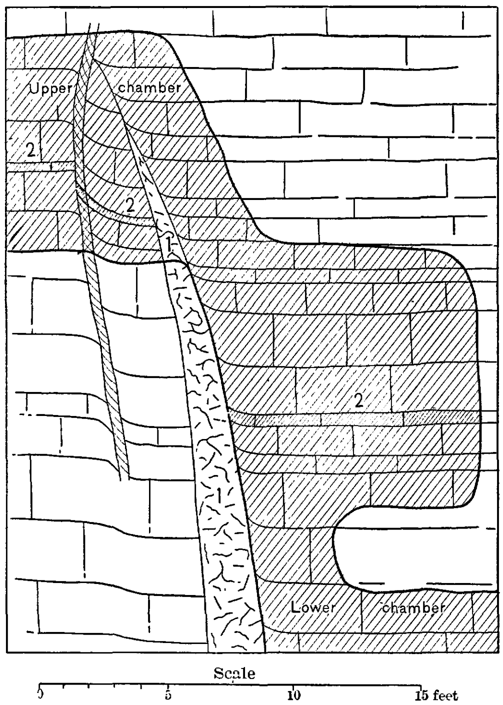


FIG. 30.—Vertical section, Crosson Cave, showing west wall of upper and part of lower chamber. 1, Fluorite vein; 2, bed in limestone, showing amount of faulting.

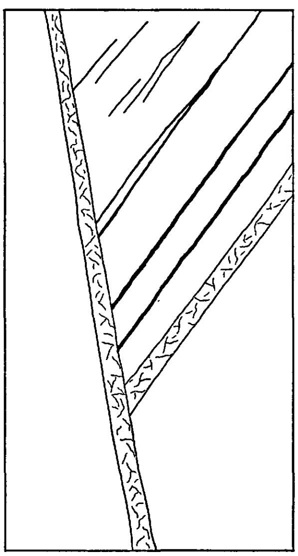


FIG. 31.—Diagram showing relation of veins at lower level, Crosson Cave.

Both of these veins fill fissures due to faulting, although in both cases the amount of faulting is small. The throw of the northwestern fault, as seen on the north wall of the upper level, is 2 feet 11 inches, while that of the northeasterly fault, seen at the same level, is a little over 7 feet. The northwestern vein dips toward the east at an angle ranging from 70° to 81° at the upper level to approximately vertical at the lower level. Its width varies from about 8 inches to a little more than 2 feet, and it is composed of fluorite, calcite, and some barite. The northeastern vein has a southerly dip ranging from about 65° at the upper level to about 84° at the lower. Its width is nearly 3 feet in the lower chamber, while it pinches in the upper, as shown in figure 30. This vein, like the other, is composed of fluorite, calcite and barite. It is not continuous, but is cut off abruptly where it meets the northwesterly vein, as shown in figure 31. The western wall of the latter vein at the upper level gives no indication of a fracture corresponding to the northeasterly vein, though this wall at the lower level shows a nearly vertical series of short and very thin calcite seams arranged en echelon along the course which the vein would take if continued. North of the northeastern vein at the lower level are seen a number of smaller parallel veins, as shown in figure 31, varying from a fraction of an inch to about 3 inches in width, and composed of calcite, fluorite, and barite, or of one or two of these minerals.

NOTES ON RECENT DISCOVERIES.

The following notes on some of the more important recent discoveries and developments in the district were drawn up by Mr. Ulrich, in part from personal observations, but chiefly from information furnished by Mr. F. J. Fohs and others.

Struck-it-rich mine.—The developments at the Struck-it-rich mine, operated by the Mountain Lead, Zinc, Fluorspar Company, and located about a half mile northeast of the Crittenden Springs Hotel, consist of two shafts, several minor prospect holes, and an open cut. All of these openings seem to be short distances east of the main Columbia fault, apparently on a vein or veins diverging northeastward from the Columbia fault. At both the Struck-it-rich and Lone Rock shafts both walls consist of Ste. Genevieve limestone, either overlain on one side by the lower part of the Cypress sandstone or with this sandstone outcropping near by. The stratigraphic relations of the two walls, therefore, indicate only a slight degree of faulting; also that the vein or veins in these shafts belong to the subsidiary set of fractures of which the Memphis and Klondike veins are the best known. Being much nearer the Columbia fault than the Memphis vein, the Struck-it-rich vein is likely to contain more brecciated material, and in this respect to partake more of the character of the Columbia vein.

In the Struck-it-rich shaft, as reported by Mr. Fohs, Ste. Genevieve limestone occurs within 5 feet of the surface in the southeast wall and at a depth of 15 feet in the northwest wall. Overlying the limestone on the latter side of the vein is a bed of shale, apparently belonging to the Ohara member of the Ste. Genevieve. At the surface the vein has a width of nearly 10 feet; at a depth of 35 feet, however, the vein had gradually narrowed to 2 feet. At this depth the northwest wall showed seams of calcite with sphalerite and galena, the southeast wall seams of calcite only. Between the walls the ore, of which over 100 tons was extracted, consists chiefly of smithsonite, some of it containing a large percentage of galena. Small amounts of smithsonite were secured also from two prospect holes southwest of the shaft.

Sinking in the Struck-it-rich shaft was continued during the past winter, and, according to latest advices from the president of the company operating at this mine, the ore body has widened again to between 7 and 8 feet at a depth of

48 feet. Abundant samples sent with this information are very rich in medium fine-grained sphalerite and much coarser galena, mixed with calcite and unreplaced fragments of limestone. No fluorite was observed in these samples, but Mr. Fohs reports that very small quantities of this mineral occur in this shaft above the 35-foot level.

Lady Farmer mine.—This mine is situated mainly between and near the junction of the Old Jim and Walker dikes, a short distance southeast of the Old Jim mine. The property is owned and operated by the Henderson Company, and the ore is smithsonite, similar to that at the Old Jim mine. At present the mine consists of a number of prospect holes and an open cut, from which a drift was run about 75 feet toward the southeast. In the cut and drift the carbonate varied in width from nothing to 10 feet. About 50 tons of ore were shipped in 1903, several car loads remaining on the dump.

Cartwright mine.—At this mine there are two shafts which were sunk by the Deer Creek Mining Company on the Widow Clark land, less than a mile south of Sheridan. The vein which this company proposes to mine here is in or adjacent to the plane of the Glendale fault.

At a depth of 62 feet the more promising of the two shafts contained a streak of zinc and lead sulphide ores about 2 feet in width. Between this and the Birdsville shale in the hanging wall there are between 12 and 14 feet of limestone carrying small amounts of sphalerite, galena, calcite, and fluorite. The other shaft, about 20 feet north of the first, was sunk 70 feet in the St. Louis limestone, which forms the country rock on the northwest side of the Glendale fault. Being quite off the vein, nothing of value was found in this shaft, though the limestone penetrated was here and there plentifully intersected by thin seams of fluorite and calcite containing insignificant amounts of zinc and lead.

Hoisting machinery is being installed at this mine and active developments are to be carried on during the present season.

Keystone mines.—These mines, which are being operated by the Keystone Mineral and Mining Company, are on the T. C. and J. B. Carter land, a mile or less southeast of Siloam Church. The shafts are located on or near the Columbia fault, which here brings Ste. Genevieve limestone in juxtaposition with the Birdsville formation.

Work was begun in April, 1903, the first shaft being sunk 50 feet in quartzite. At this depth two crosscuts were made—one east, cutting quartzite only, the other west for 40 feet, passing through 30 feet of barren quartzite and then 10 feet of shale. The sudden transition from quartzite to shale probably indicates an unmineralized subsidiary fault plane. The east crosscut should have been continued to the main fault plane between the Birdsville and Ste. Genevieve formations, providing the location of this shaft is not too far west of the fault line.

A second prospect shaft was next sunk, about 200 yards northeast of the first, to a depth of 40 feet. A crosscut for 10 feet to the west from the bottom of this shaft passed through a vein of mainly No. 2 fluorspar about 6 feet in width. The walls of this vein being of Birdsville shale on the west and Ste. Genevieve limestone on the east, it lies most probably in the main plane of the Columbia fault.

Shaft No. 3, which is to be the main shaft, is located about 25 feet northeast of shaft No. 2. Sinking was begun in September, 1903, and continued to the close of the year, when the shaft had reached a depth of about 85 feet. The vein was cut on the dip, the first fluorspar coming in at 30 feet and the water level at 50 feet. The vein dips westerly, but not enough to pass entirely out of the shaft at its present depth, about 2 feet of it, consisting of white and purple fluorspar bowlders in residual clay, remaining within at the bottom. Where entirely within the shaft, the maximum width of the vein is about 5.5 feet. About one-third of the 75 to 100 tons of fluorspar on the dump is No. 1 white, the remainder containing some unreplaced or only partially replaced limestone and small amounts of disseminated galena. The east wall is much corroded, but the bottom of shaft is nearly solid Ste. Genevieve limestone. Shales of the Birdsville formation form the west wall to a depth of 75 feet, beneath which it consists of quartzite. Some of this quartzite is brecciated and recemented with purple fluorspar.

L. F. White mine.—This is situated about 1 mile north of View, on either an extension of the Woods fault or on one of the subsidiary planes of the Marion fault. The vein was worked by open cut and considerable gravel spar was shipped by the Kentucky Fluorspar Company. Owing to excessive royalties this company has given up its lease on the property.

Senator mine.—This mine is located on one of the planes of the Bodard fault, about 5 miles northwest of Princeton. The main shaft is sunk on the south side of a linear mass of Chester quartzite and between this and the edge of a considerable bed of Chester limestone, the exact age of which remains to be determined. Above water level, which is within 2 feet of the surface, some zinc carbonate and galena were procured. Beneath water level the ore, which occurs principally in the form of large bowlders, is a mixture of high-grade sphalerite and galena, with smaller percentages of brown and purple fluorite and calcite. As a rule the fluorite occurs in a separate band on the limestone side of the shaft, with the lead and zinc ore on the opposite side.

At the close of the year 1903 this shaft had been sunk to a depth of 65 feet. At this depth the vein is reported as 4 feet to 5 feet in width, and as consisting of two well-marked and nearly equal bands. The band on the limestone side of the shaft still consists mainly of fluorite, with small grains of galena disseminated through it, while the band on the sandstone side is largely composed of rich but intimately mixed galena and sphalerite ore, with very little fluorite.

A number of prospect holes and shafts that it was hoped might strike this vein have been sunk in the immediate vicinity of the Senator mine, but so far as known without notable success.

Professor Wright shaft.—This shaft seems to be located on or very near the Fairview fault, about three-fourths of a mile southwest of Carrsville and a short distance west of the road to Joy. In October, 1903, when the shaft was visited by Mr. Fohs, the Ohio Valley Mining Company had sunk it to a depth of 58 feet. The east wall consists of nearly horizontal lower Birdsville, the west wall of upper Birdsville sandstone, shale, and finally limestone, dipping strongly to the west. Small deposits of lead and zinc sulphides, with smaller amounts of quartz and fluorspar, occur between the bedding planes of the limestone and also in the interstices where the limestone was jointed and brecciated. Above the limestone and shale the vein was filled with brecciated quartzite carrying good lead and zinc values from the water level, which is within 5 feet of the surface.

At a depth of 70 feet two crosscuts were run, one east for 4 feet in only slightly brecciated white quartzite containing little ore, the other west for 16 feet. In the latter the quartzite is reported as being more brecciated and stained dark by shales; also that it contains considerable bodies of lead and zinc sulphides, the heaviest being a few feet west of the shaft and nearly 2 feet thick.

SUMMARY.

All of the foregoing mines and prospects are shown on the map (Pl. VIII) opposite page 116. Many other prospects within the area covered by this map are shown on it, but as they are either insufficiently known or very much like those described, it has seemed unnecessary to consider them in detail. Most of them, as for instance the Corn, Eaton, B. W. Belt, and Old Dad mines and prospects in Crittenden County, the Burns and Ferral in Livingston County, and the Satterfield, Stone, Lowery, Ray, and Bright prospects in Caldwell County, are promising, and some doubtless will prove to be valuable properties. Some very encouraging prospects occur also in the areas shown on the general map (p. 22), but are not included in the map locating the mines. The most notable of these are the Beard and other prospects, on or adjacent to the Larue fault, on either side of the Marion and Cave in Rock road.

INDEX.

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[Professional Paper No. 36.]

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