UNITED STATES DEPARTMENT OF THE INTERIOR
Harold L. Ickes, Secretary

U.S. GEOLOGICAL SURVEY
W. C. Mendenhall, Director

Bulletin 853

ZINC AND LEAD DEPOSITS OF NORTHERN ARKANSAS

BY

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Prepared in cooperation with the
ARKANSAS GEOLOGICAL SURVEY
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UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1935

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By Edwin T. McKnight

ABSTRACT

Introduction.—Zinc and lead ores occur in the northern counties of Arkansas, from the Arkansas-Oklahoma line on the west to the Coastal Plain, in Lawrence County, on the east, but are concentrated chiefly in Marion, Boone, Newton, Searcy, Sharp, and Lawrence Counties. Lead ore was reported in the region as early as 1818, and small reduction plants were built in the vicinity of Lead Hill in 1851 or 1852. The Confederate forces obtained lead from northern Arkansas during the Civil War. Zinc mining began at a somewhat later date and reached its peak between 1914 and 1917, but since that time mining has been at a low ebb. The later history of lead mining in the region has closely paralleled that of zinc. The production from the region since 1907, according to statistics compiled by the United States Geological Survey, has been, in round numbers, 1,900 tons of lead sulphide concentrates, 11,500 tons of zinc sulphide concentrates, and 51,300 tons of zinc carbonate and silicate concentrates.

Geography.—The deposits are north of the Boston Mountains. They crop out chiefly along the Eureka Springs escarpment, which separates the Salem Plateau below from the Springfield Plateau above. Owing to the dissected nature of the Springfield Plateau, the escarpment is very sinuous. A considerable number of deposits are also found within the area included in the Salem Plateau. Vigorous dissection along the White River and its tributaries in northern Arkansas, especially in the more richly mineralized districts, has destroyed the plainlike character that is typical of both the Springfield and Salem Plateaus in parts of the Missouri Ozarks. The Springfield Plateau is narrow along the north base of the Boston Mountains and in places is not developed at all. The White River and its tributaries are entrenched to depths of 300 to 400 feet below the Salem Plateau and 500 to 600 feet below the Springfield Plateau. Much of the entrenched drainage shows pronounced meanders that are characterized by asymmetric profiles on the bends.

Stratigraphy.—The rocks of northern Arkansas are all sedimentary and range in age from Lower Ordovician to Pennsylvanian. The Devonian is not represented in the more richly mineralized districts, and the Silurian formations are thin and discontinuous. The Ordovician and Carboniferous systems, however, are well represented. The stratigraphic column in the Yellville quadrangle includes a maximum of 2,400 feet of rocks, divided into 19 formations. There are 12 well-established unconformities within the stratigraphic section and 2 additional ones that are questionable. The occurrence of so many unconformities has produced numerous discontinuities in the distribution of

the formations. In general, the stratigraphic breaks recorded in the unconformities increase in amount from south to north, indicating that the axis of the uplifts was north of the lead-zinc region. The uplifts probably began some time in the late Cambrian and were recurrent throughout the rest of the Paleozoic and into post-Paleozoic time.

The richer ore deposits occur either in the Everton formation, of the Lower Ordovician, or in the Boone formation, of the Mississippian. The Everton is 400 feet in maximum thickness and is composed of limestone, dolomite, and sandstone. The Boone formation is about 350 feet thick and is made up of limestone and chert. Other mineralized strata are the Cotter dolomite and a certain bed, about 10 feet thick, lying in the Powell dolomite 60 feet above its base. In Sharp and Lawrence Counties the ore occurs in the Smithville formation, which occupies, together with the Black Rock formation, approximately the same position in the geologic column as the Everton farther west but which is believed by Ulrich to be older than the Everton.

Structure.—The rocks of the lead-zinc region appear to be horizontal, but when studied over wide areas they show a low regional dip to the south, more marked in the Ordovician beds than in the Carboniferous beds. Locally faulting and gentle folding have occurred. The faults are normal and fall into two systems, one northeasterly and the other east-southeasterly. Many of the faults are grouped to form graben blocks. They are post-Pennsylvanian except one that is post-Ordovician and pre-Mississippian. Certain of the folds (low domes, shallow basins, and monoclines) had their inception in the Ordovician period and have been accentuated at least three times.

Ore deposits.—A few of the ore deposits occur on faults where the Boone limestone forms one or both walls, but most of them are runs and blanket veins. These are limited to certain beds; the mineralization followed zones of shattering, produced by very slight structural deformation of the rocks. The runs are simply the more richly mineralized portions of blanket veins, formed along the main channels of circulating ore solutions. The vicinity of faults was especially favorable for the development of runs. In the Everton formation ore is limited to dolomite beds or else to limestones that were silicified early in the period of mineralization. In the Boone, on the other hand, the ore may occur in unaltered limestone. The ore has in part filled preexisting open spaces and in part replaced the shattered rock. Which one of these modes of occurrence prevails in a given deposit depends upon the character of the country rock and especially upon its texture.

The primary ore minerals are sphalerite and galena. The sphalerite is widely distributed over the region; the galena is restricted to certain districts, being conspicuously absent from those districts in southern Marion County and Searcy County that have produced most of the zinc. The sphalerite is comparatively pure, containing only small amounts of iron and cadmium. The galena is very low in silver. Small amounts of chalcopyrite and pyrite are widely distributed, and a few small crystals of enargite have been identified at one mine. The gangue minerals are jasperoid chert (which has replaced the country rock), pink spar dolomite, quartz, and calcite. The primary minerals show a paragenetic order of crystallization. Aside from variations in lead content, the mineralizing solutions appear to have been very similar throughout the region, and the differences that appear in the ore deposits result chiefly from differences in the character and texture of the country rock. The ore solutions are believed to have been, in part at least, of magmatic origin.

The lead ore marketed from northern Arkansas has been chiefly sulphide, but most of the zinc ore has been oxidized. The zinc carbonate (smithsonite) is notable for the variety of forms in which it occurs. The zinc silicate (calamine) is especially characteristic of the district around Zinc. Oxidation of the zinc has occurred essentially in place, without enrichment. Incomplete oxidation, resulting in mixtures of sulphide and carbonate or silicate, presents commercial difficulties of separation that are not surmounted in the methods of milling that have been used in the region. Aside from this tendency for some suphide to occur with it, the oxidized ore is uncommonly free from objectionable impurities.

INTRODUCTION

EXTENT OF THE FIELD

Lead and zinc ores are found in northern Arkansas from Lawrence County on the east to Benton and Washington Counties on the west, but the most valuable deposits are in Marion, Boone, Newton, Searcy, Sharp, and Lawrence Counties.

HISTORY AND DEVELOPMENT

Lead ore was found in the region at an early date. In 1818 Schoolcraft,[1] an explorer and ethnologist, during an expedition from the lead-mining region of southeastern Missouri to the headwaters of the White River in Arkansas, and back by way of what is now Batesville, recorded the occurrence of lead at Bull Shoals and on Trimble's plantation on the White River, in Marion County, and on the Strawberry River, in Lawrence County. This trip was made when the White River Valley was uninhabited by white people in its headwater region, above Taney County, Mo., and only sparingly inhabited below there. Featherstonhaugh,[2] in a volume based on an expedition made in 1834, mentions the reported occurrence of lead on the Strawberry River.

Inasmuch as lead, in the form of ammunition, played an indispensable part in the economy of pioneer life, it naturally received attention much earlier than the zinc. Years before the Civil War many of the occurrences of float lead had been traced to their sources, where small-scale gouging operations were undertaken, producing a yield that was negligible in comparison to the production from other parts of the country and yet ample enough to satisfy the domestic needs of the operators. More ambitious operations were undertaken in a few places. Branner [3] reports three small lead smelters in the vicinity of Lead Hill, Boone County, before the Civil War, the earliest one having been built in 1851 or 1852. During the Civil War

[1] Schoolcraft, H. R., A view of the lead mines of Missouri, pp. 60, 61, New York, 1819.
[2] Featherstonhaugh, G. W., Excursion through the slave States, p. 88, New York, 1844.
[3] Branner, J. C., Zinc and lead region of north Arkansas: Arkansas Geol. Survey Ann. Rept. for 1892, vol. 5, p. 65, 1900.

some of the deposits were worked more systematically as a source of lead for the Confederate forces. Two of these were the Bald Hill and Old Confederate mines, both on a tributary of Cave Creek, in Newton County. Since the Civil War lead deposits have been worked intermittently and with varying success until the present day, although never on a very large scale as compared to other lead regions of the United States. The later history of lead mining in the State has closely paralleled that of zinc.

Although zinc is of much commoner occurrence than lead in northern Arkansas, it was neglected until a somewhat later date. The earliest attempts to work zinc deposits were made at Calamine, in Sharp County, in 1857 and again in 1871. Smelters were erected at both of these dates, but operations were short-lived. Active zinc mining began in the counties farther west in 1899 and reached its peak in the early years of the World War, from 1914 to 1917. In 1916 and again in 1917 northern Arkansas produced zinc ores that would have yielded almost 7,000 tons of metallic zinc had the ore been all reduced to the metallic state instead of being converted in large part to other forms, such as the oxide.

Since 1918 the mining industry in the lead and zinc fields has been at a low ebb. Many of the mills, including the machinery, were torn down and removed when the slump came in 1918, but perhaps more were left standing. At first some attempt was made to keep the properties in good condition, in the hope that the shutdown would be only temporary, but as time wore on it became evident that the shutdown was to be of indefinite duration. Today, with the exception of the Morning Star mill at Rush, the Excelsior mill at St. Joe, the Bald Hill mill on Cave Creek, the Butler mill at Lynn, and perhaps one or two others, all the mills are in varying degrees of dilapidation. Machinery that has cost many hundreds of dollars is rapidly deteriorating to the point where it can never be salvaged. Many of the shafts and tunnels have caved, so that they have been inaccessible to examination during the past few years.

TRANSPORTATION FACILITIES

Three railroads cut across different parts of the northern Arkansas field. The White River branch of the Missouri Pacific Railroad follows up the White River to Cotter, whence it swings west through Yellville, Zinc, and Bergman, reaching and crossing the White River again at Branson, Mo. This line goes directly through the mining district centering around Zinc and passes within a few miles of the Rush Creek, Dodd City, and Jimmie Creek districts. The Missouri & North Arkansas Railway follows a course roughly parallel to the Missouri Pacific but 10 to 15 miles on an average to the southwest of it. It runs through Marshall, St. Joe, and Harrison. This is the line over which most of the ore mined in Searcy and Newton Counties has been shipped. Some of the mines in the Ponca district, Newton County, are 30 miles or more from the shipping point but most of the workings are within 10 to 15 miles. The St. Louis-San Francisco Railway, running between Springfield, Mo., and Memphis, Tenn., crosses the northeast corner of Arkansas a few miles northeast of the mineralized area in Sharp and Lawrence Counties. Most of the mines that have been worked lie between 10 and 20 miles from this railroad, although the actual haulage over the existing roads may be somewhat greater.

Outside of Sharp and Lawrence Counties, the lead and zinc deposits of northern Arkansas are generally in rough, hilly country. In areas of this type the construction and maintenance of roads become problems, not only because of the steepness of grades, but also because of the universal wash and scour to which the roads are subjected during the heavy spring rains. The average road is therefore likely to be very poor. In the past most of the ore freighting was done by wagon and team. Beginning in 1927, however, a program of road building in northern Arkansas has left the district with at least a skeletal network of good State highways. To this nucleus is being added a system of improved county roads, especially in Marion County, so that one of the long-standing barriers to the development of the country is rapidly being removed. Where practicable the highways, especially the State highways, follow drainage divides, which run fairly level for miles, and they descend only where necessary to cross the drainage lines. Most of the mines and prospects are in steep-sided hollows away from the highways, so that the initial problem of getting the ore onto a main highway still exists. Beyond this, however, the freighting problem of the future should be somewhat simplified. It has already been demonstrated that, given a good road, transportation by trucks is more feasible than by wagon and team.

PRODUCTION

Only incomplete figures of the production of northern Arkansas were kept before 1907. According to information collected by G. I. Adams [4] for the years prior to 1903 and records kept by W. R. Willet [5] for the years 1903 to 1906, the production prior to 1907 was as follows:

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[4] Adams, G. I., and others, Zinc and lead deposits of northern Arkansas: U.S. Geol. Survey Prof. Paper 24, p. 15, 1904.

[5] Manufacturers' Record, Jan. 6, 1916, p. 64.

Zinc and lead produced in northern Arkansas prior to 1907, in short tons

Year	Lead concentrates (galena)	Zinc concentrates (chiefly carbonate and silicate, some sulphide)	Year	Lead concentrates (galena)	Zinc concentrates (chiefly carbonate and silicate, some sulphide)
Prior to 1901	500	1,500	1905		2,205
1901		500	1906		2,254
1902		1,000			
1903		1,385		500	10,939
1904		2,095			

The selling price of galena concentrates is based on a metal content of 80 percent of lead, that of sphalerite concentrates on a metal content of 60 percent of zinc, and that of zinc silicate and carbonate concentrates on a metal content of 40 percent of zinc. In the absence of more definite information on metal content these figures may be assumed as the average smelter assays of the respective products.

The following table gives the production from 1907 to 1930, according to the figures compiled by the United States Geological Survey [6] and the United States Bureau of Mines.[6]

Zinc and lead produced in Arkansas, 1907–30 [a]

Year	Ores						Metal content [b]			
	Lead concentrates (galena)		Zinc concentrates				Lead		Zinc	
			Sphalerite		Silicate and carbonate					
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
1907	15	$800	538	$15,233	663	$16,210	12	$1,272	474	$55,932
1908	18	985	516	18,270	939	21,469	15	1,260	605	56,870
1909	30	1,800	896	33,948	98	2,736	24	2,064	510	55,080
1910	80	3,714	1,857	74,136	128	2,641	63	5,544	994	107,352
1911	80	4,321	1,407	40,425	183	4,239	64	5,760	664	75,696
1912	39	2,180	1,419	56,235	462	11,231	31	2,790	748	103,224
1913	23	1,179	594	16,916	680	15,050	18	1,584	478	53,536
1914	52	2,408	743	19,406	1,143	25,187	41	3,198	608	62,016
1915	79	4,961	606	41,341	7,925	408,079	63	5,922	3,209	795,832
1916	339	28,097	1,670	112,726	16,609	940,224	272	37,536	6,815	1,826,420
1917	474	47,593	916	57,824	17,053	650,585	382	65,704	6,691	1,364,964
1918	155	13,594	310	16,450	2,156	68,333	120	17,040	951	173,082
1919	35	2,400			510	18,170	28	2,968	189	27,594
1920	10	755			917	28,925	8	1,280	329	53,298
1921	27	1,510			42	580	21	1,890	15	1,500
1922	55	4,000			425	6,870	42	4,620	134	15,276
1923	32	2,559			444	9,919	25	3,500	148	20,128
1924	25	2,730			13	330	20	3,200	4	520
1925	93	8,546	58	2,380	44	1,296	58	10,092	43	6,536
1926	28	2,544	8	346	246	7,012	18	2,880	87	13,050
1927	30	2,590			386	9,453	23	2,898	128	16,384
1928	50	4,010			224	5,600	38	4,408	86	10,492
1929	66	5,500			25	605	51	6,426	9	1,188
1930	68	4,033					53	5,300		
	1,903	152,809	11,538	505,636	51,315	2,254,744	1,490	199,136	23,919	4,895,970

[a] This is almost entirely from the northern Arkansas field.

[b] In calculating the metal content of the ores from assays, allowance has been made for smelting losses of both lead and zinc. In comparing the values of ore and metal it should be borne in mind that the value given for the ore is that actually received by the producer, whereas the value of the lead and zinc is calculated from the average price for all grades.

[6] Mineral Resources of the United States, 1907–30 (1907–9 by C. E. Siebenthal; 1910–30 by J. P. Dunlop).

In the production of zinc and lead sulphides the northern Arkansas field has held a very insignificant place as compared to other mining districts. As a producer of oxidized zinc ores, however, it was during 1916 and 1917 one of the leaders in the Central States. As the table shows, about two-thirds of the total production of zinc silicate and carbonate in northern Arkansas was shipped in these 2 years. The production since 1918 has been very low.

PREVIOUS LITERATURE

Earlier reports dealing with the zinc and lead deposits of the region were issued some 30 years ago. Branner's report, already cited, is the most thorough treatment from an economic standpoint that the region has received. The minerals, ore deposits, and geologic structure are described, and detailed descriptions are given of most of the known mines and prospects. Bain,[7] in 1901, devoted 7 pages to a general discussion of the Arkansas ore deposits, based on a reconnaissance examination in Sharp and Lawrence Counties, as well as in the counties farther west. In 1902 Hedburg gave a short account of the ore deposits and described a few of the mines of the district.[8] Adams' report [9] in 1904 covered much the same subjects as the Branner report, though the mines were not treated so thoroughly, and Sharp and Lawrence Counties were not touched. This report contains a fairly detailed map of the geology of the Yellville quadrangle, and a discussion by E. O. Ulrich of the stratigraphy of the lead and zinc region. Adams' report was the last dealing with the lead and zinc deposits that was based on original work. The most important stratigraphic report on the lead and zinc district was that by Purdue and Miser,[10] published in 1916.

PRESENT INVESTIGATION

After the publication of Adams' report, E. O. Ulrich and E. F. Burchard, of the United States Geological Survey, both of whom had collaborated with Adams, spent some time in the Yellville quadrangle, which lies in the heart of the mineralized region, with a view toward revision of the stratigraphy and the geologic map as presented in the zinc and lead report. In the course of this later field work several formations were recognized in the southern part of the quadrangle that had been overlooked in the earlier, more hasty

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[7] Bain, H. F., Preliminary report on the lead and zinc deposits of the Ozark region: U.S. Geol. Survey 22d Ann. Rept., pt. 2, pp. 195–202, 1901.

[8] Hedburg, Eric, The Missouri and Arkansas zinc mines at the close of 1900: Am. Inst. Min. Eng. Trans., vol. 31, pp. 379–404, 1902.

[9] Adams, G. I., Zinc and lead deposits of northern Arkansas: U.S. Geol. Survey Prof. Paper 24, 1904.

[10] Purdue, A. H., and Miser, H. D., U. S. Geol. Survey Geol. Atlas, Eureka Springs-Harrison folio (no. 202), 1916.

reconnaissance. In the fall of 1916 Burchard spent a month examining mines and prospects in Marion, Boone, and Searcy Counties in anticipation of war-time demands for information on zinc ore supplies. Many of the results of these different investigations, including a preliminary manuscript and a partly revised map of the Yellville quadrangle, have been at the disposal of the writer in the preparation of the present report.

In September 1927, in response to numerous inquiries for later information on the ore deposits than is given in the Branner and Adams reports, field work was begun by the present writer under a cooperative arrangement between the United States Geological Survey and the Arkansas Geological Survey, for the purpose of preparing a complete geologic report on the zinc and lead deposits of the northern Arkansas region. Work in the field continued, with interruptions, until December 1930. In this time the stratigraphy and structure of the Yellville quadrangle was completely remapped in as much as the base map would permit; a detailed topographic and geologic map was made of about 8 square miles in the Rush district; the stratigraphy and correlation of certain Ordovician formations were studied between Yellville and Cave City, in Sharp County; and an examination was made of practically all the important lead and zinc prospects in the northern Arkansas field. The present report embodies the results of these investigations.

During the preparation of the Rush special map able assistance was rendered by Cecil D. Robinson and Bryan Parks as rodmen and by Jack Layton as recorder. The writer was visited in the fall of 1927 by E. F. Burchard, who spent some 2 weeks in the field going over a number of the prospects. H. D. Miser spent 10 days in the fall of 1928, 4 days in the fall of 1929, and 2 days in the fall of 1930, going over certain stratigraphic problems that came up during the course of the work.

ACKNOWLEDGMENTS

The writer is indebted especially to Mr. Hugh D. Miser, of the United States Geological Survey, for his help in untangling some of the stratigraphic problems in the Yellville quadrangle and for unpublished information on the deposits of Sharp and Lawrence Counties; to Mr. E. F. Burchard, also of the Geological Survey, for aid and suggestions in starting the mine examinations and for an unpublished manuscript on the Yellville quadrangle; to Messrs. E. O. Ulrich and R. D. Mesler, of the Geological Survey, for numerous determinations of fossils; to Mr. George M. Fowler, of Joplin, for cooperation in various ways and especially for suggestions on the interpretation of the structural relations of the ores; to Mr. J. B.

Brown, of Little Rock, for the use of several private reports on mining properties in northern Arkansas; to Mr. James K. Lyons, superintendent of the Morning Star Mining Co., of Rush, for data on the production of the Morning Star holdings and for numerous other courtesies; to Mr. W. A. Myles, of the Big Hurricane mine, for information on the production of the J. C. Shepherd mining properties during the period of high production; to Mr. J. H. Hand, of Yellville, for production statistics during 1917; to Capt. Charles LeVasseur, of Yellville, for a number of mine maps; and to Mr. George C. Branner, State geologist of Arkansas, for his cooperation in various ways and for his interest and encouragement in making the project a success.

To name everyone who has contributed to the present report by furnishing information or by volunteering his services as a guide would be a hopeless task. Certain men, however, have contributed considerably more than others in these respects, and as they have been taken, in a way, as authorities on the past mining activities in their respective districts, when first-hand information can no longer be obtained, it is fitting that such services should be acknowledged. Mr. R. M. Willett contributed a week as guide through Sharp and Lawrence Counties, and owing to his wide acquaintance in the district was able to collect a mass of information that might otherwise never have been assembled. The following men have furnished information and served as guides in their respective districts: Messrs. W. A. McCurry and Lon Brown, of Zinc; Dale Owens, John Benton, and Drew Markle, of Dodd City; Ben Fee, of Kingdon Springs; Ike Kilgore and Ed Minicus, of Ponca; R. F. Truitt, of St. Joe (Cave Creek district, Newton County); W. P. Campbell, of St. Joe; Sam Davis, of St. Joe (Tomahawk Creek district); George McClain, of Maumee; J. Frank Rea, of Rea Valley (Halls Mountain district); A. M. Goatley, of Rush (Dodd City district).

GEOGRAPHY

SURFACE FEATURES

The northern Arkansas zinc and lead region lies well down on the south flank of the Ozark uplift, which is a broad, low structural dome lying chiefly in southern Missouri and northern Arkansas but extending slightly into the southeast corner of Kansas and the northeast corner of Oklahoma. The dome is rudely oval in outline, the longer axis extending from southwest to northeast. The length of the longer axis is about 300 miles, and of the shorter axis about 200 miles. The uplift is roughly bounded on the north by the Missouri River, on the east by the Mississippi River, on the southeast by the lower course of the Black River, on the south by the Arkansas River, and on the west by the Neosho and Spring Rivers. Most of the Arkansas portion of the Ozarks lies on the south and southeast slopes of the dome.

Besides being a structural high, the Ozark region is also a topographic upland. Two major physiographic divisions have been recognized in the highland—namely, the Ozark Plateau, which embraces most of the Ozark region, and the Boston Mountains, which lie in Arkansas along the south side of the Ozark uplift. The Ozark Plateau has in turn been subdivided into the St. Francis Mountains, the Salem Plateau, and the Springfield Plateau (pl. 1 and fig. 1).[11]

St. Francis Mountains.—The St. Francis Mountains occupy a small area in southeastern Missouri, at the east end of the crest of the Ozark structural dome. They are made up of granitic hills which, originally carved in pre-Cambrian time, have been buried beneath Cambrian and later sediments and have only recently, in a geologic sense, begun to be reexcavated. These hills reach a maximum altitude of about 1,800 feet.

Salem Plateau.—On the central part of the Ozark dome in Missouri the dominating topographic feature is a rolling plain of gentle relief, known as the Salem Plateau, from the town of Salem. It averages around 1,300 feet in altitude but rises to 1,500 feet as it approaches the St. Francis Mountains. The plain is developed on Cambrian and Ordovician rocks, chiefly dolomites and sandstones. Southward toward the Boston Mountains, in Arkansas, the plain loses altitude and becomes more deeply and intricately dissected by drainage lines, although the interstream areas still tend to be flat or gently rolling.

That portion of the Salem Plateau lying in Arkansas is bounded on the southwest roughly by the course of the White River; along certain large tributaries, however, such as the Kings River in Carroll County, it may show considerable extent south of the White River. On the southeast the Black River separates the Salem Plateau from the Gulf Coastal Plain. The

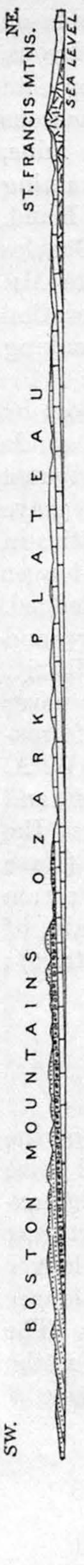
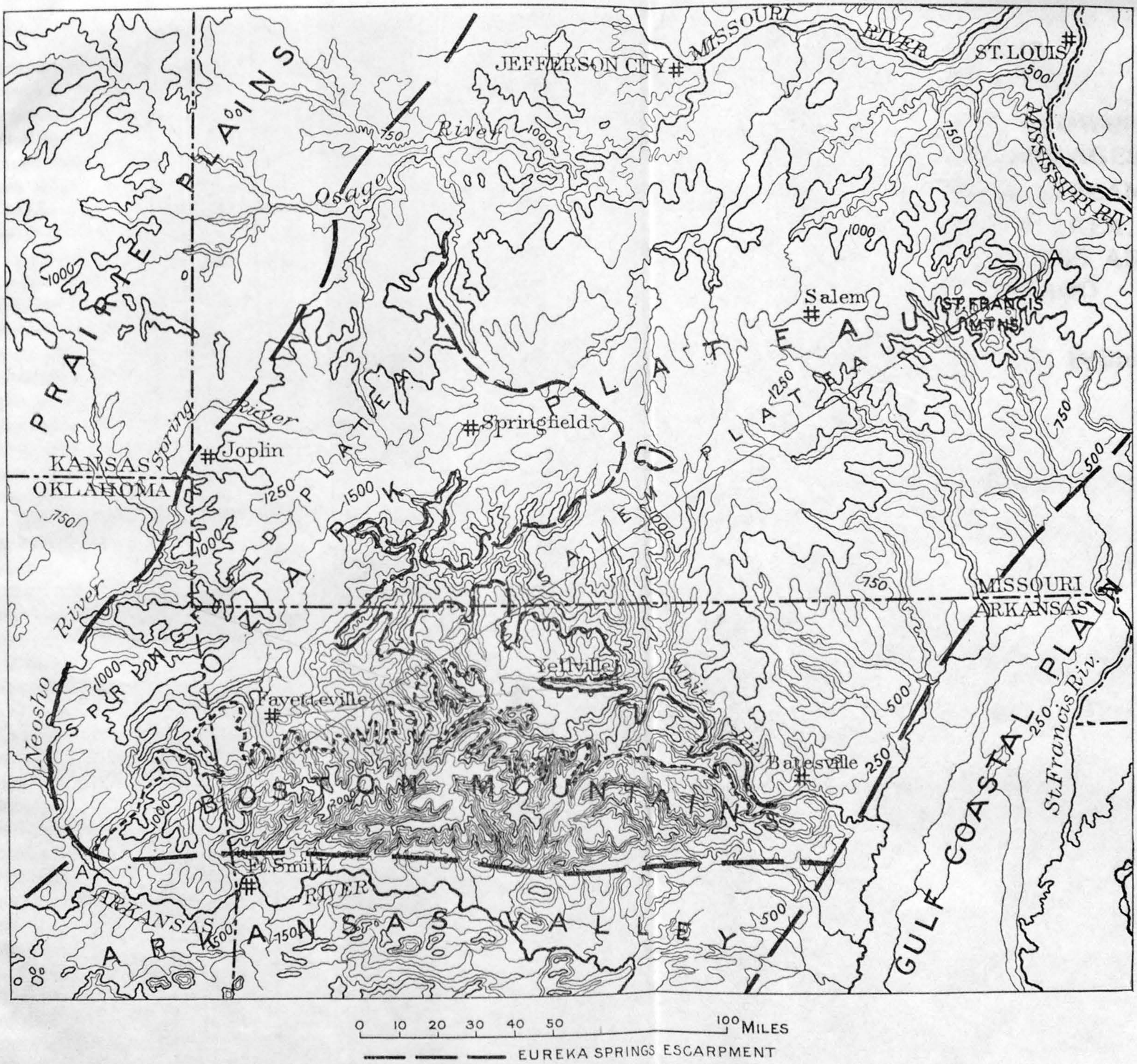


FIGURE 1.—Sketch section across the Ozark region along the line A–A in plate 1. Shows the pre-Cambrian crystalline rocks of the St. Francis Mountains at the right, overlain by Cambrian and Ordovician dolomites and Mississippian cherty limestones of the Ozark Plateau, and these formations in turn overlain by Pennsylvanian sandstones and shales in the Boston Mountains at the left.

[11] The physiographic terminology here used is that of Purdue and Miser in the Eureka Springs-Harrison folio, which in turn is modified from the terminology presented by C. F. Marbut (Physical features of Missouri: Missouri Geol. Survey, vol. 10, pp. 13–109, 1896). Much of the information on the Missouri Ozarks here summarized is taken from Marbut.



SKETCH MAP OF THE OZARK REGION.

Showing its physiographic divisions and its relations to the adjacent Prairie Plains, Arkansas Valley, and Gulf Coastal Plain regions. The Ozark region comprises the Boston Mountains and the Ozark Plateau. The Ozark Plateau is divided by the Eureka Springs escarpment into the Springfield Plateau and the Salem Plateau.

altitude of the plateau in northern Marion, northern Baxter, and western Fulton Counties, where topographic maps have been made, is between 800 and 1,000 feet, the higher country tending to lie toward the north. Above the general level rise a few residual hills and knobs, some of them abruptly, to heights as great as 250 feet. Wallace Knob, near Mountain Home, is a typical example. Below the plateau the drainage has entrenched itself to a depth of as much as 400 feet along the main rivers.

Springfield Plateau.—The Springfield Plateau lies chiefly on the western and southwestern slopes of the Ozark dome and rises to a maximum altitude of about 1,700 feet in Webster and western Wright Counties, Mo. It is developed on resistant cherty limestone of the Mississippian series and is separated from the Salem Plateau throughout most of its extent by the Burlington escarpment, known also in Arkansas as the Eureka Springs escarpment. This escarpment faces the Salem Plateau and averages between 200 and 300 feet in height in Missouri; in Arkansas its height is somewhat greater, ranging from 300 to 400 feet in Carroll and Boone Counties and reaching 700 feet in Marion County.

The Springfield Plateau is not very prominent in northern Arkansas as compared to its great extent in Missouri. In the northwest corner of the State, however, it is developed over a few hundred square miles, chiefly in Benton and northern Washington Counties. Farther east it is present to some extent as a more or less dissected belt of variable, in places narrow width, between the Boston Mountains and the Salem Plateau. It supports everywhere a thriving agricultural population.

The plateau over much of its extent in Washington and Benton Counties is remarkably level, with a summit altitude between 1,250 and 1,350 feet. In Madison, Carroll, and Boone Counties, where the plateau is less extensive and more dissected, the altitude ranges between 1,250 and 1,700 feet, the maximum being on Pension Mountain, southeast of Eureka Springs. Below the level of the upland the drainage is entrenched to a depth in places of 500 feet. The Eureka Springs escarpment, separating the Springfield Plateau from the Salem Plateau, exhibits a very intricate pattern in these counties, advancing far out on the spurs and retreating around the heads of the hollows.

In the Yellville quadrangle, which includes practically all of Marion County, an eastern strip of Boone County, a northern strip of Searcy County, and the northeast corner of Newton County and thus embraces a large part of the mineral region, the Springfield Plateau has been so thoroughly dissected that over much of the region the only remnant is a maze of long, narrow, fairly level-topped ridges that are capped by the Boone chert. These ridges show a very irregular pattern. They stand up above the Salem Plateau to a height of as much as 700 feet (Halls Mountain, east of Yellville), although their average height is somewhat less. Many of the dissecting streams, especially the smaller tributaries, have not yet eroded to the level of the Salem Plateau. The highest altitude in the quadrangle, 1,450 feet, in sec. 8, T. 16 N., R. 18 W., is on a remnant of the Springfield Plateau, and there are numerous other places throughout the quadrangle where the altitude of such remnants is greater than 1,300 feet. The hollows between the ridges are steep-sided and have steep gradients, so that the resultant topography is extremely rugged. This is the type of country in which most of the mines and prospects have been developed, at various levels between the summit plain and the basal platform.

Southeast of the Yellville quadrangle the Springfield Plateau has not been studied except in a reconnaissance way, but it is known to be much narrower and to be confined to the southwest side of the White River.

Boston Mountains.—The highest and most rugged features of the Ozark region are encompassed in the Boston Mountains. These trend east and west along the south side of the Ozark uplift and are very nearly confined to northern Arkansas, although they extend a little way into Oklahoma, as far as the Neosho River. They are terminated on the east, in the region of Batesville, by the Coastal Plain, but are very much lower here than they are farther west, between Searcy County and the State line. A few of the highest points along the north side of the range in this western region are as much as 2,400 feet in altitude, although the average summit level is around 2,200 feet. The average width of the range is about 35 miles. Southwest of Harrison a prong of the mountains projects northward for 20 miles beyond the main front and includes some of the highest parts of the range. The mountains are developed on Pennsylvanian sediments, dominantly sandstones, that show a very slight regional dip to the south.

The Boston Mountains are the remnant of a thoroughly dissected plateau. The residual ridges and spurs are flat-topped but are generally less than 1 mile in width. Here and there, however, flats or near-flats of rudely equidimensional outline embracing several square miles may be preserved, as, for example, the one on which Compton, southwest of Harrison, is situated. The creek valleys that head in the mountains are veritable canyons, some of them being incised as much as 1,400 feet below summit levels less than a mile away. In places the canyon slopes are interrupted by sheer cliffs, developed on certain resistant beds, that may be as much as 100 feet high. The north front of the range takes the form of a steep escarpment of the same general character as the canyon walls, except that it is not quite as steep. As this front is really formed by the ends of the intercanyon spurs, it is very irregular in outline. On the south side of the mountains, where the southward dip of the strata becomes increasingly pronounced toward the Arkansas Valley, the general altitude of the surface falls off gradually with the dip of the beds, and the range lacks the rugged aspect that it shows north of the divide.

DRAINAGE

The master stream of northern Arkansas is the White River. Heading in the Boston Mountains south of Huntsville, Madison County, it flows northward into Missouri and after traversing parts of three of the southern counties of that State turns back southeastward across northern Arkansas. The largest tributary in the lead-zinc field is the Buffalo River, which flows eastward and drains the north side of the Boston Mountains in Newton and Searcy Counties, although the lower course of the river traverses part of Marion County. Crooked Creek also flows eastward to the White River but drains a basin in the Springfield Plateau north of the Buffalo Basin. These are the two large tributaries of the White River that traverse the most productive part of the lead and zinc region. Others outside of the mineralized district are War Eagle Creek, the Kings River, and the North Fork of the White. War Eagle Creek is really one of the larger headwater prongs of the White River. The Kings River heads in the Boston Mountains in Madison County and, crossing Carroll County, enters the White in Missouri. The North Fork heads in Missouri and flows southward to the White River through Baxter County, Ark. Outside of the direct White River drainage, the Strawberry River, a tributary to the Black River, flows southeastward across the Salem Plateau, traversing the ore-bearing region of Sharp and Lawrence Counties.

In addition to the main streams, northern Arkansas is cut by a host of smaller tributary creeks and branches, many of which are perennial over all or parts of their courses. An abundance of springs throughout the region accounts in large part for the water that flows during the summer, when precipitation may be scant. Such springs have played an important part in the settlement and economic development of the region. Although no figures can be given on the flow of any of them, many give rise to streams of considerable volume. As might be predicted from the large contribution by springs, the stream water is clear, except for short periods during flood times, but is rather hard.

All the streams have cut channels below the upland surfaces which they traverse. The depth to which they have cut differs on different streams and in different parts of the same stream. The beds of the White River and the North Fork lie on the average from 300 to 400 feet below the adjacent uplands of the Salem Plateau. The Buffalo River over much of its course has cut from 400 to 600 feet below the Springfield Plateau, but in its upper part, where it lies in the Boston Mountains, the depth of the gorge is as much as 1,400 feet. The valley of the Strawberry River, cut in the Salem Plateau, is neither as deep nor as steep-sided as those belonging more directly within the White River drainage system.

Enclosed meanders [12] are characteristic of the valleys of the Ozark highlands and are found on practically all the streams in northern Arkansas. They are not as well developed in the Boston Mountains as on the Springfield Plateau or the Salem Plateau, but perhaps most of this difference is due to the fact that only the headwaters of the streams are cut in the mountains; normally meandering occurs only in the middle and lower courses of a stream. The profile of the average meander bend is characteristically asymmetric throughout the Ozark region, with a bluff on the outside of the bend and an even, moderate slope from the river level to the upland above on the inside. This feature has been cited as evidence in support of a theory of origin for the Ozark meanders, whereby they are assumed to have been developed, during downcutting of the streams, by a process of lateral corrasion on the outsides of bends that existed originally, at a much higher level, as minor irregularities in the courses of the streams.[13] It should be pointed out that sinuosity in the courses of the northern Arkansas streams was well developed when the drainage lines stood at the levels of the upland plains in which they are entrenched, to judge from the way in which spurs of the upland plains overlap from opposite sides of the streams. Although lateral corrasion during downcutting has undoubtedly been influential in development of the meandering, its operation does not preclude the possibility that an earlier system of meanders may have been developed on a baseleveled surface according to the normal habit of streams at baselevel, and that these meanders were

[12] The term "enclosed" is applied to any meander that is more or less narrowly enclosed by valley walls; it carries no connotation as to origin. See Moore, R. C., Origin of enclosed meanders on streams of the Colorado Plateau: Jour. Geology, vol. 34, pp. 44–46, 1926.

[13] Winslow, Arthur, The Osage River and its meanders: Science, new ser., vol. 22, pp. 31, 32, 1893. Marbut, C. F., The physical features of Missouri: Missouri Geol. Survey, vol. 10, pp. 98–109, 1896. Tarr, W. A., Intrenched and incised meanders of some streams on the northern slope of the Ozark Plateau in Missouri: Jour. Geology, vol. 32, pp. 583–600, 1924.

entrenched by uplift of the region and greatly modified by lateral shifting of the streams on the bends during the downcutting to their present positions.

Owing to the canyonlike character of the valleys, the heavy cyclonic storms, which are characteristic of the spring and fall but which may occur at any season, produce extremely high floods. Rises of 30 to 40 feet in the White River and Buffalo Fork are common. The highest recorded rise on the White was at Calico Rock, Izard County, on January 31, 1916, when the river reached a level 51 feet above the low stage. The Buffalo River at Gilbert, on August 18, 1915, rose to 54 feet above the low stage. Such floods are very destructive of crops, property, and livestock.

VEGETATION

Except where they are under cultivation the hills and valleys of northern Arkansas are rather heavily wooded. White oak, shortleaf pine, walnut, and cedar are commercially important but are rapidly being removed. Most of the timber is deciduous, in which oaks and hickories of various species predominate, but is of too scrubby a character to be of commercial value. Generally an inferior grade springs up after the removal of the commercially valuable timber.

According to the old settlers, this mantle of timber has grown largely since the Civil War. Before that time the ridges and valleys supported a luxuriant carpet of wild grasses, with only a few scattered trees. Such names as "Bald Jesse", "Bald Dave", and "Bald Tom", which are applied to heavily wooded knobs and which seem singularly inappropriate today, are relics of these early days when they really had a meaning. The cause generally ascribed to the change since the Civil War is the displacement of the Indians, under whose occupation the land was periodically fired for the express purpose of suppressing the timber, in order that game might be more easily obtained, because less protected by cover.

ROCK OUTCROPS

Outcrops, though by no means continuous, are nevertheless fairly good along the valley slopes, owing to their steepness. It is to the prevalence of rock exposures at the ore-bearing horizons in the thoroughly dissected region of Marion, Boone, Newton, and Searcy Counties that the location and development of so large a number of mineral prospects in these counties has been due. In Sharp and Lawrence Counties the topography is more subdued and outcrops are not so conspicuous.

STRATIGRAPHY

GENERAL FEATURES

The rocks of northern Arkansas are all sedimentary and range in age from Lower Ordovician to Pennsylvanian. The intervening Silurian and Devonian systems and the Mississippian series of the Carboniferous system are represented, though very unequally. The sediments record an ever-changing configuration between land and shallow interior seas throughout most of this time interval. Unconformities are numerous in the stratigraphic section and account for most of the discontinuities in the present distribution of the formations. When considered regionally, the stratigraphic breaks recorded in the different unconformities increase in amount from south to north, though locally they may increase in any direction. The regional distribution and thickness of the different formations, combined with the regional structure, show that the Ozark region had been differentially uplifted along the general location of its present axis before the Mississippian sediments were deposited. It is probable that the differential uplift had begun as early as the Lower Ordovician or Upper Cambrian and was accentuated at several later times before the Mississippian.

The stratigraphy of different areas in northern Arkansas has been studied by numerous workers,[14] and no attempt will be made in the present report to include all the information that has been gathered, as such a treatment would transcend the purpose of an economic report. Instead, the discussion of the rock formations will be limited to those regions in which the principal occurrences of lead

[14] Penrose, R. A. F., Manganese, its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, 1891. Treats Batesville district.

Simonds, F. W., The geology of Washington County: Arkansas Geol. Survey Ann. Rept. for 1888, vol. 4, 1891.

Hopkins, T. C., Marbles and other limestones: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 4, 1893.

Branner, J. C., The phosphate deposits of Arkansas: Am. Inst. Min. Eng. Trans., vol. 26, pp. 580–598, 1897.

Williams, H. S., The Paleozoic faunas of northern Arkansas: Arkansas Geol. Survey Ann. Rept. for 1892, vol. 5, pp. 268–375, 1900.

Branner, J. C., and Newsom, J. F., The phosphate rocks of Arkansas: Arkansas Agr. Exper. Sta. Bull. 74, pp. 61–123, 1902.

Adams, G. I., and Ulrich, E. O., Zinc and lead deposits of northern Arkansas: U.S. Geol. Survey Prof. Paper 24, 1904.

Adams, G. I., and Ulrich, E. O., U.S. Geol. Survey Geol. Atlas, Fayetteville folio (no. 119), 1905.

Purdue, A. H., U.S. Geol. Survey Geol. Atlas, Winslow folio (no. 154), 1907.

Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, pp. 281–680, 1911.

Purdue, A. H., and Miser, H. D., U.S. Geol. Survey Geol. Atlas, Eureka Springs-Harrison folio (no. 202), 1916.

Miser, H. D., Deposits of manganese ore in the Batesville district, Arkansas: U.S. Geol. Survey Bull. 734, 1922.

Giles, A. W., St. Peter and older Ordovician sandstones of northern Arkansas: Arkansas Geol. Survey Bull. 4, 1930.

Names and equivalents of formations in zinc and lead region of northern Arkansas

System.	Series.	Composite general section showing the standard equivalents of formations in northern Arkansas and adjoining parts of Oklahoma.	McKnight, E. T., Yellville quadrangle (present report).	Purdue, A. H., and Miser, H. D., U.S. Geol. Survey Geol. Atlas, Eureka Springs-Harrison folio (no. 202), 1917.	Branner, J. C., Williams, H. S., and others, Arkansas Geol. Survey reports published in 1900 and previous years.	Ulrich, E. O., U.S. Geol. Survey Prof. Paper 24, 1904.
Carboniferous.	Pennsylvanian.	Pottsville.	Winslow formation.	Winslow formation.	Millstone grit.	Winslow formation.
			Morrow group. Absent.	Morrow group. Bloyd shale.	[Shales and sandstone.]	Morrow formation. Shale.
				Kessler limestone member.	Boston group. Kessler limestone.	Kessler limestone.
					Coal-bearing shale.	Coal-bearing shale.
				Brentwood limestone member.	Pentremital limestone.	Brentwood limestone.
			Hale formation.	Hale formation.	Washington shale and sandstone.	Washington shale and sandstone.
	Mississippian.	Chester.	Pitkin limestone.	Pitkin limestone.	Archimedes limestone.	Pitkin limestone.
			Fayetteville shale. Absent?	Fayetteville shale.	Shaly sandstone.[1]	Fayetteville formation.
			Wedington sandstone member.	Wedington sandstone member.		Wedington sandstone member.
					Marshall shale.[2]	
			Batesville sandstone.	Batesville sandstone.	Batesville sandstone.	Batesville sandstone.
			Hindsville limestone member.[3]	Hindsville limestone member.		
		St. Louis.	Absent.	Absent.	Spring Creek limestone.[4]	Moorefield shale (including Spring Creek limestone.)[4]
					Fayetteville shale.[5]	
		Spergen.			Wyman sandstone.[6]	
		Warsaw.	Boone formation.	Boone limestone.	Boone[7] chert and limestone. Cherty beds.	Boone limestone.[3]
					Carrollton limestone.	
		Osage (Keokuk, Burlington, and Fern Glen).	St. Joe limestone member (Fern Glen age).	St. Joe limestone member.	St. Joe marble.	St. Joe limestone member.
Devonian or Carboniferous.	Upper Devonian or Mississippian.		Absent.	Upper Devonian. Chattanooga shale.[8]	Eureka shale (typical).	Noel shale.
				Sylamore sandstone member.[9]	Sylamore sandstone.[9]	Neo-Devonian. Sylamore formation.[11]
					Eureka shale, in part.[10]	
Devonian.	Middle Devonian.	Hamilton.	Not known.	Clifty limestone.	Not known.	Not known.
Silurian.		Niagara.	St. Clair limestone.	Absent.	St. Clair limestone.	St. Clair limestone.
		Albion.	Brassfield limestone.			
Ordovician.	Upper Ordovician.	Richmond.	Cason shale.	Cason shale.	Cason shale.	Cason shale.
			Fernvale limestone.	Fernvale limestone.	Polk Bayou limestone.[12]	Polk Bayou limestone.[12]
		Lorraine.	Absent.	Absent.		
	Middle Ordovician.	Trenton.				
		Black River.	Kimmswick limestone.			
		Black River. Lowville.	Plattin limestone.		Izard limestone.	Izard limestone.
	Lower Ordovician.	Chazy and possibly older beds not represented in the New York section.	Joachim dolomite.			
			St. Peter sandstone.		Saccharoidal sandstone.	Key sandstone.
			Jasper limestone.[13]	Jasper limestone.[13]	Magnesian limestones, sandstones, cherts, etc.	Yellville limestone.
			Everton formation.[14]	Joachim limestone.[15]		
			Newton sandstone member.	St. Peter sandstone.[15]		
				Everton limestone.[14] Kings River sandstone member.		
				Sneeds limestone lentil.		
		Beekmantown.	Powell dolomite.[14]	Powell limestone.[14]		
			Cotter dolomite.	Cotter dolomite.		
			Jefferson City dolomite.[16]			

[1] This shaly sandstone of the †Boston group seems to be the same as the Wedington sandstone, which F. W. Simonds, in his report on Washington County, calls the "Batesville sandstone."

[2] The †Marshall shale at the type locality is the same as the Fayetteville shale, but what Simonds called †"Marshall shale" is only the upper member of the Fayetteville.

[3] In northwestern Arkansas, where the Moorefield shale is absent, the limestone corresponding to the Hindsville was apparently included in the Boone by Branner, Ulrich, and others.

[4] The †Spring Creek limestone is the basal part of the Moorefield shale, which is now considered of pre-Chester (St. Louis?) age.

[5] The Fayetteville shale really occupies the interval between the Pitkin (†*Archimedes*) limestone above and the Batesville sandstone beneath.

[6] The †Wyman sandstone is the same as the Batesville sandstone.

[7] The limestone corresponding to the Hindsville was described by T. C. Hopkins as overlying the chert bed of the Boone, but it was considered by him a part of the Boone.

[8] Some geologists regard the Chattanooga shale of the southern Ozark region as of lower Kinderhook age and assign it to the Mississippian series, but the Chattanooga as exposed near Batesville, Ark., is shown by its fossils to be of Genesee age.

[9] The Sylamore sandstone apparently transgresses the geologic age boundaries and is probably represented in the Yellville quadrangle by a sandstone of Osagean age that lies at the base of the Boone formation.

[10] This †Eureka shale is probably the Cason shale.

[11] The Cason shale is locally included in the Sylamore formation.

[12] The †Polk Bayou limestone at its type locality consists of the Fernvale and Kimmswick limestones, which are separated by an unconformity that represents the time interval of the Lorraine and Trenton of New York.

[13] Future work may show that the Jasper limestone should be classed as a part of the Everton formation. Ulrich believes that the Jasper may be older than the St. Peter sandstone though it might occupy part of the interval between the Joachim dolomite and Plattin limestone.

[14] The Black Rock and Smithville formations in Sharp and Lawrence Counties resemble the Everton formation in lithology but are believed by Ulrich, on the basis of fossil evidence, to occupy an interval between the Everton and Powell.

[15] The so-called "Joachim limestone" and so-called "St. Peter sandstone" of the Eureka Springs and Harrison quadrangles are equivalent to the upper portion of the Everton formation of the Yellville quadrangle.

[16] The base of the Cotter has never been definitely defined in Arkansas. Ulrich now believes that the lower part of the Cotter, as mapped in the Harrison quadrangle, is Jefferson City.

and zinc are found. During the course of the field work on the present report the area within the Yellville quadrangle (see pls. 3 and 5) was studied in detail, and, except as otherwise stated the discussion of stratigraphy applies essentially to this quadrangle. The accompanying table shows the names and equivalents of the formations.

The territory included within the Yellville quadrangle appears to have been, through Middle and Upper Ordovician, Silurian, and Devonian time, in the critical position along the south border of the Ozark land mass, where it stood alternately above and below sea level. Certainly this region oscillated around a higher level than the Batesville district, to the southeast, for the unconformities between successive formations represent greater stratigraphic breaks than they do in that district. During the Carboniferous period subsidence was more pronounced, so that most or all of the Ozark region was submerged beneath an interior sea at different times.

The rocks of the Yellville quadrangle include representatives of the Ordovician and Silurian systems and of the Mississippian and Pennsylvanian series of the Carboniferous system. No rocks of Devonian age have been found. (See pl. 2.)

ORDOVICIAN SYSTEM

The Ordovician is well represented in the Yellville quadrangle by a maximum of about 1,300 feet of marine sediments, mostly limestone and dolomite but with considerable sandstone. Shale is very subordinate. Deposits of Lower, Middle, and Upper Ordovician age are present, but there are at least 5 and perhaps 6 or 7 unconformities within the section, so that the different series are unequally represented. The Lower Ordovician is best developed and is indeed the only subdivision that has been preserved over much of the lead and zinc region, the Middle and Upper series having been removed at the north, if ever deposited, by the erosion represented in the unconformity at the base of the Mississippian.

LOWER ORDOVICIAN SERIES

COTTER AND JEFFERSON CITY DOLOMITES

NAME

The term "Jefferson City" was applied to a series of magnesian limestones in central Missouri by Winslow[15] in 1894. In 1912 Ulrich[16] restricted this name to the lower part of the series and

[15] Winslow, Arthur, Lead and zinc deposits: Missouri Geol. Survey, vol. 6, pt. 1, p. 331, 1894.

[16] Purdue, A. H., and Miser, H. D., U.S. Geol. Survey Geol. Atlas, Eureka Springs-Harrison folio (no. 202), pp. 4, 5, 1916.

proposed the names "Cotter" and "Powell" to cover, in ascending order, certain higher formations, first differentiated in northern Arkansas. The Cotter takes its name from the town of Cotter, on the White River in the eastern part of the Yellville quadrangle. All these formations were included in the †Yellville formation[17] of the Adams report and in the "magnesian limestones, sandstones, cherts, etc." of the Branner report.

DISTRIBUTION

The Cotter dolomite is widely exposed over the northern part of the Yellville quadrangle. With the exception of the Jefferson City dolomite, which has not been differentiated in the quadrangle, it is the only formation that occurs along the inner valley of the White River. It forms the uplands on the left side of the river and in most places extends back several miles from the river on the right side. It extends up the valley of Crooked Creek as far as the mouth of Georges Creek. The details of its distribution in the Yellville quadrangle are shown on plate 3. This is the formation whose outcrop forms most of the Salem Plateau in Arkansas.

According to Ulrich,[18] the Jefferson City dolomite is exposed in the valley of the White River around Oakland. The same strata that are there exposed crop out along the river above Oakland at least as far as the mouth of Big Music Creek, in the lower valley of which they are undoubtedly exposed, to judge from the high level at which the top of the Cotter lies in this region. For the purposes of this economic report the Jefferson City dolomite, because of its lithologic similarity to the Cotter dolomite, was not differentiated from the Cotter. Strata that are possibly referable to the Jefferson City contain no important ore deposits in Arkansas.

THICKNESS

The greatest observed thickness of the combined Cotter and Jefferson City was about 400 feet near Pine Mountain, southwest of Oakland, but it is possible that the thickness exceeds this at other places in the White River Valley. According to Ulrich, the lower 75 feet of this is Jefferson City. Ulrich classes 125 feet of the section exposed on Long Mountain, 6 miles northeast of Oakland, as Jefferson City.[19]

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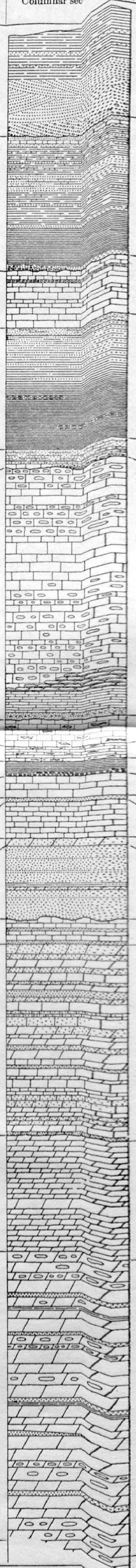
[17] A dagger (†) preceding a geologic name indicates that the name has been abandoned or rejected for use in classification in publications of the U.S. Geological Survey. Quotation marks, which were formerly used to indicate abandoned or rejected names, are now used only in the ordinary sense.

[18] Ulrich, E. O., and others, Geologic map of Arkansas, Arkansas Geol. Survey, 1929.

[19] Personal communication from Josiah Bridge.



System	Series	Formation	Thickness (feet)	Character
Carboniferous	Pennsylvanian	Winslow formation.	130+	Shale with soft flaggy sandstone interbedded.
			(80)	Buff to whitish cross-bedded sandstone, containing white quartz pebbles in lower 20 feet.
		Unconformity		
		Hale formation.	190	Black fissile shale with brown seams of clay ironstone; gray and olive-green sandy and limy shale; brownish sandstone, in part limy and shaly; brownish sandy and shaly limestone; thin beds of dark-gray limestone.
		Unconformity		
	Mississippian	Pitkin limestone.	55–115	Massive gray bituminous limestone, in places oolitic.
		Unconformity		
		Wedington sandstone member.	(10±)	Thin-bedded buff to brown limy sandstone.
		Fayetteville shale.	150–200	Black shale with limy septarian nodules; grades into drab shaly sandstone at top.
		Batesville sandstone.	25	Platy gray limy sandstone; weathers buff; some sandy limestone and sandy shale.
		Hindsville limestone member.	(0–10)	Locally, dark-gray bituminous oolitic limestone with chert fragments in base.
		Unconformity		
		Boone formation.	350±	Massive gray crystalline crinoidal limestone, containing much crinoidal chert.
		St. Joe limestone member.	(20–45)	Fairly thin-bedded reddish and gray crystalline limestone.
			(0–18)	White to brown sandstone with phosphatic pebbles in places.
		Unconformity		
Silurian		St. Clair limestone.	0–60	Gray to flesh-colored, variably crystalline limestone, containing small vugs of crystalline calcite.
		Unconformity		
		Brassfield limestone.	0–30	Glauconitic gray, pink, or flesh-colored (locally white) crystalline limestone, containing vugs of crystalline calcite.
		Unconformity		
Ordovician	Upper Ordovician.	Cason shale.	0–23	Greenish to blue-gray shale; some black; phosphate nodules near base.
		Unconformity		
		Fernvale limestone.	0–50	Massive coarsely crystalline gray to pinkish limestone.
		Unconformity		
	Middle Ordovician.	Kimmswick limestone.	Thin	Porous gray fossiliferous sandstone; does not crop out.
		Unconformity		
		Plattin limestone.	0–100	Dense blue-gray limestone with cubes of limonite; some drab limestone and gray dolomite.
		Unconformity		
	Lower Ordovician	Joachim dolomite.	0–13	Massive dark-gray sandy dolomite.
		St. Peter sandstone.	0–136	White to buff saccharoidal sandstone; middle zone greenish, with dolomitic and shaly facies.
		Unconformity		
		Jasper limestone.	0–50	Compact bluish-gray limestone and saccharoidal sandstone.
		Everton formation.	0–400	Compact bluish-gray limestone, sandy limestone, friable white to buff sandstone, sandy gray dolomite, and dolomite, all interbedded.
		Unconformity		
		Powell dolomite.	85–170	Medium-bedded compact gray argillaceous dolomite; massive, slightly more crystalline ledge 60 feet above base.
		Unconformity?		
		Cotter and Jefferson City dolomites.	400+	Gray dolomite containing some chert, interbedded with a little saccharoidal sandstone and blue-gray or greenish shale.

GENERALIZED SECTION OF ROCKS EXPOSED IN THE YELLVILLE QUADRANGLE.

The thicknesses in parentheses apply to lithologic subdivisions of a formation; thicknesses not in parentheses apply to the whole formation.

CHARACTER

The Cotter dolomite consists chiefly of alternating beds of two types of dolomite—a fine-grained argillaceous "cotton rock" type and a coarser-grained, visibly crystalline type. Both types are gray when fresh but weather to light gray, drab, or buff and eventually to red clay. The "cotton rock", when in an advanced stage of decay, is a soft chalky substance, generally buff and of low specific gravity. At an intermediate stage of weathering some of the thicker coarse-grained beds are mottled in different shades. Most of the dolomite is in beds from 1 to 2 feet thick, but local massive beds may reach 4 or 5 feet.

Beds of sandstone and of shale 2 feet or so in maximum thickness occur here and there in the dolomite but are inconspicuous. The shale is blue-gray or greenish and weathers to olive-drab.

Nodular chert is very abundant in certain layers and is characteristic of the formation. Many of the masses are several feet in size. In places the chert becomes so predominant as to form practically a solid bed that may be 5 or 6 feet thick. Much of the nodular chert is concentrically banded in different shades of gray or buff. The nodules that are widely distributed in a thin zone at the very top of the formation have the banding developed to remarkable perfection. Some of them show as many as 40 or 50 alternating white and dark-gray bands to the inch, although the widths of the different bands within this inch are variable. These nodules are generally oblong, but many are irregular in shape, owing to subsidiary nodular growths on the main masses. They average 3 or 4 inches in length but may reach 8 or 10 inches. The larger nodules are not so delicately banded.

It has been frequently observed that chert nodules in the Cotter have been broken in place and the different fragments separated and perhaps rotated. The material that fills the gaps between the fragments is massive dolomite of the same type as that which normally surrounds the nodules. Although no flow lines or any indication of granulation or other structural weakness is evident in the material that fills in between the broken edges of the fragments, nevertheless it appears that these examples are evidence of a deformation that, in its end results, simulates plastic deformation. Only the dolomite behaved plastically, while the chert was broken.

That much of the Cotter chert was formed by replacement of dolomite is indicated by the continuation of bedding laminations from the dolomite into the chert in a few places (fig. 2). Ordinarily, however, the process was accompanied by complete obliteration of such depositional features. The general massiveness of the chert-bearing beds is an additional factor in making such occurrences exceptional. The replacement is believed to have been effected early in the history of the sediments, probably only a short time after deposition. While outcrops of the Cotter show a certain amount of crusty silicification that is related to weathering at the surface, the greater part of the chert, especially the nodular chert, shows no such dependence on surface conditions; typical development is found in mine shafts and drill holes that penetrate well below the level of ground water. After its formation the chert was locally brecciated by rock stresses, and the dolomite that was squeezed into the interstices was completely recrystallized, as described above.

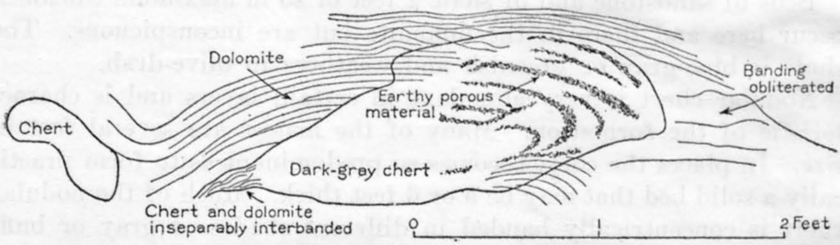


FIGURE 2.—Field sketch showing continuation of lamination lines of Cotter dolomite into the chert.

Unfilled cracks and irregular solution cavities in the chert are lined with crystalline (pyramidal) quartz that is sometimes as coarse grained as an eighth of an inch in crystal diameter. This drusy quartz is not confined to chert but may occur in the dolomite.

At a few places beds of oolitic dolomite have been found in the Cotter. Some of this oolite has been silicified, in scattered spots, to chert. As none was recognized in the overlying Powell, the presence of oolite becomes a criterion that, if due caution is exercised, may be used in distinguishing Cotter from Powell. All the occurrences noted were near the top of the formation.

OUTCROPS

Except in actively eroding creek valleys or in the bluffs of the larger streams, the Cotter does not commonly form bedrock outcrops. Usually it weathers down to a stony red clay. Some of the chert in this clay appears to be due to surface silicification, although the greater part of it represents the original chert that has been concentrated in the residual soil. Except for their stony nature, soils derived from the Cotter are fairly fertile.

FOSSILS AND AGE

The Cotter dolomite is, on the whole, rather unfossiliferous, but certain beds have yielded a characteristic fauna. This fauna has been studied in connection with other geologic investigations of northern Arkansas, and only incidental collections were made during the field work for this report. The best collecting is always found on weathered outcrops, where the fossils that have been silicified during weathering are preserved in the surficial cherts. Most of the fossil types are either gastropods or cephalopods, but the genus *Cryptozoon*, a colonial algal form, is also well represented. It is uncommon or absent in the overlying Powell. A colony of this ancient plant appears as a flat dome-shaped concentric structure, as much as 1 or 2 feet across, on the bedding surface of a dolomite layer. Generally the colonies themselves tend to occur in considerable numbers at the horizon where they are developed.

The Cotter is of Lower Ordovician age and, from the character of its fossils, is correlated with the upper part of the Beekmantown limestone of the type New York section.

STRATIGRAPHIC RELATIONS

The contact betwen the Cotter and the overlying Powell has been described as one of erosional unconformity,[20] with the occurrence of a basal chert breccia in the Powell. No breccia that could be definitely ascribed to this origin was observed by the writer at this horizon within the Yellville quadrangle.

The zone of banded chert nodules mentioned previously was arbitrarily chosen as the top of the Cotter. It occupies an interval of only a foot or so in a 4- or 5-foot ledge of fine-grained dolomite. The dolomite is overlain by 5 feet of greenish shale, followed by "cotton rock", which in places shows mud cracks in a slightly sandy layer 10 feet above the chert. Below the chert comes a 5- to 10-foot zone of "cotton rock", then 5 feet of greenish or blue-gray dolomitic shale.

Although this chert zone may not be at exactly the horizon that has been previously chosen as the contact between Cotter and Powell, it is close to that horizon and has the practical advantage that, for purposes of mapping, it is easy to locate in the field.

POWELL DOLOMITE

NAME

The Powell was included in the "magnesian limestones, sandstones, cherts, etc.," of the Branner report and in the †Yellville formation of the Adams report. In 1911 Ulrich[21] restricted the term †"Yellville" to the middle part of the formation as recognized by

[20] Purdue, A. H., and Miser, H. D., U.S. Geol. Survey Geol. Atlas, Eureka Springs-Harrison folio (no. 202), p. 5, 1916.

[21] Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, pp. 667-671, 1911.

Adams, calling the upper part Everton and the lower part Jefferson City. In 1912[22] he substituted the name "Powell" for his †Yellville (restricted), and subdivided the Jefferson City of earlier reports into two formations, the Cotter above and the Jefferson City (restricted) below. The name "Powell" is taken from a now abandoned settlement on Crooked Creek near the center of the Yellville quadrangle. Only the top part of the formation is exposed at the type locality.

DISTRIBUTION

The Powell dolomite is widely exposed over the north two-thirds of the Yellville quadrangle, but unlike the Cotter, whose outcrop forms broad flats, it is largely restricted to the lower part of the Eureka Springs escarpment, or else it may form low and usually gently sloping hills or ridges that lie out some distance from the main escarpment. Owing to the southward dip of the strata, it is buried over most of the south third of the quadrangle, but it crops out in the Rush district and along the Buffalo River at Mount Hersey.

THICKNESS

The thickness of the Powell is nearly everywhere between 140 and 170 feet, the most common figure being 160 feet. From Short Mountain westward along the Eureka Springs escarpment to the western edge of the quadrangle the thickness decreases to 85 feet, although unevenly. From Elixir Springs westward this decrease can be attributed in part to the unconformity at the base of the Mississippian, but in the stretch between Short Mountain and Elixir Springs, where the minimum thickness is about 100 feet, the lower part of the Everton formation is still present beneath the Mississippian. It is possible that the unconformity at the base of the Everton, which elsewhere is only a break in the stratigraphic section indicated by a basal breccia, in this region cuts out some of the beds at the top of the Powell.

CHARACTER

The Powell is dominantly a fine-grained gray argillaceous dolomite (locally called cotton rock) that effervesces very slowly with dilute acid. Analyses made on three specimens by J. G. Fairchild in the chemical laboratory of the United States Geological Survey show a slight excess of calcium over the theoretical ratio for dolomite, the molecular ratio being 1.1 : 1.0 instead of 1 : 1. Microscopic examination of powdered samples of these and other specimens confirms the analyses in showing only dolomite. The amount of insoluble clay material is high, reaching 34 percent in one of the

[22] Purdue, A. H., and Miser, H. D., op. cit., pp. 4, 5.

samples analyzed. As exposed in the beds of running streams, the surface of the fresh rock is usually coated by a thin crust that is buff in color. Under conditions of atmospheric weathering the rock bleaches to a drab or white; more advanced weathering produces a buff chalky material of low specific gravity and finally red clay. The bedding of the "cotton rock" is rather thin, the individual layers averaging 1 to 6 inches thick but in places reaching 5 feet or so.

Interbedded with the fine-grained rock are a few thicker beds of a coarser-grained type. One of these beds, 7 to 10 feet thick, which lies about 60 feet above the zone of chert nodules that marks the top of the Cotter, is persistent over the whole quadrangle wherever the beds at its horizon crop out. It is also present in the northeast corner of the Harrison quadrangle, just west of the Yellville. Those who have prospected for lead and zinc in northern Arkansas have recognized it as a bed that commonly carries ore, and have designated it the †"Black Ledge", in allusion to the fact that it generally weathers dark. Aside from its massive character and medium-grained texture, the †Black Ledge is characterized by quartz-lined druses and, in places, greenish or gray chert segregations. Where weathered, the quartz of the druses projects beyond the main surface of the rock, producing a very rough, hackly surface. The †Black Ledge is commonly fossiliferous.

There are other ledges in the Powell of the same general type as the †Black Ledge, though not so thick, but they were not traced over the quadrangle. A more detailed stratigraphic study might show some of them to be as persistent as the † Black Ledge itself.

The Powell dolomite is more or less siliceous throughout but is especially so in the upper part. On weathering the silica crystallizes as fine drusy quartz that lines cracks and small solution pockets, or else in a more advanced stage it segregates on the erosion surface as hackly masses of dull gray, whitish, and locally greenish chert, with numerous drusy quartz surfaces. The formation contains some primary nodular white and gray chert at certain horizons and some bedded chert, but these are not so characteristic as they are of the Cotter. Some of the nodules are roughly banded, but nowhere on so fine a scale as those of the Cotter; they also incline to be in lighter shades of gray. At several localities in the eastern part of the Yellville quadrangle south of Crooked Creek a prominent bed of chert was observed at approximately the horizon of the †Black Ledge. At the time that part of the region was examined the writer was not familiar with the †Black Ledge as a stratigraphic unit; hence the opinion here presented, that the chert is a lateral variation of the †Black Ledge, lacks the substantiation that a critical reexamination of the region might give. Partial evidence that is at least suggestive of such a relationship, however, is found in the occurrence of fossils in weathered phases of the chert, where it crops out on Ingram Branch of Blue John Creek, in sec. 27, T. 18 N., R. 15 W.; in parts of the Yellville quadrangle where the †Black Ledge is present fossils are rare in the Powell except at this particular horizon. In addition to the locality on Ingram Branch, the chert was recognized on Rush Creek in secs. 5 and 6, T. 17 N., R. 15 W.; on Warner Creek at the mouth of Williams Branch, just east of the quadrangle boundary; and at several places along and near the road that leads east from Onset (Rea Valley). The chert is gray to whitish, is commonly mottled, and in certain parts shows imperfect concentric banding, locally on a rather fine scale. It weathers usually to a buff or brown color. The maximum thickness of 6 to 8 feet occurs on Ingram Branch.

A small amount of greenish to blue-gray shale, more or less dolomitic, is bedded with the dolomite of the Powell and grades into it. These shaly beds do not average more than 2 or 3 feet in thickness. Seams of sandstone and of sandy dolomite, only a few inches thick, are present in the formation but are rather uncommon. An exceptional occurrence of sandstone was noted about 2 miles east-northeast of Monarch, in the NW¼SW¼ sec. 17, T. 20 N., R. 17 W. Here, at a horizon somewhere above the †Black Ledge, a lens of horizontally bedded and rather thick bedded sandstone, 300 feet in length, shows a maximum thickness of 15 feet in its center. The sand grains are well rounded except for a certain amount of crystalline material that has been added to the grains since their deposition.

Evidences of shallow-water deposition and of emergence are not uncommon in the lower part of the Powell. The existence of sun cracks in "cotton rock," 10 feet above the base of the formation, has already been mentioned (p. 21), and ripple-marked "cotton rock" is occasionally found. At one place near Yellville a layer of fine-grained sandstone was deposited over a thin greenish mud film that contained casts of salt crystals. The molds of these crystals, which are as much as an inch across, are preserved as partly deformed cubes on the bottom of the sandy layer.

At a few places masses of quartzite stand as huge residuals on the weathered surface of the Powell, near the top of the formation. Such masses are apparently more common in the Harrison and Eureka Springs quadrangles than in the Yellville quadrangle, but one is present on the north slope of a ridge in sec. 23, T. 20 N., R. 19 W., 2 miles northwest of Elixir Springs. It is rudely cylindrical, and about 30 feet in height and diameter, and its base is 40 feet below the contact of the St. Joe limestone (Mississippian) with the

Powell. The rock is massive except for joints that dip into the mass at rather low angles (30°–45°) from the north and south. There is also one horizontal joint near the top. Miser [23] reports having seen a similar quartzite mass in the vicinity of Zinc when he traversed the region in 1912.

These quartzite masses have been interpreted as the fillings of solution cavities in the Powell by sand from the Everton.[24] Their formation was accomplished, in part at least, at some time before the Mississippian, because, in the occurrence cited near Elixir Springs, the unconformity at the base of the St. Joe has cut out all the sandy beds that could have served as a source for the sand.[25] Under the present erosion cycle, on the solution of the enclosing dolomite by weathering, the more resistant quartzite remains as residual knobs.

OUTCROP

The Powell as a general rule carries only a very thin film of soil, and in many places even this is absent, so that the bedrock crops out at the surface. Owing to the thinness of the bedding and the corresponding tendency to flake off, the outcropping surface is in general partly covered by a loose mantle of small rock chips. As a rule no ledges project above the surface of the ground. This type of outcrop is especially characteristic of the cedar brakes that form on such areas of barren soil. The absence of soil is probably due to the impervious, earthy nature of the rock, with its resultant lack of chemical weathering. This impermeability also accounts for the fact that one of the usual horizons for springs is at or just above the contact of the Powell with the overlying Everton. Water percolating downward through the Everton is arrested when it reaches the Powell dolomite and is forced to seek an outlet by moving laterally.

FOSSILS AND AGE

The Powell dolomite is not conspicuously fossiliferous. Organic remains are not uncommon in the †Black Ledge, and the fauna is a characteristic one, but elsewhere in the formation fossils are rare. One collection was made from residual drusy chert at a horizon near the base of the formation, along the road down Fallen Ash Creek, 3 miles east of north from Yellville. As in the Cotter, the dominant forms in the Powell are gastropods and cephalopods, but some brachiopods and trilobites are represented. Most of the species of the fauna are as yet undescribed. From the character of its

[23] Miser, H. D., oral communication.

[24] Purdue, A. H., and Miser, H. D., U.S. Geol. Survey Geol. Atlas, Eureka Springs-Harrison folio (no. 202), p. 5, 1916.

[25] See also Purdue, A. H., and Miser, H. D., op. cit. fig. 9.

fossils the Powell is definitely Lower Ordovician and has been correlated with the upper part of the Beekmantown of the New York section.

STRATIGRAPHIC RELATIONS

Ulrich maintains that the contact between the Powell and Cotter dolomites is one of erosional unconformity, with a chert breccia at the base of the Powell. Evidences of shallow water and of slight emergence at the stratigraphic level of the lower Powell have already been cited by the writer, but no evidence of erosion has been observed, and in the experience of the writer the two formations appear to be conformable. The Powell differs lithologically from the Cotter in being on the average thinner-bedded and finer-grained, in containing less and generally lighter-colored chert, and in its characteristic type of outcrop. In many places the contact between the two can be approximated fairly closely at the line where deep soil gives way to shallow barren soil.

The Powell is unconformably overlain by the basal chert breccia of the Everton or, west of Elixir Springs, by the St. Joe member of the Boone.

SMITHVILLE AND BLACK ROCK FORMATIONS

The ore deposits of Sharp and Lawrence Counties occur in rocks which resemble certain phases of the Everton but which, according to Ulrich, are older than the Everton. He distinguishes two formations on paleontologic grounds, the Smithville and the Black Rock. The Smithville is the older. According to Bridge,[26] the ores occur in the lower part of the Smithville and particularly at its base.

NAMES

The Smithville and Black Rock formations are included in the "magnesian limestones, sandstones, cherts, etc.", of the Branner report. In 1911 they were included in the †Yellville (restricted, =Powell) formation by Ulrich[27] but were believed at that time to be older than the Powell dolomite of the Yellville quadrangle. More recent work by Ulrich has led him to consider them younger than the Powell but older than the Everton. The names "Smithville" and "Black Rock" were first published on the geologic map of Arkansas,[28] but the characters and limits of the formations have never been satisfactorily defined in print.

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[26] Bridge, Josiah, personal communication.

[27] Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, pp. 667–668, 1911.

[28] Geologic map of Arkansas, Arkansas Geol. Survey, 1929.

DISTRIBUTION

These formations have never been mapped in detail. Practically all the stratigraphic information on them is contained in the unpublished notes of Ulrich, which were used in plotting the distribution of the formations on the State map. According to the map, the two formations crop out in a northeast-southwest belt from southeastern Sharp County through western Lawrence County to southern Randolph County.

THICKNESS

Approximate thicknesses of 200 feet are given for both the Smithville and Black Rock formations on the geologic map of Arkansas, but Ulrich, in an unpublished manuscript, records thicknesses of 65 feet and 55 (perhaps plus) feet respectively.

CHARACTER

The writer is acquainted with the Smithville and Black Rock formations only as they occur with or in the vicinity of the lead and zinc ores of Sharp and Lawrence Counties. The dominant rock type is a fine-grained gray magnesian limestone or dolomite that weathers to a drab or whitish color. This type is somewhat thicker-bedded than similar lithologic phases of the Powell. With it are associated minor amounts of sandstone and blue-gray limestone. No attempt has been made to distinguish between the two formations in the field, as information on their stratigraphic limits was not available at the time the region was examined.

OUTCROPS

The Smithville and Black Rock formations, so far as known, are confined in Arkansas to the drainage basins of the Strawberry and Spring Rivers on the Salem Plateau.[29] The region is gently rolling and well wooded and shows little relief. Outcrops of the formations are covered by a moderate thickness of reddish clayey soil, through which project here and there massive rounded exposures of bedrock. Such exposures generally do not extend far above the surrounding ground level. Ledges and bluffs are absent except for low ones along the main drainage lines.

FOSSILS AND AGE [30]

The faunal peculiarity of the Smithville and Black Rock formations is the presence of graptolites. In addition to these, the Smith-

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[29] Bridge reports (personal communication) that the Smithville, with its characteristic fauna, has been found above the Powell dolomite south of Marble Hill, Mo.

[30] Taken from Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, p. 668, 1911. The Smithville and Black Rock formations had not been defined as separate formations when this was written.

ville contains a large molluscan fauna (gastropods and cephalopods). The dominant fossil forms of the Black Rock fauna comprise sponges, bryozoans, and brachiopods. Both formations are Lower Ordovician in age and are referred by Ulrich to the uppermost †Canadian, equivalent to the uppermost Beekmantown of the New York section.

STRATIGRAPHIC RELATIONS

Nothing has been published on the relations of the Black Rock and Smithville to each other or to the Powell. The Black Rock is believed by Ulrich to be overlain unconformably by the Everton.

The Smithville and Black Rock formations occupy all or a large part of the stratigraphic interval between the Powell dolomite and St. Peter sandstone. This interval is occupied by the Everton formation in regions to the west. In the course of the field work on the present report the writer traced the Everton formation eastward from the Yellville quadrangle to the section between Cave City and Evening Shade, Sharp County. In this distance its lithologic character shows a progressive change which, if persistent over the remaining distance to the region where the Smithville and Black Rock formations are exposed, would lead to sediments whose lithology would be approximately that shown by these formations. More specifically, the lithology changes from a section that contains limestone, sandstone, and medium- and fine-grained dolomite to a section that contains less limestone, less sandstone, and less medium-grained dolomite, but more fine-grained dolomite. Before the stratigraphic relations between the Smithville, Black Rock, and Everton formations are worked out satisfactorily it will be necessary to trace the basal breccia of the Everton, or its stratigraphic equivalent if it varies, from the one region to the other. This will be difficult and may prove to be impossible, owing to the extreme scarcity of outcrops within the Strawberry River Basin.

EVERTON FORMATION

A knowledge of the distribution, character, and stratigraphic limits of the Everton formation in northern Arkansas is of practical importance, owing to the fact that this formation is one of the two principal sources of lead and zinc ores. Practically all the mines that have produced in Marion, Searcy, and Boone Counties, as well as certain less productive ones in Newton County, were developed on ore deposits in the Everton.

NAME

The strata making up the formation were included in the "magnesian limestones, sandstones, cherts, etc.", of the Branner report and in the †Yellville formation of the Adams report. In 1911

Ulrich [31] proposed the term "Everton limestone" to cover the uppermost part of the very much generalized and all-inclusive unit recognized in the earlier lead and zinc reports. The name is taken from the town of Everton, in the Yellville quadrangle, where the upper part of the formation is well exposed.

DISTRIBUTION

The Everton is the most widely distributed formation in the Yellville quadrangle. In the north half, where it is thinner, it forms a part of the slopes of the high ridges that stand out as such conspicuous elements of the topography in this region. In the south half it forms the steep valley walls of practically all the main drainage lines. Wherever it crops out it tends to make steep slopes, but this is apparently due to the fact that it is overlain by more resistant beds that protect it in an escarpment. The Eureka Springs escarpment contains the Everton formation wherever the formation is present in the stratigraphic section. Where the Everton is the top formation on a drainage divide, as on Cowan Barrens, southeast of Yellville, it may exhibit a more subdued topography.

THICKNESS

The thickness of the formation ranges from 400 feet in the Rush Creek district to the vanishing point at the north end of Short Mountain and northwest of Elixir Springs. It is between 100 and 125 feet at Zinc; 75 feet 2 miles northwest of Dodd City (Edna Bee mine); 80 feet on the east head of Big Music Creek; 225 feet on Lee Mountain, 1 mile northwest of Flippin; 340 feet on the north side of Halls Mountain, 3 miles east of Yellville; 330 feet 1½ miles east of Onset; about 400 feet at the west end of the mountain north of Rush; and about 370 feet at Mount Hersey. The thickness in the Yellville quadrangle increases to the south and east and decreases to the north and west. The decrease is produced largely by the regional unconformity at the base of the Mississippian, which truncates the underlying beds, including the Everton. The thicknesses at Rush and Mount Hersey are approximate measures of the original thickness of the Everton, for at these localities it is overlain by St. Peter sandstone, which is the overlying formation in the normal stratigraphic section.

CHARACTER

The Everton formation consists of alternating limestone, dolomite, and sandstone in varying proportions with a very minor amount of shale. An inconspicuous chert and dolomite breccia forms the base of

[31] Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, pl. 27, 1911.

the formation in most places. No single lithologic unit is continuous over any great area, so that the section at any one locality is in general not duplicated elsewhere, except in a very rough way.

The limestones normally have a dense groundmass but always contain small irregular patches and individual crystals of calcite; they are blue-gray to brownish gray. A common variation from the normal is produced by partial recrystallization, in which the calcite patches increase in number and size and grade into the residual groundmass, which takes on a lighter-colored, more "sugarized" appearance. Much of the limestone contains crystalline dolomite, either scattered as small individual rhombs through the groundmass of the limestone or else concentrated along certain bedding planes. On the weathered surface these rhombs stand out in relief, owing to their greater resistance to solution. Many of the limestone beds are sandy, with individual grains of the same size and character as those making up the purer sandstones. Small amorphous blebs and, less commonly, small cubes of pyrite are of local occurrence in the limestone, especially near the top of the formation, within a few feet of the unconformable contact with the overlying limestone of the Mississippian epoch (St. Joe limestone). Gray nodular chert is not uncommon in the Everton limestones, and beds that have been wholly converted to chert (jasperoid) are characteristic accompaniments of one of the types of ore deposits. The bedding of the limestone may be on the scale of a fraction of an inch, or it may reach 3 or 4 feet.

Intraformational limestone conglomerates are common in the Everton. They are generally only a few inches thick, but some are 1 or 2 feet thick. The limestone pebbles are subangular, are commonly lath-shaped, and tend to lie parallel with the bedding. They rarely exceed an inch in their greatest dimension. The groundmass in which they are embedded may have a few sand grains scattered through it, or it may contain dolomite crystals, or it may simply possess a slightly different texture that is not especially evident on the fresh surface but that produces a sharp difference in appearance between pebble and matrix on the weathered surface. That the pebbles were deposited in their present situation while the lime composing them was still soft is indicated, in certain occurrences where the matrix is sandy, by grains of sand that are embedded in the surfaces of the pebbles. Under conditions of present-day weathering the sand grains may break out, leaving the pebble surfaces pitted with their casts.

Additional evidence of shallow-water deposition of at least a part of the Everton limestone is found in the development of ripple marks here and there in thin-bedded phases of the limestone.

Emergence during the period of sedimentation is recorded in a few places by the presence in the limestone of sun cracks, which were filled, when the next overlying bed was deposited, by the sand or sandy lime that was spread over the lime surface.

Certain structural features of the bedding in the Everton limestones have been interpreted as *Cryptozoon* colonies. In cross section they appear as rather abrupt concentric upcurves in the lines of bedding (pl. 6, *B*). When viewed on the bedding surface from above they are seen to be small domes, whose diameters range generally from 2 to 6 inches, although locally reaching 1 foot. Usually the domes are fairly closely spaced in certain beds, so that the basins between the domes are almost as conspicuous as the domes themselves. Some of these features are developed in fine-grained dark-gray dolomite, and in places, as at the Madison mine, southwest of Zinc, they are preserved even after the limestone has been altered to coarse-grained dolomite. The bedding at the Madison mine has been accentuated by grains of disseminated sphalerite that have developed more freely along the bedding surfaces.

The Everton dolomites are extremely variable in character. There is every gradation in texture from a dense porcelaneous rock to a coarse-grained one in which the individual dolomite crystals approach the size of a small pinhead. There is also a coarse "gray spar" dolomite, associated with ore deposits, in which the individual crystals average around a quarter of an inch in size, but between this and the coarser-grained rock-forming type gradation is rare. The coarser dolomites are gray, in places with flesh or brownish tints; the finer-grained ones are generally much darker and browner, almost basaltic in appearance, and are in many places distinctly bituminous. Some of the fine-grained dolomites, however, are plain gray and are indistinguishable from the dominant lithologic type in the underlying Powell. Although this type may appear at any horizon, it is more likely to occur in the basal part of the formation. Where it does, unless the distinctive chert breccia that occurs at the base of the Everton is present or unless the gray dolomite is underlain by a bed that is more definitely of Everton type, it becomes a problem to determine the boundary between the two formations. Usually the lower Everton dolomites tend to form dark-colored ledges where they crop out, whereas those of the Powell weather down to more even slopes, in which bedrock lies either at or very close to the surface.

Many of the Everton dolomites are sandy, and all weather to much darker ledges than the limestones with which they are associated. Some gray to whitish chert is locally developed along the bedding of the dolomite but is not especially abundant or distinctive. At two or three localities the chert was observed to have replaced an oolitic dolomite.

The occurrence of authigenic feldspar in limestones and dolomites has been reported by several writers.[32] A microscopic examination of the insoluble residues from specimens of limestone and dolomite

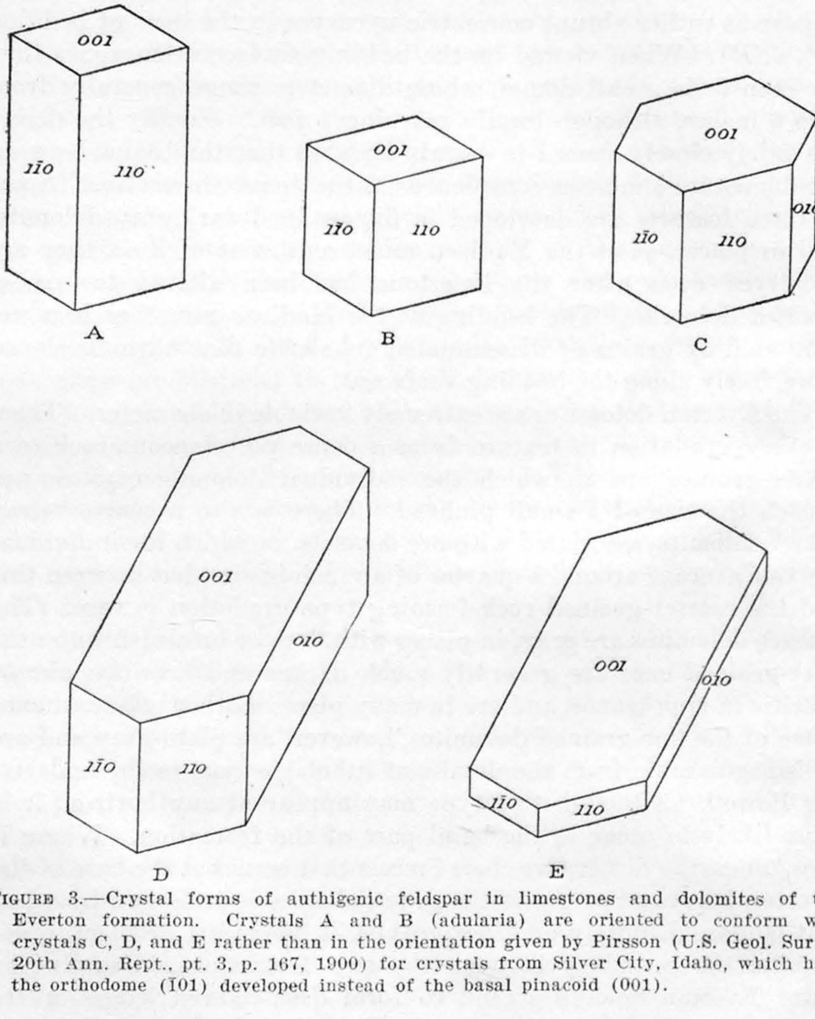

FIGURE 3.—Crystal forms of authigenic feldspar in limestones and dolomites of the Everton formation. Crystals A and B (adularia) are oriented to conform with crystals C, D, and E rather than in the orientation given by Pirsson (U.S. Geol. Survey 20th Ann. Rept., pt. 3, p. 167, 1900) for crystals from Silver City, Idaho, which have the orthodome (1̄01) developed instead of the basal pinacoid (001).

from the Everton formation has revealed its presence, along with variable amounts of detrital feldspar, in every instance. The subjoined table lists the specimens that were examined. The individual feldspar crystals are minute, averaging 0.01 to 0.05 milli-

[32] Singewald, J. T., Jr., and Milton, Charles, Authigenic feldspar in limestone at Glen Falls, N. Y.: Geol. Soc. America Bull., vol. 40, pp. 463–468, 1929. This paper gives references to several earlier ones.

meters in diameter, with a maximum diameter of about 0.12 millimeters. Many of the crystals have irregular, frayed borders, but a large percentage of them have euhedral faces. The common feldspar forms are developed, as shown in figure 3. The smaller crystals tend toward simple rhombic outlines. Cleavage is rarely visible.

Specimens from the Everton formation showing authigenic feldspar

No.	Rock type	Locality	Horizon	Kind of feldspar
1	Limestone	North end of ridge between Clear and Hampton Creeks, probably NE¼ sec. 18, T. 18 N., R. 17 W.	Immediately below Newton sandstone.	Orthoclase (microcline probably detrital).
2	do	Brushy Fork of Jimmie Creek, probably sec. 12, T. 19 N., R. 17 W.	Near top of formation (here about 110 feet thick).	Do.
3	do	Moccasin Creek, sec. 15, T. 19 N., R. 16 W.; a short distance downstream from fault.	Near base of formation.	Do.
4	Fine-grained light-gray dolomite.	Old road up Lee Mountain, sec. 28, T. 19 N., R. 16 W.	50 feet above base of formation.	Do.
5	Fine-grained brownish-gray bituminous dolomite.	Foot of bluff, 1,000 feet downstream from Silver Hollow mine, near Rush.	310 feet below top of formation (here about 400 feet thick).	Do.
6	Medium-grained dark-gray bituminous dolomite.	Head of Williams Branch (tributary to Warner Creek), probably sec. 19, T. 18 N., R. 14 W.	40 feet above base of formation.	Do.
7	Medium-grained light-gray dolomite.	North side of Halls Mountain, sec. 7, T. 18 N., R. 15 W.	90 feet above base of formation.	Do.
8	Medium-grained gray dolomite.	Old road leading up from Clear Creek, probably SW¼ sec. 18, T. 18 N., R. 17 W.	About 45 feet below Newton sandstone.	Do.
9	Coarse-grained light-gray dolomite.	West prong of Mill Creek, NW¼ sec. 28, T. 18 N., R. 16 W.	5 feet above base of formation.	Do.
10	Greenish-blue opaque argillaceous chert.	Clabber Creek, sec. 24, T. 18 N., R. 16 W.	Base of formation.	Do.
11	White, porcelaneous argillaceous chert.	Greasy Creek near road crossing, E½ sec. 26, T. 18 N., R. 17 W.	Just above basal breccia.	Orthoclase, rather abundant in crushed material.

No refractive index has been found exceeding 1.53, which indicates that the dominant feldspar is the potash variety. Most of the crystals are untwinned orthoclase, but several, especially among the larger ones, show good microcline twinning. These microcline crystals tend to be anhedral and are probably detrital, but many of them show euhedral selvage zones of orthoclase. The presence of untwinned microcline in the cores of a few crystals is indicated by extinction angles ($X \wedge 010$) on basal plates that attain 18° in the centers of such crystals, as compared to angles of 0–4° in the border zones,[33] and by slightly higher indices of refraction in the central cores as compared to the bordering zones.

Authigenic feldspar has been found not only in the calcareous sediments, but also in argillaceous chert lying at the base of the

[33] The angles were measured on crystals lying naturally on the 001 face in oil; hence they may depart slightly from the true values.

Everton. In none of the specimens cited in the preceding table can the occurrence of the feldspar be ascribed with any certainty to processes of ore deposition; the specimens were taken from apparently undisturbed beds at points remote from known ore deposits. As will be pointed out later, feldspar showing the same type of occurrence is equally abundant in the ore deposits.

At many places within the Yellville quadrangle limestone grades along the bedding into medium- or coarse-grained dolomite, or more rarely to rather fine grained dolomite. Such gradations are especially well illustrated in some of the mines—for example, the McIntosh, Capps, Madison, Ohio, Sure Pop, Ike Emery—owing to the more favorable exposures, but they occur at many other places. The varying amounts of dolomite contained in a given interval of the Everton section in different places is indirect evidence of this gradation. Thus, on Halls Mountain, 3 miles east of Yellville, the basal 40 feet consists almost entirely of dolomite, with no limestone, but on Lee Mountain, 5 miles to the north, limestone occupies the 10-foot interval from 4 to 14 feet above the base.

It is believed that the medium- and coarser-grained dolomites were formed by replacement of limestone, and probably during sedimentation, each bed having been dolomitized or partially dolomitized very shortly after its deposition on the floor of the sea.[34] In the Rush mining district the ore deposits in several of the mines that are distributed over an area more than a mile in diameter occur in a discontinuously dolomitized limestone at a certain definite horizon. This dolomite is rarely more than 15 feet thick. Its upper surface, against sandstone or limestone, is well defined, but its lower boundary, against limestone, is very irregular. It is difficult to see how, under any theory of subsequent alteration, the dolomitization could have been confined so closely to a certain definite bed. In the Capps mine the dolomite is separated from an overlying limy sandstone by 2 feet of unaltered limestone, which precludes any possibility that the sandstone has acted as a channel for the subsequent introduction of magnesium-bearing solutions.

Ordinarily any fossil remains that may have been present in the original limestone are destroyed when the rock is converted to a medium or coarse grained dolomite, but exceptions to this generalization occur. *Cryptozoon* remains have survived the change at the Madison mine and at a few other localities. In addition, microscopic examination of specimens from the Red Cloud mine shows that the outlines of ostracodes have survived not only the replacement of limestone by coarse-grained dolomite, but also that of the dolomite

[34] See Van Tuyl, F. M., The origin of dolomite: Iowa Geol. Survey, vol. 25, pp. 251–422, 1916.

by jasperoid chert. These outlines are preserved in the final state by a fine granular stippling of some highly birefringent material, resembling dolomite, in the chert.

In the recrystallization to dolomite the argillaceous matter in the original limestone is segregated interstitially, and where it is abundant, it appears as a pale bluish or greenish matrix to the dolomite crystals. The same material is segregated, apparently by solution, in cracks and small pockets and along bedding lines in limestone, so that its origin is in no way related to the process of dolomitization. According to C. S. Ross, who examined specimens of the clay, the mineral represented is a member of the beidellite group containing little or no ferric iron.

The finer-grained dolomites are more problematical. At Rush the ore-bearing bed, which ordinarily varies between limestone and medium to coarse dolomite but which is believed to have been originally deposited as limestone, contains, in the Capps and Red Cloud mines, lenses of very fine grained dolomite. These are the only occurrences observed by the writer that indicate a replacement of limestone by the fine-grained dolomite. At stratigraphic levels above the mine level at Rush certain fine-grained to dense dark-colored dolomites, some of them only a foot or two thick, were found to extend over the whole district (as restricted, see p. 197) and thus to be regular stratigraphic units. Their upper and lower boundaries are fairly sharply defined. In the Harrison quadrangle dark-colored fine-grained "magnesian limestones" were recognized as stratigraphic units at certain horizons in the Everton—for example, the Sneeds limestone lentil and the limestone that was erroneously designated the "Joachim limestone" in the Harrison folio. Although, except at the Capps and Red Cloud mines, no clear-cut transition from these fine-grained magnesian limestones and dolomites into limestone has been noted in either the Harrison or the Yellville quadrangle, still it seems probable that they have the same replacement origin as the coarser-grained types. They show every textural gradation to the coarser dolomites that have definitely replaced limestone, and they contain fossil remains, such as cryptozoans and casts of ostracodes, that are ordinarily characteristic of the limestones, although of course there is no evidence to prove that such fossils could not have been formed in primary dolomite. In comparison to the coarser-grained types, the fine-grained dolomites show fewer evidences to prove that they have replaced limestone but more evidences to show that they owe their origin to conditions that prevailed at the time of sedimentation.

Whatever the origin of the different types of dolomite may have been, there is evidence to show that both fine- and coarse-grained dolomite existed in the Everton before the transgression of the Mississippian sea. A basal breccia of the Boone (Mississippian), exposed on the old Yellville-St. Joe road where it first enters the Water Creek drainage basin from the north, contains fragments of both types of dolomite as well as of the normal Everton limestone.

Sand in the Everton occurs both in the form of definite beds, interstratified with the limestones and dolomites, and also as sandy phases of what are otherwise normal limestones and dolomites. Between beds of pure sandstone on the one hand and calcareous beds with only a few scattered grains of sand on the other, there are all gradations. Except for a tendency toward secondary enlargement in the purer and more porous sands, the sand grains have the same character, regardless of the proportions in which they may occur in the beds.

Within the Yellville quadrangle individual beds of Everton sandstone do not attain the thickness and prominence that they show in regions both to the east and to the west. A maximum thickness of 20 feet is shown by a sandstone on the left side of Clear Creek, a short distance below the mouth of Kings Branch. What is probably the same sandstone is well exposed at various places along Clear Creek between Kings Branch and some locality several miles above Everton, also on the point between Clear and Hampton Creeks, on the northern part of the ridge between Hampton and Greasy Creeks, and along Crooked Creek near the west edge of the quadrangle. At these places the sandstone lies near or at the top of the truncated Everton section. Details of its distribution were not worked out, owing to confusion with the St. Peter at the time the region was mapped, and to the fact that the bed thins eastward and southward, losing its identity among other similar but thinner sandstone layers in the Everton. This sandstone member of the Everton is here named the "Newton sandstone" from its prominence in northern Newton County. In the Yellville quadrangle its base is estimated to lie between 160 and 200 feet above the base of the Everton.

In addition to the Newton sandstone, the Everton contains many thinner ones, from less than a foot up to 10 feet in thickness. These sandstones are otherwise similar to the Newton but have not been traced from one section to another and presumably do not have the horizontal extent shown by it.

The sandstones of the Everton consist of relatively pure quartz sand, generally friable but in places with siliceous concretions. Locally they are completely silicified to quartzite. This is especially true in the neighborhood of ore deposits or along faults. The sand is locally coarse-grained but is usually medium to rather fine grained. The individual grains are well rounded except where they have been enlarged by secondary crystallization. The color of the sandstones ranges from white to buff, or to gray in some of the silicified phases; where they are limy or dolomitic they are gray or flesh-colored.

The Everton sandstones are horizontally bedded or cross-bedded on a low angle. They tend to weather with a fluted surface, in contrast to the more massive cliff produced on the St. Peter. Many of the bedding surfaces are ripple-marked.

Most of the sandstones overlie limestones or dolomites conformably, but the Newton sandstone, especially in the Harrison and Eureka Springs quadrangles, shows a pronounced erosion unconformity at its base. The line of contact is very irregular but does not oscillate over a very great stratigraphic interval, 20 feet being the maximum noted, and this along 100 feet of outcrop. The contact commonly cuts 5 to 8 feet of the underlying beds in a horizontal distance of 10 feet or so before the direction of slope is reversed. The sandstone may extend down in the limestone in the form of a channel, or the limestone may extend up into the sandstone in the form of a steep-sided hillock. This type of unconformity was apparently produced by solution of the limestone a short time prior to the deposition of the sandstone. It is identical with the type of unconformity shown at the base of the St. Peter of the Rush district.

Shale is very subordinate within the Everton. A 6-inch bed of greenish shale lies 5½ feet below the base of the St. Peter sandstone at the Big Hurricane mine. As this particular shale is fossiliferous, it represents primary sedimentation. At a few other places, also, beds of greenish-blue shale 3 or 4 feet thick are undoubtedly original sediments. In many of the mines of the district greenish shale seams are present, but they cut across the bedding lines and are thus of secondary origin, either produced in place by the solution of the limestone or dolomite, or else emplaced by transportation of material a short distance to its present position.

The basal bed of the Everton is unique wherever it is developed but is commonly inconspicuous. It is 4 feet in maximum thickness and is generally a dark-colored dolomitic sandstone or a more or less sandy fine-grained gray dolomite, containing rather sparingly scattered chips of angular gray to whitish chert and also (but much less commonly) angular fragments of "cotton rock", derived from the underlying Powell. The breccia fragments are generally limited to the lower 1 foot. Those of chert average one-eighth to one-half inch and rarely exceed an inch in size, but the Powell fragments may reach 3 or 4 inches. This basal breccia is described in the Harrison-Eureka Springs folio and was observed through the Yellville quadrangle and as far east as the vicinity of Violet Hill, in Izard County.

Where the basal bed of the Everton is only slightly sandy, it may be hard to distinguish from the underlying Powell, and unless the chert fragments can be found, the base of the Everton may be impossible to locate. Generally, however, the Everton shows either a limestone or a medium- to coarse-grained dolomite within its lower 10 feet, so that the contact can be placed within a few feet. The top foot of the Powell is frequently found to contain nodular gray or greenish chert that is apparently related to the unconformity.

REGIONAL VARIATIONS IN CHARACTER

The foregoing discussion of the Everton formation applies essentially to its occurrence within the Yellville quadrangle. Considered regionally, the extreme variability in the Everton lithology so complicates the stratigraphy of northern Arkansas that much difficulty has been experienced in working out the relations between the rocks in different areas. Nor have all the problems presented by the formation yet been satisfactorily solved. Increase in the relative amount of fine-grained dolomite eastward toward Sharp County, accompanied by decrease in the relative amounts of limestone, sandstone, and coarse-grained dolomite, suggests a lithologic gradation to the Smithville and Black Rock formations which, according to Ulrich, is directly opposed by the paleontologic evidence. Another source of confusion is the development within the Everton, chiefly outside of the Yellville quadrangle, of thick saccharoidal sandstone members that are indistinguishable from one another and from some phases of the overlying St. Peter. These sandstones lie at different horizons and are not coextensive areally, either with one another or with the St. Peter.

A sandstone member of the Everton, 40 feet in maximum thickness, called the "Kings River sandstone", was described by Purdue and Miser.[35] This sandstone lies at the base of the Everton at most places in the Eureka Springs quadrangle, but in the southern part of the Harrison quadrangle it is underlain by as much as 50 feet of a dark magnesian limestone, called the Sneeds limestone lentil. The Kings River sandstone has so thinned as to be indistinguishable in the Yellville quadrangle.

A similar sandstone, called the "Calico Rock sandstone" on the Arkansas State geologic map, occurs in the Everton east of the Yellville quadrangle.[36] Its thickness, according to Giles, ranges from a knife-edge to 150 feet. Examination by the writer in the vicinity of Norfork shows its base to lie about 150 feet above the

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[35] Purdue, A. H., and Miser, H. D., U.S. Geol. Survey Geol. Atlas, Eureka Springs-Harrison folio (no. 202), pp. 5–6, 1916.

[36] See also Giles, A. W., St. Peter and older Ordovician sandstones of northern Arkansas: Arkansas Geol. Survey Bull. 4, 1930.

base of the Everton. The Calico Rock sandstone extends westward toward the Yellville quadrangle but thins rapidly and is indistinguishable at the quadrangle boundary.

A third prominent sandstone in the Everton, from a knife-edge to 150 feet thick, is mapped in the Eureka Springs and Harrison quadrangles as St. Peter.[37] It was formerly supposed that this sandstone was correlative with the St. Peter of the Rush mining district, in the Yellville quadrangle, but when the latter sandstone is traced westward to the Harrison quadrangle in the vicinities of Yardelle and Hasty, it is found to overlie the sandstone mapped as St. Peter in that region by about 150 feet. It is a rather peculiar coincidence that both of these sandstones should thin out, the lower to the east and the upper to the west, in a relatively narrow, poorly exposed and inaccessible strip along the boundary line between the two quadrangles. The Joachim and (in the opinion of the writer) Jasper formations, as mapped in the Harrison quadrangle, occupy the interval between the two overlapping sandstones. The writer proposes the term "Newton sandstone member of the Everton" for the lower sandstone. This sand was confused with the St. Peter of the Rush district by Branner,[38] who recognized only one "saccharoidal sandstone" in the lead-zinc region. The saccharoidal sandstone of the Ponca mining district is the Newton sandstone.

The beds that were mapped as Joachim limestone in the Harrison quadrangle are classed as part of the Everton in the present report. The Jasper limestone, because of its distinctive fauna, is retained as a separate formation but with the feeling that more detailed work will probably show that it should be considered a member of the Everton.

OUTCROP

The Everton crops out typically in a series of discontinuous ledges, of variable thickness. Usually the softer beds do not crop out unless they are held up by harder ledges. Along many of the more actively eroding streams the ordinarily steep outcrop of the Everton may be broken by bluffs of variable height and extent. This is especially true on the outsides of stream bends. The thicker sandstone members tend to form bluffs, at least along drainage lines.

FOSSILS AND AGE

Although the Everton is not an especially fossiliferous formation, organic remains are by no means rare in it. They are scattered from the top to the bottom but occur only in certain beds sepa-

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[37] Purdue, A. H., and Miser, H. D., op. cit.

[38] Branner, J. C., Zinc and lead region of north Arkansas: Arkansas Geol. Survey Ann. Rept. for 1892, vol. 5, 1900.

rated by barren zones. The most characteristic remains are several species of ostracodes which commonly are the only forms represented in certain beds, but gastropods and uncoiled cephalopods are fairly common; trilobites, pelecypods, and bryozoans are occasionally found. A 6-inch shale bed, lying 5 feet below the base of the St. Peter at the Big Hurricane mine, has a few small brachiopods (*Lingula*).

On the basis of fossils collected in the course of the field work for the Eureka Springs-Harrison folio, Purdue and Miser[39] state that the Everton is Lower Ordovician, of post-Beekmantown and pre-Chazy age.

STRATIGRAPHIC RELATIONS

The Everton overlies the Powell unconformably, having a basal breccia. The surface of unconformity is very even, and only rarely is there evidence of truncation of the Powell. Over most of the Yellville quadrangle the Powell maintains a fairly uniform thickness, but between Short Mountain and Elixir Springs it decreases by 50 or 60 feet. As it is overlain by the Everton in this interval, the decrease is probably due to erosion before the basal bed of Everton was laid down. At one locality on Greasy Creek the basal sand of the Everton, with its characteristic chert fragments, was observed to descend for a foot or more into cracks in the underlying Powell.

The Everton in the Yellville quadrangle is overlain unconformably by the St. Peter sandstone or by the basal sandstone member or St. Joe member of the Boone. The contact with the St. Peter, which is the next overlying formation in the normal section, is an erosion unconformity identical in character with the one that occurs at the base of the Newton sandstone. Where the basal sandstone of the Boone overlies sandstone in the Everton, the exact contact between the two formations may be very difficult to place, owing to the similarity of the two sandstone types.

In the southeastern part of the Harrison quadrangle the Everton is overlain by the Jasper limestone.[40] The relation between the two formations is taken up in the discussion of the Jasper (p. 41).

JASPER LIMESTONE

The Jasper limestone was originally named and described from its occurrence in the southern part of the Harrison quadrangle, chiefly in and east of the valley of Little Buffalo Fork below Jasper.[41] Its maximum thickness is 50 feet. Lithologically, it is indistinguishable from denser phases of the Everton limestone; and interbedded sand-

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[39] Purdue, A. H., and Miser, H. D., op. cit., p. 6.
[40] Idem, p. 8. The upper Everton in this work is called "Joachim limestone."
[41] Idem, p. 8.

stones and sandy limestones are an added feature of similarity. The stratigraphic position of the Jasper is above what were thought to be the Joachim limestone and St. Peter sandstone, but work in the Yellville quadrangle has shown that the so-called "St. Peter" and the so-called "Joachim" of the Eureka Springs-Harrison folio are part of the Everton, lying below the true St. Peter. In the opinion of the writer the Jasper limestone also occupies this same position. However, the true St. Peter sandstone has not yet been found overlying limestone that contains the distinctive Jasper fauna, although a detailed study of the region between Pindall, Yardelle, Carver, and Mount Hersey has not been made with this point in mind. The Jasper limestone is mapped to a point within 2 miles of the Yellville quadrangle, but only the underlying dolomitic phase of the Everton (or so-called "Joachim") is mapped at the boundary line. In the southwest corner of the Yellville quadrangle limestone beds that are lithologically identical with the Jasper are interstratified locally with sandstone, dolomitic sandstone, and dolomite near the top of the interval between thin representatives of the St. Peter and Newton sandstones. The evidence is not complete, but it suggests that the Jasper limestone interfingers with the dolomitic facies in the upper part of the Everton and should be considered a member of the Everton. It seems significant in this respect that the thicknesses of the so-called "Joachim" and Jasper limestones, as given in the Eureka Springs-Harrison folio, amount to 145 feet, which is approximately the interval between the Newton and St. Peter sandstones.

At Pindall, in the Yellville quadrangle, the Jasper limestone with its distinctive fauna is well exposed but is overlain by the basal sandstone of the Boone. According to the interpretation of the writer the St. Peter sandstone was removed from above the Jasper at and north of this locality by the regional truncation before the Boone was laid down.

The Jasper fauna is characterized by distinctive species of ostracodes and coiled cephalopods. In addition there are gastropods, pelecypods, trilobites, worm borings, and fossil algae. Purdue and Miser [42] state, on the authority of Ulrich, that the formation is almost certainly older than Plattin and probably related in age to the Everton, St. Peter, and Joachim.

The Jasper limestone is overlain at one place in the Harrison quadrangle by the Fernvale limestone, probably with unconformity. Elsewhere the basal member of the Boone is the next overlying unit.

[42] Idem, p. 8.

ST. PETER SANDSTONE

NAME

The St. Peter sandstone was named by Owen [43] in 1847, from its occurrence along the St. Peter River (now the Minnesota) in Minnesota. The formation in Arkansas was called the "saccharoidal sandstone" in Branner's report; the same term was applied in Newton County to the Newton sandstone of this report, as Branner was not aware of the existence of more than one sandstone. In the Adams report the term †"Key sandstone" covered, in different areas, the St. Peter, Newton, and Sylamore sandstones, under the mistaken assumption that only one sandstone was represented. In 1905 Ulrich [44] stated that the †Key sandstone at its type locality (in Benton County) is Sylamore and used the term "St. Peter" in referring to the Ordovician saccharoidal sandstone.

DISTRIBUTION

The St. Peter is exposed only in the southern third of the Yellville quadrangle, being cut out to the north by the unconformity at the base of the Mississippian. Its northern limit is close to the drainage divide between the Buffalo River and Crooked Creek. Westward along the south edge of the quadrangle the formation thins and changes in character until it finally disappears near the boundary between the Yellville and Harrison quadrangles. Probably this disappearance is due as much to nondeposition as to erosion before the deposition of later beds.

THICKNESS

The thickness of the formation within the Yellville quadrangle varies from 136 feet to the vanishing point; the maximum was measured on the point west of the mouth of Cedar Creek, a small tributary that empties into the Buffalo River about 3 miles east of Rush. Here the St. Peter is overlain by the Joachim dolomite. Owing to pronounced unconformities at the bases of the Plattin (Ordovician) and St. Joe (Mississippian), the thickness of the St. Peter is subject to abrupt variations within short distances, so that there is small point in quoting thicknesses for different regions. For example, at the Silver Hollow mine, which lies 1½ miles from the Cedar Creek locality, the St. Peter is only 40 feet thick. It is here overlain directly by the St. Joe. Near the Red Cloud mine, at Rush, approximately the same thickness is capped by the Plattin. Two miles above the mouth of Water Creek, on the right side, the

[43] Owen, D. D., Preliminary report of the geological survey of Wisconsin and Iowa: 30th Cong., 1st sess., S. Ex. Doc. 2, p. 169, 1847.

[44] Ulrich, E. O., and Adams, G. I., U.S. Geol. Survey Geol. Atlas, Fayetteville folio (no. 119), p. 3, 1905.

St. Peter is 80 feet thick, overlain by the Plattin. Along Shaddock Branch, in the southwest corner of the Yellville quadrangle, the formation is only 18 feet thick, overlain by the Plattin. East of the Yellville quadrangle, on the other hand, the thickness increases considerably over the 136 feet recorded at Cedar Creek. As the locality at Cedar Creek is the only place observed in the Yellville quadrangle where the Joachim, conformable on the St. Peter, is preserved, the thickness of the St. Peter here is somewhat more significant than it is elsewhere in the quadrangle in that it represents the true original thickness of the sandstone. Elsewhere an unknown thickness has been removed from its top by erosion prior to deposition of the Plattin or of the St. Joe.

CHARACTER

The St. Peter, throughout the southeastern part of the quadrangle, and typically in the Rush district, is divisible into three lithologic units. The lowest member is a massive cliff-forming sandstone, from 30 to 50 feet thick, and is commonly the only part of the formation exposed. (See pls. 6, *A*, and 7, *B*.) It is generally pale buff to whitish but grades in places to a deeper buff. The sand grains are medium to fine grained, are fairly well rounded, and are probably, in the unweathered rock, cemented by calcite, though near the weathered surface the cementing material may be leached out, leaving a friable sand. This member, in the Cedar Creek section, is 43 feet thick.

The middle member comprises soft sandstone, dark brownish-gray fine-grained dolomite, and thin-bedded greenish to bluish shale. The sandstone, which makes up most of the member, is composed of well-rounded medium to fine quartz grains and is especially characterized by the development of more or less greenish to bluish clay, which may form the matrix for the sand grains or may appear as small flecks in the sandstone. The outcrops are commonly colored by this material. Except where the clay is especially abundant, the sandstone is also very limy. The interstitial lime tends to segregate into definite crystalline growths, so that rather large cleavage faces of calcite show when the rock is broken. In some sections the sandstone contains small segregated bodies of limonite, altered from pyrite. The dolomite is massive, usually 3 to 8 feet thick, and is more or less muddy and sandy, grading into the sandstone. It is especially characterized by ramifying veinlets and irregular segregated masses of colorless calcite. Owing to its lack of resistance to weathering, its exposed surface is everywhere rounded and generally worn down to the level of the surface that surrounds it. The shale is not invariably present and is nowhere more than 1 or 2 feet thick. The dolomite and shale are stratified at different levels in the sandstone, and although in the southeastern part of the quadrangle only one bed of each has been observed in any given section, there is no apparent constancy in their actual or relative positions in the middle member of the St. Peter. The shale usually lies somewhere above the dolomite but in a few places lies below it.

The middle member of the St. Peter is rarely exposed, except in the beds of small rivulets that may cross it. Ordinarily its presence is indicated by a soil-covered interval, as much as 40 or 50 feet in thickness, between the exposed sandstone ledge below and either the upper member of the St. Peter sandstone or the Plattin or St. Joe limestone above. In the Cedar Creek section the middle member of the St. Peter is 49 feet thick, but only the upper 6 feet (sandstone) and a 3-foot zone (dolomite), 5 feet above the base, are exposed. Owing to the fact that the soft sandstone of the middle St. Peter grades imperceptibly into the somewhat more resistant sandstone of the upper St. Peter, the thickness of the middle member is very poorly defined. One of the common spring horizons of the region is at its level. This is probably to be explained by the impervious nature of the shaly material that it contains, which impedes the downward-percolating water and forces it to seek a lateral escape.

The upper member of the St. Peter is much like the lower member except that it does not have a sharply defined base. The foot of the cliff produced on it in consequence exhibits a scalloped profile. In the Cedar Creek section this member reaches a maximum thickness of 44 feet.

Owing to unconformities at the base of the Plattin and especially at the base of the St. Joe, the upper St. Peter has a rather spotty distribution in the quadrangle. The middle St. Peter, because it lies somewhat lower in the section, is somewhat more widely distributed, but over much of the area in which the St. Peter has been mapped even the middle member has been cut out.

All the sands of the St. Peter are alike in being composed of medium to rather fine quartz grains that are fairly well rounded. The bedding is horizontal and massive but may show more or less horizontal fluting where the formation crops out in a cliff. Cross-bedding is not common, and where noted here and there in the upper or lower member it occurs in fairly thin beds (1 to 2 feet), at a low angle, and obliquely truncated by the bedding plane below. Ripple marks are rarely observed. The bedding of the St. Peter, the peculiar lithology of the middle member, and the presence of worm borings (p. 46) tend to confirm the idea that the formation is of marine origin.[45]

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[45] Dake, C. L., The problem of the St. Peter sandstone: Missouri Univ. School of Mines and Metallurgy Bull., Tech. ser., vol. 6, no. 1, pp. 210–216, 1921.

Certain peculiar pipelike forms, similar to a type found in the Kings River sandstone and in the Newton sandstone of the Harrison quadrangle,[46] were noted in the lower St. Peter of the Rush district. Only the upper ends of such pipes were exposed in isolated occurrences on the top surface of the ledge. They show as concentric rings that may be slightly elliptic, the largest noted being about 6 feet in diameter. In the sandstones of the Harrison and Eureka Springs quadrangles they range from 2½ inches to 150 feet. Some of them were observed to pass into limestone caves in the Everton or Powell below, and their origin was ascribed to settling, after partial solidification, into the underlying caves, which probably formed after deposition of the sandstone. As none of these pipes were observed in longitudinal section in the Yellville quadrangle, little can be added to the discussion of their origin.

The lower and middle members of the St. Peter can be traced westward at least as far as the general vicinity of St. Joe and the headwaters of Tomahawk Creek, north of St. Joe. The upper St. Peter would presumably be present if it had not been cut out by the erosion represented in one or more unconformities. From St. Joe westward the character of the formation changes by the thinning and final disappearance of the lower member. Outcrops are too few and too poor between St. Joe and Shaddock Branch to determine whether the result is accomplished by a stratigraphic overlap of the middle member beyond the limits of deposition of the lower, or by the lateral gradation of the lower member into the lithology of the middle member. But to one who has traced the St. Peter westward from the Rush district the change itself is clear. At the Big Hurricane mine, on the boundary between Newton and Searcy Counties, the lower member forms a 20-foot ledge and is overlain by 22 feet of typical middle St. Peter, including the sandstone, dolomite, and shale types, and then by Plattin. On the head of Shaddock Branch the complete St. Peter is 32 feet thick and is composed entirely of alternating soft white and drab to greenish limy sandstone, dark-brownish dolomite, and greenish-blue shale, lithologic types that are characteristic of the middle St. Peter to the east. The sandstone contains more calcareous ledges that are whitish, gray, and drab. The dolomite, instead of being confined to a single bed within the sandstone, is distributed through the interval in three separate beds, the thickest 4½ feet thick. The shale seam lies near the top of the section, above the dolomites, but is not persistent. The St. Peter is here overlain by only a foot or two of Plattin, then by St. Joe. A short distance down Shaddock Branch only 18 feet of St. Peter remains, overlain by 8 feet of Plattin, then St. Joe. A little over a mile south-

[46] Purdue, A. H., and Miser, H. D., op. cit., p. 7.

west of the Shaddock Branch localities the St. Joe rests directly on the Everton.

Similar lithologic gradation and thinning of the St. Peter is exhibited in the Mount Hersey region and westward. Although its final disappearance is undoubtedly due to the erosion marked by one or both of the unconformities at the base of the Plattin and St. Joe, it seems probable that the westward change in the lithologic facies of the St. Peter was accompanied by a primary thinning that makes the actual amount of truncation by this erosion somewhat less than it would at first seem to be.

FOSSILS, CORRELATION, AND AGE

The only evidence of organic life found by the writer in the St. Peter is the presence of worm borings (?), observed on the south side of the ridge west of Mount Hersey and in Green Haw Hollow, near Maumee. The tubes range from half an inch to 1 inch in diameter, are perhaps 5 or 6 inches long, and have indications of cross partitions and of a slightly excentric longitudinal cord, similar to the siphuncle in a straight cephalopod. The sandstone in both localities is of the middle St. Peter type but was not observed in place in Green Haw Hollow.

As the St. Peter of the Yellville quadrangle cannot be correlated directly with that of the upper Mississippi Valley on fossil evidence, actual tracing of the formation must be relied upon. The outcrop can be traced continuously between the Yellville quadrangle and the southwest corner of Lawrence County, but between that point and Cape Girardeau, Mo., a distance of 130 miles, it is either buried beneath the sediments of the Coastal Plain or removed by erosion. The lithologic character and sequence on the two sides of this gap, however, indicate that the St. Peter in Lawrence County is the same as that at Cape Girardeau. Across Missouri and Iowa it has been traced, partly along the outcrop and partly by means of well logs, to the type locality along the lower course of the Minnesota River in Minnesota. The sandstone is Lower Ordovician, lying at what is considered by some geologists to be a stratigraphic horizon between the Beekmantown and Chazy.

STRATIGRAPHIC RELATIONS

The lower St. Peter shows a pronounced erosional unconformity at its contact with the underlying Everton (see pl. 7) but although the line of contact may cut up and down rather abruptly over several feet of the underlying beds, no angular discordance between the bedding of the two formations has been noted within the Yellville quadrangle. This unconformity is identical in nature with that at the base of the Newton sandstone. It is not believed to be of very great time significance. To the west, where sandstone of the middle St. Peter type rests on the Everton, the contact appears to be conformable. To the east, in Izard County, the unconformity at the base of the St. Peter increases greatly from south to north, strongly truncating the underlying Everton in that direction.[47]

The St. Peter is overlain conformably by the Joachim at only one locality in the Yellville quadrangle, on the right side of the mouth of Cedar Creek. Elsewhere it is overlain unconformably by the Plattin or the St. Joe. The contact is fairly even, but there may be an angular divergence between the bedding of the St. Peter and that of the overlying limestone, more pronounced where the limestone is St. Joe than where it is Plattin.

JOACHIM DOLOMITE

NAME

The Joachim formation was named by Winslow [48] in 1894 from exposures along Joachim Creek, in Jefferson County, Mo. In the Branner and Adams reports it was included in the †Izard limestone, making up the lower part of that unit. The term "Joachim" was first applied to the formation in Arkansas by Ulrich,[49] in 1911.

DISTRIBUTION AND THICKNESS

The occurrence of the Joachim dolomite in the Yellville quadrangle is limited to a single outcrop, about 100 feet long, on the point west of the mouth of Cedar Creek, 3 miles east of Rush. Its thickness in the section increases from a thin edge to 13 feet within a horizontal distance of 60 feet, the truncation being due to the erosion represented by the unconformity at the base of the Plattin.

CHARACTER

The Joachim consists of fine-grained, dark gray dolomite, more or less sandy, and a subordinate amount of flesh-colored to gray dolomitic sandstone. The sand grains are medium to coarse and well rounded. The bedding is in massive layers from 1 to 2 feet thick. On the weathered surface the different beds form angular ledges, dark gray with the suggestion of a brownish tinge.

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[47] Giles, A. W., St. Peter and older Ordovician sandstones of northern Arkansas: Arkansas Geol. Survey Bull. 4, p. 10, 1930. According to observations of the writer the unconformity at the base of the St. Peter sandstone truncates Everton strata within 135 feet of the Calico Rock sandstone in outlying hills northwest of Melbourne, but at no place are the St. Peter and Calico Rock sandstones believed to be in contact.

[48] Winslow, Arthur, Lead and zinc deposits of Missouri: Missouri Geol. Survey, vol. 6, p. 331, 1894.

[49] Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, p. 456, 1911.

STRATIGRAPHIC RELATIONS

The Joachim lies conformably on the St. Peter and is overlain unconformably by the Plattin. The Cedar Creek locality is the only place in northern Arkansas where an angular divergence has been observed between beds of the Joachim and Plattin, although evidence that such a divergence exists elsewhere is found in the regional variation in the thickness of the Joachim beneath the Plattin, from 20 to 150 feet in the Batesville district.[50] According to Ulrich,[51] the break between the Joachim and Plattin is represented in the New York section by the Chazy limestone, which is about 2,000 feet thick.

At several places in the Yellville quadrangle dolomitic beds occurring at or near the base of the Plattin resemble the Joachim, but generally they grade laterally into limestones of the Plattin type and have consequently been interpreted as examples of dolomitization of the Plattin. Where evidence of such gradation to limestone may be lacking, this interpretation is nevertheless borne out by comparison of the underlying St. Peter with its complete development in the Cedar Creek section, which usually shows that a varying amount of its upper part is missing beneath the dolomitic beds. As the Joachim, so far as known, is everywhere conformable on the St. Peter, whereas the Plattin is unconformable on it, the evidence is convincing that these dolomitic beds are basal Plattin and not Joachim.

MIDDLE ORDOVICIAN SERIES

PLATTIN LIMESTONE

NAME

The Plattin limestone, named by Ulrich [52] from Plattin Creek, in Jefferson County, Mo., was included in the †Izard limestone of the Branner and Adams reports, forming the upper part of that unit. The name Plattin was first applied in Arkansas by Purdue and Miser,[53] on the authority of Ulrich.

DISTRIBUTION

The Plattin in the Yellville quadrangle occurs only within the Buffalo River drainage basin, where it is everywhere underlain by the St. Peter, but its distribution is somewhat more restricted than that of the St. Peter in that it does not extend as far north. Nor is it continuous within the area bounded by its extreme limits, but, in a zone along its north border, it shows outlying remnants pre-

[50] Miser, H. D., Deposits of manganese ore in the Batesville district, Ark.: U.S. Geol. Survey Bull. 734, p. 17, 1922.

[51] Quoted by Miser, idem, p. 19.

[52] Ulrich, E. O., in Buckley, E. R., and Buehler, H. A., The quarrying industry of Missouri: Missouri Bur. Geology and Mines, 2d ser., vol. 2, p. 111, 1904.

[53] Purdue, A. H., and Miser, H. D., op. cit., p. 8.

served in small synclinal flexures beneath the unconformity at the base of the St. Joe. To the south and east, along the Buffalo River Canyon and southeast of the river, it becomes more continuous but even here there are certain structural highs, as in the neighborhood of Maumee and around the mouth of Kimball Creek, from which the Plattin has been eroded. Some of these areas where the Plattin is absent are 5 or 6 miles from the north limit of the formation.

THICKNESS

The thickness of the Plattin is subject to abrupt variations within short distances, owing to the unconformity at the base of the St. Joe. Less abrupt but almost as great variations are produced by the unconformity at the base of the Fernvale. The thickness ranges from a featheredge to 100 feet in the Yellville quadrangle, but probably the average is from 20 to 60 feet. The formation thins irregularly to the west and finally dies out along the border between the Yellville and Harrison quadrangles.

CHARACTER

The Plattin is made up dominantly of dense blue-gray limestone but has some fine-grained drab limestone and some fine to medium grained gray dolomite that is generally darker than the normal limestone. Local thin seams are sandy. At 60 feet above the base is a highly fossiliferous bed, only a few feet thick, of fine-grained rather dark gray limestone, but this bed is usually cut out by unconformity. A 1-foot bed of blue-green shale, lying 35 to 40 feet above the base of the Plattin, was noted near Gilbert, just off the south edge of the Yellville quadrangle. Here and there a little gray nodular chert has been developed in the limestone by replacement, especially at the very top, where it is apparently related to the unconformity with the overlying Fernvale or St. Joe.

The texture of the normal blue-gray limestone is as dense as that of a lithographic limestone, and indeed the Plattin has been considered as a possible source for lithographic stone. Most of it, however, contains small crystalline segregations and veinlets of calcite that destroy its value for this purpose. This dense limestone is also characterized by small cubes of limonite, pseudomorphic after pyrite. They range from pinhead size up to three-sixteenths inch or so in diameter, and commonly several such cubes are clustered together. In addition to the definitely crystalline material, half-inch amorphous blebs of limonite are common. The beds of this phase range from a fraction of an inch to 3 or 4 feet in thickness.

The drab limestone has a fine-grained porcelaneous texture and is further characterized by small dark-colored dendrites, produced by manganese or iron. It contains amorphous limonite blebs and streaks but no cubes. Commonly it shows small veinlets of clear calcite, and crystalline interstitial calcite faces that reflect the light as a unit over a distance of as much as an inch are very characteristic. This type is observed only in the upper part of the section, though not necessarily at the very top.

The dolomite may appear at almost any horizon in the section but is rather common at the base. It lies in poorly defined beds that in places grade laterally into limestone. It is believed to have been produced by replacement of the limestone on the floor of the sea shortly after deposition.

Sand that may occur in the limestone is composed of rounded quartz grains of the type that is characteristic of the Ordovician formations.

OUTCROP

The Plattin crops out as a series of rough steplike ledges, generally in a fairly steep slope (pl. 7, *A*). The limestones form very light-colored blue-gray ledges, in contrast to the dolomites, which are conspicuous, owing to their much darker gray color.

FOSSILS AND AGE

A cursory examination of the dense limestones of the Plattin gives the impression that they are unfossiliferous, but when examined carefully they are found to contain the remains of a small type of ostracode, though in nowhere near the abundance as in the Everton. These forms are especially characteristic of the lower few feet. The bed 60 feet above the base of the formation has yielded several species, of which the following have been determined by E. O. Ulrich:

Bryozoa:
- Escharopora cf. E. subrecta (Ulrich) and E. ramosa (Ulrich).

Brachiopoda:
- Zygospira aff. Z. recurvirostris (Hall).
- Rafinesquina aff. R. alternata (Emmons).
- Strophomena, one of the many forms usually referred to S. incurvata (Shepard).
- Small Camerella aff. C. panderi Billings.

Trilobita:
- Illaenus sp.
- Bumastus sp.
- Ceraurus cf. C. plattinensis Foerste.
- Ceraurus n. sp.
- Pterygometopus n. sp.; occurs in upper Mississippi Valley high in Platteville limestone.

The fauna of the Plattin, therefore, to judge from these rather incomplete collections, consists of brachiopods, bryozoans, trilobites, and ostracodes. The Plattin is Middle Ordovician and corresponds to part of the Platteville of the Upper Mississippi Valley and to the Lowville of the New York section.[54]

STRATIGRAPHIC RELATIONS

The Plattin overlies the Joachim disconformably throughout the Batesville district,[55] but the stratigraphic break becomes more pronounced to the northwest, and in the Yellville quadrangle the break has reached the proportions of an angular unconformity that has everywhere, with one exception previously described, cut out the Joachim, so that the Plattin rests on the truncated surface of the St. Peter sandstone.

At one locality, 2 miles northeast of Mount Hersey, the Plattin is overlain unconformably by a sandstone containing the fauna of the Kimmswick limestone. Elsewhere in the Yellville quadrangle it is overlain unconformably by the Fernvale limestone. Within the quadrangle the Plattin ranges in thickness from 100 to 15 feet beneath the Fernvale, but in the Harrison quadrangle it has been cut out completely, together with the St. Peter, so that the Fernvale rests on the Jasper. Southeast of the Yellville quadrangle, in the Batesville district, the thickness of the Plattin increases to 240 feet, and overlying this is as much as 50 feet of Kimmswick beneath the unconformity at the base of the Fernvale.

Where the Plattin is not overlain by Fernvale it is overlain unconformably by the St. Joe member of the Boone limestone (Mississippian).

KIMMSWICK LIMESTONE

NAME

The Kimmswick limestone was named by Ulrich[56] from typical exposures in the vicinity of Kimmswick, Jefferson County, Mo. Where present in Arkansas, it was included in the St. Clair marble of early reports of the Arkansas Geological Survey,[57] and in the †Polk Bayou limestone of Williams.[58] The Branner and Adams reports on the zinc-lead region used the above terms in the respective order given, but it is doubtful whether the Kimmswick was included in either case, as the formation does not generally occur in the zinc-lead

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[54] Ulrich, E. O., quoted in Miser, H. D., Deposits of manganese ore in the Batesville district, Ark.: U.S. Geol. Survey Bull. 734, p. 19, 1922.

[55] Miser, H D., idem, p. 19.

[56] Ulrich, E. O., in Buckley, E. R., and Buehler, H. A., The quarrying industry of Missouri: Missouri Bur. Geology and Mines, 2d ser., vol. 2, p. 111, 1904.

[57] Penrose, R. A. F., Jr., Manganese, its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, pp. 124–128, 1891. Hopkins, T. C., Marbles and other limestones: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 4, pp. 212–252, 1893.

[58] Williams, H. S., The Paleozoic faunas of northern Arkansas, in Branner, J. C., The zinc and lead region of north Arkansas: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 5, p. 283, 1900.

district. In 1911 Ulrich[59] correlated the lower part of the † Polk Bayou limestone of the Batesville district with the Kimmswick limestone of Missouri and extended the application of the name Kimmswick to Arkansas.

DISTRIBUTION, THICKNESS, AND CHARACTER

The only locality in the Yellville quadrangle where strata referable to the Kimmswick limestone have been found lies about 2 miles northeast of Mount Hersey. Here, in the head of a shallow draw that is tributary eventually to Mill Branch, blocks of sandstone containing an abundant Kimmswick fauna lie scattered over a surface that is otherwise entirely covered with Boone chert debris. There are no bedrock exposures in the immediate vicinity. The closest outcrops show, at the appropriate horizon, Plattin limestone overlain by St. Joe limestone (Mississippian), so that the occurrence of Kimmswick is extremely localized in its extent. The area over which the float blocks are strewn is not more than 100 feet in diameter. The thickness of the formation is not known but must be small.

The sandstone is light gray, medium-grained, and porous. The quartz grains have been enlarged by the addition of secondary silica, which has preserved casts of the fossils to the minutest detail, but the process has not been complete enough to prevent the sand from crumpling unless it is handled very carefully. Small lenses of light-gray porous chert in the sandstone probably represent limestone lenses that have been silicified.

The Kimmswick limestone is widely distributed throughout the Batesville district, ranging in thickness from 12 to 55 feet.[60] At one locality Miser reports a basal limy sandstone which, on weathering, leaves a porous sand similar to the one exposed near Mount Hersey.

FOSSILS AND AGE

The sandstone near Mount Hersey contains abundant fossils, but as only a small collection was made by the writer for purposes of identification, and as certain conflicting elements appear to be contained in the fauna, it has been thought advisable to have a list of species await the collection of further material. The fauna contains brachiopods, cystids, and trilobites. The assignment of the age to the Kimmswick is made by both Kirk and Foerste,[61] chiefly on the abundance of the cystid *Echinosphaerites*, a wide-spread and characteristic Kimmswick genus. Bridge[62] also recognizes certain other

[59] Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, pl. 27, 1911.

[60] Miser, H. D., Deposits of manganese ore in the Batesville district, Ark.: U.S. Geol. Survey Bull. 734, pp. 19–20, pl. 1, 1922.

[61] Kirk, Edwin, and Foerste, August, oral communications.

[62] Bridge, Josiah, personal communication.

forms that occur elsewhere in the uppermost beds of the Kimmswick. Ulrich, on the other hand, placing more weight on the brachiopod fauna, classes the sandstone as of Richmond (Fernvale) age.

The Kimmswick is of Middle Ordovician age and is correlated by Ulrich [63] with the uppermost Black River of the type New York section.

STRATIGRAPHIC RELATIONS

The Kimmswick sandstone described in this report overlies the Plattin limestone, and although the contact is not exposed, it is undoubtedly an unconformity. The Kimmswick is unconformable on the Plattin in the Batesville district [64] and unconformable on the Decorah or Plattin on the east flank of the Ozark dome.[65] The formation overlying the sandstone near Mount Hersey may be the Fernvale but is more probably the St. Joe limestone member of the Boone (Mississippian). In either case the contact is one of unconformity.

UPPER ORDOVICIAN SERIES

FERNVALE LIMESTONE

NAME

Hayes and Ulrich [66] named the Fernvale formation in 1903, the type locality being near the town of Fernvale, in west-central Tennessee. The formation was called the " St. Clair marble " by Branner in his report on the lead and zinc deposits of northern Arkansas, but Williams,[67] in the same volume, restricted the term " St. Clair " to the upper part of the St. Clair as recognized by Branner and proposed the name †" Polk Bayou limestone " for the lower part. In the Adams report the Fernvale limestone was called †" Polk Bayou limestone." In 1911 Ulrich [68] pointed out that the †Polk Bayou was separable into two formations, the Fernvale (above) and Kimmswick, that were already well known from different parts of Missouri, Kentucky, and Tennessee. The Kimmswick is represented at only a single locality in the Yellville quadrangle, so that the Fernvale, as here recognized, is essentially the same as the Polk Bayou of the Adams report.

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[63] Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, pl. 27, 1911.

[64] Miser, H. D., op. cit., p. 20.

[65] Weller, Stuart, and St. Clair, Stuart, Geology of St. Genevieve County, Mo.: Missouri Bur. Geology and Mines, 2d ser., vol. 22, pp. 113–115, 1928.

[66] Hayes, C. W., and Ulrich, E. O., U.S. Geol. Survey Geol. Atlas, Columbia folio (no. 95), p. 2, 1903.

[67] Williams, H. S., The Paleozoic faunas of northern Arkansas, in Branner, J. C., The zinc and lead region of north Arkansas: Arkansas Geol. Survey Ann. Rept. for 1892, vol. 5, p. 283, 1900.

[68] Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, pl. 27, 1911.

DISTRIBUTION

The Fernvale occurs along the whole length of the south side of the Yellville quadrangle. At the west end of this strip small isolated exposures appear near the mouth of Shaddock Branch, and on the point west of the mouth of Cane Branch, east of Mount Hersey. Other outcrops occur on Mill Creek northwest of St. Joe, along the St. Joe fault west of St. Joe Mountain, and on the south side of Davy Crockett Mountain. East of Duff the outcrops become more continuous, and along Rocky and Little Rocky Creeks and the north side of Spring Creek they are unbroken for several miles. The formation extends northward along the east side of the quadrangle as far as the Rush district, but its outcrops are discontinuous and very spotty between Spring Creek and Rush. Like the St. Peter and Plattin, the Fernvale has been cut out in the Yellville quadrangle along a northeast-southwest line by the erosion that produced the unconformity at the base of the Mississippian, which accounts for its greatest thickness and extent being toward the southeast corner of the quadrangle. Within the Harrison quadrangle only a single small outcrop of the Fernvale occurs, near Jasper, but southeast of the Yellville quadrangle, over most of the Batesville district, the formation is continuous and has a considerably greater average thickness.

THICKNESS

The thickness in the Yellville quadrangle ranges from 50 feet to the vanishing point. The maximum was observed at several localities—along Rocky and Little Rocky Creeks, at the mouth of Rock Creek, at the junction of Panther and Little Panther Creeks, at the "narrows" of Buffalo River 3 miles southeast of Rush (pl. 8, *A*), and near the Red Cloud mine, at Rush. The outcrop on Shaddock Branch is 20 feet thick; that on Cane Branch is 6 feet. Probably the average maximum thickness of each outcrop throughout the district is 10 to 30 feet, but variations may be very abrupt, owing to the way in which remnants of the formation are preserved in synclinal depressions beneath the unconformity at the base of the St. Joe. The thickness of the outcrop near Jasper, in the Harrison quadrangle, is about 5 feet.

CHARACTER

The Fernvale is composed of massive coarsely crystalline limestone, the usual grain size averaging one-sixteenth inch. The fresh fracture is very light gray or whitish but nearly always with a slight pinkish tinge. In much of the rock certain grains are more pinkish than others, but the brownish-red colors of the St. Joe are not developed. Besides the normal coarse-grained texture, the Fernvale commonly shows indefinite segregated bodies of fine-grained gray limestone, as much as 3 or 4 inches across. Small patches of crystalline calcite may also be developed. The bedding is coarse, and some sections appear to be made up of single massive units (pl. 8, *A*), but usually beds from 4 to 10 feet thick are discernible.

OUTCROP

The Fernvale limestone crops out characteristically as a dark-colored, massive but generally discontinuous ledge. It is very friable on the exposed surface, and hence the ledges generally show rounded corners.

FOSSILS AND AGE

The Fernvale is one of the most fossiliferous formations in the lead and zinc region. A very characteristic form is a type of crinoid stem, the individual segments of which are shaped like small barrels, one-quarter to three-eighths inch long. Unfortunately these forms tend to disintegrate on the weathered surface, so that they are not as valuable as they might be as key fossils. Other types of organic remains consist dominantly of brachiopods, but the trilobites and bryozoans are also well represented. From its abundant fauna the Fernvale is correlated with the Richmond of the Mississippi Valley, which is of late Upper Ordovician age.

STRATIGRAPHIC RELATIONS

The Fernvale is unconformable on the Plattin and possibly also on the Kimmswick at one locality. (See p. 53.) The Plattin formation ranges between 15 and 100 feet in thickness beneath the unconformity in the Yellville quadrangle, and has been completely removed, together with the underlying St. Peter, at the locality near Jasper, in the Harrison quadrangle. To judge from the much greater thickness of the Plattin in the Batesville district, together with the considerable thickness of overlying Kimmswick that has been cut out in the Yellville quadrangle, the unconformity at the base of the Fernvale appears to represent erosion of considerable magnitude.

The Fernvale in a few places is overlain by the Cason shale, which comes next in the normal section. The contact is an unconformity: the Fernvale underlying the Cason is only 20 feet thick where the road that leads up Dry Creek from Gilbert first descends the hill into the creek valley, while on Rocky Creek, 4 miles to the east, the Fernvale is in places 50 feet thick with no Cason present. Around the mouth of Tomahawk Creek, along the Buffalo River south of Tomahawk Creek, and along parts of Rocky Creek the Fernvale is unconformably overlain by the St. Clair. At most localities in the Yellville quadrangle, however, the Fernvale is overlain unconformably by the St. Joe (Mississippian).

CASON SHALE

NAME

The formation that carries manganese ore in the Batesville district was named the " Cason shale ", from the Cason tract, in that district, by H. S. Williams in 1894.[69] In the Branner report the name † " Eureka shale " was applied to both the Chattanooga shale of the Eureka Springs district and the Cason shale at the only locality where it was seen in the Yellville quadrangle—namely, at St. Joe. In the Adams report the name " Sylamore formation " included the Cason shale, below, and the Sylamore (?) sandstone at the base of the Mississippian, above, although Ulrich, in the same volume (p. 100), used the name " Cason shale " in referring to outcrops within the Yellville quadrangle. Purdue and Miser, in the Eureka Springs-Harrison folio, differentiated the Cason from the Chattanooga shale and presented fossil evidence to show that the Cason, as represented near Jasper, is the equivalent of the Cason in the Batesville district.

DISTRIBUTION AND THICKNESS

The Cason shale occurs at only a few places in the southern part of the Yellville quadrangle. It is 4 feet thick at the cement quarry on Mill Creek, northwest of St. Joe; 23 feet on Dry Creek, below Duff; 6 feet where the road from St. Joe to Maumee crosses Tomahawk Creek; 5 feet in the head of one of the hollows northeast of Gilbert; and 15 feet on the east side of Rocky Creek in T. 16 N., R. 16 W. These localities are the only ones where it has been identified and its horizontal extent is only a fraction of a mile in each locality. The maximum thickness of 23 feet is found on the south bank of Dry Creek below Duff, opposite the mouth of a well-developed tributary branch from the north.

CHARACTER

The Cason consists essentially of black and blue-gray shale, the latter commonly weathering blue-green or drab. The black shale in the different sections lies below the gray or green and ranges from 2 to 6 feet in thickness. It is fissile, whereas the green shale is more massive. Black phosphatic pebbles, 1 to 2 inches in size, are very common at the base of the Cason but also occur less abundantly within

[69] Williams, H. S., On the age of the manganese beds of the Batesville region of Arkansas: Am. Jour. Sci., 3d ser., vol. 48, pp. 326–329, 1894.

the lower 6 feet of the formation, in both types of shale. These pebbles are in general irregularly rounded and show smooth, shiny but pitted surfaces. Some of the larger ones, as much as 6 inches in size, that occur in the black shale have dull unpitted surfaces and resemble concretions in place, but those of the more usual type have apparently been transported some distance. The latter are commonly traversed by small pin-sized "worm borings" filled with earthy whitish calcite, or more rarely dolomite. The section at the St. Joe quarry shows, instead of distinct basal pebbles, a layer 2 inches thick that appears to be of the same composition as the material that elsewhere makes up the pebbles. This material is brownish black, is dull in luster, and shows in detail numerous small whitish fragments of shells. It contains a few spots of greenish-blue shale that appears to have been introduced as a matrix into the phosphate rock after a slight amount of fragmentation.

Pyrite occurs in the Cason, both as fine cubes (pinhead size or smaller) in the blue-green shale, and as amorphous blebs in both types of shale and in some of the larger phosphatic pebbles. In the lime quarry at St. Joe the top 3 feet of the Fernvale, beneath the Cason, is impregnated with pyrite along irregular zones. This is plainly a secondary development and evidently related to the Cason above. In places thin films of gypsum lie along the fractures and parting planes of the lower black member of the Cason where it is conspicuously pyritic; the mineral was probably formed by the reaction of sulphuric acid, from the oxidation of the pyrite, with calcium carbonate waters.

FOSSILS AND AGE

Fossils collected by the writer from the Cason of the Yellville quadrangle comprise small brachiopods of the genus *Lingula*, found in the black shale near the base of the formation, and poorly preserved ostracodes and gastropods found in the basal phosphate bed at St. Joe. The gastropods are preserved only as internal molds and include, according to Ulrich, forms of the genus *Cyclora* and a larger form that may be a depauperate type of *Holopea*. *Cyclora*, according to Ulrich, is a long-ranging Ordovician and Silurian genus. The formation is correlated with the Cason of the type locality, near Batesville, on its lithologic character and its stratigraphic position between the Fernvale and Brassfield. It is of late Upper Ordovician (Richmond) age and is probably the equivalent or partial equivalent of the Maquoketa of Iowa, Missouri, and Illinois.[70]

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[70] Purdue, A. H., and Miser, H. D., U.S. Geol. Survey Geol. Atlas, Eureka Springs-Harrison folio (no. 202), p. 9, 1916.

STRATIGRAPHIC RELATIONS

The Cason is unconformable on the Fernvale, as shown by variations in the thickness of the Fernvale (from 15 to 50 feet in the Yellville quadrangle) beneath the plane of unconformity. It is overlain unconformably at different places by different formations, including the Brassfield, the St. Clair, and the basal sandstone or the St. Joe member of the Boone, the magnitude of the break increasing in the order given. Evidence for an unconformity at the base of the Brassfield is found in the variation in the thickness of the Cason beneath it, from 23 feet on Dry Creek to 6 feet on Tomahawk Creek, less than 2 miles to the north.

SILURIAN SYSTEM

The Silurian is represented in the Yellville quadrangle by a maximum of about 100 feet of marine limestones. Two formations with an unconformity between them are recognized, one of late Medina (lower Silurian) and the other of late Clinton (middle Silurian) age. The system is unconformable on the underlying Ordovician, although the stratigraphic break recorded in the unconformity is apparently of less magnitude than breaks recorded by internal unconformities within each of these systems. The Silurian rocks are restricted to a small area along the south edge of the quadrangle. If they were ever more widely distributed they were cut out by the erosion that produced the unconformity at the base of the overlying Mississippian, or the lower limestone was cut out in part by the erosion recorded in the unconformity within the Silurian.

BRASSFIELD LIMESTONE

NAME

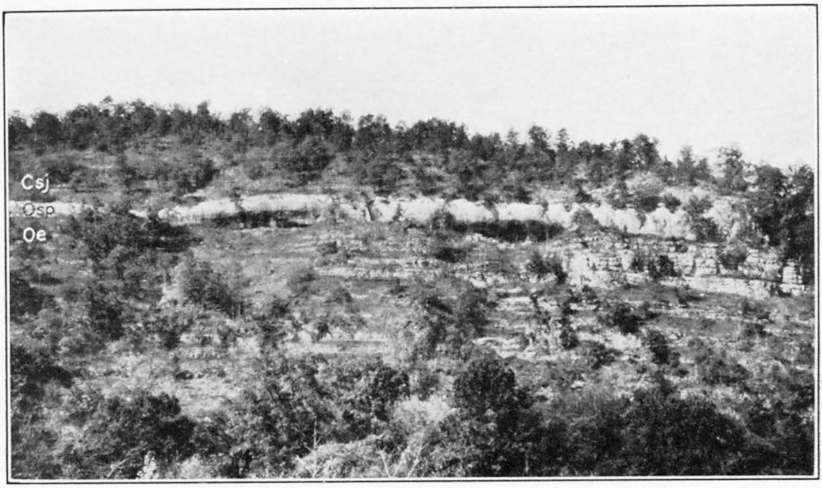
The Brassfield formation was named by Foerste [71] in 1905, from exposures between Brassfield and Panola, Madison County, Ky. Its characteristic fauna was discovered within the Yellville quadrangle by Ulrich at some time prior to 1911.[72] It is probable that the formation, which has a very restricted distribution in Arkansas, was never seen by Branner; if it was, he grouped it in his St. Clair. In the Adams report the Brassfield, together with the St. Clair, was confused with the St. Joe member of the Boone.

DISTRIBUTION AND THICKNESS

The Brassfield limestone is everywhere underlain by the Cason shale but is somewhat more restricted in distribution, owing to the fact

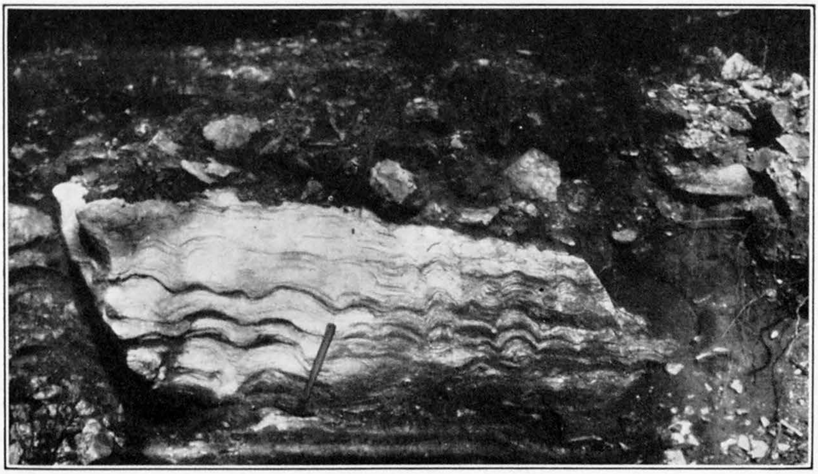
[71] Foerste, A. F., Silurian clays: Kentucky Geol. Survey Bull. 6, p. 145, 1905.

[72] Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, p. 558, 1911.

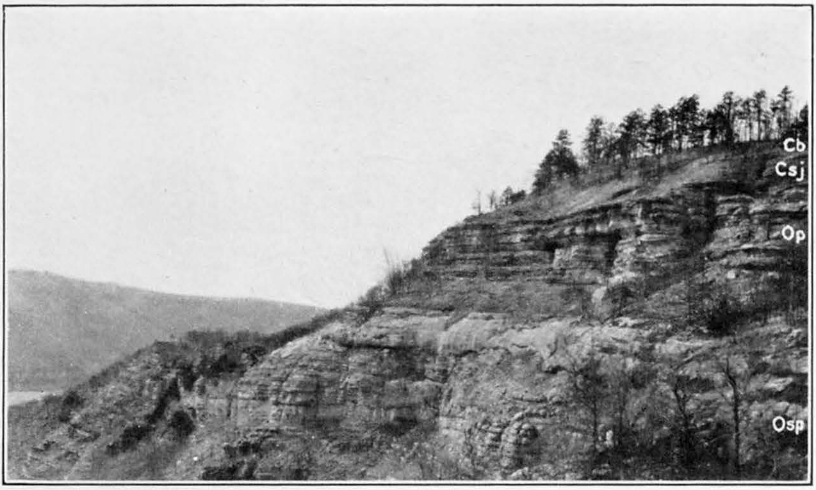


A. LEFT SIDE OF THE BUFFALO RIVER ABOUT 1½ MILES ABOVE MOUTH OF WATER CREEK.

Shows typical outcrops of Everton formation (Oe) and St. Peter sandstone (Osp) as they appear over much of the region. Ledges of St. Joe limestone (Csj) crop out above the St. Peter.

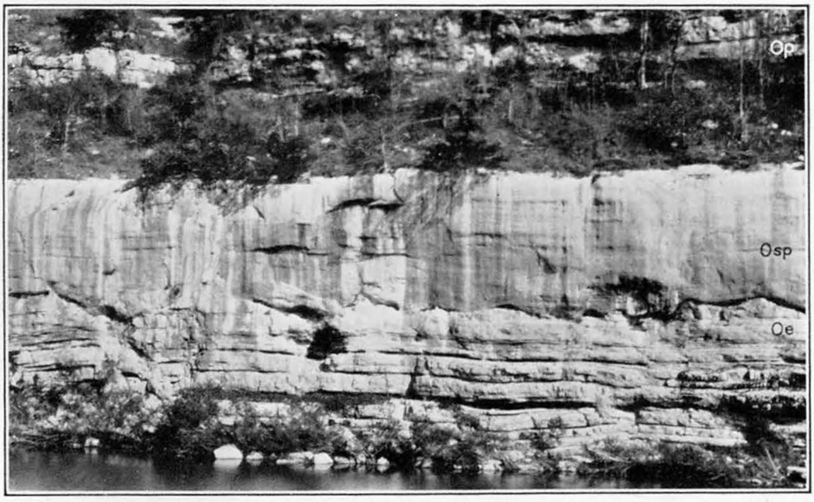


B. CRYPTOZOON STRUCTURES IN EVERTON LIMESTONE NEAR MORNING STAR MINE, RUSH.



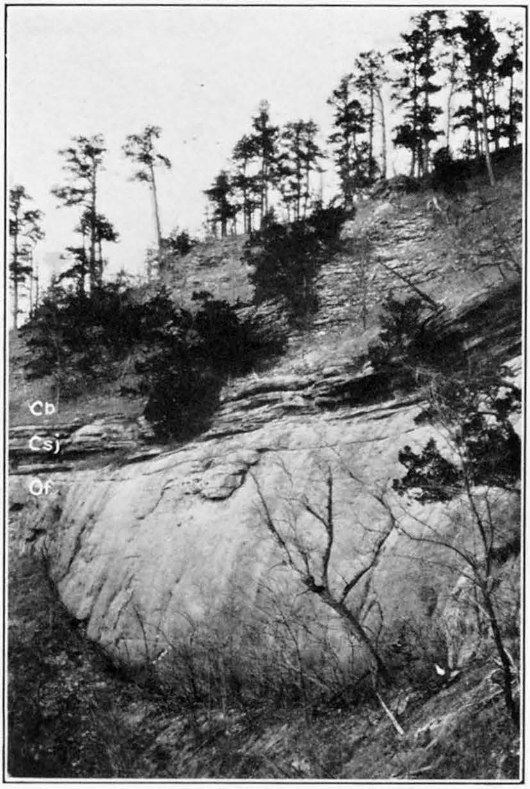
A. RIGHT SIDE OF THE BUFFALO RIVER 3 MILES SOUTHEAST OF RUSH.

From the west side of the "narrows," looking downstream. Section shows Everton formation, St. Peter sandstone (Osp) (including concealed slope of middle part of St. Peter above), Plattin limestone (Op) (vertical cliff), St. Joe limestone (Csj) (dark ledges at top of cliff), and concealed Boone chert (Cb) slope to top of hill.



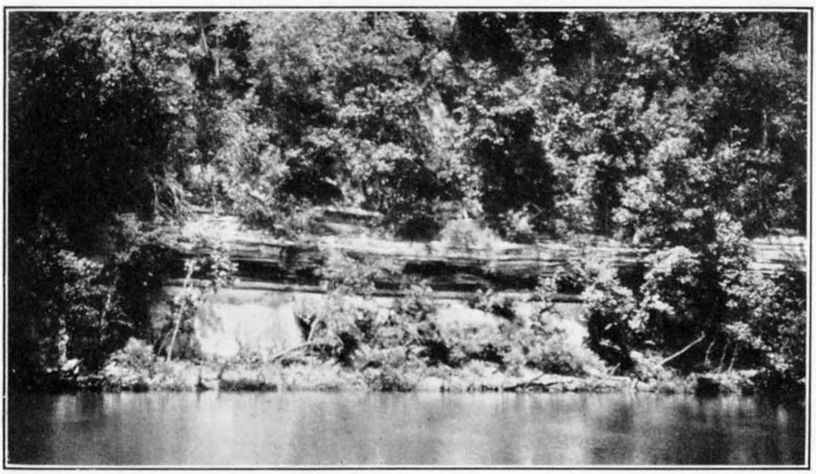
B. RIGHT BANK OF THE BUFFALO RIVER JUST ABOVE THE MOUTH OF ROCK CREEK.

Shows St. Peter sandstone (Osp) between Plattin (Op) and Everton (Oe) limestones. Note characteristic erosion unconformity at base of St. Peter.



A. OUTCROP ON WEST SIDE OF THE "NARROWS" OF THE BUFFALO RIVER, 3 MILES SOUTHEAST OF RUSH.

Shows Fernvale limestone (Of), St. Joe limestone member (Csj), and chert (Cb) of Boone formation. Note unconformity at base of St. Joe.



B. LEFT BANK OF THE BUFFALO RIVER A QUARTER OF A MILE BELOW THE MOUTH OF TOMAHAWK CREEK.

Shows contact of St. Joe limestone with St. Clair limestone (at top of massive bed). Outcrops characteristic of the two formations.

that it may have been removed from above the shale by erosion prior to the deposition of the St. Clair or of the basal sandstone of the Boone. It occurs at several points on Dry Creek within a mile or so above Gilbert, and the maximum thickness of about 30 feet is recorded on the point above the first grade crossing northwest of Gilbert. On Tomahawk Creek at the crossing of the road between St. Joe and Maumee the Brassfield is 23 feet thick. The third and last locality where it was found is in and around the mouths of two small hollows that discharge into the Buffalo River from the north a mile or so below Gilbert. A thickness of 16 feet was measured on the point west of the mouth of the upper one of these hollows.

CHARACTER AND OUTCROP

The Brassfield limestone is rather variable in character. Texturally it consists of crystalline fragments of calcite, averaging one-sixteenth to one-eighth inch, embedded in a fine-grained matrix, but the relative proportion of these fragments to the matrix is subject to all gradations. Many of the fragments are plainly broken from crinoid stems, and possibly all of them have this origin. The limestone is commonly pink or deep flesh-colored, but the beds showing a high proportion of the fine-grained matrix are more nearly gray or only slightly flesh-tinted. The calcite fragments are colorless, white, flesh-colored, or red-brown. Near Gilbert one ledge of the Brassfield consists of medium- to fine-grained, rather porous white limestone. A characteristic feature of the formation is the development of irregular vugs of colorless or white crystalline calcite, and usually the limestone adjacent to such segregations has been altered to a fine-grained pink, tan, or brownish-red secondary product. Near Gilbert the lower 16 feet of the Brassfield, consisting of all the lithologic types mentioned, contains numerous rounded to oblong grains of blue-green glauconite, 1½ millimeters in maximum diameter. This mineral also occurs in the limestone of the section on Tomahawk Creek and is apparently characteristic of the formation, especially of the gray fine-grained phase. In some places the Brassfield contains pyritic segregations which are generally altered to limonite.

The Brassfield resembles the Fernvale but is somewhat less completely crystalline. On the other hand, it contains a larger percentage of calcite fragments than the overlying St. Clair. Instead of occurring in very thick, massive beds like the Fernvale, it weathers into thinner ledges, a foot or less thick, more on the order of the St. Joe limestone (p. 66).

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FOSSILS AND AGE

The Brassfield of the Yellville quadrangle contains abundant fossils. The following list includes the species that have been identified by Messrs. Ulrich and Mesler from the collections made by the writer:

Bryozoa:
- Rhinopora verrucosa Hall.
- Lichenalia sp.
- Fenestella sp.
- Pachydicta sp.
- Hemitrypa ulrichi Foerste.

Brachiopoda:
- Leptaena rhomboidalis (Wilckens).
- Strophomena sp.
- Sowerbyella 2 sp.
- Atrypa reticularis (Linnaeus).
- Triplecia ortoni (Meek).

Gastropoda:
- Platyceras sp.

Trilobita:
- Bumastus 2 sp.
- Sphaerexochus n.sp.
- Encrinurus sp.
- Illaenus sp.

The brachiopods, bryozoans, and trilobites are all well represented, and in addition a few remains of gastropods occur. This fauna serves as the basis for correlating the Brassfield of the Yellville quadrangle with that of Kentucky, Missouri, and Tennessee. The age of the fauna is lower Silurian (late Medina).

STRATIGRAPHIC RELATIONS

The Brassfield overlies the Cason with apparent unconformity, as shown by variations in the thickness of the Cason, and is in turn overlain unconformably by either the St. Clair or the basal sandstone of the Boone. Erosion preceding the deposition of the St. Clair in places removed the Brassfield or the Brassfield and Cason, so that the St. Clair may rest on the Cason or on the Fernvale.

ST. CLAIR LIMESTONE

NAME

The name of the St. Clair limestone was first presented by Penrose [73] in 1891. The type locality is at St. Clair Springs in Independence County, Ark. As originally defined, the formation included the Kimmswick limestone, the Fernvale limestone, the Cason shale, and the St. Clair limestone as recognized in the present report.

[73] Penrose, R. A. F., Jr., Manganese, its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, p. 124, 1891.

In 1900 H. S. Williams [74] restricted the term to the uppermost of these formations. The formation was confused with the St. Joe limestone in the Adams report on the lead-zinc district of northern Arkansas, although Ulrich,[75] in the same volume, shows that he was aware at that time of the existence of St. Clair limestone in at least one locality within the Yellville quadrangle.

DISTRIBUTION AND THICKNESS

The St. Clair limestone has a rather restricted distribution along the south edge of the Yellville quadrangle, between Duff and Little Rocky Creek. It ranges in thickness from 60 feet to the vanishing point. Outcrops occur on Dry Creek within the first mile or so above Gilbert, where several small patches of the limestone are preserved beneath the unconformity at the base of the St. Joe, maximum thickness about 10 feet; on Tomahawk Creek where it is crossed by the road from St. Joe to Maumee, maximum 37 feet; along the Buffalo River and its tributary hollows from a point a little above the Missouri & North Arkansas Railway bridge to the fault below the mouth of Tomahawk Creek, varying between 10 and 25 feet over most of this stretch but increasing around the mouth of Tomahawk Creek to a maximum thickness of 60 feet, measured on the right side of the creek a short way above the mouth; and, finally, on the lower courses of Rocky and Little Rocky Creeks, 40 feet having been measured on the right side of Rocky Creek about 1,000 feet above the southern of two faults.

CHARACTER AND OUTCROP

The St. Clair is typically a gray or pale flesh-colored, occasionally pinkish fine-grained limestone, with crystalline plates rather sparingly scattered through it. These plates may be gray, white, or red-brown. The normal phase of the formation, as just described, is characterized by small vuggy segregations of colorless or white crystalline calcite, with indefinite borders. Usually the vugs are irregular in shape, but they may also take the form of thin veinlets developed along the bedding plane, or in places across it. Scattered small blebs of pyrite occur in the fine-grained groundmass of the limestone.

Less common lithologic types are produced by increase in the proportion of the crystalline plates relative to the groundmass of the limestone. At one place on Dry Creek a short way above Gilbert a facies of the St. Clair, 2 feet above the base, is made up almost

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[74] Williams, H. S., The Paleozoic faunas of northern Arkansas: Arkansas Geol. Survey Ann. Rept. for 1892, vol. 5, p. 273, 1900.

[75] Ulrich, E. O., Determination and correlation of formations [in northern Arkansas]: U.S. Geol. Survey Prof. Paper 24, p. 98, 1904.

entirely of coarsely crystalline flesh-colored limestone with very little groundmass.

The bedding of the St. Clair, ranging from 1 to 5 feet, is not so massive as that of the Fernvale, and the ledges formed on the weathered surface are more angular. Where the St. Clair is being actively eroded, as, for example, along the left side of the Buffalo River below the mouth of Tomahawk Creek (see pl. 8, *B*), it forms a massive bluff in which the bedding is very obscure.

FOSSILS AND AGE

Like the Fernvale and Brassfield limestones, the St. Clair contains fossils rather abundantly. The following list of species identified by Ulrich and Mesler from collections made by the writer, though it by no means includes all the species known from the St. Clair of northern Arkansas, is nevertheless fairly representative of the formation in the Yellville quadrangle:

Coral:
- Streptelasma sp.

Bryozoa, at least 2 species.

Brachiopoda:
- Atrypa reticularis (Linnaeus).
- Leptaena rhomboidalis (Wilckens).
- Streptis grayi (Davidson).
- Clorinda n. sp.
- Atrypina disparilis (Hall).
- Whitfieldella nitida (Hall).
- Dalmanella sp.
- Eospirifer radiatus (Sowerby).
- Bilobites sp.
- Schuchertella aff. S. subplana (Conrad).
- Sowerbyella sp.
- Camarotoechia sp.

Pelecypoda: Conocardium sp.

Gastropoda:
- Platyceras sp.
- Hormotoma? sp.

Cephalopoda, 2 or 3 species.

Trilobita:
- Bumastus ioxus (Hall).
- Encrinurus sp.
- Dalmanites n. sp.
- Staurocephalus sp.
- Illaenus sp.
- Proetus sp.
- Illaenoides n. sp.
- Cheirurus niagarensis (Hall).
- Arctinurus sp.
- Cyphaspis sp.
- Calymene sp.
- Dicranopeltis sp.

The dominant forms of the St. Clair are brachiopods and trilobites, but corals, bryozoans, pelecypods, gastropods, and cephalopods are also represented. The fauna of the limestone places it in the middle Silurian (late Clinton), approximately at the same horizon as the Rochester shale of New York, according to Ulrich.[76]

STRATIGRAPHIC RELATIONS

Owing to the unconformity at its base, the St. Clair may rest on either the Brassfield or the Cason, or it may overlap both of them and rest on the Fernvale. It is unconformably overlain by the basal sandstone of the Boone, or by the St. Joe limestone member where the sandstone is not developed.

CARBONIFEROUS SYSTEM

Rocks of Carboniferous age are represented by about 1,000 feet of sediments within the Yellville quadrangle, comprising sandstone, shale, limestone, and chert. Both the Mississippian and Pennsylvanian series are well developed, with an unconformity between them. There are, in addition, unconformities within each of these series. The system as a whole shows regional unconformity with the underlying Silurian and Ordovician rocks. Only the basal formation of the Mississippian series is widely distributed in the quadrangle; higher formations, which are the youngest rocks in the region, have been largely removed by erosion from a former extension that must have at least covered the quadrangle. Erosional remnants, however, have been preserved in the southern part of the quadrangle. The Carboniferous rocks of the Yellville quadrangle are probably all of marine origin, with the possible exception of the uppermost formation.

MISSISSIPPIAN SERIES

BOONE FORMATION

The Boone formation ranks second to the Everton as a producer of lead and zinc in northern Arkansas. Perhaps its lesser yield is attributable more to its general absence, by erosion, from the more richly mineralized districts than to any inherent unfitness as a carrier of ore. As is well known, the lead-zinc deposits of the Tri-State (Joplin) region occur in the Boone. In Arkansas most of the ore produced in Newton County has been obtained from the Boone, but the formation has yielded very little elsewhere in the lead-zinc district.

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[76] Quoted in Miser, H. D., Deposits of manganese ore in the Batesville district, Ark.: U.S. Geol. Survey Bull. 734, p. 31, 1922.

NAME

The term "Boone" was first introduced in 1891 by Penrose [77] and Simonds [78] simultaneously, although the name was proposed to them by J. C. Branner. The formation is named for Boone County, Ark., where it crops out over wide areas.

DISTRIBUTION

Except in certain down-faulted areas along the south side of the quadrangle, between the head of Cane Branch and Tomahawk Creek, where upper Mississippian and Pennsylvanian rocks are preserved, the Boone is the highest formation in the stratigraphic section. It forms the tops of practically all of the high ridges from Pilot Knob, Short Mountain, and Pine Mountain southward to the quadrangle boundary and in addition underlies such broad flats as Pine Flat, near Dodd City; Kings Prairie and Ham Flat, between Everton and Bruno; and similar flat or gently rolling uplands in the general regions of Valley Springs, Western Grove, and St. Joe. Owing to the proximity of the White River, the north half of the quadrangle has been more thoroughly degraded by erosion, with consequent reduction of the area underlain by the Boone, while the south half, lying farther from the master stream, has been less eroded and consequently shows a more extensive development of this formation. The existence of a number of structural lows to the south has also tended to preserve the Boone over wider areas than would otherwise have been possible.

THICKNESS

Nowhere in the quadrangle are the top and bottom of the Boone exposed in the same stratigraphic section, and therefore the thickness of the formation cannot be measured directly. The thickness given in the Harrison quadrangle is from 350 to 400 feet, and that in the Batesville district is between 300 and 400 feet.

CHARACTER

The Boone is essentially a limestone and chert formation containing a basal sandstone that may or may not be present. The lowermost strata of limestone, immediately above the basal sandstone, possess certain lithologic characteristics that have led to their separation as a member of the formation under the name "St. Joe limestone." In the following description of the Boone lithology the three members are discussed in the order of their thickness, which is also their stratigraphic order from the top down.

[77] Penrose, R. A. F., Jr., op. cit., pp. 129–138.
[78] Simonds, F. W., The geology of Washington County, Ark.: Arkansas Geol. Survey Ann. Rept. for 1888, vol. 4, pp. 27–37, 149, 1891.

Upper part of Boone.—That part of the Boone lying above the St. Joe limestone member is composed of gray limestone and chert. Certain beds are pure limestone; others are limestone containing a considerable percentage of chert as lenses and nodules; and in extreme cases zones that may be as much as 70 feet or perhaps more thick are composed almost entirely of chert with a minor amount of limestone appearing as small residual lenses. The change from limestone to chert or from chert to limestone in a stratigraphic section is not sharply defined but gradational, by increase of one and decrease of the other, although the change may be accomplished in a relatively narrow zone. Owing to the scarcity of outcrops and to the difficulty of determining the horizon when an outcrop is found, the regional variations in the character of the Boone were not studied. On a prong of Tomahawk Creek in sec. 7, T. 16 N., R. 16 W., about 3 miles northeast of Pilot Mountain, the lowest 100 feet of the Boone, exclusive of the St. Joe (20 feet), is cherty, and indeed all except the lowest 25 feet is dominantly chert, the limestone appearing as lenses only an inch or two thick and a foot or two long. In the Rush district, more specifically at the Silver Hollow mine, that part of the Boone immediately overlying the St. Joe limestone is 80 to 90 percent chert. On Halls Mountain, 1 mile north of Bald Jesse, 35 feet of Boone chert occupies the same horizon. That the relative percentage of limestone and chert varies laterally as well as vertically is made evident by comparing these sections with those in the Harrison quadrangle,[79] where the lower part of the formation, exclusive of the St. Joe, is as a rule limestone. Lateral variations in the chert content were recognized by Purdue and Miser [80] in the Eureka Springs and Harrison quadrangles, where the formation is much better exposed than in the Yellville quadrangle.

The limestones range from fine- to coarse-grained and in color from very light gray to olive-gray, or locally pinkish. The bedding is rather massive, generally in beds from 1 to 3 feet thick. The medium- and coarser-grained varieties contain, besides numerous other fossils, abundant fragments of crinoid stems. Where nodular or lenticular chert appears in crinoidal limestone of this type, it also contains stem fragments; where the limestone is fine-grained and barren of fossils, the associated chert is also unfossiliferous. A crinoid stem in chert is preserved as calcite and leaches out when the chert weathers, leaving a conspicuous cast that may contain a central siliceous core that marks the central tube of the stem. If the chert has been formed by replacement of the limestone, either very soon

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[79] Purdue, A. H., and Miser, H. D., U.S. Geol. Survey Geol. Atlas, Eureka Springs-Harrison folio (no. 202), p. 10, 1916.

[80] Idem, p. 10.

after deposition or at some subsequent period, it is evident that the coarse crystallinity of the fossil has protected it against replacement.

The Boone chert, where fresh, is gray, blue-gray, greenish gray, drab, flesh-colored, or rarely red, and possesses a dense texture, but on weathering it becomes white or light gray or perhaps buff or dark brown. Coincident with the change in color the texture becomes more porcelaneous, and in extreme cases the residual material may be so porous as to approach the consistency and specific gravity of chalk. The bedded cherts generally show a poorly defined layering on a 1- to 3-inch scale. The small amount of limestone included in these cherts normally appears as irregular lenses parallel to the bedding. Closely superimposed lenses of limestone may be connected in one or more places across the intervening chert layers, as if the chert were a later development along bedding planes in an originally continuous limestone mass.

In the Tri-State zinc-mining region, embracing the corners of Oklahoma and Kansas and the adjacent part of Missouri, the upper part of the Boone contains an oolitic limestone (Short Creek oolite member) which has been of considerable service as a horizon marker in that region. A similar lithologic unit near the top of the formation was found in the Eureka Springs and Harrison quadrangles,[81] but it was not recognized in the Yellville quadrangle. This is more probably due to general erosion of the upper Boone, coupled with lack of outcrops, than to any lack of original deposition of the oolite. At the Bald Hill mine, which lies in the drainage basin of Cave Creek, several miles south of the Harrison quadrangle, oolitic limestone is exposed in one of the tunnels at an unknown but probably high horizon in the Boone.

St. Joe limestone member.—The St. Joe member of the Boone was named by Branner from exposures near St. Joe, in the Yellville quadrangle, although the name was first presented in the literature by Hopkins.[82] The St. Joe is commonly the only part of the Boone that is exposed and is of considerable geologic importance as a horizon marker in the stratigraphic section. Its thickness in the Yellville quadrangle ranges from 20 to 45 feet. From the overlying strata of the Boone it differs chiefly in being noncherty, thin-bedded, and usually, in part, red. The individual layers making up the member are typically from 1 to 4 inches thick, though they may locally be as much as 1 foot. The division planes between these layers are not sharply defined in the sense that they form good cleavage surfaces; they are manifested chiefly as zones of weakness

[81] Purdue, A. H., and Miser, H. D., op. cit., p. 10

[82] Hopkins, T. C., Marbles and other limestones: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 4, p. 253, 1893.

on the weathered surface of the ledge and account for the horizontal fluting that is characteristic of the outcrop of the St. Joe (pl. 8, *B*).

Lithologically the St. Joe is a fine-grained limestone, containing crystalline fragments of crinoid stems that here and there are a quarter of an inch in size but are generally somewhat smaller. The relative proportions between groundmass and crinoid fragments vary in different layers. The abundance of these fragments gives the impression of a coarse-grained limestone or marble, and in fact the St. Joe has been quarried as marble to a small extent. Its fine-grained matrix, however, together with its well-preserved fossils, and the mildness of its known structural history are all contrary to the geologic concept that marble implies a thoroughly recrystallized metamorphic limestone. A large percentage of the crystalline fragments are circular or partly circular sections of crinoid stems. The color of the St. Joe ranges from gray to brownish red in different zones. The crinoid fragments are white, light gray, or flesh-colored and are especially conspicuous in the red phases of the limestone. Small blebs of limonite, about half an inch in maximum size, are common in the matrix, and in places pyrite, from which the limonite was derived, is preserved as similar noncrystalline blebs. Where the basal sandstone of the Boone is absent or poorly developed, the basal 6 inches or so of the St. Joe may contain the phosphatic brownish pebbles that normally occur in the sandstone.

As a general rule the lithology of the St. Joe is distinctive enough to admit of ready identification. However, certain phases of the St. Clair may resemble some of the gray phases of the St. Joe. Usually the more massive character of the St. Clair bedding will serve to distinguish between the two, but the surest criterion is the position of the basal sandstone of the Boone, whether above or below the outcrop in question.

At a few places in the Yellville quadrangle, especially in the heads of the several creeks that rise around Dodd City, 6 inches or so of soft greenish to buff shale that may contain sporadic grains of well-rounded sand is exposed at the base of the St. Joe, overlying a few inches of the basal sandstone of the Boone. It is possible that this shale facies may be fairly widespread at this horizon, but from its nature it would rarely be exposed.

Basal sandstone.—Considering the fact that it is usually the most insignificant unit in the stratigraphic section, the sandstone at the base of the Boone is surprisingly persistent. Its thickness in the Yellville quadrangle ranges from a knife-edge to 18 feet but is mostly 2 inches to 5 feet. The maximum thickness was noted near the head of a small south tributary that empties into Rush Creek about 1½ miles above Rush. The sandstone is 16 feet thick on the point east of the head of Monkey Run, 2 miles northwest of St. Joe. It is probable that these thicknesses are approached or equaled elsewhere within the Yellville quadrangle, but only for short distances. The greatest thicknesses that are sustained over any considerable distance lie in an indefinite belt extending from the vicinity of Everton to the mouth of Greasy Creek; in this stretch the sandstone averages between 5 and 12 feet, although locally it may be thinner. Near Everton the combination of a fairly heavy sandstone at the base of the Boone with underlying remnants of what the writer has interpreted as Newton sandstone has produced prominent sandstone cliffs that have in the past been classed as St. Peter.

The basal sandstone of the Boone is made up of coarse to fine quartz grains, indistinguishable in character from those of the Everton and St. Peter. Where they have not been altered by later solutions the grains are well rounded, but commonly material has been added to the grains, producing crystalline faces and, in extreme cases, perfect small quartz crystals, but always with rounded sand-grain nuclei that can be seen under proper microscopic conditions. The sandstone is generally calcareous, and where it is very thin it may show cleavage faces of calcite developed interstitial to the sand grains. Where the limy cement has been leached out on the weathered surface, the sand becomes very friable. The color of the sand is whitish to buff, or, less commonly, brown. Small segregated masses of pyrite weather to brown or blackish spots, and local cementation, either of whole beds or of concretionary spots, may produce hard gray siliceous phases.

The most characteristic feature of the sandstone is the occurrence of small rounded phosphatic pebbles, either sporadically scattered through the sand or else concentrated along certain bedding planes near its base if it possesses any considerable thickness. These pebbles are dark grayish brown, earthy in texture, and structureless; they rarely surpass an inch in greatest dimension, although a few are 2 or even 3 inches across. They weather light gray or brown. Many of them are penetrated by small slightly curved tubes, of the diameter of a pin or smaller, that resemble some type of worm boring. Some of the tubes, instead of being round, are slitlike or crescentic in cross section, as if mashed together while the material making up the pebble was still soft. Usually these tubes are filled by an earthy whitish form of calcite, but a few of them contain, in addition, grains of sand, both rounded and with secondary quartz faces. The phosphate pebbles are diagnostic of the basal sandstone of the Boone wherever they occur, but they may be either entirely absent or so scarce that considerable effort has to be spent in finding one.

If the sandstone shows any bedding lines at all they are generally horizontal, breaking it up into massive beds from 6 inches to 5 feet thick. Cross-bedding is rare but is occasionally observed. At one place, along a small northward-flowing tributary of Rush Creek, a type of small-scale low-angle cross-bedding is developed, in which the individual sets of laminae dip in various directions, truncating the sets below and in turn truncated by the overlying sets. The sweep of the foreset beds is generally not more than 3 or 4 inches before they flatten out (fig. 4). These features are believed to have been produced by wave action along the beach during submergence into the Mississippian sea. The submergence must necessarily have been rather rapid for such features to have withstood destruction by later wave action.

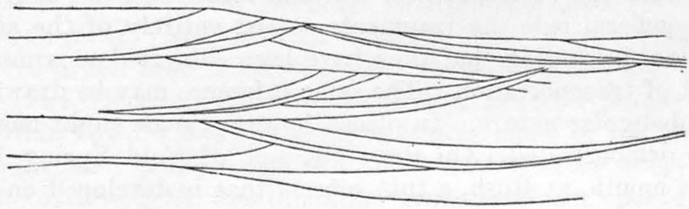

FIGURE 4.—Field sketch showing cross-bedding in the sandstone at the base of the Boone formation. One-fourth natural size.

At two places in the Yellville quadrangle the basal sandstone contains lenses of black fissile shale, only a few inches thick, of the type that has been called "Chattanooga shale" in the Eureka Springs quadrangle. Where the sandstone horizon crosses the bed of the small branch traversed by the railroad west of Everton, 8 inches of black pyritic shale lies near the base of a 4-foot ledge of the sandstone. Isolated quartz grains, or else small groups of 15 or 20 such grains, appear in the shale. The shale is underlain by $1\frac{1}{2}$ inches of sandstone containing abundant phosphatic pebbles and is divided by a sandstone parting that, increasing from a thin edge to a foot or so in thickness, cuts out the shale completely in a distance of 50 feet. This sandstone parting contains fragments of the black shale.

The second shale locality is on the road leading from Eros to the mouth of Kings Branch, where it first crosses the base of the Boone. The sandstone in the bed of the creek just below the road is 11 feet thick and contains two black-shale partings, each 6 inches thick, one 2 feet and the other $6\frac{1}{2}$ feet above the base. The lower shale is pyritic; the upper one slightly sandy. The 4 feet of sandstone at the top of the section contains phosphatic pebbles.

At a few places in the quadrangle the sandstone begins with or is completely displaced by a basal breccia, whose fragments have been derived from the immediately underlying formation and whose matrix shows evidence of derivation, in part, from the attrition of the underlying formation. Where the fragments are St. Peter or Everton sandstone their presence is rarely detected in a matrix composed of similar sandstone, although a slight difference in texture may reveal them. Where the fragments are limestone or dolomite, however, the matrix, though it may not be sharply separable from the fragments, is nevertheless fairly well defined by the inclusion of sand grains and locally phosphatic pebbles of the type that characterize the basal sandstone of the Boone. Distinction between fragments and matrix may be less well defined on the fresh fracture than on the weathered surface. Certain of the breccias, especially those made up of Plattin limestone, contain an extremely high percentage of fragmental material relative to the matrix.

As a general rule the fragments consist entirely of the adjacent formation, indicating that they have been subjected to a minimum amount of transportation. The same inference may be drawn from their subangular nature. In places, however, some slight movement can be demonstrated. On the right side of Cold Spring Hollow near its mouth, at Rush, a thin breccia that is developed on top of Plattin limestone contains fragments of this formation as its chief constituent but also contains fragments of Fernvale limestone. The nearest Fernvale mass from which fragments could have been derived lies 100 feet or so away; in the intervening distance the Fernvale has been cut out by the erosion marked by the unconformity at the base of the Boone. This gives a minimum distance over which the fragments must have moved; actually the distance may have been somewhat greater.

One of these basal Boone breccias overlying the Everton was observed to contain fragments of fine- to coarse-grained dolomite and also of ostracodal limestone. Whatever the origin of the Everton dolomite, it was apparently formed before the deposition of the Mississippian.

The thickest bed of breccia observed in the quadrangle was about 6 feet thick and was overlain by 7 feet of sandstone. The breccia fragments are usually 1 to 3 inches in greatest diameter but exceptionally reach 6 inches.

Where the sandstone and breccia are absent from the base of the Boone, the characteristic phosphate pebbles usually found in the sandstone may occur rather plentifully in the basal 6 inches or so of the overlying St. Joe limestone. Locally this limestone, where it contains pebbles, is slightly sandy, so that there are all gradations between the sandstone and limestone. This evidence of gradation, together with the extremely thin but persistent character of the sandstone beneath the St. Joe, seems convincing testimony in favor of the view that the two were laid down successively in the same Mississippian sea without a regression of the sea between the two phases of deposition.

The name " Sylamore sandstone ", taken by Branner from a locality on South Sylamore Creek in Stone County (sec. 21, T. 15 N., R. 11 W.), has been widely applied over northern Arkansas to the sandstone treated as the basal member of the Boone in the present report. The first regional correlations were made by Hopkins [83] and by Branner,[84] both of whom included localities within the Yellville quadrangle. In 1905 Ulrich [85] accepted Branner's extension of the term into northwestern Arkansas and described the Sylamore as the basal member of the Devonian Chattanooga shale (=†Eureka shale of Branner, †Noel shale of Adams) in the Fayetteville quadrangle. Purdue and Miser, in their description of the Eureka Springs and Harrison quadrangles, follow Ulrich's usage; where the Chattanooga shale is absent, as it is over much of the Harrison quadrangle, they believe that the Sylamore sandstone is separated from the overlying St. Joe limestone by an erosional unconformity representing the shale interval. They state, however,[86] that the thin sandstone mapped as Sylamore in the absence of the shale might possibly be basal Mississippian (St. Joe) and imply that if such is true, it is a different sandstone from the one underlying the Chattanooga shale. Moore,[87] in his discussion of the early Mississippian formations in southwestern Missouri, implies throughout that the St. Joe is disconformable on the Sylamore, although he makes no direct statement to this effect. His view thus accords essentially with that of Purdue and Miser, although he considers the Sylamore to be of Kinderhookian age (lowermost Mississippian) instead of Devonian.[88]

To summarize some of the more salient features of what has been described as Sylamore: We have a widely distributed sandstone, characterized by its remarkable thinness and by certain lithologic peculiarities that are fairly persistent over wide areas; only one

[83] Hopkins, T. C., Marbles and other limestones: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 4, 1893.

[84] Branner, J. C., The phosphate deposits of Arkansas: Am. Inst. Min. Eng. Trans., vol. 26, pp. 580–598, 1897.

[85] Ulrich, E. O., and Adams, G. I., U.S. Geol. Survey Geol. Atlas, Fayetteville folio (no. 119), p. 3, 1905.

[86] Purdue, A. H., and Miser, H. D., op. cit., p. 9.

[87] Moore, R. C., Early Mississippian formations in Missouri: Missouri Bur. Geology and Mines, 2d ser., vol. 21, 1928.

[88] See also Ulrich's later view (Kinderhookian age of the Chattanoogan series: Geol. Soc. America Bull., vol. 26, pp. 96–99, 1915).

sandstone has ever been recognized in a given locality[89]; it appears to be conformable with the overlying formation (even though theoretical considerations have in places caused a disconformity to be postulated); its base always marks an important unconformity; its age appears to be in some places early Osagean (St. Joe) and in others early, middle, or late [90] Chattanoogan (which may be Devonian or Kinderhookian according to different authorities).

According to the interpretation of the writer, the Sylamore as described in the literature is simply the basal sandstone of an overlapping series of strata and was formed from the residual sand that had accumulated on the pre-Sylamore land area; its age varies in different localities, according to the time at which the particular locality was submerged beneath the sea.

While the name "Sylamore" has come to mean a certain definite sandstone whose characters have been carefully studied and described over a wide area in Arkansas and Missouri, what the Sylamore is at its type locality is another matter. Branner's description of the type locality (sec. 21, T. 15 N., R. 11 W.)[91] is apparently based on information he received from Hopkins.[92] So far as known to the writer, the locality has not been visited by a geologist since Hopkins was there, some 40 years or more ago. At that time there was some confusion of stratigraphic units by the workers on the Arkansas Survey. For instance, the Cason shale and the Chattanooga shale were thought to be the same formation (†Eureka shale), and the St. Clair included Kimmswick, Fernvale, and Cason as well as true St. Clair. In the description of localities along South Sylamore Creek, the Sylamore sandstone is said to be associated with †Eureka shale. According to Branner [93] the outcrops are so concealed by the decay of overlying beds that the relative positions of shale and sandstone cannot be seen. Hopkins,[94] in a sketch, shows two different sandstones bedded in shale. It is very possible that Hopkins may have included considerable Cason shale in his Sylamore sandstone. His definition of the Sylamore says in part: "In other places it is a soft earthy rock of a yellowish-brown color; in still other places an arenaceous shale. The dark-colored [phosphate] pebbles are a peculiar feature of this rock, yet they are not always present." Phosphate pebbles are as characteristic of the

[89] Purdue and Miser (op. cit., p. 9) state that the sandstone where it underlies St. Joe limestone is apparently continuous with the sandstone where it underlies Chattanooga shale.

[90] See Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, pp. 455–456, 1911.

[91] Branner, J. C., The phosphate deposits of Arkansas: Am. Inst. Min. Eng. Trans., vol. 26, p. 580, 1897.

[92] Hopkins, T. C., op. cit., pp. 213, 243.

[93] Branner, J. C., op. cit., p. 581.

[94] Hopkins, T. C., op. cit., pl. 10, opp. p. 212.

Cason shale as of the sandstone that lies at the base of the Boone, and the above description fits the Cason more closely than it does the sandstone.

In view of the fact that the type Sylamore locality has not been reexamined in the light of more recent stratigraphic determinations in northern Arkansas, and especially as the thickness at the type locality (40 feet) represents an abrupt increase over the very few feet or even inches that has been cited as the thickness of the Sylamore in closely adjacent localities, the writer has preferred to describe the sandstone in the Yellville quadrangle simply as a sandstone at the base of the Boone, without correlating it with the Sylamore. This method of treatment is further dictated by the consideration that, whereas in regions remote from the type locality of the Sylamore it has heretofore been considered to be of Devonian or of lowermost Mississippian (Kinderhookian) age, in the Harrison and Yellville quadrangles the sandstone appears to be of Osagean age. Nevertheless it is the opinion of the writer that the sandstone is the same lithologic unit in different places, although differing in age from place to place, and that the type locality at least includes this sandstone within the 40-foot interval ascribed to the Sylamore.

OUTCROP

In contrast to the St. Joe member, which as a rule outcrops as a horizontally fluted ledge, the overlying parts of the Boone are rarely exposed. At a few places, however, as along Tomahawk Creek below the Maumee-St. Joe road crossing and along the Buffalo River 2 miles above the mouth of Tomahawk Creek, the upper Boone forms a massive cliff. Here and there it is exposed in road cuts and along the beds of actively eroding streams. The average Boone outcrop, however, is mantled with a thick layer of residual chert fragments as much as 2 or 3 inches in size, which conceals not only the limestone itself but also, where the formation occupies the crests of ridges, as it commonly does in the Yellville quadrangle, the upper beds of underlying formations in the adjacent slopes. On the narrower ridges the clay material that is residual from the solution of the limestone is washed out, leaving only the barren chert, unfit for agriculture. The broader ridges and flats, however, are able to retain the finer soil particles and consequently give rise to fertile though very stony soils. The topography developed on the Boone limestone possesses the usual sink holes and obstructed hollows that are characteristic of limestone terrane, in which underground drainage is likely to be just as effective as surface drainage. Sink holes may be developed on narow ridges whose crests are at most only a few rods wide. Much of the ground water that sinks into the Boone eventually escapes at the level of the base of the St. Joe, which is one of the two most persistent spring horizons of the region. The other is at the base of the Everton.

The sandstone at the base of the Boone crops out generally as a sand ledge that is relatively inconspicuous, owing to its thinness. In some places, especially in the neighborhood of Everton, where the member is thick and unusually massive, it forms an overhanging rounded ledge that caps the bluff usually developed on the Everton. The top surface of the ledge tends to develop a rock bench, of varying width, whose surface is peculiarly pitted, owing to the intimate differences in the cementing material of the original rock, or possibly to peculiar differences in the leaching of a cement that was originally homogeneous in its distribution.

FOSSILS AND AGE

The Boone formation, including the St. Joe member, contains abundant fossils, but no special study was made of them in the preparation of this report. The brachiopods and crinoids are the dominant elements of the fauna, although the crinoids are represented chiefly by stem fragments that are indeterminate as to genera and species. Corals and bryozoans are present but not so prominent, and the pelecypods, gastropods, and trilobites are rather rare.[94a]

The only fossil found in the sandstone at the base of the Boone is a fragment of a fish bone, compared to the genus *Dinichthys* by Ulrich. The black shale in the sandstone at the locality west of Everton contains a few brachiopods of the genus *Lingula* and also a well-preserved conodont fauna. The conodonts are also found in the black shale on Kings Branch. The following genera have been identified by R. S. Bassler from a small collection: *Prioniodus*, *Bryantodus*, *Lonchodina*, *Hindeodella*, *Polygnathus*, *Palmatolepis*, *Panderodella*. According to Bassler and Ulrich, species of these same general types are found in Tennessee in the Chattanooga shale and in the Hardin sandstone, which is the basal member of the Chattanooga shale and which they consider to be of lower Mississippian age. As detailed faunal zones based on the conodonts have not yet been worked out for the Mississippian, if indeed they exist, an exact correlation cannot at present be made between the Arkansas and Tennessee collections. On other evidence, chiefly the extreme thinness in places of the containing sandstone below the St. Joe limestone, and the evidence of gradation of this sandstone into the limestone, the shales in the Yellville quadrangle are believed to be

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[94a] For a detailed study of the Boone fauna at one locality in the Yellville quadrangle, see Girty, G. H., Faunas of the Boone formation at St. Joe, Ark.: U.S. Geol. Survey Bull. 598, pp. 5–50, 1915.

slightly younger than the Chattanooga shale. The conodont fauna would thus represent the survival of the Chattanooga fauna, under favorable conditions, into the beginning of the next stage of the Mississippian.

The Boone formation is of Osage and Warsaw (Mississippian) age. The St. Joe limestone, a small part of the overlying Boone beds, and probably the basal sandstone, are the age equivalents of the Fern Glen limestone that occurs on the east flank of the Ozark dome. The rest of the formation covers the stratigraphic interval included in the Burlington, Keokuk, and part of the Warsaw limestones of the Missouri Ozarks.[95]

STRATIGRAPHIC RELATIONS

The base of the Boone marks an unconformity which, though its plane is extremely even, represents a greater amount of erosion than any other in the stratigraphic section. The stratigraphic break that is recorded increases in amount from south to north. Thus, 12 formations are present below the Mississippian in the south half of the Yellville quadrangle, but toward the north boundary of the quadrangle all except 3 have been cut out by pre-Mississippian erosion unless possibly some were never deposited. The basal member of the Boone, at one place or another within the quadrangle, lies on every one of the preceding formations in the stratigraphic section except the Joachim, Cotter, and Jefferson City. In many places a marked angular divergence shows for a short distance between the basal member of the Boone and the beds of the underlying series, but in general the unconformity is revealed by the manner in which the Boone overlaps different units of the underlying formations.

The Boone is overlain unconformably by the Hindsville limestone member of the Batesville sandstone. The unconformity, at least so far as observed in the Yellville quadrangle, is indicated solely by the presence of a basal conglomerate in the overlying member.

BATESVILLE SANDSTONE

NAME

The Batesville sandstone was named from the town of Batesville by Branner, although the name was first introduced into the literature by Simonds[96] and Penrose,[97] whose reports appeared simultaneously in 1891.

[95] Purdue, A. H., and Miser, H. D., U.S. Geol. Survey Geol. Atlas, Eureka Springs-Harrison folio (no. 202), pp. 10–11, 1916.

[96] Simonds, F. W., The geology of Washington County, Ark.: Arkansas Geol. Survey Ann. Rept. for 1888, vol. 4, pp. 49–53, 1891.

[97] Penrose, R. A. F., Jr., Manganese, its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, pp. 139–140, 1891.

DISTRIBUTION

In the Yellville quadrangle the Batesville sandstone is preserved only in certain down-faulted blocks between Tomahawk and the head of Cane Branch. The most extensive outcrops occur on the uplands within a radius of 3 miles of St. Joe, chiefly east, south, and southwest of that town, but considerable areas of the sandstone are preserved on the ridge at the head of Cane Branch and on the northeast side of Tomahawk Creek in the general neighborhood of Tomahawk. Small exposures appear along the branch of Tomahawk Creek that lies north of St. Joe and Pilot Mountains.

THICKNESS

The formation is 23 feet thick where its outcrop is crossed by the Missouri & North Arkansas Railway in the north limb of the St. Joe syncline, on Mill Creek north of St. Joe. The beds here dip about 25° SE. (strike N. 30° E.), allowing the complete thickness of the formation to be encompassed within a small horizontal distance. Ordinarily, where the sandstone lies in a horizontal or nearly horizontal position, it caps benches and ridges, so that its uppermost beds are either eroded or else very poorly exposed if at all. Accurate measurements of thickness are therefore hard to make, but it is believed that the thickness developed in the St. Joe syncline is fairly representative for the quadrangle, considering the fact that the formation is rather restricted in distribution to the general vicinity of St. Joe. A section measured on a small branch of Tomahawk Creek half a mile or so south of Pilot Mountain shows 21 feet of Batesville, without, however, the overlying Fayetteville being present. It is very probable that the 10 feet of sandstone forming the top of this outcrop represents the top of the Batesville, so that the thickness given is approximately the complete thickness of the formation at this locality.

CHARACTER

The most conspicuous facies of the Batesville is a platy buff to brown micaceous sandstone, medium to rather fine grained and generally porous, owing to leaching out of the lime cement. In places it shows asymmetric ripple marks. The individual beds making up a ledge of the sandstone range in thickness from 3 inches to 3 feet, but the thinner beds are more common. The perfectly fresh rock from which this sandstone type is derived is gray and very limy, resembling to some extent a limestone; indeed, it grades in places into limestone. At one locality on Tomahawk Creek north of Pilot Mountain the fresh sandstone is glauconitic. Besides these more sandy types, the Batesville may show considerable shaly sandstone and sandy muscovitic shale, generally gray in color when fresh, but weathering to olive-drab or buff. At the very edge of the quadrangle, 2 miles south of St. Joe, the basal part of the Batesville contains a considerable thickness of black paper shale, suggesting the Moorefield shale that occurs beneath the sandstone in the Batesville district. The section in the north limb of the St. Joe syncline also contains 1 foot of blue-gray shale, 7 feet above the base, underlain by beds of limestone, sandy limestone, and sandy shale.

Both the shale and the limestone of the Batesville occur in the basal part, interbedded with some sandstone; the thicker beds of sandstone (maximum 10 feet) occur at the top, although they may contain a few thin shale partings.

A basal limestone containing some interbedded sandstone and described in the Eureka Springs-Harrison folio as the Hindsville limestone member [98] is exposed in the Tomahawk region and at one locality south of Pilot Mountain but is not represented in the St. Joe syncline. The limestone of this member is coarse-grained and dark gray and gives off a bituminous odor when struck with a hammer. It occurs in rather massive beds as much as 4 feet in thickness, though generally less. The interlayered sandstone is in beds 2 to 3 feet thick and is of essentially the same character as the sandstone of the overlying Batesville proper.

The basal few inches of the member, consisting of limestone, locally contains rounded and angular fragments of chert some of which measure 3 inches across, although diameters of an inch or less predominate. The chert is dark gray, in places black, and weathers to red-brown. Some of the fragments contain casts of crinoid stems and are clearly derived from the underlying Boone. South of Pilot Mountain the basal 3 feet of the Hindsville is oolitic. The Hindsville is perhaps 10 feet in maximum thickness in the Tomahawk district and is at least 6 feet thick at the locality south of Pilot Mountain.

The limestones that occur a little higher in the section, interstratified with the sandstone and shale of the Batesville proper, are generally thinner-bedded than those of the Hindsville and of the Boone and occur in zones not more than 2 or 3 feet thick. They range in texture from fine to medium grained and are commonly rather sandy, muscovite being a common constituent. They are also a lighter gray than the Hindsville limestone.

The stratigraphic details of the Batesville vary from place to place, only the general dominance of the heavy sandstones in the upper part and the restriction of the limestones and shales to the underlying beds being common to the different sections. Limestone is conspicuous in the Tomahawk district but is very subordinate at St. Joe. In

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[98] Purdue, A. H., and Miser, H. D., op. cit., p. 12.

the Ponca mining district, which lies in the Harrison quadrangle, the formation begins with a foot or less of sandy clay shale.

OUTCROP

The upper platy sandstones of the Batesville form wide benches and long dip slopes on which the sandstone is in general poorly exposed but at the same time well enough preserved as blocks and slabs in the sandy soil to greatly hinder cultivation. Roads are notoriously poor across these Batesville outcrops, on account of their stone-slab nature. The rocks making up the lower part of the Batesville are less resistant and are therefore exposed only under the most favorable conditions, chiefly along drainage lines where erosion is most active.

FOSSILS AND AGE

The Batesville is abundantly fossiliferous in all of its commoner lithologic phases. The fine-grained and originally limy character of the more massive sandstones makes them almost as good collecting ground as the limestones, although the fossils contained in them are preserved as casts. The fauna differs from that of the Boone in the prominence of the pelecypods and gastropods, but the brachiopods and bryozoans are still common elements. Crinoid stems are very common. A few trilobite and ostracode remains are present, but these forms are not conspicuous. Worm trails are noticeable in some of the sandstones. No detailed study was made of the Batesville fauna of the Yellville quadrangle in the preparation of this report, but an earlier study of the quadrangle [99] and studies in adjacent regions [1] show it to be of Chester (upper Mississippian) age.

STRATIGRAPHIC RELATIONS

The Batesville is unconformable on the Boone, as shown by the presence in places of a basal conglomerate that contains fragments of chert derived from the underlying formation. It is overlain, apparently with conformity, by the Fayetteville shale.

FAYETTEVILLE SHALE

NAME

The Fayetteville shale was named by Simonds [2] from the town of Fayetteville, Ark. In the Branner report on the lead and zinc

[99] Ulrich, E. O., in Adams, G. I., Purdue, A. H., and Burchard, E. F., Zinc and lead deposits of northern Arkansas: U.S. Geol. Survey Prof. Paper 24, p. 104, 1904.

[1] Weller, Stuart, The Batesville sandstone of Arkansas: New York Acad. Sci. Trans., vol. 16, pp. 251–282, 1897. Purdue, A. H., and Miser, H. D., U.S. Geol. Survey Geol. Atlas, Eureka Springs-Harrison folio (no. 202), p. 12, 1916. See also Girty, G. H., The fauna of the Batesville sandstone of northern Arkansas: U.S. Geol. Survey Bull. 593, pp. 17–25, 1915.

[2] Simonds, F. W., op. cit., pp. 42–48.

deposits it was called the †"Marshall[3] shale", and the name "Fayetteville" was applied to the Moorefield shale, which underlies the Batesville sandstone at Marshall. The Moorefield shale is apparently absent from the Yellville quadrangle, although some black paper shale at the base of the Batesville on the edge of the quadrangle, 2 miles south of St. Joe, may represent its most northerly extension. Ulrich's work as part of the Adams report[4] first showed the true relations of these various formations above the Boone in northern Arkansas.

DISTRIBUTION

The Fayetteville has a rather restricted distribution in the Yellville quadrangle. It is preserved in one down-faulted block between the old town of St. Joe and Pilot Mountain and in another along the northeast side of Tomahawk Creek between Davy Crockett Mountain and Tomahawk. A third occurrence is a very small outcrop in the angle of a faulted wedge on the prong of Tomahawk Creek that lies north of St. Joe Mountain.

THICKNESS

Owing to lack of favorable exposures, no satisfactory determination of the thickness of the Fayetteville could be made, but the estimated thickness is between 150 and 200 feet. In the Harrison quadrangle, to the west, it varies, locally within short distances, from 30 to 350 feet.

CHARACTER

The formation consists of a black shale at the base that grades up through drab sandy shale into a buff to brown sandstone, the Wedington sandstone member, at the top. Although no shale was observed to overlie the Wedington such as is reported in the quadrangles to the west,[5] it cannot be affirmed that such a shale does not exist, on account of the very poor exposures at this horizon. If present, however, the shale must be thin. Ulrich,[6] who has perhaps studied the outcrops of the Fayetteville in the St. Joe region more thoroughly than the writer, states that in the vicinity of St. Joe and Pilot Mountain the upper shale of the Fayetteville [overlying the Wedington, although he does not commit himself to the conclusion that the sandstone is Wedington], is either wanting or only a few feet thick.

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[3] Marshall is the county seat of Searcy County, lying several miles south of the Yellville quadrangle.

[4] Ulrich, E. O., Determination and correlation of formations [in northern Arkansas]: U.S. Geol. Survey Prof. Paper 24, pp. 102–109, 1904.

[5] Purdue, A. H., and Miser, H. D., op. cit., p. 13.

[6] Ulrich, E. O., in Adams, G. I., Purdue, A. H., and Burchard, E. F., Zinc and lead deposits of northern Arkansas: U.S. Geol. Survey Prof. Paper 24, p. 108, 1904.

The basal shale is fissile and may be finely micaceous. In places it contains septarian nodules—black limy concretions as large as 4 feet that are traversed by irregular veinlets of calcite. Some of these nodules contain fine granular pyrite along thin curving planes, similar in occurrence to what might be expected if the pyrite had replaced the shell of a pelecypod. The black-shale phase of the Fayetteville is especially prominent in the town of St. Joe and along the main highway for a mile or so northwest of the town.

Upward from the base an olive-drab shaly sandstone begins to come in, at first merely as a parting that recurs on a rather fine scale in the shale, but increasing gradually in prominence until the relative proportions are reversed, and the shale appears only as thin films in the thin-bedded sandstone. At no place was a complete exposure of this shaly sandstone phase observed, but it is in places at least 70 feet thick. The upper part of it might logically be classed with the Wedington, but as there is no clear-cut line of demarcation between this part and the underlying shale, it has been grouped with the lower unit, the name "Wedington" being restricted to the more typical sandstones at the top.

The Wedington sandstone is a thin-bedded medium- to fine-grained buff to brown sandstone that closely resembles the Batesville. Like the Batesville, it generally shows muscovite mica on the bedding surfaces. Some of the sandstone blocks that accumulate on the weathered surface show a pronounced reddish tinge, but when the rock is broken this color is commonly seen to be confined to a zone near the surface, decreasing in intensity toward the center of the block. It is thus evidently related in origin to weathering. The Wedington is apparently only a few feet thick, but it is possible that there are two or three such sands separated by shaly beds and if so the thickness of the interval over which they occur may amount to 40 or 50 feet. Exposures are ordinarily too poor to determine the exact relations.

OUTCROP

The Fayetteville shale, owing to its nonresistant character, tends to form lowlands on which it is very poorly exposed except in scattered outcrops along some of the stream beds that traverse it. Around the bases of St. Joe and Pilot Mountains it is largely concealed by debris from the slopes above. Around St. Joe its outcrop is largely occupied by farms. Some of its best exposures are along the headwater prongs of a small branch that enters Tomahawk Creek from the north near the line between Rs. 16 and 17 W., 2 miles east of Pilot Mountain. Here, where steep headwater gradients prevail, erosion has been vigorous enough to carve small canyons in the soft shale, leaving the formation exposed in walls that are too steep for a mantling cover of soil to form.

The Wedington, in an area west of Tomahawk, caps two or three poorly defined benches but is rarely exposed in place, appearing instead in the form of sandstone blocks that mantle the subjacent slopes. The same type of outcrop is shown on the lower slopes of St. Joe and Pilot Mountains, although the sandstone is exposed in place over a small area in the saddle between the two mountains.

FOSSILS AND AGE

Both the black-shale phase and the sandstone member of the Fayetteville contain marine fossils. The shale holds very few species, consisting of small pelecypods and gastropods. The most common form is a small thin-shelled, concentrically ringed pelecypod. The Wedington is much richer in the number of species, the bryozoans, brachiopods, pelecypods, and, to a less extent, the gastropods being well represented. Especially conspicuous are individuals of the bryozoan genus *Archimedes*, a form that resembles a nontapered screw except that it lacks a prominent central shaft. Although this fossil also occurs in the Batesville sandstone, which is very similar lithologically to the Wedington, it is not nearly so common in this lower sandstone. A few cephalopod remains occur in the Wedington, but they are not conspicuous. The fauna of the Fayetteville shows it to be of Chester (upper Mississippian) age.

STRATIGRAPHIC RELATIONS

The Fayetteville shale is conformable on the Batesville and is overlain everywhere by the Pitkin. The writer found no evidence in the scanty exposures of the St. Joe region to indicate that the Pitkin contact is not also conformable. Ulrich,[7] however, states that an unconformity was definitely recognized at this horizon in several sections near St. Joe.

PITKIN LIMESTONE

NAME

The Pitkin limestone was named by Ulrich and Adams [8] from the post office of Pitkin, in Washington County, Ark. It was known in the reports of the Arkansas Survey, including the Branner lead and zinc report, as the †*Archimedes* limestone, from the prominence of the fossil bryozoan of the genus *Archimedes*.

[7] Ulrich, E. O., Determination and correlation of formations [in northern Arkansas]: U.S. Geol. Survey Prof. Paper 24, p. 108, 1904.

[8] Idem, pp. 27–28, 109.

DISTRIBUTION

The Pitkin is preserved in only three places in the Yellville quadrangle—in St. Joe Mountain, in Pilot Mountain, and in a down-faulted block 2 miles northeast of Pilot Mountain—all in the general St. Joe-Tomahawk district.

THICKNESS

The formation varies in thickness between 55 feet at the east end of Pilot Mountain and 115 feet at the west end, only a mile or so away. The abrupt variation appears to be due to the unconformity at the base of the overlying Pennsylvanian series. The thickness on the southwest side of St. Joe Mountain is 60 feet.

CHARACTER AND OUTCROP

The Pitkin is typically a gray to dark-gray bituminous limestone, somewhat darker than the Boone. Certain beds, when slightly weathered, take on a grayish-brown tinge, and these beds may show leached pores with an ocherous or brownish-red (iron oxide) lining. The texture of the limestone is fine-grained to dense, and the unfossiliferous phases exhibit this texture throughout, but a high percentage of the beds are so thickly studded with calcite plates of crinoidal and perhaps other fossil origins as to give the impression of being very coarse grained. Most of the calcite plates are lath-shaped rather than rounded or partly rounded and are a quarter of an inch or so in maximum length. Oolitic beds occur both within the formation and at its very top. A little concretionary chert appears near the base. A few of the unfossiliferous zones are very thin bedded and platy, but the formation is on the whole rather massive, in beds from 2 to 4 feet thick. It crops out as a series of superposed thick blocky ledges, locally forming low bluffs, but there are stretches where it is concealed by debris from above.

FOSSILS AND AGE

Certain beds in the Pitkin are totally barren of fossils; others are highly fossiliferous. Fragments of crinoid stems are very conspicuous, and some of them are as much as an inch in diameter. Brachiopods, bryozoans, and corals, especially solitary cup corals, are all abundant. The bryozoan genus *Archimedes* is very common. Trilobite remains are sometimes found in the Pitkin, as well as an occasional pelecypod. Cup corals, crinoid stems, and *Archimedes* occur in an oolitic limestone at the top of the formation on the northeast side of St. Joe Mountain. The fossils of the Pitkin show it to be of upper Chester (Mississippian) age.

STRATIGRAPHIC RELATIONS

The Pitkin rests on the Wedington sandstone member of the Fayetteville or, in places, according to Ulrich (see p. 79), on the overlying thin shale of the upper Fayetteville. Although as far as the writer's observations go the contact seems to be conformable, Ulrich states that an unconformity was definitely recognized in several sections near St. Joe. Purdue and Miser suggest that the superposition of the Pitkin on different members of the Fayetteville in different regions within the Harrison and Eureka Springs quadrangles may indicate an unconformity at its base, but they found no other evidence of such a break.

The Pitkin is unconformably overlain by the Morrow group of the lower Pennsylvanian, which has a basal conglomerate containing pebbles of limestone derived from the Pitkin.

PENNSYLVANIAN SERIES

MORROW GROUP

The Morrow formation as originally defined by Adams and Ulrich[9] was later subdivided into the Hale formation below and the Bloyd shale above. The Hale formation is the only one of the two that occurs within the Yellville quadrangle.

HALE FORMATION

NAME

The Hale formation was originally named as a member of the Morrow formation by Taff[10] in 1905. The name is taken from Hale Mountain, in Washington County, Ark. In the Branner report the rocks here described as the Hale were called the † "Washington shale and sandstone", and in the Adams report they were treated as a part of the Morrow formation.

DISTRIBUTION AND THICKNESS

The Hale formation is preserved in the Yellville quadrangle only in St. Joe and Pilot Mountains, near St. Joe. It shows an average thickness of about 190 feet.

CHARACTER

The formation consists of interbedded shale, sandstone, limestone, and conglomerate, with all intergradations between these types. At no place can a section be examined that is anywhere near com-

[9] Adams, G. I., and others, Zinc and lead deposits of northern Arkansas: U.S. Geol. Survey Prof. Paper 24, pp. 28, 109–113, 1904.

[10] Taff, J. A., U.S. Geol. Survey Geol. Atlas, Tahlequah folio (no. 122), p. 4, 1905.

plete; nevertheless, isolated outcrops here and there on the slopes of the two mountains give a fair idea of the formation as a whole even though the relations between these various outcrops cannot be determined, at least without an exhaustive examination that is beyond the scope of the present report.

The formation begins with a basal conglomerate, which is only 1 or 2 feet thick where it was observed at the east end of St. Joe Mountain. The fragmental material making up the conglomerate includes types evidently derived from the underlying Pitkin—namely, pebbles as much as 2 inches in diameter of very fine grained dark-gray limestone; pebbles of fine-grained drab limestone that weather yellow; pebbles of oolite identical in type with that of the Pitkin ledge on which the conglomerate rests; and worn remnants of *Archimedes*, crinoid stems, and cup corals. Less common pebbles of fine-grained gray limy sandstone may have come from either the Wedington or the Batesville, or perhaps from both, although the Wedington seems the more probable source. Decidedly subordinate are pebbles of white chert that may have come from the Boone, but this source is perhaps somewhat more open to question. A fairly plentiful type of uncertain origin consists of brownish-black argillaceous pebbles, only in part limy, that resemble the phosphatic pebbles contained in the basal sandstone of the Boone. All the pebbles in this basal conglomerate of the Hale are fairly well rounded. The matrix in which they are embedded is brownish-gray to reddish-gray limestone, not always sharply separable from certain of the Pitkin limestone pebbles.

On the south side of St. Joe Mountain the basal member of the Hale is a ledge, 5 feet in maximum thickness, of brown medium-grained sandstone that contains scattered through it angular quartz pebbles similar to those characteristic of the overlying Winslow. It also contains in places pebbles of dark-brown shale 3 inches or less in diameter.

Some of the shales occurring in the Hale formation are of the extremely fissile black paper-shale type; others are limy or sandy, gray or olive-greenish, and nonfissile, though they may still be rather thin bedded. The black paper shales locally and rather sparingly contain thin platy concretions of buff to brown clay ironstone. The lower 60 feet of the formation on the southwest slope of Pilot Mountain is composed largely if not wholly of black shale.

The sandstones are similar on the whole to those of the Wedington and Batesville. They are generally medium to fine grained, and a large percentage of them are shaly. Muscovite, occurring in fine flakes along the bedding planes, is a common constituent. Certain beds, besides the basal ledge on the south side of St. Joe Mountain, already mentioned, contain scattered pebbles of white quartz of the type that is characteristic of the overlying Winslow. Although here and there a rather pure sandstone may be whitish, the more normal color of the Hale sandstones grades from drab or more generally buff to brown. Many of the loose blocks lying on the surface show the reddish tinge, produced by surficial weathering, that is characteristic also of the Wedington. A 20-foot bed of sandstone exposed at the east end of St. Joe Mountain is very limy and carries numerous crinoid stems. This bed is dark brownish gray but weathers dark brown. It is thin bedded but poorly bedded.

The Hale limestones are usually sandy or shaly, but a few beds of fairly pure dark-gray limestone, as much as 3 or 4 feet thick, that resemble certain phases of the Pitkin, appear in the section. Some of the sandy limestones are almost black; others are dark gray or, where more weathered, dark brown. The bedding is usually massive, but in one locality a 4-foot thickness of sandy limestone was observed to be cross-bedded at a low angle.

OUTCROP

The formation as a whole is a topographically weak unit. Its usual topographic expression is in the form of a slope mantled by a considerable thickness of debris in which blocks of sandstone, derived not only from the formation itself but from the overlying Winslow, are conspicuous. In this slope a rounded ledge of sandstone or limestone may crop out in places, or shale may be exposed in some shallow gully, but such exposures are not extensive, nor do they seem to be of more than accidental origin.

FOSSILS AND AGE

The calcareous sediments of the Hale formation, including the limy sandstones, are very fossiliferous. The fauna is a varied one. Crinoid stems are especially conspicuous, but other types are well represented, including the corals, both colonial and solitary, the bryozoans, brachiopods, gastropods, pelecypods, and to a less extent, the cephalopods. Trilobite remains are occasionally found but are not common. The fauna is closely related to that of the Bloyd shale, which overlies the Hale formation in the quadrangles west of the Yellville but which was removed by erosion before the deposition of the Winslow formation in the Yellville quadrangle. The age is Pottsville (early Pennsylvanian), but the original correlation was based on the fossil flora of the overlying Bloyd shale rather than on the invertebrate marine fauna of the Hale, which is very different from and older than other marine faunas known from the Pennsylvanian of Kansas, Missouri, and Illinois.[11]

STRATIGRAPHIC RELATIONS

The Hale is unconformable on the Pitkin in St. Joe and Pilot Mountains, having a basal conglomerate. In the Eureka Springs and Harrison quadrangles the plane of unconformity truncates successively older formations to the north, until in the northernmost outliers of the Boston Mountains the Hale rests on the lower part of the Fayetteville.[11] It is overlain unconformably by the Winslow formation in St. Joe and Pilot Mountains, but in the Harrison quadrangle around Ponca and in a good part of the Eureka Springs quadrangle it is overlain conformably by the Bloyd shale. This shale was removed by erosion before the deposition of the Winslow farther east.

BLOYD SHALE

Although the Bloyd shale does not occur in the Yellville quadrangle, it is present in the Ponca mining district of the Harrison quadrangle, and to make the list of formations likely to be encountered in the lead and zinc districts complete, the following brief description is abstracted from the Eureka Springs-Harrison folio.

The formation was named in 1907 by Purdue,[12] from exposures in Bloyd Mountain, Washington County, Ark. In its complete development the formation is a carbonaceous clay shale, containing two limestone members near the base. The lower of these, the Brentwood (=†Pentremital limestone of the Branner report), ranges from 3 to 30 feet in thickness and lies at or within 10 feet of the base of the formation. The upper limestone, called the "Kessler", is from 2 to 10 feet thick and lies 10 to 20 feet above the Brentwood.

In the southwest corner of the Harrison quadrangle the Brentwood limestone forms the base of the formation and is overlain by shale, but neither the Kessler nor the shales that overlie it are exposed, although the thickness of 70 feet for the Bloyd, recorded near Ponca, suggests that these beds may be present but not exposed.

The Brentwood generally consists of a single bed, but south of Compton, in the Harrison quadrangle, there are two beds separated by 6 feet of shale. The limestone is "heavy-bedded, bluish to gray, highly fossiliferous, partly crystalline, slightly porous to compact, and in parts somewhat rusty." The shale normally lying between the Brentwood and Kessler limestones, which is the shale overlying

[11] Purdue, A. H., and Miser, H. D., U.S. Geol. Survey Geol. Atlas, Eureka Springs-Harrison folio (no. 202), p. 14, 1916.

[12] Purdue, A. H., U.S. Geol. Survey Geol. Atlas, Winslow folio (no. 154), p. 3, 1907. Purdue, A. H., and Miser, H. D., op. cit., p. 15.

the Brentwood in the Ponca district, is a "thinly fissile black clay shale with thin layers of sandstone near its base."

The two limestones of the Bloyd contain a rather abundant marine fauna that is very closely related to that of the underlying Hale. Many of the species are new and undescribed. The genera represented are in large part the same as those occurring in the Mississippian (Pitkin and lower), but very few of the species are identical, although many are closely related. On the other hand, some of the species are identical with known Pennsylvanian species. The shale between the two limestones contains in places a fossil flora of Pottsville age, and it was on the basis of this flora that the first assignment of the Bloyd shale and the underlying Hale formation to the Pennsylvanian was made. The Bloyd overlies the Hale conformably and in turn is overlain unconformably by the Winslow.

WINSLOW FORMATION

NAME

The Winslow formation was named by Adams in 1904 [13] from the town of Winslow, in Washington County, Ark. It was called the † "Millstone grit" in Branner's report on the lead-zinc district.

DISTRIBUTION

Only two occurrences of the Winslow formation are shown in the Yellville quadrangle—one capping Pilot Mountain, 2 miles northeast of St. Joe, and the other capping St. Joe Mountain, 1½ miles west of Pilot Mountain. Outside of the quadrangle, however, the formation is extensively developed in the Boston Mountains, where it forms the summits of most of the high ridges.

THICKNESS

On St. Joe Mountain only the basal 5 to 10 feet of the formation is preserved, but Pilot Mountain is capped by 130 feet of sediments referable to the Winslow. Even this thickness represents only the basal part of the formation, which has a total thickness of 500 feet in the Eureka Springs quadrangle and 2,300 feet in the Winslow quadrangle. The Atoka formation, with which that part of the Winslow occurring in the Yellville, Harrison, and Eureka Springs quadrangles is correlated, is 8,000 to 9,500 feet thick in the Arkansas Valley south of the Boston Mountains.[14]

[13] Adams, G. I., and others, Zinc and lead deposits of northern Arkansas: U.S. Geol. Survey Prof. Paper 24, p. 29, 1904.

[14] Croneis, Carey, Geology of the Arkansas Paleozoic area: Arkansas Geol. Survey Bull. 3, pp. 116, 119–132, 1930.

CHARACTER AND OUTCROP

The lower 80 feet of the Winslow on Pilot Mountain is a massive buff sandstone, varying in some places to whitish and in others to brownish red. It is especially characterized by numerous rounded white quartz pebbles in the basal 20 feet. These pebbles average a quarter to half an inch in diameter, but a few reach three-quarters of an inch. The sandstone in which they are embedded is composed of coarse, rather angular quartz grains and is cross-bedded. Above the basal 20 feet the sandstone is more medium-grained, is slightly muscovitic, and is cross-bedded only in certain zones, the individual beds making up a cross-bedded interval ranging between 6 inches and 2 feet. The whole sandstone member tends to crop out as a single massive ledge. Huge blocks break away and may settle slightly down the slope without rotating to any great extent from their original position or, on the other hand, they may roll or slump down the slope and eventually come to rest at considerable distances from their points of derivation. Owing to the highly resistant nature of the basal part of the sandstone, blocks containing the quartz pebbles are very conspicuous over the slopes and around the bases of both Pilot and St. Joe Mountains.

The rocks in the top 50 feet of Pilot Mountain, above the 80-foot ledge, are poorly exposed and evidently contain some shaly beds. The few exposures consist of dominantly buff medium-grained sandstone, in part muscovitic. In common with the Wedington sandstone and sandstones of the Hale formation, exposed surfaces of this sandstone take on a reddish crust, the color in places approaching a hematite-red. Black crusts are also formed. This top part of the series crops out as a debris-covered slope, in which the sandstone blocks are conspicuous, surmounted by a flat though narrow top to the mountain.

AGE

No fossils have been found in the Winslow formation within the Yellville quadrangle. The Atoka formation of the Arkansas Valley, with which these beds are correlated, is of Pottsville (Pennsylvanian) age.

STRATIGRAPHIC RELATIONS

The Winslow on Pilot and St. Joe Mountains is unconformable on the Hale formation, as indicated by the absence of the Bloyd shale, apparently owing to erosion preceding the deposition of the Winslow. Where the Bloyd shale is preserved in the Eureka Springs quadrangle and in the southwest corner of the Harrison quadrangle, the Winslow overlies it, also unconformably.[15]

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[15] Purdue, A. H., and Miser, H. D., U.S. Geol. Survey Geol. Atlas, Eureka Springs-Harrison folio (no. 202), p. 16, 1916.

STRUCTURE

GENERAL FEATURES

GENERAL CHARACTER OF STRUCTURE

Stated in a general way, the strata of northern Arkansas, north of the Boston Mountains, show an approximation to horizontality over the greater part of the area but are locally marked by simple dislocations along faults, by depressed blocks (grabens) bounded by faults, and by monoclines, low domes, and shallow basins that in places are of considerable magnitude. Away from the more disturbed areas the strata that appear to be essentially horizontal show when mapped in detail low-angle dips that are generally measured in terms of feet to the mile. These dips are inclined in various directions, producing minor undulations that are best shown on structure-contour maps. Owing to crustal movements between the times of deposition of unconformable formations, the structure contoured on any given horizon may differ considerably in its flatter portions from that on any other horizon. Better-defined structural features, such as monoclines and basins, tend to be common to all the geologic horizons but are more pronounced in the older formations. The accompanying structure-contour map of the Yellville quadrangle (pl. 3, oversheet) was drawn on the base of the St. Joe limestone member of the Boone, which crops out more widely than any other horizon in the quadrangle. The map pictures only the structural deformation that has taken place since the deposition of the St. Joe member. Contours on a horizon in the Lower Ordovician would include not only the post-St. Joe deformation but also the deformation that occurred between Lower Ordovician time and the beginning of the Mississippian. Owing to the less extensive outcrops of Ordovician key horizons within the quadrangle, the construction of such a map has not been attempted for the quadrangle as a whole. Plate 4, oversheet A, shows the structure of the St. Peter sandstone in the Rush mining district, and for comparison, plate 4, oversheet B, on the same scale, shows the structure of the base of the St. Joe limestone.

REGIONAL DIP

The location of the lead and zinc field on the south flank of the Ozark dome determines the direction of the average regional dip—namely, to the south. Purdue and Miser,[16] from a study of structure-contour maps on the top of the Boone formation, state that the beds show a slight dip to the south, which is apparent in the Eureka Springs quadrangle but is largely disguised in the Harrison quad-

[16] Purdue, A. H., and Miser, H. D., U.S. Geol. Survey Geol. Atlas, Eureka Springs-Harrison folio (no. 202), p. 16, 1916.

rangle by minor folding. In the Yellville quadrangle the regional dip is not evident in the map contoured on the base of the St. Joe limestone. There is, however, an irregular lowering of the average altitude of this horizon from north to south, even though isolated structural highs at the south, such as those near Salgado and Mount Hersey and along the north side of the Mill Creek graben, may attain as great an altitude as any of the isolated highs at the north. Most of the lowering to the south is accomplished along the St. Joe and Water Creek monoclines and faults connected with them, especially the Rush Creek fault. The altitude of the basal Mississippian over large areas in the northern part of the Yellville quadrangle is only 400 to 500 feet lower than the altitude of the same horizon on top of the Ozark dome, in Missouri.[17]

If a horizon in the Lower Ordovician were contoured, a more pronounced regional dip to the south would be evident. The Everton formation and those above it to the base of the Mississippian, amounting all told to several hundred feet in the southern part of the quadrangle, are truncated northward, so that this whole thickness of rocks is completely cut out at the northern limit of the area covered by the map contoured on the base of the St. Joe. Hence, to any regional dip in the Mississippian there will be added, in Lower Ordovician beds, a considerable effect due to the divergence of these lower beds from the Mississippian in the direction of the regional dip.

EVOLUTION OF THE OZARK DOME

The question whether the steepening of regional dip on the south flank of the Ozark dome during the Paleozoic era took place in only 2 or 3 distinct steps or was, on the other hand, a gradual and continuous process, is of considerable interest because of the light that it may throw on the structural evolution of this dome. No pertinent evidence can be obtained from a study of the Yellville quadrangle alone, but a regional study in northern Arkansas of the variations in thickness of different formations in the Paleozoic is suggestive. Thus, with the exception of the Brassfield limestone, all the formations of the Yellville quadrangle lying between the base of the Everton and the base of the St. Joe are present in the Batesville district, 60 miles to the southeast,[18] but all of them are there considerably thicker. In addition, certain formations lacking in the Yellville quadrangle are well developed in the Batesville

[17] Siebenthal, C. E., Origin of the zinc and lead deposits of the Joplin region: U.S. Geol. Survey Bull. 606, pl. 4, 1916.

[18] Miser, H. D., Deposits of manganese ore in the Batesville district, Ark.: U.S. Geol. Survey Bull. 734, pp. 16–36, 1922.

district. A cross section between the two districts thus shows a fanlike increase in the thickness of the sediments to the southeast. While thinning to the northwest may be due, in unknown part, to lack of deposition of initial deposits of the different formations by overlap higher on the flanks of the Ozark dome,[19] it is also certainly due to differential uplift and erosion in this direction. The fact that each formation in the Yellville region shows considerable and often abrupt variation in thickness from place to place beneath the formation that next overlies it in the normal section, taken in conjunction with the fact that abrupt increases may be limited to detached structural basins, is evidence that uplift and erosion have played an important part in thinning the formations in this region. If it can be assumed that this process has been the major factor operating, then the evidence seems to be clear that the Ozark dome has been a region of repeated small differential uplifts that continued from Everton or earlier [20] time up to and beyond the period of Boone deposition, probably to the end of the Paleozoic era. Thinning by overlap would not materially alter this general conclusion except that the thinning would be accomplished by a smaller number of uplifts, for the formation above as well as that below an unconformity is thinned by overlap.

It should be borne in mind that the section between Yellville and Batesville, which runs from northwest to southeast, is simply one component that shows a fanlike increase away from the Ozark dome. Perhaps a section more nearly north and south, radial to the dome, would show a more abrupt thickening away from the dome.

RECURRENT DEFORMATION

A peculiarity of northern Arkansas structure is the tendency for certain folds to be accentuated in the older beds, indicating that these folds were established at an early date and that later crustal movements simply intensified them. Thus the Water Creek monocline, which is a pronounced northeast-southwest feature on the base of the St. Joe limestone, limits fairly definitely the distribution of the Ordovician and Silurian formations above the Everton to its down-

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[19] For interpretations of thinning of strata on top of the Ozark dome by overlap during Cambrian and early Ordovician time see McQueen, H. S., Insoluble residues as a guide in stratigraphic studies: Missouri Bur. Geology and Mines 56th Bienn. Rept., pp. 126–128, 1930; Bridge, Josiah, Geology of the Eminence and Cardareva quadrangles: Missouri Bur. Geology and Mines, 2d ser., vol. 24, pp. 69, 110, 1930; Dake, C. L., Geology of the Potosi and Edgehill quadrangles: Missouri Bur. Geology and Mines, 2d ser., vol. 23, p. 153, 1930.

[20] According to Josiah Bridge (personal communication) a study of formational distribution and thicknesses throughout the Ozark region indicates that such differential uplifts had begun as early as late Cambrian time.

thrown side. This indicates that prior to the widespread erosion that preceded the invasion of the Mississippian sea, uplift was greater northwest of the general line of the present monocline than it was southeast of it. The Cabin Creek monocline shows a similar control in limiting the distribution of the St. Peter, Plattin, and Fernvale on the north. Preservation of the Fernvale limestone in the Panther Creek and Rock Creek basins and in the Rush Creek and Mill Creek grabens, while it has been eroded from their various rims, shows that these structural depressions likewise originated before the deposition of the St. Joe limestone and have been later intensified. Similar evidence shows that at least the north limb of the depression that later became the Tomahawk graben was developed before the deposition of the St. Joe, although there is no evidence of faulting at this early date. The Water Creek basin, at least on certain of its limbs, limits fairly definitely the distribution of the Plattin limestone beneath the St. Joe.

The examples cited show that crustal movements which produced certain structural features at some time between the deposition of the Fernvale and the deposition of the St. Joe were continued along the same lines after St. Joe time, accentuating the earlier deformation. There is in addition some evidence to show that several of these structural features were in existence even in pre-Fernvale time and that movement took place along them at some time between the deposition of the Plattin and the deposition of the Fernvale. The evidence comes from a study of the variations in thickness of the Plattin beneath the Fernvale. The thickest sections of Plattin limestone tend to lie in the same structural depressions that have been mentioned as the sites of movement before and after St. Joe time. Although as a general rule the Fernvale has been removed on the structural highs adjacent to these depressions by the erosion that accounts for the unconformity at the base of the St. Joe, locally it is still preserved, and in such places the Plattin beneath it is not so thick as in the depressions. Thus, along the Buffalo River between the mouth of Cedar Creek and the "narrows" the Plattin is in places estimated to be from 70 to 100 feet thick, and as the Fernvale was removed before the St. Joe was deposited here, these figures represent a minimum thickness beneath the Fernvale; 2 miles to the north, near the foot of the Cabin Creek monocline, the Plattin is only 15 feet thick beneath the Fernvale. In the Rock Creek structural basin the Plattin is 85 feet thick beneath the Fernvale, but near the top of the structural high on Kimball Creek, 2 miles to the south, it is only 40 feet thick beneath the Fernvale. (See pl. 9.) Five miles west-southwest from the Kimball Creek locality the Plattin is again 80 to 100 feet thick, in and adjacent to the east end of the Tomahawk graben.

Detailed mapping of the region south and east of the St. Joe, Water Creek, and Cabin Creek monoclines on a more accurate and larger-scale base than the existing topographic map of the Yellville quadrangle would undoubtedly yield much information on the pre-Fernvale structural features that is little more than indicated in the results of the writer's work in the region. The Tomahawk graben is especially interesting, as it appears to contain maximum thicknesses of the Plattin, Fernvale, and St. Clair limestones, though not necessarily superposed. Unfortunately, these formations are buried beneath the Boone formation throughout the greater part of the graben and are exposed only toward its east end. The Panther Creek structural basin also appears to have been in existence and separated from the Rock Creek basin in pre-Fernvale time. This basin is of special interest in that the Fernvale limestone preserved within it does not lie at the lowest part of the basin but on its northeast limb, suggesting that the axis of the depression that preceded the deposition of the St. Joe lay slightly northeast of the axis for the later movement.

The occurrence of Fernvale limestone on top of the Salgado dome indicates that this dome unlike many of the others described in the region had its inception in post-Mississippian time.

Purdue and Miser [21] state that certain anticlinal flexures in the Eureka Springs and Harrison quadrangles are more pronounced in the Cotter dolomite than in the Boone formation and more pronounced in the Boone than in the Hale and Winslow formations. They thus recognize not only a pre-Boone warping and post-Boone accentuation, as observed in the Yellville quadrangle, but break up the post-Boone movement into a pre-Pennsylvanian and post-Pennsylvanian accentuation.

The evidence at hand indicates that certain gently folded structural features in northern Arkansas are the resultant of crustal movements along essentially the same axes at several different periods. At least four such periods of movement have been recognized—(1) between the Plattin and Fernvale periods of deposition, (2) between the Fernvale and Boone (St. Joe) periods of deposition, (3) between the Boone and Hale periods of deposition, and (4) in post-Hale time. These movements were in the nature of local warpings and are to be distinguished from regional oscillatory movements that affected large blocks of the earth's crust as units. Plate 9 shows the relation between the two types of movement in

[21] Purdue, A. H., and Miser, H. D., op. cit., pp. 16, 17.

the Rock Creek basin. For the sake of simplicity the warping along the axis of the basin is here illustrated as contemporaneous with the regional uplifts (stage 3 in each cycle). All that the field evidence indicates, however, is that warping occurred in the periods between the initial depositions of certain limiting formations (between A1 and B1, between B1 and C1, and between C1 and the present); a measure of the amount of warping in any period is given by the magnitude of the unconformity between the two limiting formations. Whether these warping movements were actually as illustrated—namely, contemporaneous with certain uplifts, of short duration, and separated by long periods of quiescence except for broad regional oscillations that are recorded elsewhere in the minor unconformities—or whether, on the other hand, they have been practically continuous from their beginnings up to the present time is not known. However, in view of the fact that each of the four periods of warping, recorded above, has been recognized only because of rather pronounced unconformity between its two limiting formations [22] and as smaller unconformities are known to have been developed within each of these four principal unconformities, the probability is that the warping movements were simultaneous with the movements, whether up or down, that produced the smaller as well as the larger regional unconformities. As a matter of fact, the larger unconformities are probably nothing more than summations of the smaller unconformities within them, and the larger warpings whose time limits have been determined may be simply summations of the smaller warping movements that took place within the given time interval.

REGIONAL TRENDS IN STRUCTURE

Certain structural trends are very pronounced in northern Arkansas. In figure 5 the directions of all the faults mapped in the tier of United States Geological Survey quadrangles that cover the region from the northwest corner of the State eastward through the Yellville quadrangle and also the directions of the faults mapped in the Winslow and Batesville quadrangles are plotted together through a common point. The figure shows that with two exceptions (the Green Forest and Long Creek faults, in the Harrison quadrangle) all the faults lie between N. 31° E. and S. 53° E. The exceptions strike about S. 25° E., although this figure is only a rough average for the Green Forest fault, which curves from S. 50° E. at the south end to north-south at the north end. Most of the faults lie between N. 85° E. and S. 55° E. A similar figure (fig. 6) for

[22] In the fourth period the unconformity is between the Hale formation and the present plane of horizontality.

the Yellville quadrangle alone, in which all the faults whose directions have been determined are plotted, is even more striking. Of 28 faults, all but 4 strike between S. 55° E. and N. 86° E. The four exceptions strike between N. 52° E. and N. 63° E.; three of them are on the Water Creek-St. Joe monoclinal flexure, which trends in a northeasterly direction, transverse to all the other prominent structural features of the region.

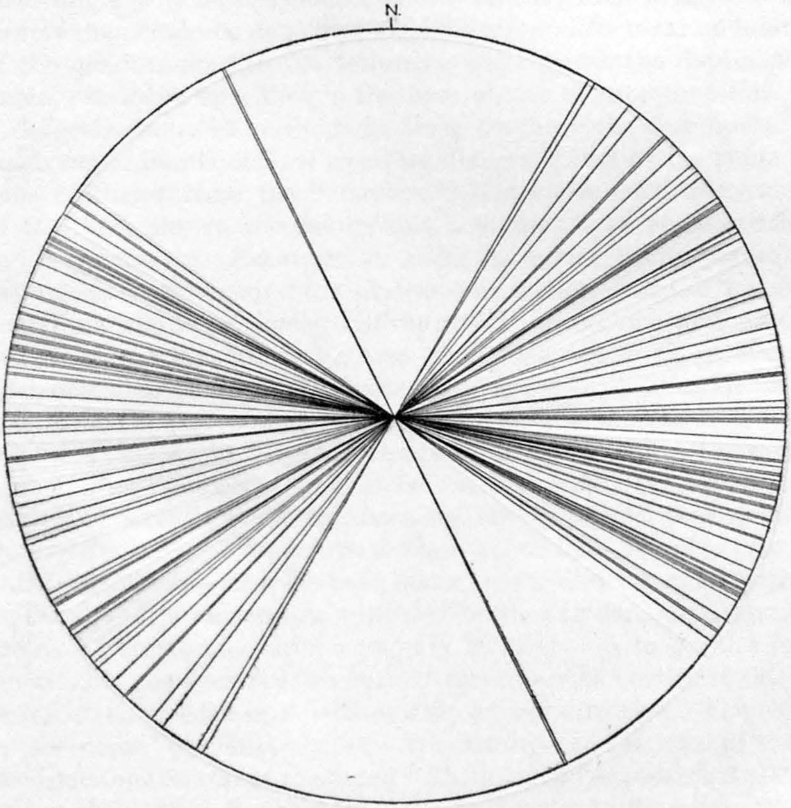


FIGURE 5.—Strikes of faults mapped in the Winslow, Fayetteville, Eureka Springs, Harrison, Yellville, and Batesville quadrangles.

Not only the faults but, within the Yellville quadrangle, many of the domes and basins show an elongation of their major axes parallel to the dominant southeasterly trend (pl. 3, oversheet). This parallelism between folds and faults is not marked in the Harrison and Eureka Springs quadrangles.

CHARACTER OF FAULTS

So far as can be observed, all the faults in the northern Arkansas region are either normal, with steep dips, or else, in a few examples along the Buffalo River in the Harrison quadrangle, they show small horizontal displacements with no vertical components.

AGE OF FAULTING

Crustal movements were taking place at different times during the Paleozoic era, but practically all the faulting occurred after the deposition of the Winslow formation, and probably near the end

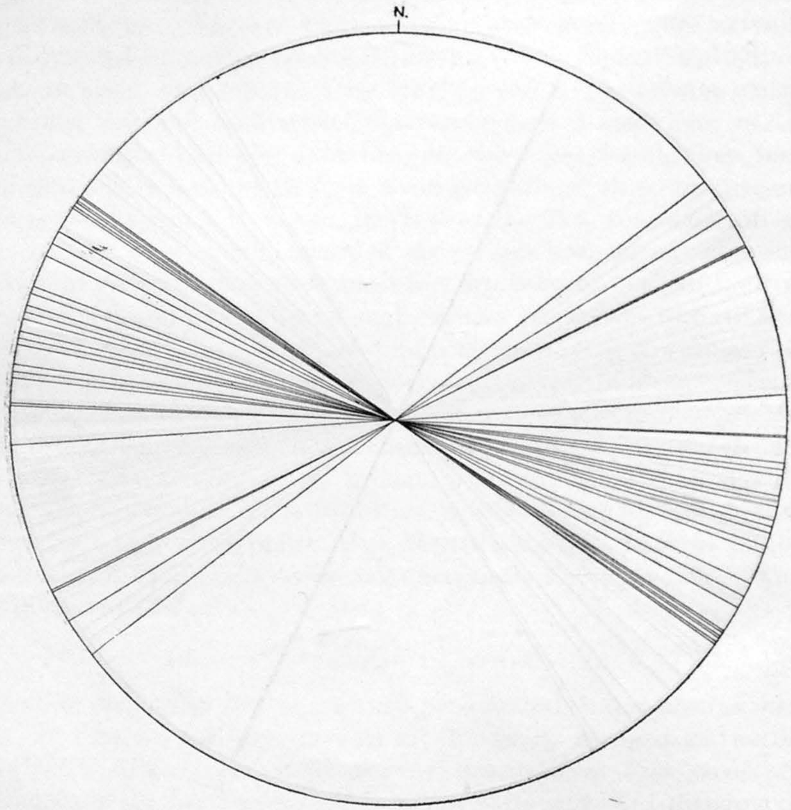


FIGURE 6.—Strikes of faults mapped in the Yellville quadrangle.

of Paleozoic time. The crustal movements as expressed in the amount of folding of the strata were apparently somewhat greater at this time than at earlier periods. The only fault that has been found in which the break occurred earlier than the general period of faulting that affected the region is on the west side of the "narrows" of the Buffalo River, 3 miles southeast of Rush, in the Yellville quadrangle. Here a fault with a throw of 43 feet displaces the Everton, St. Peter, Plattin, and Fernvale but is truncated above by the unconformity at the base of the St. Joe limestone.

DOMES, BASINS, AND MONOCLINES IN THE YELLVILLE QUADRANGLE

As only the Yellville quadrangle has been studied in detail in the preparation of this report, the domes, basins, and monoclines here described will be limited to that area. Purdue and Miser described and figured similar features in the Eureka Springs and Harrison quadrangles. Only the more prominent flexures of the Yellville quadrangle will be mentioned, as the contour map illustrates more clearly than could be done by words the minor structural undulations of the quadrangle. In the following descriptions the datum plane, unless otherwise specified, is the base of the St. Joe limestone.

Salgado dome.—The Salgado dome lies near the east line of the quadrangle, its major axis trending along the line of the ridge that runs southeast from the "narrows." Only the northwestern part of the dome lies in the quadrangle, and the shape of its southeast end is not known. Future work in the Mountain Home quadrangle, to the east, may modify the present assumption that the feature is actually a structural dome. On that part of the dome contoured the difference in altitude of the base of the St. Joe is about 300 feet. The west side of the dome, however, dips off to the Panther Creek and Rock Creek basins, about 4 miles away, where the base of the St. Joe is almost 600 feet lower than on top of the dome. The average dip on the southwest flank is between 2° and 3°; the northeast flank is apparently somewhat steeper. The altitude of the base of the St. Joe limestone on top of the dome is about 1,175 feet.

De Soto dome.—The De Soto dome apexes about 1 mile northeast of De Soto (Sylva), in line with the Panther Creek and Rock Creek basins. Its extreme limit is roughly circular, 3½ to 4 miles in diameter, but the apex is excentrically placed at the northeast side and shows an elongation in a north-northwesterly direction. The closure on the dome is about 150 feet. The altitude of the base of the St. Joe limestone on top of the dome is about 1,000 feet, which is 400 feet higher than in the Panther Creek basin, 3 miles to the southeast.

Mount Hersey dome.—The Mount Hersey dome is on the edge of the quadrangle and is therefore imperfectly known. The highest point of the dome located in the quadrangle lies about 1 mile southeast of Mount Hersey, where the base of the St. Joe is a little more than 1,200 feet above sea level. On the north side of the dome the base of the St. Joe descends between 200 and 250 feet below this point, but on the east side the rocks dip continuously, although irregularly, to the bottom of the St. Joe syncline, 10 miles away, where the base of the St. Joe is about 850 feet lower. The dips are low, though locally they may steepen to 3° or 4°.

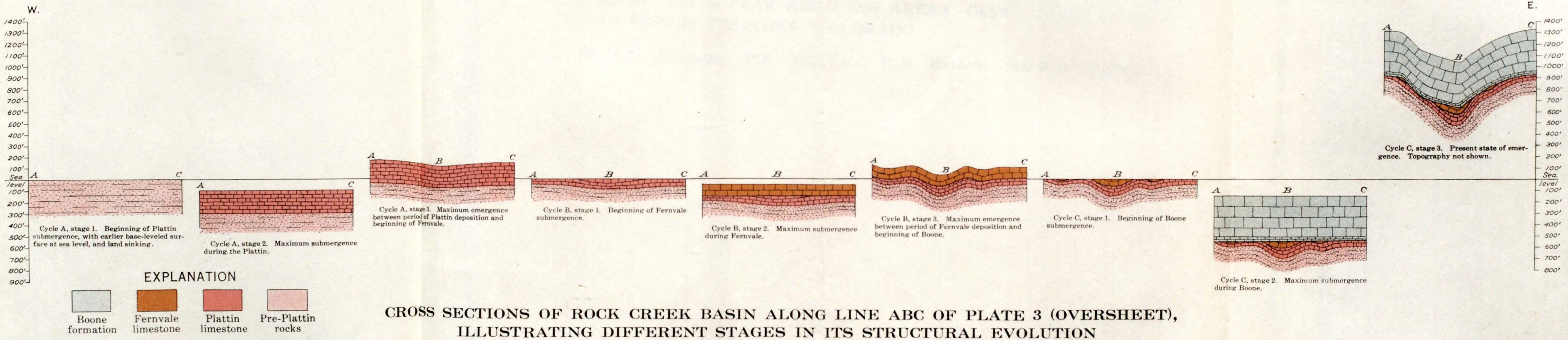
Pilot Knob dome.—The low Pilot Knob dome lies on the line between Marion and Boone Counties, 4 miles north of Zinc. The major axis runs about east by southeast. The closure is about 100 feet, but on the southeast the beds dip gently for about 5 miles to the structural low around the mouths of Tarkiln Branch and Sugar Orchard Creek, and in this direction the base of the St. Joe drops about 350 feet below its altitude on top of the dome (1,220 feet).

Ingram Branch dome.—Although the Ingram Branch dome does not show on plate 3, oversheet, the description of the domes in the Yellville quadrangle would be incomplete without some mention of it. It apexes on the Ingram Branch of Blue John Creek, near the southwest corner of sec. 14, T. 18 N., R. 15 W., and is apparently developed entirely below the base of the St. Joe. The structure was worked out on the base of the Everton, which here lies between 100 and 150 feet higher than it does in the escarpment overlooking Crooked Creek, about 1 mile to the north. On the east, south, and west the structural relief is considerably greater.

Panther Creek basin.—A structural depression covers a large part of the valleys of lower Panther Creek and Little Panther Creek, 3 miles south of Rush. It is about 2½ miles long in an east-southeasterly direction and 1½ miles wide but is not symmetrical in outline. The southeast rim is a narrow structural ridge, separating the basin from the Rock Creek basin and standing a little less than 200 feet above the bottom of the Panther Creek basin. The southwest rim is much broader and stands a little more than 200 feet above the bottom of the basin. On the other sides the borders of the basin are considerably higher than on these two. The altitude of the base of the St. Joe limestone in the bottom of the basin is 600 feet. The base of the St. Joe dips into the basin at an angle of about 5° on the southwest side, which is the steepest side. The dip on this side is very noticeable also, because somewhat steeper, in the St. Peter sandstone ledge along Panther Creek, between the Big Bell mine and the mouth of the Sylva (DeSoto) fork.

Rock Creek basin.—The Rock Creek basin lies 2 miles southeast of the Panther Creek basin. Its low point is on the Buffalo River near the mouth of Rock Creek, where the base of the St. Joe is at an altitude of 650 feet. The basin is about 3 miles long in a southeasterly direction along Rock Creek and Hogskin Hollow. Its width is about half its length. The lowest rim is the one that separates it from the Panther Creek basin; this rim is 150 feet above the low point on the Buffalo River. Dips into the basin are gentle, the average on the southwest being between 2° and 3°.

Water Creek basin.—A broad, flat basin lies along Water Creek on the Marion-Searcy County line. It represents an overdeepened



CROSS SECTIONS OF ROCK CREEK BASIN ALONG LINE ABC OF PLATE 3 (OVERSHEET), ILLUSTRATING DIFFERENT STAGES IN ITS STRUCTURAL EVOLUTION

For the sake of simplicity, the warping along the axis of the basin is here illustrated as contemporaneous with the uplifts (stage 3 of each cycle). It is known from a study of adjacent regions that each of the oscillation cycles here shown (cycles A, B, C) contains several oscillations, but records of these individual oscillations in the form of sediments have not been preserved in the Rock Creek Basin, and they have consequently been omitted. Stage 3 of each cycle is hypothetical, as the modification produced by erosion during uplift is not shown.

area in an irregular synclinal depression that extends in a northwesterly direction from a point near the southeast corner of the quadrangle to the Water Creek monocline. The basin itself is about 6 miles long, 2½ miles wide, and 170 feet deep. The altitude of the base of the St. Joe in its bottom is near 600 feet.

St. Joe syncline.—The axis of the St. Joe syncline runs from southwest to northeast, along the downthrown side of the St. Joe monocline and associated portions of the St. Joe and Tomahawk faults. The syncline is limited on the northeast by the southeastward-trending portion of the Tomahawk fault and is crossed diagonally by the Pilot Mountain and South Tomahawk faults, which also follow the dominant east-southeast trend of the region. The axis of the unbroken portion of the syncline, southwest of the Pilot Mountain fault, goes through a point just north of the old town of St. Joe and runs between St. Joe Mountain and Pilot Mountain. The southeast limb of the syncline has not been mapped in the Marshall quadrangle, to the south, but the rise from the low point southwest of the Pilot Mountain fault is at least 250 feet in this direction and at a very low angle. The northwest limb of the syncline is formed by the St. Joe monocline and is much steeper. The only occurrences of the Fayetteville, Pitkin, Hale, and Winslow formations in the quadrangle are along the St. Joe syncline. The St. Joe limestone is not exposed along the axis of the syncline, but computations show its base to lie about 350 feet above sea level in the lowest part of the structural trough west of Pilot Mountain, and only 300 feet above sea level where the synclinal axis crosses the graben between the Tomahawk and South Tomahawk faults.

St. Joe and Water Creek monoclines.—The St. Joe and Water Creek monoclines are really parts of a single monoclinal flexure, running from northeast to southwest, that drops the rocks in the southeastern part of the quadrangle. They are separated by a stretch, between St. Joe and Tomahawk Creek, in which the movement is taken up in part or wholly by segments of the St. Joe and Tomahawk faults. Smaller faults take up part of the displacement farther up Tomahawk Creek and on Mill Creek near St. Joe. The complete flexure runs southwestward from the Rush Creek fault (south of Cowan Barrens), through a point near the town of St. Joe, and, according to Adams,[23] on across the Buffalo River toward the head of Cave Creek in Newton County. The displacement varies from place to place along the monocline. Along the Water Creek section the usual drop is between 250 and 300 feet, and the dip rarely exceeds 6° or 7°, except where the monocline is passing over

[23] Adams, G. I., Purdue, A. H., and Burchard, E. F., Zinc and lead deposits of northern Arkansas: U.S. Geol. Survey Prof. Paper 24, p. 38, 1904.

into a fault. Along the St. Joe section, where the structural high that lies south of the Mill Creek fault is at the top and the St. Joe syncline is at the foot, the amount of drop is around 600 feet. The dip is here 9° or 10° unless part of the displacement is taken up by faulting. This dip has been calculated from differences in altitude of certain horizons, as no rocks were found exposed along the monocline at the particular place cited. The highest dips found in the quadrangle are near the head of the Davy Crockett fork of Tomahawk Creek, north of the locality where the St. Joe fault near its east end has cut down diagonally across the monocline nearly to its foot. A dip of 41° was measured on the Batesville sandstone where it crosses the creek.

The St. Joe-Water Creek monocline, with its associated faults, and the St. Joe syncline, which is intimately related to it, are the only structural features of pronounced northeasterly trend in the quadrangle.

Cabin Creek monocline.—The Cabin Creek monocline strikes roughly east-west along the north side of the Buffalo River east of Blue John and Clabber Creeks and dips to the south. The structural drop is about 450 feet within 3 miles. The dip is not even, however, but increases in amount over the south half of the monoclinal slope. Both Cabin Creek and Cedar Creek flow down the dip of the monocline.

FAULTS

The faults of northern Arkansas have had little or no effect on the topography, and even where the general line of a fault may be followed by a stream—as, for example, that of the Rush Creek fault—the stream winds back and forth across it according to the usual habit of streams in the region and without any apparent effect of the fault. Nor do the minor tributary gullies that plunge into the main streams select the lines of faults that may crosscut the major drainage lines. Locally the outcrop of a fault may be marked by a siliceous reef, but more commonly the actual outcrop is concealed. Hence, in the absence of any aid that may be obtained from a study of topography or from an examination of outcrops, the location of faults becomes dependent upon a detailed search of the multitudinous hollows of the region with a thorough knowledge of the stratigraphic section in mind. The present report, in which the structure of only the Yellville quadrangle is covered in detail, records a larger number of faults within the area considered than the earlier reports on the lead-zinc district, because it is more detailed, but still more faults will undoubtedly be found on more thorough examination. The area covered by the outcrop of the

Cotter and Jefferson City dolomites especially has been very imperfectly examined. The faults located are shown on plate 3. Only the major breaks will be here discussed. The maximum displacements on the smaller ones are indicated on the structure-contour map. In considering strikes of faults it should be borne in mind that the figures given are subject to error because of imperfections in the topographic map on which the faults are plotted.

Rush Creek fault.—The Rush Creek fault runs about S. 65° E. from some point on the ridge between the two main forks of Mill Creek to the Edith mine, which lies a quarter of a mile up the Buffalo River from the mouth of Rush Creek (pls. 3, 4). The length is between 7 and 8 miles. The maximum displacement near the Morning Star Hotel, in Rush, is about 450 feet, down on the southwest.

Cold Spring fault.—The Cold Spring fault runs parallel to and about a quarter of a mile southwest of the Rush Creek fault at Rush. Its displacement is down on the northeast and amounts to a maximum of about 150 feet near the point where it crosses the new ridge highway into Rush. The displacement is in the opposite direction from that of the Rush Creek fault, so that the block between them has been dropped and forms a graben. The location of the fault is shown on the detailed map of the Rush district (pl. 4). Near the mouth of the hollow that enters Rush Creek from the south in sec. 5, T. 17 N., R. 15 W., about 1½ miles above Rush (pl. 3), what is believed to be the same fault is exposed with a displacement of 35 feet. Its direction is more nearly southeast-northwest, so that it undoubtedly joins the Rush Creek fault a short distance to the northwest. A smaller fault (not shown on pl. 3), 1,000 feet farther up the hollow, is more nearly in line with the fault at Rush and may represent one prong of it that dies out a short distance to the northwest. The total length indicated for the Cold Spring fault is about 2 miles.

Climax fault.—The Climax fault parallels the Rush Creek fault over part of its northwest end, lying about 2,000 feet southwest of it. The length is around 2½ miles. The maximum displacement is between 100 and 150 feet, down on the northeast.

Silver Hollow fault.—The Silver Hollow fault is nowhere exposed, and evidence for its existence is derived solely from the structural relations near the Silver Hollow mine. Above the mine the St. Peter sandstone forms a prominent cliff whose top lies at an altitude of 800 feet. Across the Buffalo River the altitude of the same cliff is 600 feet. (See pl. 4.) As the strike and dip of the strata are about the same at the two localities, and as a line between them is nearly parallel to the strike, there must be a fault between them with a displacement of about 200 feet. It has been drawn in line with a small fault that is exposed along the Buffalo River near the Red Cloud mine and also near the forks of Bear Hollow.

Narrows fault.—A fault that shows at only one point, on the west side of the "narrows," 3 miles southeast of Rush, cuts the Everton, St. Peter, Plattin, and Fernvale formations but is truncated by the overlying St. Joe. The displacement is 43 feet, down on the north.

North Rocky Creek fault.—The North Rocky Creek fault extends in a direction S. 80° E. from the acute bend of the Buffalo River below the mouth of Tomahawk Creek to the Buffalo River a short distance below the mouth of Rocky Creek, a distance of about 2½ miles. In the intervening stretch the fault lies an eighth to a quarter of a mile south of the river. The maximum displacement is about 100 feet, down on the south, in the NW¼ sec. 23, T. 16 N., R. 16 W.

South Rocky Creek fault.—The South Rocky Creek fault lies about half a mile south of the North Rocky Creek fault and strikes about S. 75° E. It is exposed only on the two sides of Rocky Creek; the maximum displacement of 90 feet, down on the north, shows on the west side of the creek.

Section 22 fault.—A fault that strikes about S. 60° E. in secs. 22 and 21, T. 16 N., R. 16 W., is about 2 miles long. Its displacement is a little more than 100 feet, down on the northeast, but over much of its course it is accompanied by a small fault that branches at a low angle from it, diverging to the west, and that has a displacement in the opposite direction. Owing to the smaller displacement of the second fault, the net maximum displacement of the two is about 100 feet, down on the northeast.

Tomahawk fault.—One of the major faults of the district is the Tomahawk fault, which is peculiar in that its middle course swings into the general direction of the St. Joe-Water Creek monocline and takes up the complete displacement on this structure. The middle segment strikes about N. 63° E. and runs from St. Joe Mountain to Tomahawk Creek, a distance of 2 miles. The two end segments strike across the direction of the monocline, in accordance with the regional fault trend. The eastern one runs S. 70° E. from Tomahawk Creek almost to Mud Hollow (Gulf Hollow), a distance of 4 miles. A mile and a half from the east end it breaks into two parts of about equal displacement, one following the course of the segment as given above and the other running more nearly east. The west segment of the main fault is only a mile or so long and appears to run about S. 55° E., although imperfections of the topographic map on which it has been plotted make this figure subject to considerable error.

The displacement is everywhere down on the south. The north side of the fault is structurally an unbroken block, but the south side is broken into four separate blocks by the South Tomahawk, Pilot Mountain, and St. Joe faults, all of which terminate against the Tomahawk fault. Hence the displacement on the Tomahawk fault varies according to which of the south blocks happens to be opposite the point of measurement. The maximum displacement of about 725 feet is between the ends of the St. Joe and Pilot Mountain faults. This is also the maximum for the quadrangle. A displacement of 650 feet is developed on the east segment a short distance west of the Tomahawk copper mine.

South Tomahawk fault.—The South Tomahawk fault is roughly parallel to the east segment of the Tomahawk fault and lies from half a mile to 1½ miles southwest of it. It runs along the general course of Tomahawk Creek from the middle segment of the Tomahawk fault to some point in the NE¼ sec. 20, T. 16 N., R. 16 W., a distance of 4 or 5 miles. The northwest half of its course runs about S. 65° E. and the southeast half about S. 50° E. The downthrow is on the north, and the displacement is between 250 and 300 feet, on Tomahawk Creek near the mouth of the branch lying west of Tomahawk.

Pilot Mountain fault.—Another break runs about S. 70° E. along the north side of Pilot Mountain. Its length is 2 miles, and the maximum displacement is estimated to be about 200 feet, down on the southwest, where it joins the Tomahawk fault.

St. Joe fault.—Most of the St. Joe fault follows a trend that averages a few degrees south of east, but the easternmost 2 miles swings into the St. Joe monocline and takes up part of the movement on it. The southeastward-trending portion shows some variation in strike; between Shaddock Branch and Hurricane Branch the trend is a few degrees north of east. The fault runs from the head of Wells Creek, in the Harrison quadrangle, to St. Joe Mountain, a distance of 15 miles. The downthrow is on the south, and the maximum displacement is about 500 feet where the highway leading from St. Joe to Valley Springs crosses the fault. It is quite possible that the throw at this locality is increased by the junction of a fault from the southwest that lies on the St. Joe monocline in line with the east end of the St. Joe fault. Such a fault is exposed in the Boone formation on the west bank of Mill Creek, just below the point where the St. Joe limestone member dips under, but its course cannot be traced. The Hurricane fault of previous reports is the western part of the St. Joe fault.

Mill Creek fault.—The Mill Creek fault lies about half a mile south of the St. Joe fault, which it closely parallels from its west end to the St. Joe monocline, a mile or so west of the old town of St. Joe. The displacement, however, is down on the north, the maximum being about 150 feet near the head of Mill Creek.

Section 35 fault.—A fault developed on the Water Creek monocline crosses Tomahawk Creek in sec. 35, T. 17 N., R. 17 W., running about N. 60° E. It is also exposed up a small tributary hollow from the east. Its total length is about 1¼ miles. The maximum displacement at the crossing of Tomahawk Creek is 130 feet, down on the southeast.

Pine Hollow fault.—A notable break crosses Clear Creek at the mouth of Pine Hollow, running about S. 60° E. Its length is about 6 miles, two-thirds of which is east of Clear Creek, along the ridge between Kings Branch and Pine Hollow. The downthrow is on the northeast, and the maximum displacement is 170 feet, about 2 miles southeast of Clear Creek.

Crooked Creek fault.—Most of the Crooked Creek fault lies in the Harrison quadrangle along the north side of Crooked Creek, but the east end of it crosses into the Yellville quadrangle for 2 miles or so. The general direction of the fault is about S. 60° E. The maximum displacement in the Yellville quadrangle is about 50 feet, down on the northeast. This fault is directly in line with the Pine Hollow fault, but the two are evidently not connected.

Sugarloaf fault.—The Sugarloaf fault trends about S. 75° E. and crosscuts the heads of several branches of East Sugarloaf Creek between Dodd City and the Broome County mine. The maximum displacement of 100 feet occurs on the branch half a mile or so above the Markle mine. The downthrow is on the north. At two or three places along the course of the fault its outcrop is marked by a siliceous reef which, on the east side of the hollow that contains the Broome County and Salina mines, shows a maximum width in the Everton formation of 15 feet.

Georges Creek fault.—A break of considerable magnitude crosses the headwaters of several branches of Georges Creek and at the east end passes over the ridge into the head of Moccasin Creek, north of Lee Mountain. The length is around 7 miles. The general direction is about S. 75° E. The downthrow is on the north, and the maximum displacement of about 230 feet occurs where the fault crosses the hollow half a mile or so above Butler & Wassel's lead mine. On the maps accompanying this report the fault is represented as being very sinuous in trend, but most of this sinuosity is due to the poor character of the topographic map, on which the geologic features were plotted.

DOWN-FAULTED AREAS (GRABENS)

The faults that bound the down-faulted areas, or grabens, have been described, but the four grabens developed in the quadrangle are believed worthy of attention as such.

Climax graben.—A dropped block lies between the Rush Creek and Climax faults. Its length is between 2 and 3 miles, and its width varies between 1,600 and 2,000 feet. The floor of the graben dips to the southeast, in harmony with the dip of the Water Creek monocline, which abuts against its southwest side. The northeast rim of the graben shows a maximum height of 300 feet, and the southwest rim a maximum of 150 feet.

Rush Creek graben.—The Rush Creek graben lies between the Cold Spring and Rush Creek faults. It is about 2 miles long and a quarter of a mile wide. At its southeast end the faults bounding it die out, but at the northwest end they come together, so that the end of the graben in this direction is wedge-shaped. The southwest rim of the graben shows a maximum height of 150 feet; the northeast rim shows a maximum of 450 feet. The floor dips in from all sides, basinlike, to a low point on Cold Spring Hollow just above its mouth. The base of the St. Joe limestone lies at an altitude of about 520 feet in the bottom of this basin.

Tomahawk graben.—The Tomahawk graben is not a simple one, for over parts of its course it is bounded by monoclinal dips rather than by faults. Nor do the faults that form parts of the respective sides lie in line. On the contrary, two adjacent faults may be offset in such a way that the monocline connecting them runs oblique to the axis of the graben.

The graben extends in a southeasterly direction from the northeastward-trending portion of the Tomahawk fault to the east ends of the Rocky Creek and South Rocky Creek faults, a distance of 8 miles. Its width is half a mile in the northwest portion, 1½ miles near the middle, and half a mile in the southeast portion. Bounding it on the northeast are the Tomahawk and North Rocky Creek faults and a connecting monocline; on the southwest, the South Tomahawk, Section 22, and South Rocky Creek faults and two connecting monoclines. The floor of the graben dips irregularly to the northwest along with the adjacent limb of the St. Joe syncline, of which it is essentially a part, and the lowest structural block in the quadrangle is located where the graben, near its northwest end, crosses the axis of the St. Joe syncline. The southwest rim of the graben is nowhere very high, varying in general between 50 and 275 feet. The northeast rim, on the other hand, while it does not dip in any general direction, is higher at the northwest than at the southeast end. This change in altitude is opposite to that shown by the floor of the adjacent graben and leads to a pronounced increase in the height of the rim to the northwest, up to 650 feet.

Mill Creek graben.—The Mill Creek graben lies between the St. Joe and Mill Creek faults. Its length is 12½ miles and its width varies between 2,000 and 3,200 feet. It is thus unique among the structural features of the quadrangle. Its north rim varies in height between 150 and 350 feet, and its south rim between 80 and 150 feet. The floor of the graben shows a structural high along the Newton-Searcy County line that is accompanied by similar highs in both of the adjacent rims.

ORE DEPOSITS

PRELIMINARY OUTLINE

The zinc and lead deposits of northern Arkansas are confined to the Paleozoic limestone and dolomite belt, averaging less than two counties wide, that runs from Lawrence County on the east to Washington County on the west. The belt includes the northern tier of counties and extends for variable distances into or through the next tier to the south. Although the mineralization has thus been widely distributed, its intensity was highly variable, and only in certain districts has the concentration of mineral been great enough to produce ore deposits of commercial importance. These lie in Marion, Boone, Newton, Searcy, Sharp, and Lawrence Counties.

The ores occur in the Cotter, Powell, Smithville, and Everton formations of the Ordovician, and in the Boone formation and Batesville sandstone of the Mississippian. Of these formations the Everton and Boone are the most favorable and contain all the mines that have been of any commercial importance. Without exception, the mineralized beds in the Ordovician rocks are dolomites or else limestones that have been silicified in the early stages of mineralization; on the other hand, many of the deposits in the Boone are developed in unaltered limestone.

Two or three mines that have been productive are located on faults of considerable throw, but the great majority of the ore deposits are developed in the form of "runs." These are confined to certain strata within the horizontal or gently tilted series of beds but may assume any shape, though typically a linear one, in ground plan. The runs have been formed by mineralization along fractures or zones of shattering that have been produced by very slight movements in the rock. They may or may not lie in the vicinity of major faults.

The mineralogy of the deposits is simple. The primary sulphide minerals consist of sphalerite and galena, a little chalcopyrite, pyrite, and locally marcasite, and a minute quantity of enargite (at one mine only); the gangue minerals are dolomite (pink spar), chert (jasperoid), quartz, calcite, and feldspar (adularia). Oxidation has produced smithsonite, calamine, and cerusite in commercial quantities; malachite, aurichalcite, and azurite appear in traces, as alteration products of the chalcopyrite. Wulfenite accompanies cerusite as an alteration product of galena at one mine. Gypsum is common as a secondary gangue mineral but is nowhere abundant. The mines that have yielded the greatest commercial production have been largely in oxidized ores (smithsonite and calamine).

The ore and accompanying gangue minerals have been developed either by simple mechanical filling of the openings between the shattered fragments of the country rock or by replacement of the country rock out from these shatter cracks and from the accompanying bedding cracks. There are all gradations between these extremes, but usually replacement has played an important part in the deposition and final form of the ore. Owing to the intimate admixture with the country rock, the average ore has to be milled before it can be shipped. In most mines, however, certain large replacement blocks of ore can be picked out by hand and marketed as " free " ore.

MINERALOGY OF THE ORES

In their mineral composition the ores of northern Arkansas present no great contrast with the class of ore deposits that has come to be recognized as the Mississippi Valley type. Notable additions to the simple assemblage of minerals common to this class are enargite, wulfenite, and feldspar (adularia), but of these the first two have been found at only one mine each, and there only in minute quantity, while the feldspar, although widely distributed, is everywhere a minor microscopic constituent. In the following discussion the minerals are divided for convenience into primary (hypogene) and secondary (supergene) minerals. The latter have been derived, under conditions of weathering near the surface, from the former. Each of these groups is further subdivided into ore minerals and gangue minerals, although most of those recorded as ore minerals occur in such small amounts in northern Arkansas as to have no commercial value.

PRIMARY MINERALS

ORE MINERALS

Sphalerite (black jack, rosin jack, ruby jack, blende; ZnS—Zn 67, S 33).—Sphalerite is the most common and widely distributed of the primary ore minerals. It is rather coarsely crystalline, the individual crystal grains, as shown by cleavage faces, averaging between a quarter of an inch and 1 inch in diameter, though a few measure 5 or 6 inches. The larger crystal units are irregular in shape, but crystals under 2 inches and especially under 1 inch in size may show crystal boundaries where they are developed in vugs or in jasperoid chert.

The commonest color is described in the term "rosin jack", but black jack is also plentiful. In many places the two are intimately intermixed, even in the same crystal. Although there are numerous deposits in which the black jack is developed to the exclusion of the rosin, none of these have proved to be of commercial importance; the richer deposits are rosin jack (or carbonate derived from rosin jack) or rosin jack with a varying though generally subordinate amount of admixed black jack. Ruby jack, a brownish-red variety, is associated in small amounts with the rosin and black jack at certain mines and, in addition, constitutes the sole product of a few low-grade mines in the Jimmie Creek district. It usually occurs as small but well-formed and clear crystals. In several deposits where it is associated with other types of jack it shows a tendency toward crystalline development in vugs, indicating that it was the last variety of sphalerite to crystallize. The Morelock mine, on the other hand, shows a unique development of ruby jack as a rim around kernels of black jack, and exceptionally there may be an additional thin shell of black jack outside of the ruby shell.

The theoretical composition of sphalerite (Zn 67, S 33) is rarely attained in nature, but the northern Arkansas occurrences show a much closer approach to it, as indicated by the high percentage of zinc that they contain, than is commonly shown by occurrences throughout the Cordilleran region. Branner [24] records seven analyses of sphalerite from northern Arkansas in which the percentage of zinc ranges between 64.48 and 66.46, averaging 65.77. The chief impurities of sphalerite are ferrous iron and cadmium. No complete analyses were made for the present report, but partial analyses for cadmium, iron, and manganese were made on three samples by J. G. Fairchild, as follows:

	Cd	Fe	Mn
Rosin jack, Monte Cristo mine, Rush district	0.45	0.10	0.00
Ruby jack, Olympia mine, Jimmie Creek district	.57	.17	.00
Black jack, Hawkeye mine, Baxter County	.61	.31	.00

These analyses show a progressive increase in iron and cadmium from rosin jack through ruby jack to black jack.

Galena (PbS—Pb 86.6, S 13.4).—Galena is the chief ore of lead in the northern Arkansas field. It is not so widely distributed as the sphalerite, nor has it yielded so great a tonnage production. It may occur in association with sphalerite, or, in other deposits, it may be the only ore mineral present. It is rather coarsely crystalline, in cubes that may reach 2 or 3 inches in size, though the average is between half an inch and 1 inch. Some of the cube corners are truncated by the octahedron, and in the Pigeon Roost mine this truncation has increased in certain crystals to such an extent that the octahedron is dominant, with the cube present only as a modifying form. Where the

[24] Branner, J. C., The zinc and lead region of north Arkansas: Arkansas Geol. Survey Ann. Rept. for 1892, vol. 5, p. 265, 1900. In the analyses here cited cadmium is not recorded; it was apparently calculated as zinc, which would tend to indicate a higher percentage of zinc than actually exists.

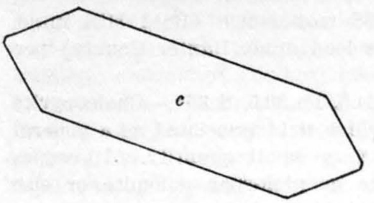
crystals have not developed external forms they may have cleavage faces as much as 6 inches in diameter. The galena shows a peculiar habit where it is developed by replacement in homogeneous and rather fine grained dolomites, in the formation of irregular crystalline networks whose parts exhibit, by their cleavage, the same crystalline orientation. Such masses may contain a larger volume percentage of the country rock than of the mineral matter.

Galena from ore deposits of the Mississippi Valley type is characteristically low in silver, and the Arkansas occurrences prove to be no exceptions. Two assays for silver made by E. T. Erickson in the chemical laboratory of the United States Geological Survey showed 0.38 troy ounce (Bald Hill mine, Newton County) and 0.09 troy ounce (Shiras lead mine, Baxter County) per ton of galena.

Chalcopyrite (copper pyrites; $CuFeS_2$—Cu 34.5, Fe 30.5, S 35).—Chalcopyrite is almost as widespread as sphalerite, with which it is associated as a general rule, but it is everywhere present in only very small quantity. It occurs typically as small crystals coating sphalerite or pink-spar dolomite or else embedded in one of these minerals or in calcite. In a few places the crystals reach an eighth of an inch in size, and at the Turkey Fat prospect, near Maumee, the largest crystals are a quarter of an inch in size. At the Tomahawk copper mine chalcopyrite occurs in the form of small irregular-shaped blebs in massive pyrite.

Pyrite (mundic, fool's gold; FeS_2—Fe 46.6, S 53.4).—Although pyrite is rather widespread in northern Arkansas ore deposits, it is usually present in such very small traces as to have no effect on the quality of the ore. Locally, however, as on the upper level of the Silver Hollow mine, it may be developed in considerable quantity, with corresponding detriment to the zinc ore. The most usual occurrences are in the form of disseminated small crystals, or imperfect crystal clusters, or amorphous blebs, in the country-rock dolomite or sandstone, commonly along minute cracks. It is a question whether such occurrences are in any way related to the zinc ores, as they are of no greater quantitative importance than the normal occurrence of this mineral in sediments. Where the pyrite is well crystallized, the cube is the usual form, though in a few mines small octahedrons, combinations of the cube and octahedron, or pyritohedrons are found. Another type of occurrence, apparently more closely related to the mineralization that produced the zinc ores, is in the form of finely but distinctly crystalline pyrite disseminated in chert (jasperoid) that has replaced limestone or dolomite. As a general rule the pyritic chert forms small lenses, pockets, or pipes in the normal unpyritic chert, but on the upper level of the Silver Hollow mine all of a large block of chert is pyritic. The pyrite crystals, which are of microscopic size, are cubes modified by the octahedron, by the octahedron and trapezohedron, or by the pyritohedron. A third and characteristic occurrence of pyrite is in the form of a thin selvage between the country rock and the sphalerite or pink-spar dolomite that forms the ore material. In this occurrence the pyrite is usually massive but locally it is in small cubes, or octahedrons modified by the cube. The country rock is generally dolomite or sandstone; in the few places where it is chert the chert appears to be "primary" and not related to the jasperoid that was produced apparently in the early stages of the zinc mineralization. Rarely the pyrite shows a fourth form of occurrence, as crystals along with the ore and gangue minerals, in vugs. Small cubes are most common; octahedrons next. In the Susquehanna mine octahedrons as large as an eighth of an inch are developed in vugs with sphalerite and pink-spar dolomite. Two additional types of occurrence, represented by a single example each, are worthy of mention. At the Tomahawk copper mine pyrite appears on the dump in the form of massive blocks showing a tendency toward pyritohedral crystallization and containing a little chalcopyrite; it was not observed in place. At the Thomas Barclay mine pyrite replaces the crinoid stems in blocks of Boone chert that have been carried down into the underlying formation along underground solution channels.

Marcasite (mundic, white pyrites; FeS_2—Fe 46.6, S 53.4).—The only occurrence of marcasite observed by the writer in northern Arkansas is at the Olympia mine, near Kingdon Springs, where it is developed as a minor constituent in the form of hemispherical (botryoidal) or stalactitic growths in open cavities. The hemispheres are small, ranging between an eighth of an inch and a sixty-fourth of an inch or less. The marcasite is here definitely earlier than the ruby jack with which it is associated.



Enargite[25] (Cu_3AsS_4—Cu 48.3, As 19.1, S 32.6).—Enargite is represented in the Mississippi Valley, so far as known, by a single occurrence in northern Arkansas, at the Governor Eagle mine.[25a] It is developed sparingly as isolated small crystals and nests of small crystals on the surfaces of crystalline rosin jack, in association with pink-spar dolomite, calcite, and chalcopyrite. The crystals are very simple in form, showing a combination of the front and end pinacoids with the prism (fig. 7). The largest crystals are about 4 millimeters in length.

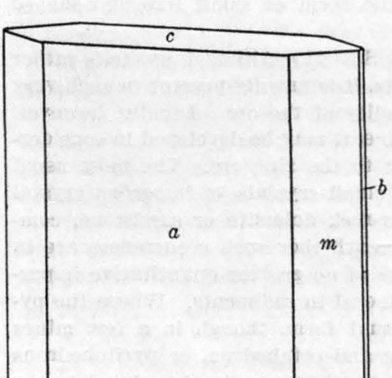


FIGURE 7.—Crystal form of enargite from Governor Eagle mine. The face *b* is really narrower than here shown. (Drawing by W. T. Schaller.)

GANGUE MINERALS

Dolomite (pink spar, gray spar; $CaMg(CO_3)_2$).—The characteristic gangue mineral of the northern Arkansas field is a pale-pink to whitish form of dolomite, commonly called pink spar. It appears generally in the form of replacement pockets, fracture veinlets, and bedding veinlets and commonly forms a matrix for the less abundant ore and gangue minerals. Only rarely has it replaced a limestone bed completely, this mode of occurrence being assumed chiefly by a gray form of dolomite (gray spar). Pink spar crystallizes in curved rhombohedrons that average between ⅛ and ½ inch in size. This range between rather narrow size limits is a marked mineralogic feature of the district and is in contrast to the habits of other minerals whose crystals show wider variations in size. Most of the pink-spar masses contain vugs in which the mineral has crystallized unhindered. Although developed typically as a gangue of the ores, pink spar is not limited to this association but may occur as iso-

[25] The writer is indebted to M. N. Short, of the University of Arizona, for microchemical identification of this mineral.

[25a] Since this was written enargite has been found to occur rather commonly in several mines in the Kansas-Oklahoma part of the Tri-State district.

lated pockets and veinlets in the Ordovician dolomites and limestones where there is no evident connection with lead or zinc mineralization.

A partial analysis of a sample of pink spar from the Red Cloud mine, made by J. G. Fairchild, shows 0.90 percent of iron and 0.08 percent of manganese. The color of the mineral may be due to the trace of manganese present. In specimens that have lain out for several years on the dumps of the mines the pink color has commonly bleached to almost white. Underground weathering of pink spar leaches the magnesium or replaces it by calcium, leaving a brown pseudomorph that is colored apparently by permeated limonite; complete solution leaves a reddish claylike residue that is probably in large part limonite.

Gray spar, another form of dolomite, is similar to pink spar in crystal shape and size but differs in its gray color and in its mode of occurrence. Whereas pink spar has been formed in comparatively open channels by deposition following active solution during which all of the preexisting rock was removed, gray spar has been formed by replacement of limestone and sandy limestone beds, a process in which the residual green clay of the limestone is retained between the crystals of gray spar. The solutions are believed to have been stagnant in comparison to those from which pink spar was precipitated. The pink spar is believed to have been formed by simple chemical precipitation from solutions, all of whose components had traveled considerable distances, even though they may have been identical with those of the adjacent dolomite. The calcium and carbonate radicles of the gray spar, on the other hand, are believed to have been derived from the replaced limestone, so that only magnesium was added from extraneous sources.

Recrystallization of dolomite to gray spar is not common and is rarely distinguishable from replacement of residual limestone in dolomite. At the Mays & Redwine mine, however, the development of gray spar along a narrow zone that crosscuts a 4-foot bed of fine-grained dolomite indicates recrystallization of the dolomite.

Gray spar rarely crystallizes in vugs; where vugs occur in bodies of gray spar they are lined with pink spar. Wherever pink spar instead of gray spar has been developed by mass replacement, conditions have seemingly favored rather rapid circulation of the solutions through the rock. Such is likely to be the situation where the replaced rock is sandstone or very sandy limestone, or where the replaced limestone was originally coarse-grained, as, for example, at the Big Hurricane mine, where coarse-grained Boone limestone has been replaced by pink spar on the border of the ore deposit.

Calcite (tiff; $CaCO_3$).—Calcite is not especially prominent in the northern Arkansas mines but occurs as a minor gangue mineral in a large number of the deposits. It crystallizes in vugs as clear scalenohedrons, steep negative rhombohedrons, and, rarely, flat negative rhombohedrons, or it may completely fill the centers of other vugs so that the crystal forms do not develop. Some occurrences of the latter class show cleavage faces as much as 1 foot in diameter. Locally the calcite has an amber tinge. In the upper level of the Silver Hollow mine the amber color of the outer parts of certain scalenohedral crystals is sharply demarcated from colorless cores. Calcite also forms white or colorless veinlets or coarsely crystalline patches in limestone where it is in no way connected with the ore deposits.

A secondary form of calcite, later than the oxidation of the ores, is described on page 117.

Chert (flint, jasperoid; SiO_2).—In many of the ore deposits the limestone, dolomite, or less commonly sandstone that makes up the country rock has been replaced by a dense gray to black chert. The bedding of the replaced rock is faithfully preserved. Limestone is more easily replaced than dolomite, and where it is banded on a fine scale by the dolomite it may be replaced selectively, leaving a banded mixture of dolomite and chert. Similarly, scattered rhombohedral grains of dolomite in chert have been inherited from a similar occurrence of dolomite in limestone. In addition to its formation through replacement of sediments, some chert has probably also been developed by direct crystallization in open cracks, but the amount is small.

Microscopically the chert is usually found to contain residual grains of the replaced rock, the proportional amount of such residual material showing all variations. Dolomite grains, even where partly replaced, tend to preserve their rhombic (cleavage) outlines (pl. 11, *A*). The microscopic quartz grains making up the chert form a mosaic in which the individual grains tend toward prismatic elongation (pl. 10, *A*, *B*), regardless of whether the replaced rock is limestone, dolomite, or sandstone. Where the quartz grains have not developed so abundantly as to interfere with one another, they commonly appear as well-formed microscopic crystals enclosed within the limestone or dolomite grains. Part of the silica that is added to the mineralized sandstones crystallizes as secondary enlargements of the sedimentary quartz grains, but there is likely to be some development of prismatic jasperoid in the interstices (pl. 10, *B*).

Certain of these cherts that replace calcareous beds show cross sections of fossil ostracodes, preserved as a stippling of minute dolomite granules in the chert. These fossils may show in chert that has replaced dolomite, whereas adjacent remnants of unreplaced dolomite, though they undoubtedly contain the fossils, do not show them, or else show them rarely and very imperfectly. It is of interest to observe that these fossils have withstood two replacements—first of limestone by dolomite, and second of dolomite by chert.

Feldspar (adularia; $KAlSi_3O_8$).—The authigenic occurrence of feldspar in limestones and dolomites of the Everton formation has already been described (p. 32). The same type of feldspar is found in the ore deposits, either in the jasperoid chert, where it may be interstitial or included in the quartz grains (pl. 11), or in the residual clay (beidellite) that has segregated along the bedding planes or interstitially to the constituent grains of the country rock. Feldspar is commonly developed where the jasperoid and clay minerals are mixed together in the same band or segregated mass. It also occurs within secondary enlargements of sedimentary quartz grains in certain sandstones that have been mineralized (pl. 10, *B*).

The feldspar of the ore deposits is perhaps more predominantly rhombic in outline than that found in the unmineralized sediments (pl. 10, *B*). The rhombic shape characterizes that type of potash feldspar known as adularia (see fig. 3, A, B). The average size of the grains, as in the sediments, is between 0.01 and 0.05 millimeter, and the maximum about 0.12 millimeter. Although the greater part of the feldspar is optically identifiable as orthoclase, a certain percentage is microcline, some of which is apparently untwinned, as in the sediments. The microcline does not possess crystal boundaries of its own and is probably of detrital origin, but it may have a euhedral border of orthoclase, formed at a later time.

The close similarity of the feldspar in the jasperoids to that in the sediments suggests the possibility that the former is residual from the latter. If so, the replacement of limestone, dolomite, and sandstone around the feldspar crystals has been highly selective, for the crystal boundaries of the feldspar in the jasperoid are as perfect as those in the unaltered sediments. On the other hand, the association of adularia with ore deposits is widespread and well known,[26] so that there is no special reason to question the contemporaneity of the feldspar with the jasperoid. Corroborative evidence for such contemporaneity was found in thin sections from the Red Cloud and Silver Hollow mines that show replacement veinlets of jasperoid, with a little adularia, cutting through dolomite and dolomitic sandstone in which no feldspar can be found.

At a few mines there are certain highly feldspathic beds whose relations to the associated ore deposits are uncertain. A typical occurrence, at the Salina mine, is in the form of a 4-foot bed in the dolomite layers adjacent to the ore deposit, extending at least 30 feet from the ore run. The bed appears to be a white opaque porcelaneous chert containing small lenses of embedded dolomite rhombs, but under the microscope the "chert" is found to be composed of adularia and clay (beidellite), with only a minor amount of fine equidimensional chert. The clay particles tend to aggregate into lenses having parallel optical orientation. The dolomite bed underlying this feldspathic layer has been irregularly invaded by the white feldspar rock along a zone of slight crumpling, the unaltered dolomite showing both sharp and gradational boundaries against the feldspathic material. The latter is finely pyritic and locally contains grains of dolomite that are larger and grayer than those in the invaded rock, but it may in turn be contained as small nondolomitic flecks and lenses in purer masses of the gray dolomite. The evidence is somewhat conflicting as between later replacement of the invaded dolomite by the feldspar and the mechanical squeezing of the feldspar rock into the underlying dolomite while all the materials concerned were more or less plastic. The first interpretation is favored. The replacement, however, apparently bore little relation to the structural lines of the ore deposit and may possibly have had no genetic connection with the mineralization, although an opaque white chert, of very similar appearance, of which no specimens were taken for microscopic examination, is closely associated with the ore in the adjacent ore body.

Quartz (SiO_2).—Although rather widespread, quartz is nowhere very abundant in the ore deposits. Quartz of an early generation accompanies the chert and is simply the form in which the silicification was manifested where crystallization was allowed to take place in open vugs. This quartz is clear, is finely crystalline (from pinhead to microscopic size), and forms a thin initial film in the vugs. Where it is not covered by later minerals the crystal faces are very perfect, but underneath a layer of sphalerite or pink spar the crystals are poorly formed and many of them are rounded. Possibly some of this quartz in certain low-grade replacement deposits in siliceous dolomite where a chert phase is not developed may represent residual but recrystallized silica after solution of the dolomite.

Quartz of a second generation, later than the main zinc and pink-spar phase of the mineralization, has been developed in a number of the deposits. This quartz is coarser-grained, the crystals ranging from a quarter of an inch to 2 inches in size, although crystals larger than 1 inch are not common.

All the quartz has crystallized as pyramids extending up from the surface on which the crystallization has taken place; the prism faces are either wanting or else very small.

Asphaltum (pitch).—Small black globules of asphaltum occur with the ores at the Iola and Michigan mines. At the Iola it is earlier than the calcite, which is apparently a product of the primary mineralization, and it has consequently been placed among the primary gangue minerals.

[26] See Lindgren, Waldemar, Mineral deposits, 4th ed., pp. 446–447, 1933.

SECONDARY MINERALS

ORE MINERALS

Smithsonite (carbonate, turkey fat, dry bone; $ZnCO_3$—Zn 52 percent).—Of all the minerals in the field smithsonite shows by far the greatest variety in form and appearance. The average carbonate miner of the district has learned to recognize the different types through experience, so that rarely is the ore overlooked. To a mineralogist unfamiliar with the field, however, some of the varieties would be very puzzling without chemical or blowpipe tests. In the following paragraphs the different varieties are described under separate heads.

Gray carbonate (sometimes called "crystalline" carbonate): This is the most widespread and characteristic variety, and the one that has been of greatest commercial importance. It has crystallized in vugs in the form of reniform, botryoidal, mammillary, or stalactitic masses, whose free surfaces commonly show a pearly-gray, flesh-colored, purplish, or brownish "bloom", similar to that on a grape before it has been destroyed by handling. When these masses are broken they show a fibrous structure perpendicular to the free surfaces. Gray carbonate has been formed by precipitation from solution, the zinc having been transported for a short distance from its primary occurrence in sphalerite. Carbonate with the same physical form and with apparently the same mode of origin may locally show some color other than the usual gray. Besides the yellow and red modifications referred to below, it may be brown or sometimes black.

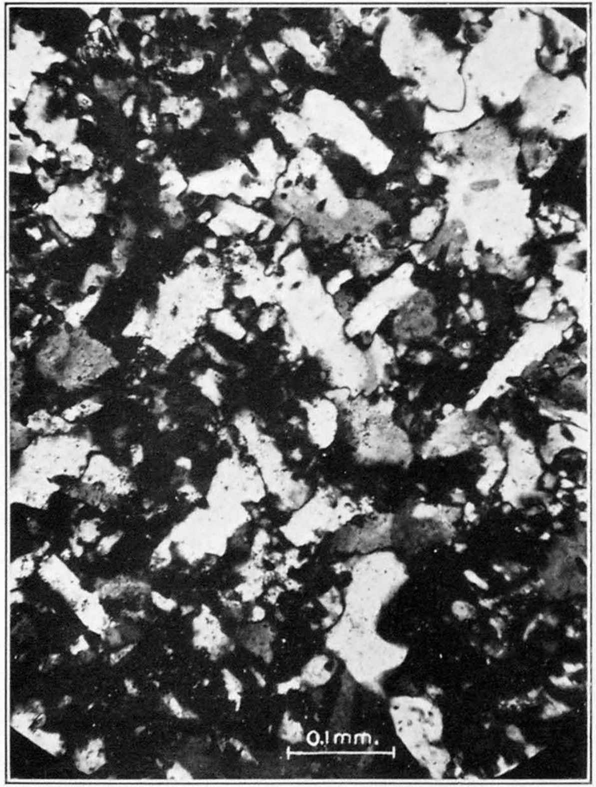
A partial analysis of gray carbonate from the Philadelphia mine, made by J. G. Fairchild, shows 0.32 percent of cadmium. This element is probably isomorphous with zinc in the carbonate, for examination under the microscope at oil-immersion magnifications reveals no impurities. Smelter assays of carbonate ore (carload lots) from the Philadelphia, Capps, Big Hurricane, and Sure Pop mines report 0.23, 0.20, 0.14, and 0.11 percent of cadmium, respectively.

Turkey fat: This variety is similar in form to the gray carbonate but differs in its bright-yellow color. In places it forms the cores of stalactites that are composed otherwise of gray carbonate. More rarely the two forms may be interbanded. Examination of thin sections of turkey fat under extremely high magnification discloses minute mosslike inclusions of a bright-yellow color which are believed to be amorphous cadmium sulphide. These inclusions may be concentrically banded on a fine scale. The actual amount of cadmium present as sulphide is extremely small, however—so small that the sulphur cannot be detected by ordinary methods of analysis. The cadmium that is found upon analysis to be present in appreciable amount is more probably in the form of carbonate, isomorphous with the zinc carbonate. In support of this statement, partial analyses of two samples of turkey fat, made by J. G. Fairchild, are listed below, and with them one of gray carbonate for comparison.

Partial analyses of turkey fat and gray carbonate

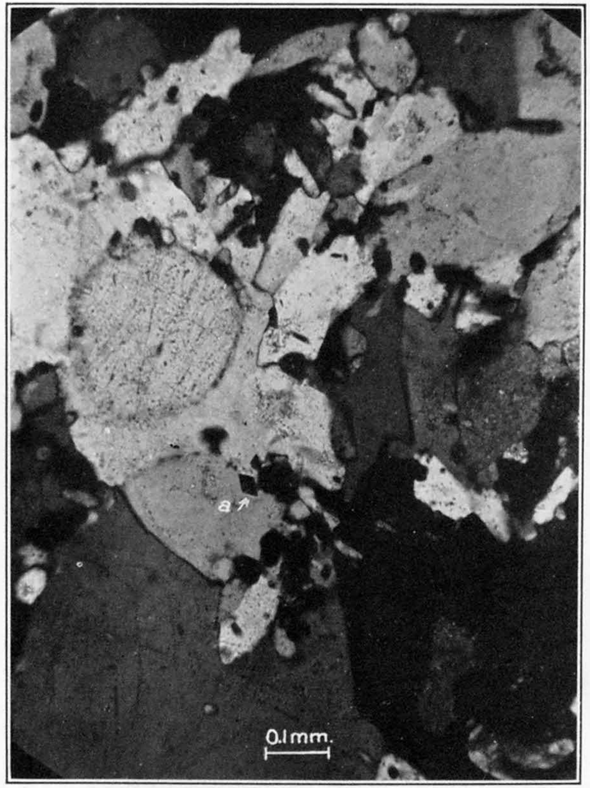
	Cd	S	Fe
1. Turkey fat, Monte Cristo mine	0.26	None	1.55
2. Turkey fat, Philadelphia mine	.24	None	Trace
3. Gray carbonate, Philadelphia mine	.32	Trace	Trace?

Samples 2 and 3 were from the core and peripheral regions, respectively, of a large stalactite. The iron in sample 1 was segregated as some form of oxide



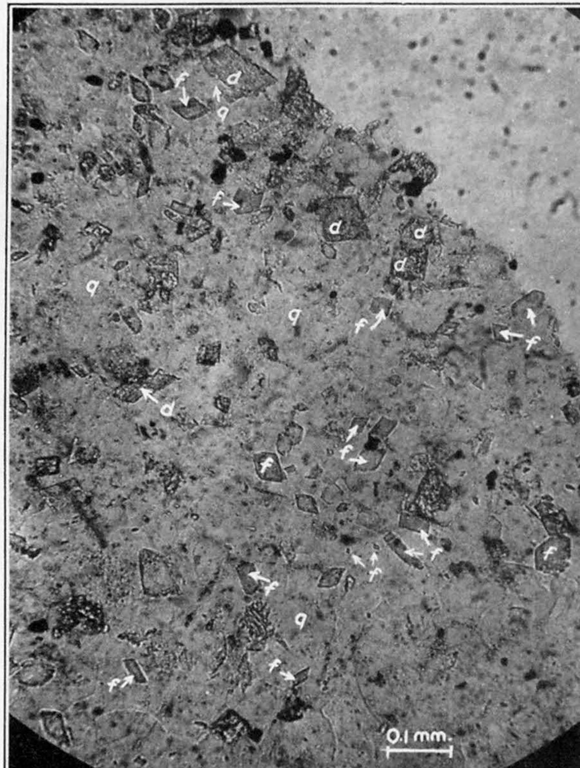
A. PHOTOMICROGRAPH OF JASPEROID FROM LUCKY DOG MINE.

Shows prismatic development of quartz grains.



B. PHOTOMICROGRAPH OF MINERALIZED SANDSTONE FROM LUCKY DOG MINE.

Shows secondary enlargement of rounded sand grains, the development of prismatic jasperoid replacing the sand grains, and a characteristic crystal of adularia (a) inside of secondary quartz.



A

B

PHOTOMICROGRAPHS OF DOLOMITIC AND FELDSPATHIC JASPEROID FROM LUCKY DOG MINE.

A, Plain light; *B*, crossed nicols. *d*, Dolomite; *f*, feldspar; *q*, quartz. Prismatic development of quartz is not as marked as in plate 10, *A*.

along certain bands where it could not be easily separated from the sample. These analyses are too few to warrant any sweeping conclusions, but it is interesting to note that the sample of gray carbonate contains more cadmium than either of the samples of turkey fat, and that traces of sulphur were detected in the gray but not in the yellow variety.

Sealing-wax carbonate: This, a lustrous red form that crystallizes similarly to gray carbonate, was found only at the Monte Cristo mine. It is there a very minor component of the ores.

Black carbonate: When sphalerite changes to smithsonite in place a blackish cellular form of carbonate is the normal product. The alteration begins along certain cleavage cracks of the sulphide, and usually during the later stages of the oxidation much of the remaining sphalerite is leached out, leaving a skeletal network of thin blackish carbonate plates that reproduce the cleavage structure of the original mineral. This platy structure is liable to be modified or in part destroyed by the solution that removed the residual sphalerite.

Honeycomb carbonate: This is a variety intermediate in character between black and gray carbonate. It has the platy structure of the black carbonate, but the plates are composed of gray carbonate. The mode of origin is a combination of the two processes which, acting alone, produce the black and gray types. If the residual plates formed along the cleavage of the sphalerite are increased in thickness by precipitation of gray crystalline carbonate from solution, without the platy structure being destroyed, the result is the distinctive-looking type called honeycomb carbonate.

Rock carbonate: In a few places carbonate has replaced the country-rock dolomite or limestone. The resulting product is a gray or flesh-colored rocklike form, distinguishable only by its weight.

Pink-spar carbonate: This term is used to describe smithsonite that has replaced pink-spar dolomite, and the variety should not be confused with the pink spar itself. All stages are represented between a mere coating of the pink spar by zinc carbonate and complete replacement. The final product of complete replacement is a dull-lustered salmon-colored or flesh-colored form of carbonate, pseudomorphic after pink spar but with the crystal forms somewhat modified in the process.

Zinc carbonate has also formed simply as a coating on top of pink spar. Such carbonate is commonly of the gray crystalline type already described. The pink spar may be leached out later, leaving a hollow carbonate shell that preserves the crystalline shape of the pink spar.

Replacement of crystalline calcite by smithsonite is rare. The only example observed by the writer was in a small vug in the Monte Cristo mine, where a flesh-colored opaque form of smithsonite is pseudomorphic after rather fine "dogtooth" (scalenohedral) crystals of calcite. A unique specimen in the collection of the late C. E. Siebenthal, labeled as from the Morning Star mine at Rush, is a rather spongy shell of gray carbonate in the form of a large scalenohedral crystal of calcite. The external form of the crystal has been preserved, within which is a network of carbonate plates, reproducing the cleavage planes of the original calcite.

Rod carbonate: Several mines, chiefly in the northern part of the district, contain small quantities of smithsonite in the form of aggregated salmon-colored or flesh-colored rods. These rods are of about the size and shape of fly eggs.

Eggshell carbonate, flour carbonate, porcelain carbonate: This variety has apparently been confused with hydrozincite. The eggshell carbonate occurs as thin chalky-white layers banded in gray carbonate. When examined under the microscope the "shells" are found to be made up of a multitude of small crystals, all oriented with their *c* axes perpendicular to the plane of the shell. Fragments of the shell give perfectly centered uniaxial interference figures. Flour carbonate is usually found filling pockets in the ore. It is the same as the eggshell variety except that the crystals, which make up the pulverulent mass, show haphazard orientations relative to each other. The material is too fine-grained to obtain optical interference figures, but the indices of refraction are those of smithsonite rather than of hydrozincite. Where the flour carbonate is not pulverulent, it may be appropriately called porcelain carbonate.

Pine-bark carbonate: At four mines in Newton County—the Bald Hill, Brewer, Ponca City, and Lamar—a peculiar type of carbonate is found, rather abundantly at the Bald Hill. It is gray or brownish and is made up of rather loosely joined concentric shells. The ore, when broken, resembles slabs of pine bark. It has formed by replacement of Boone limestone on the borders of ore-bearing fissures, the layering being parallel to the borders of the fissures. Apparently limestone rather than dolomite walls have something to do with determining the conditions under which it is formed.

Rhombohedral carbonate: A rare form crystallizes in rhombohedrons about the size of a pinhead. The form resembles that of crystalline dolomite, but the crystals are transparent and have a more brilliant luster. The crystals are usually colorless, but at the Starkey mine they are yellow.

Hydrozincite ($2ZnCO_3.3Zn(OH)_2$—Zn 59.5 percent).—Hydrozincite is rare in northern Arkansas, having been identified at only the Cane Spring and Marguerite mines, where it is sparingly developed. In the Branner and Adams reports the eggshell and flour types of zinc carbonate were apparently identified as hydrozincite, owing to the small amount of water that they commonly occlude. Microscopically, however, their properties are those of smithsonite, as pointed out above.

Calamine (zinc silicate; $(ZnOH)_2.SiO_3$—Zn 54.2 percent).—Calamine is an important oxidized ore mineral of zinc, especially in the Zinc district. A great part of it occurs in colorless, flesh-colored, brown, or black crystals. The black silicate, like black carbonate, is formed by alteration directly from sphalerite, without intermediate transportation in solution. At the Ponca City mine, in the Ponca district, some of the crystalline calamine is yellow, owing presumably to a small amount of occluded cadmium sulphide. Masses of silicate, where they develop in open vugs, resemble in shape those of gray carbonate formed under similar conditions. Locally calamine has replaced pink spar, preserving the crystal shape of the spar, or it has replaced jasperoid chert adjacent to the mineral-bearing pockets, yielding a flesh-colored product of the same texture as the replaced chert.

Tallow clay.—Tallow clay, in its purest form, is a brownish-red to orange-colored, locally white clay of very fine-grained texture, resembling tallow or lard in consistency. Upon drying it shrinks greatly in volume and usually breaks up into many small pieces that show a conchoidal fracture. Its usual mode of occurrence is as fillings of pockets in oxidized ore deposits. Tallow clay from Arkansas has been cited[27] as a zinc-bearing clay of indefinite composition, in which the zinc is supposed to be present as a silicate, resembling calamine. Three analyses for zinc, made by J. G. Fairchild in the chemical laboratory of the United States Geological Survey, bear out this statement, as follows:

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[27] Adams, G. I., Zinc and lead deposits of northern Arkansas: U.S. Geol. Survey Prof. Paper 24, p. 40, 1904. Branner, J. C., The zinc and lead region of north Arkansas: Arkansas Geol. Survey Ann. Rept. for 1892, vol. 5, p. 266, 1900.

Brownish-red tallow clay, Capps mine, Rush district, 0.6 percent Zn; light-gray tallow clay, Gloria mine, Zinc district, 17.2 percent; flesh-colored tallow clay, Silver Hollow mine (lower level), Rush district, 22.0 percent. Practically all of the zinc was extractable by treating the clays with acid. Reddish varieties of the clay resemble purer specimens of the residual clay that is left by the weathering of limestone, and this seems to be the origin of a certain component of the material under discussion. It has been carried by water, probably in colloidal suspension, to the vugs, in which it was deposited in combination with the zinc-bearing component.

Cerusite (lead carbonate; $PbCO_3$—Pb 77.5 percent).—On the whole cerusite is of no great importance in northern Arkansas. At a few mines, however, it is present in small amounts, and at the Bald Hill mine commercial stopes were opened in lead carbonate. It occurs here as white or cream-colored fibrous crystals with a silky luster. At the Pigeon Roost mine flesh-colored cerusite has replaced pink spar disseminated in the chert. Elsewhere in the region cerusite occurs sparingly as an ashy or chalky white coating of galena, or as gray to white crystals associated with galena.

Anglesite ($PbSO_4$—Pb 68.3 percent).—Although anglesite may be of commoner occurrence in the region than here indicated, it was identified only at the Tallow Clay mine, where it forms white chalky masses.

Pyromorphite (green lead ore; $3Pb_3(PO_4)_2.PbCl_2$—Pb 76.3 percent).—Pyromorphite occurs as an olive-green stain at several mines in the Dodd City and upper Cave Creek districts, and at the Pigeon Roost mine it is present in the form of minute radiating barrel-shaped crystals.

Wulfenite ($PbMoO_4$—Pb 56.4 percent, Mo 26.2 percent).—Wulfenite is represented in the Mississippi Valley, so far as known, by a single occurrence in northern Arkansas, at the Shiras mine. It forms resinous yellow crystals as much as a quarter of an inch across, in company with crystalline cerusite, on the surfaces of galena masses in residual red clay.

Malachite ($CuCO_3.Cu(OH)_2$—Cu 57.3 percent).—The association of specks of the green carbonate of copper, malachite, with black zinc carbonate or black silicate is very common. Such a combination has altered in place from specks of chalcopyrite in or on sphalerite. When, under conditions of oxidation, the metals go into solution and are transported any distance from their original site of deposition as sulphides, the copper is usually lost, although the zinc may be reprecipitated in one of several forms of carbonate or silicate, already described. Where the copper comes down again it is in the form of aurichalcite, the double carbonate of zinc and copper. At the Tomahawk copper mine, where the primary ore consists of pyrite and chalcopyrite, unlike that at any other mine or prospect in the district, the oxidized ore is green fibrous malachite in a matrix of brown and red iron oxide.

Azurite ($2CuCO_3.Cu(OH)_2$—Cu 55.1 percent).—The azure-blue type of copper carbonate forms under the same conditions as malachite in this district, but it is rare.

Aurichalcite ($2(Zn,Cu)CO_3.3(Zn,Cu)(OH)_2$).—Aurichalcite is rather common as small pale-green pearly globules, lining cavities. The globules are made up of clusters of thin scales.

GANGUE MINERALS

Calcite (tiff; $CaCO_3$).—At the Monte Cristo mine and to a less extent at two or three others in the Rush district calcite has crystallized later than zinc carbonate in the form of white, poorly formed disk-shaped crystals (flat rhombohedrons) that commonly aggregate into rosettes, or, where they are more closely packed, into globular forms that resemble hailstones. A white translucent stalagmitic type, which is very abundant at the Monte Cristo mine, probably represents another form of the same crystallization. So closely does this type resemble in shape botryoidal forms of gray zinc carbonate that much of it has been mined out and lies in an "ore pile" on the dump. The calcite is whiter and more "watery" in luster than the zinc carbonate.

Aragonite ($CaCO_3$).—A specimen picked up on the dump of the Monte Cristo mine shows long pointed columnar crystals of aragonite formed on top of gray zinc carbonate. Aragonite also occurs at the Summit Home prospect and at the Omeara mine.

Gypsum ($CaSO_4.2H_2O$).—At several widely scattered mines gypsum occurs in vugs as clear tabular crystals. It may also occur in earthy masses where waters containing sulphuric acid from oxidation of sulphide minerals, especially pyrite, have traversed calcareous rocks.

Epsomite ($MgSO_4.7H_2O$).—Although probably a common constituent of the efflorescences in old mines, epsomite was identified only at the Red Cloud mine, where it forms white hairlike soluble crystals on the mine walls.

Goslarite ($ZnSO_4.7H_2O$).—Goslarite was not identified by the writer but is recorded in earlier published reports on the district. It doubtless occurs in efflorescences on some of the old mine walls, similarly to epsomite.

Copiapite (basic ferric sulphate, perhaps $2Fe_2O_3.5SO_3.18H_2O$).—Small sulphur-like globules from oxidizing portions of the pyritic body on the upper level of the Silver Hollow mine have been identified as copiapite.

PARAGENESIS

As the order in which the different minerals were deposited is believed to have an important bearing on the origin of the ores, considerable attention has been paid to this phase of the mineralization.

As was pointed out in the discussion of the Everton lithology, the process of dolomitization is believed to have been related to sedimentation and not to ore deposition. At any rate, it everywhere preceded the silicification that constitutes the earliest recognized process definitely connected with the mineralization. As the usual method of determining order of crystallization, by noting the order in which minerals have crystallized on top of one another in vugs, is not applicable in determining the relation between dolomitization and silicification, some of the criteria used may be mentioned.

1. At numerous places in the Everton shatter breccias show fragments of dolomite in a matrix of chert. The boundaries between fragment and matrix may be sharp, especially in the fine-grained dolomites, or they may be gradational in the coarser-grained dolomites, where a coarser porosity has favored penetration and replacement of the fragments by the silica-bearing solutions. This general difference in the type of boundary indicates that the difference in porosity of the fragments existed before the silicification.

2. If silicification preceded dolomitization, then a breccia in which chert forms the matrix for dolomite fragments must have been preceded by a breccia in which chert formed a matrix for limestone

fragments. No examples of the latter type of breccia are known in the district. It is inconceivable that, had such a breccia existed, all of it should have been later completely dolomitized. Furthermore, where limestone of the Everton formation has been mechanically deformed, it seems to have yielded by shearing and by being squeezed, rather than by shattering into fragments, so that breccias of the type that is common in the ore bodies must have been produced in dolomite rather than in limestone.

3. Banding of limestone by dolomite along bedding planes in the Everton formation is characteristic, and in extreme cases the two rocks are finely interbanded in nearly equal amounts. Banding on a similar pattern of limestone by chert is unknown in the field; the boundary between limestone and chert is characteristically indefinite. Hence in the numerous examples where dolomite and chert are interbanded the dolomitization must have preceded the chert, which came in at a later epoch and selectively replaced the limestone.

4. In places chert bands between dolomite bands grade laterally, within a few feet, into limestone bands between dolomite bands. If the dolomitization came later than the chert it should have replaced the limestone bands that are a continuation of the chert bands, as well as the limestone bands that lay between the chert bands.

The order of crystallization during the period of primary mineralization, as should be expected, shows overlapping of certain minerals onto others, and variations from the normal order may appear in certain deposits. The usual paragenetic order, however, is as follows:

1. Jasperoid chert, fine drusy quartz, and probably feldspar.
2. Sphalerite and galena.
3. Pink-spar dolomite.
4. Chalcopyrite and enargite.
5. Coarsely crystalline quartz (¼ to 2 inch crystals).
6. Calcite.

Where chert and fine drusy quartz are present in the deposit they are the first, or among the first, to crystallize. They are simply two different expressions of the same process, the crystalline quartz being the form assumed where the crystallization occurs in open vugs, whereas the chert has in large part replaced sediments.

Limestone is more susceptible to replacement by chert than dolomite and in many localities has been replaced selectively. That dolomite has been frequently replaced, however, is substantiated in several ways. Veins or beds of chert parallel to the bedding of dolomite may represent a later replacement by chert of limestone that had previously escaped replacement by dolomite, but where chert veins, with irregular gradational borders, crosscut the bedding of the dolomite, the evidence is strong for replacement of dolomite directly. The replacement has occurred along crosscutting cracks. Very rarely the chert vein may preserve the banding of the dolomite parallel to the bedding by alternations in intensity of the blackness of the chert. Where the replacement occurred on a finer scale, the chert veinlets may wander about aimlessly in the dolomite, expanding, contracting, and dying out abruptly, with clear-cut boundaries in some places and gradational boundaries in others. The result may be a peculiar mottled rock, superficially resembling a breccia, as is well exemplified on the lower level of the Silver Hollow mine. In a few places the chert has replaced sandstone.

In some deposits where the chert has developed as a matrix to breccias, it probably represents in part a direct crystallization in open cracks. In such deposits it is impossible from ordinary inspection to distinguish between chert that has formed in an opening and chert that has replaced the outer edges of a breccia fragment. In fine-grained dolomites the replacement by chert along certain cracks or along the borders of breccia fragments may simulate a simple fracture filling, inasmuch as the boundary between replacing chert and replaced fine-grained dolomite is generally sharp.

The only minerals that overlap the period of crystallization of chert and quartz to any considerable extent are sphalerite and probably galena. While the mass of the sulphide crystallization was later than the silica, wherever sphalerite is disseminated in chert it is believed to have crystallized contemporaneously with the chert. This conclusion is supported by the fact that where chert is banded in dolomite or crosscuts it in replacement veinlets it may carry disseminated sphalerite, whereas the adjacent dolomite is commonly barren. It seems more reasonable to assume that the silica and zinc were introduced along the same channels at practically the same time than that the sphalerite replaced chert in preference to dolomite at some later time. That the silica was probably never in the state of a colloidal precipitate, in which form it might have been pervious to later zinc-bearing solutions, is indicated by the common occurrence of fossil ostracodes in chert that has replaced limestone. These fossils should have been destroyed had the enclosing chert ever gone through a plastic stage.

If the inference is correct that the feldspar in the jasperoid chert was formed during the ore mineralization, it probably is contemporaneous with the chert, for it has not been found with the later minerals.

Minerals that follow the chert in the paragenetic sequence occur in it in the form of bedding veinlets, crosscutting veinlets, and replacement pockets. Evidently the silicification made the rock impervious, so that later solutions were confined to comparatively open channels.

The relation between sphalerite and galena is not known, as they have never been observed together in the same vug. Where they occur together in solid masses, they are intergrown in such a way as to suggest essential contemporaneity. At the Golconda mine the tendency of galena to occupy the centers of certain veinlets, with sphalerite along the borders, suggests that the galena may have here been somewhat later, but this is the only example of its kind that was observed.

Pink-spar dolomite is almost contemporaneous with sphalerite but tends to be slightly later. Thus, while in a large number of deposits the two are intergrown in such a way as to indicate that they crystallized at practically the same time, in others pink-spar crystals have formed on top of sphalerite crystals, or pink spar forms the inner layers of drusy veinlets and pockets that contain sphalerite in their outer layers, and especially along their lower sides, indicating that the sulphide has averaged earlier than the spar. It is probable that the period of deposition of the pink spar covered a somewhat longer time than that of sphalerite.

Where pink-spar dolomite and chert are banded together along the bedding planes in Everton dolomite the pink-spar bands, which may or may not carry sphalerite, very commonly lie above the chert bands. In cross section the chert bands are usually separated from the overlying pink spar by sharp-cut straight lines (bedding lines), whereas their lower boundaries grade into the underlying dolomite. Where combined pink-spar and chert veins cut diagonally across the dolomite bedding the same relation of pink spar to chert is frequently found, although the boundary between the two is not so straight. If the pink spar and chert had crystallized simultaneously from the same solution it is difficult to see how they could have been segregated, under the force of gravity, so that the pink spar went above a certain line and the chert below it. If, on the other hand, the chert segregated first along its numerous bands, as is believed to be the case, then its imperviousness relative to the country-rock dolomite would tend to make the tops of chert bands the sites of maximum movement for later solutions, provided the rock were not completely saturated and provided, further, that the prevailing direction of water movement through the zone of deposition were lateral, with gravity as the dominant force acting. Such conditions would undoubtedly tend to concentrate the replacement by pink spar and sphalerite, effected by these later solutions, in zones immediately above the chert seams. In some deposits where pink spar is not very abundant, only sphalerite may occupy the position above chert bands, and in a few places at the Capps mine the late generation of quartz assumes this position. The occurrence of chert bands below bands of pink spar and sphalerite is best shown at the Capps mine. Most of such occurrences appear to lie outside of the richer ore runs. The occurrence of chert below replacement pockets of pink spar in sandstone has been observed but is not so common as where the country rock is dolomite.

Gray-spar dolomite is believed to have formed contemporaneously with pink spar, and especially during the later stages of pink-spar deposition. Some of the gray spar contains a small amount of chert, and some of it carries a little disseminated sphalerite, but the greater part of it is nonsiliceous and relatively free from sulphide. Seams of pink spar that occur in gray spar and that are believed to have formed contemporaneously with the gray spar are characteristically very lean or barren of ore. The evidence thus indicates that the gray spar was formed later than the main chert and sulphide mineralization. The common location of gray-spar replacement bodies on the borders of ore deposits is due to the invasion of fresh limestone by the mineralizing solutions at a relatively late stage in the period of mineral deposition. Had these particular solutions remained in the general channels followed by the earlier solutions, the dolomite would have been deposited as barren pink spar in cracks and bedding veins through the earlier formed chert.

Chalcopyrite normally occurs as small crystals on top of sphalerite or pink-spar dolomite crystals, but there are numerous deposits in which it may be embedded in one or both of these minerals, and in a few deposits (Roaring Hollow, Marguerite, Ruby, Turkey Fat near Maumee) it is rather narrowly limited in time to a period between the crystallization of the sphalerite and that of the pink spar. It may also be embedded in crystalline calcite, but nearly always in the earliest formed portions of crystals, at their bases. Although chalcopyrite may thus show considerable variation in its paragenetic relations, its position in the sequence of crystallization in a given deposit is likely to be fairly well defined. This position is usually the one given in the tabulation on page 119. Chalcopyrite is characteristically associated with sphalerite but has never been observed in close association with galena.

At the only locality where enargite is present it has crystallized on top of sphalerite crystals and is earlier than calcite. Its relation to the associated chalcopyrite, which shows the same relations to the other minerals, is not known.

A second generation of quartz was developed in several deposits at a period later than the chalcopyrite but earlier than the calcite. In places it is on top of pink spar, but very commonly the pink spar has been removed where the quartz has been deposited, indicating that it was unstable in the silica-bearing solutions.

The final mineral to crystallize during the period of primary deposition was calcite, in clear scalenohedrons or steep-sided rhombohedrons, more rarely in flat rhombohedrons.

The position of pyrite in the sequence is not known, owing largely to its modes of occurrence other than in open vugs. At the Lion Hill mine a small crystal was noted on top of crystalline chalcopyrite, and at a few other places pyrite has been observed on top of crystalline sphalerite, but these observations are so rare as to be of little value in placing pyrite in the sequence.

The single occurrence of marcasite in the northern Arkansas ores is earlier than the sphalerite (ruby jack) with which it is associated. It is possible, from the incomplete evidence available, that the marcasite may entirely antedate the zinc-lead stage of deposition; otherwise it appears to be fairly early in this stage.

REGIONAL DISTRIBUTION OF LEAD

Whereas the small amount of copper that occurs in the northern Arkansas region is more or less coextensive with the zinc in its distribution, the lead is restricted to certain districts. The three deposits in Washington and Benton Counties here described carry a little lead. The deposits of northern Newton County, more specifically those of the Ponca-Boxley, Little Buffalo River, and upper Cave Creek districts, are lead-bearing, and some of them have produced lead in commercial quantities. In northeastern Boone County lead occurs in small amounts at the Elixir, Low Gap, and Morelock prospects, in the West Sugarloaf Creek-Malden Creek district, but is not especially conspicuous. East of this district, however, throughout the Dodd City and Short Mountain districts, in northern Marion County, lead is fairly prominent. It occurs in most of the deposits of these districts and attains commercial proportions at several of the mines. It is generally accompanied by zinc and is subordinate to the zinc in quantity. The other districts of northern Marion County, including the Georges Creek-Jimmie Creek district and the Big Music Creek-Sister Creek district, contain scattered occurrences of lead, but nowhere is the amount large enough to be of very great commercial value. Lead has been found at several deposits in northern Baxter County, and the Shiras mine has produced a few tons of galena. A few of the prospects in Sharp and Lawrence Counties likewise contain galena.

Lead is conspicuously absent from the Zinc district and from the districts in Marion and Searcy Counties that lie south of Crooked Creek. Within the districts mentioned only two occurrences of lead are known to the writer, and both of them are insignificant. One of these, reported on good authority, is at the Rhodes-Manchester mine, in the Zinc district. The other is at the Water Creek lead prospect, in the Water Creek district. It is just those districts that are lacking in lead that have yielded the greater part of the zinc produced in the northern Arkansas region.

Whatever the factor or factors that have determined the present geographic distribution of lead may be, the geologic horizon of the deposit is apparently not one of them. At some place or other in the northern Arkansas region lead occurs in every formation that is known to be ore-bearing within the region.

OCCURRENCE OF THE PRIMARY ORES

GEOLOGIC HORIZON

The more productive mines and more promising prospects of the region are in either the Everton formation or the Boone formation. With the latter may be grouped three or four deposits of the Ponca district that lie at the very base of the Batesville sandstone. Low-grade deposits also occur in the Powell and Cotter dolomites. The Smithville and Black Rock formations, the first of which, according to Bridge and Ulrich,[28] contains the deposits of Sharp and Lawrence Counties, appear to occupy the same position in the stratigraphic column as the Everton formation to the west, but Ulrich, on the evidence of fossils, considers that they are older. The ore deposits contained in the Smithville are not as rich as those in the Everton and Boone, nor have they been as extensively exploited. Some of them, however, have been moderately productive.

The Everton formation is the horizon of the ore in such productive districts as Rush, Zinc, and Water Creek. In addition, it contains most of the scattered deposits that occur throughout the region. Of the 300 or more mines and prospects examined in the western part of the field, west of Sharp and Lawrence Counties, 70 percent are in the Everton. The percentage of productive mines is considerably less, however, owing to the large ratio of productive mines to prospects in the Boone formation. Apparently all horizons of the Everton have been mineralized at some place or other.

Deposits in the Boone are much fewer, although a much larger percentage of them have been productive. Most of these are in Newton County. In Marion and Boone Counties, between Kingdon Springs and Zinc, there are four deposits, not very closely associated, in the St. Joe limestone member. The most productive of these is the Coker Hollow mine, near Zinc. The Spier mine, near Yardelle,

[28] Bridge, Josiah, personal communication.

and the Big Hurricane mine, which lies in Searcy County just across the Newton County line, are both on faults that bring the Boone into contact with the Everton at the horizons of the ore deposits.

At the Brewer, Kilgore, and Beechwood mines and possibly at the Ponca City mine, all in the Ponca district, lead ore occurs in the basal clay of the Batesville sandstone, in association with lead and zinc ores in the immediately underlying Boone.

Although the Powell dolomite has been extensively prospected and shows considerable evidence of ore at widely scattered localities, it does not contain a single important mine. Mineralization is confined chiefly to a single bed 7 to 10 feet thick, that lies about 60 feet above the base of the formation. Mines and prospects in this bed, the so-called †" Black Ledge," are scattered irregularly along its outcrop in northern Marion County and northeastern Boone County, north of Crooked Creek. In northeastern Boone County a similar ledge, not quite so thick, lying about 30 feet above the base of the Powell, contains deposits in several places. Outside of these two horizons, mineralization in the Powell is very meager. The Bear Hill mine is said to have carried mineral throughout the depth of the shaft, the bottom of which penetrated for some distance into the Powell. Although the workings were inaccessible to the writer, so that this statement could not be verified directly, the lithologic character of the chat pile would indicate that much of it was Powell dolomite.

Deposits in the Cotter dolomite are very widely scattered but are nearly all of low grade. Perhaps the most promising is the Nishwitz prospect, near Bull Shoals Mountain.

The Smithville formation in Sharp and Lawrence Counties has not been studied in detail. It resembles the Everton in lithology but contains ore deposits that are of somewhat less importance. According to Bridge and Ulrich,[29] the ores are contained in the basal part of the formation.

The factor that has apparently determined whether a formation was mineralized or not is permeability to solutions. Of the two main ore carriers, the Everton is a dolomite (at least where mineralized to any extent) and the Boone is a limestone. Sandstones that are interbedded with mineralized dolomites of the Everton likewise carry ore. Finer-grained dolomites, limestones, and sandstones belonging to other formations are not so extensively mineralized. Hence the chemical composition of the rock would appear to have little weight, unless some less tangible chemical factor, such as organic content, were the determining factor, which seems improb-

[29] Bridge, Josiah, personal communication.

able. On the other hand, both the Everton and the Boone contain a considerable percentage of coarse-grained porous material, and both are recognized horizons for the movement of ground water under the present topographic conditions. The mineralized beds in the Powell are coarser-grained dolomites in an otherwise fine-grained formation. Apparently, then, the permeability to solutions has been the important factor. Undoubtedly structural conditions have cooperated with greater textural porosity to concentrate underground circulation into these two principal ore carriers, but because much of the final emplacement of the ore is effected by a process of replacement, the texture of the rock is of itself apparently very influential.

The Fernvale limestone is a coarse-grained, porous rock that is fairly well distributed, though irregularly, over the southern part of the Yellville quadrangle. The fact that it is nowhere mineralized is evidently a result of its thinness and its discontinuity. The same considerations apply to the limestones of the Silurian, which are even less extensive than the Fernvale.

STRUCTURAL RELATIONS OF THE ORES

The ore deposits of the district are developed either along faults, or else in runs and blanket veins. The fault deposits are few but include two or three very productive mines. The greater number of the deposits occur in the form of runs and blanket veins, which may be defined collectively as mineralized bodies that are irregular in ground plan and limited to certain beds or groups of adjacent beds in horizontal or gently tilted strata. The run differs from the blanket vein in that it shows an elongation in ground plan and is generally richer. There is no hard and fast distinction between them, however, as the run is simply a special linear development of a blanket vein along a line of maximum underground circulation, and very commonly the two are developed together. There are all gradations between them, and the distinction between them is applicable only to the end members of the series.

The shape of the run in ground plan may be fairly straight or it may be curved. It may be simple, or it may have numerous prongs. Locally, as at the Capps mine, several adjacent runs may parallel one another as parts of a structural system, but usually there is no system. The runs are localized along lines or zones of very slight structural break that have formed channels for the movement of underground solutions. Any sudden change of dip, however slight, may produce the requisite amount of shattering along the axis of the bend. In places the only break is an insignificant fracture or zone of fracturing, without displacement, that may be limited to the ore-bearing beds. When the ore is removed the fracturing may show on the roof of the stope, or on the other hand all evidence of it may be removed—as has been the case at the Gloria mine, at Zinc, to cite a typical example. In other places the character of the break may be more pronounced, as where the rock is shattered along the axis of a minor syncline, anticline, or monocline. The monocline in particular seems to offer very favorable structure, and a drop of 2 or 3 feet, if the movement is adjusted within a rather narrow belt, may produce a rich run. (See fig. 8.) Where such small structural features have been so important in determining the conditions that are favorable for ore deposition, it seems that irregularity as to trend, continuity, and tenor of the deposits is to be expected.

The richer deposits of the district have commonly been described as "breccias." Most of them might better be described as "shatter breccias." The movement of the fragments has been very slight, as regards both change in relative position and change in orientation. This is not obvious in the more massive beds, because in the absence of bedding lines and variations in lithology there are no criteria by which original orientations and positions can be determined. In many places, however, adjacent fragments of rock can be fitted together in their original positions, and the shattered stratum that makes up the breccia can be followed laterally to a point where it is unbroken (fig. 8). There is, of course, bound to be some random orientation of fragments in certain parts of the ore deposits as a result of the movement to which the shattering is due, and there is in addition a certain amount that can be attributed to slumpage as a result of solution, probably during the mineralization, through the shattered deposit. These more pronounced breccias grade into the shatter breccias and are subordinate to them in importance as ore carriers. Brecciation that was produced by solvent effects of the ore solutions is especially prominent in the few deposits that occur in the St. Joe limestone, as exemplified in the Coker Hollow mine.

Although fault breccias and solution breccias that antedated the ores have not generally been ore carriers, they are conspicuously associated with the ore deposits. In the Rush district most of the productive runs are directly connected with the Rush Creek, Monte Cristo, or Silver Hollow faults (pl. 4). In the Cave Creek district the Bald Hill and Confederate mines lie near the Confederate fault. Owing to the mashing of the rock along fault planes, with consequent destruction of all openings and perhaps also with the development of a clay gouge, the actual fault breccia is unfavorable for deposition. On the other hand, the shattering induced by slight movements in the rock adjacent to faults produces structural features that are highly favorable to ore deposition. Any tendency toward the development of a matrix to the fragments, whether by simple mechanical grinding or by solution, is distinctly unfavorable to later ore deposition. It is probable that in the few important

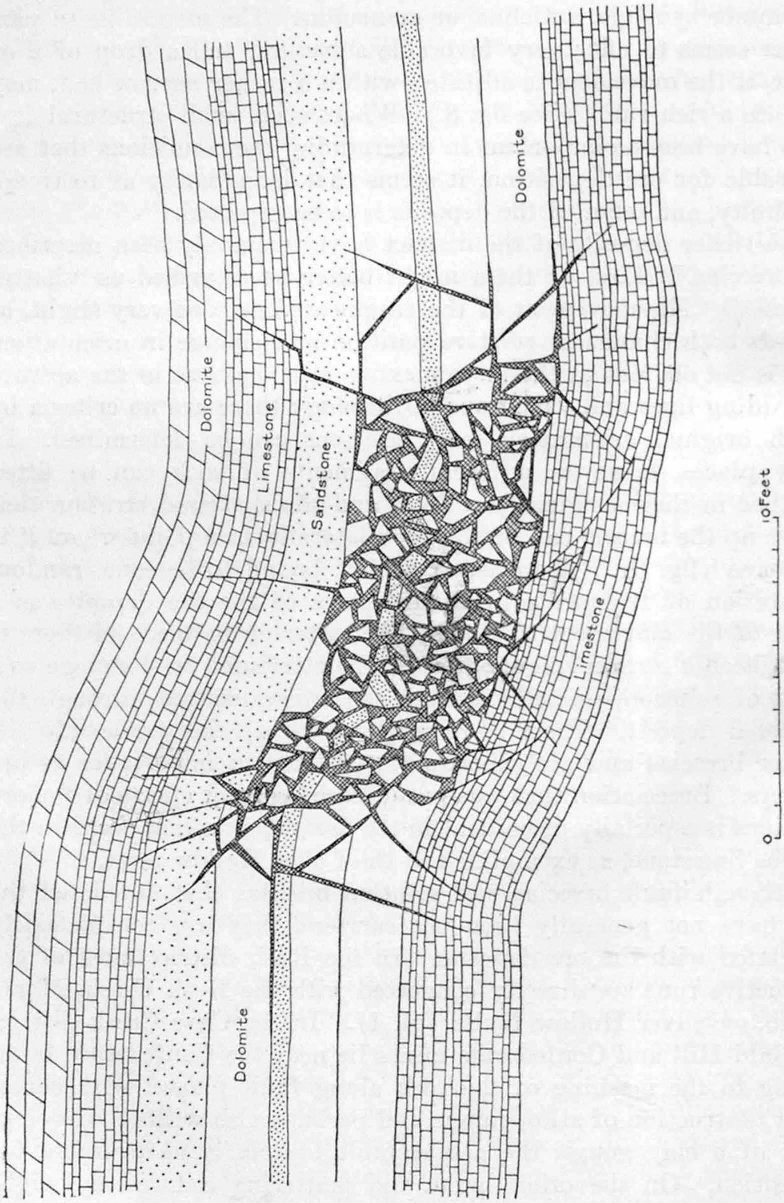

FIGURE 8.—Diagrammatic cross section of an ore run in fine-grained dolomite, formed along a small monoclinal flexure. Dark areas represent ore and gangue.

deposits developed along faults, all of which are at present inaccessible, much of the ore is developed in the shattered Boone limestone adjacent to the fault plane, rather than directly in the fault breccia.

The relation of premineral solution breccias to ore deposits appears to lie in the circumstance that shattering has been favorable to the development of both. Solution breccias of the type that occur at the Red Cloud and Lucky Dog mines are made up of dolomite fragments in a matrix of sandstone or dolomitic sandstone and were formed before the mineralization, to judge from the local occurrence of pink spar and less commonly sphalerite vugs in them, and from the development, on their very borders, of large elongated vugs which are clean and lined with pink spar but which should have been filled with sediment had the breccia developed later. Although the presence of sand in the matrix of the breccias would suggest a porosity that might have been favorable to the circulation of solutions and led to mineralization, it appears that the shattered condition of the surrounding rock, in which solutions could move in spaces greater than capillary openings, was much more favorable. Possibly certain of the solution breccias that occur in ore deposits and that have been interpreted as the product of the ore solutions may have been produced in part earlier than the ore, but without the development of a matrix that would interfere with the later deposition of mineral matter.

None of the blanket-vein deposits of the district are very large. Many of them are simply the border edges of runs, the mineralization having been accomplished by seepage from the main channels along the runs.

SIZE OF ORE DEPOSITS

The Arkansas deposits are on the whole rather small, although in many of them the full extent has not been revealed by development. The largest workings are located in the Rush district. The stopes in the Red Cloud mine are contained within an area that is about 800 feet long and 500 feet wide, although only the richer runs have been stoped out of this area. The stopes average 10 feet in height. The run on which the Philadelphia mine has been opened is more linear in shape; the opening is 1,200 feet long and mostly 10 to 30 feet wide, and the face of ore averages 6 feet in thickness, although the stope is usually somewhat higher. The main run on the lower level of the Silver Hollow mine is about 20 feet wide and 20 feet high and is reported to have been followed for about 800 feet. Other deposits of the Rush district approach these in size. Outside of the Rush district the stoped ground at the Sure Pop mine, on the left side of Water Creek, occupies a space that is about 500 feet long, less than 100 feet wide, and about 6 feet high. The Lucky Dog stope is 250 feet long, 75 to 100 feet wide, and 4 or 5 feet high. The stopes at the Gloria mine are contained within an area that is about 400 feet long and somewhat less than 400 feet wide; the thickness of the mineralized bed is 8 or 9 feet. At the Big Hurricane mine, where the ore deposit is in a fault rather than in the form of a run, the stoped block of ground is about 300 feet long, 20 feet wide, and 70 feet deep. These examples of some of the more productive mines give a general idea of the size of the larger deposits.

TYPES OF ORE DEPOSITS

All the mineralization of the northern Arkansas field is believed to have had a common origin. The character of the mineralizing solutions was evidently very uniform except for local variations in lead and silica content. Variations in lead content were not abrupt enough to produce distinct types of ore deposits, but the siliceous deposits, in their typical development, form a distinct class.

More important factors in producing different types of ore deposits were the structural conditions at the sites of deposition. These were determined not only by the character of the stresses that produced the breaks but also by the physical and to some extent the chemical characteristics of the rocks affected. Thus a dense dolomite breaks differently from a medium- or coarse-grained one, and a massive dolomite breaks differently from a thin-bedded limestone. A coarse-grained dolomite or a limestone is more affected by solution preceding and during ore deposition than a dense dolomite.

Whether the ore is formed by mechanical filling of openings or by replacement of preexisting rock is of no value in classifying the deposits, because these two processes have occurred together in nearly every deposit. However, one may be dominant over the other, dependent upon the physical and chemical characters of the rock. For purposes of classification these characters are believed to furnish more natural divisions.

The following classification of the northern Arkansas ore deposits is based entirely on the structure of the deposit and the composition and texture of the country rock:

- Deposits in faults.
- Deposits in runs and blanket veins:
  - Deposits in fine-grained dolomites.
  - Deposits in medium- and coarse-grained dolomites.
  - Deposits in Everton limestones.
  - Deposits in St. Joe limestone member.
  - Deposits in Boone limestone and chert.
  - Deposits in the basal clay of the Batesville sandstone.

The divisions of the above classification may be regarded as standard types around which the deposits in the northern Arkansas field tend to cluster. There are, however, many deposits whose characteristics are intermediate between those of the standard types.

Also, numerous deposits may be compounds of these types, as where fine-grained dolomite, medium-grained dolomite, and limestone are interbedded in the same deposit. Still, it is believed that descriptions of these simple types will be adequate for an understanding of the intermediate and compound deposits. In the description of each type certain trends in gradation to other types will be indicated.

The presence of sand in the dolomites and limestones has not materially affected the character of the deposit as determined by the constituency and texture of the calcareous component of the rock. Dolomitic sandstones behave much like medium-grained dolomites as regards the structural characteristics of the deposits formed in them. Pure sandstones are not ordinarily mineralized except locally where seams of sandstone are interbedded with dolomites and limestones. Where mineralized the sandstone is almost invariably silicified and contains the ore and gangue in modified cracks and irregular replacement pockets, much as a medium-grained dolomite does. It is not so susceptible to mineralization, however, probably as a result of its resistance to replacement.

DEPOSITS IN FAULTS

Although the deposits in faults form a relatively small class, they include such productive deposits as the Big Hurricane, Spier, Panther Creek, Keys Gap, and Brewer (lower workings), and a few other deposits of minor importance. With the exception of the Roy, which occurs in the Powell dolomite, all the mineralized faults are either in the Boone formation or else have the Boone as one of the walls. It is a rather striking fact that none of the numerous faults that cut across the Everton formation are mineralized, even though runs immediately adjacent to such faults may be rich.

None of the five productive deposits mentioned above were accessible at the time of visit. Fragments of ore picked up on the dumps show that in the Panther Creek and Keys Gap deposits the ore occurs in the shattered limestone and primary chert adjacent to the fault, with much the same relations as are found in the runs that are developed in the Boone, which are described on pages 137–138. The ore at the Big Hurricane and Spier mines is, at least in part, disseminated in the matrix of the fault breccia. The breccia fragments are barren Boone chert; the matrix was probably at one time a dolomitic jasperoid. Much of the jasperoid has been leached out during the oxidation of the deposit, leaving a cherty dolomitic clay.

The fault deposits show gradations to runs by decrease in the structural displacement. The Ohio mine, for example, is developed on a break that drops one side about 5 feet. While the break might be considered a fault, there is no definite fault plane, and the beds, though decidedly broken up, are dragged in such a way as to form a monoclinal structure. Breaks of small displacement in the Boone formation are in general more sharply confined to definite planes and are less likely to produce shattering in the adjacent limestone. It is possible also that fault deposits may be compounded with runs or blanket veins, though no well-marked examples are known.

DEPOSITS IN RUNS AND BLANKET VEINS

In composition and detailed structure a deposit that occurs in a run is very similar to that in the adjacent blanket vein if the two are associated. Only the intensity of mineralization differs.

DEPOSITS IN FINE-GRAINED DOLOMITES

The deposits in fine-grained dolomites are the typical shatter breccias that have been the least affected by subsequent processes. The dolomite tends to break as a homogeneous rock into rather small fragments, with little tendency to favor bedding planes over cross-cutting planes (fig. 8). A certain amount of random orientation of the fragments may be associated with the shattering. Although the deposits appear to have been formed by simple mechanical filling of the openings, there has been some replacement of the rock bordering the cracks. This replacement, however, has taken place from the edges of the dolomite fragments rather than interstitially, so that it is limited in amount. Chert is developed, along with the ore and other gangue minerals, in many of the deposits and has replaced the edges of the country-rock fragments to some extent, but it does not attain the prominence that it shows in many of the medium-grained dolomites and especially in the limestones, where whole beds of the country rock may be replaced. Runs that occur in the fine-grained dolomites are not so sharply limited in horizon as runs in other rocks, nor are they so extensive. Some of them, however, are fairly rich. The Bonanza (on Cow Creek), Iola, Maumee, Jackpot (at Maumee), Jackpot (at Zinc), Churchhill, Nishwitz, Pearce, Beulah, and several others are notable examples of this type.

The deposits in fine-grained dolomites are found chiefly in the Everton and Smithville formations. Most of the deposits in the Cotter also fall under this type, as well as the few low-grade deposits in the Powell that lie outside of the †Black Ledge and the ledge in northeastern Boone County that lies below it.

In many places gradations between fine- and medium-grained dolomites lead to deposits whose characteristics are intermediate between those described under the two types. The two types may also be compounded in the same deposit.

DEPOSITS IN MEDIUM- AND COARSE-GRAINED DOLOMITES

The presence of interstitial porosity in the rock has added a factor that is very favorable to mineralization and that also has had considerable effect on the character of the ore deposit. While some sort of shattering was essential to allow access of the ore-bearing solution, the mineralization so far exceeded the confines of the actual shatter cracks that these may be rather inconspicuous. The shattering is also probably on a coarser scale than in the finer-grained rocks. The feature that has been accentuated by the porosity is replacement of the country rock away from the narrow limits of the shatter cracks. This replacement has progressed along the bedding planes, along crosscutting cracks, and in irregular pockets. Pink-spar veins from 1 to 3 inches thick, containing ore and other gangues, are very common as replacement features along and across the bedding. Solution pockets lined with the ore and gangue minerals, in which pink spar is always conspicuous, may attain dimensions of 3 or 4 feet in cross section. Most of the larger pockets are developed in the form of channels that may be several tens of feet long and that tend to be elongate parallel to the bedding. The sphalerite is usually in 1- to 2-inch masses in the veins that consist dominantly of gangue minerals, but here and there it forms solid lenses along the bedding, or irregular replacement masses as much as 6 inches or more in diameter, centered chiefly on bedding planes. A small amount may be disseminated in the dolomite without gangue.

Replacement by jasperoid chert is well developed in many of the medium- and coarse-grained dolomites. Its prominence varies in different deposits, from those in which it is almost entirely absent to those in which whole beds of dolomite are partly or completely replaced. A not uncommon occurrence of the chert is in the form of replacement veins, from a fraction of an inch to 2 or 3 inches thick, that crosscut the dolomite, although these crosscutting veins are less numerous than bedding veins. The chert may also be rather finely interbanded with pink spar along the bedding of the dolomite. It is not generally possible to distinguish between chert that has replaced dolomite and chert that has selectively replaced limestone that was interbanded with or mottled by dolomite. To this extent the deposits under discussion grade into the deposits formed in limestone, which are always cherty from replacement of the limestone. The mineralization of the chert by disseminated sulphides is the same in both kinds of deposits and a description of this feature will be deferred to the discussion of the deposits in limestone (pp. 134–136), of which the disseminated sulphides are more typical.

The deposits of the †Black Ledge are a special variety of those formed in medium-grained dolomite. The ledge is massive; hence there is no tendency for mineralization along the bedding. Instead the mineral occurs in isolated pockets that are not very definitely connected into runs. Silica is usually precipitated as finely crystalline quartz lining the cavity walls, but locally it may appear as replacement chert surrounding some of the ore pockets. The amount of such chert is always insignificant. There is on the whole much less pink spar than in deposits in the Everton. Owing to the large amount of rock between the ore pockets the deposits are generally of low grade, although they may in places be successfully worked on a small scale. The mineralization of the ledge that lies 30 feet above the base of the Powell, in northeastern Boone County, is very similar in all its aspects to that in the †Black Ledge.

Most of the deposits in medium-grained dolomite are in the Everton, a few are in the Smithville, a considerable number are in the two ledges of the Powell, and a very few are in the Cotter.

Gradations from this type of deposit to the types formed in fine-grained dolomites and in limestones have already been mentioned.

DEPOSITS IN EVERTON LIMESTONES

The limestones of the Everton carry ore only where they have been silicified or, more rarely, where they have been altered to gray-spar dolomite. Only a single example was noted in the entire district of the development of sulphide in contact with unaltered Everton limestone. This was at the Capps mine, where a seam of sphalerite, a quarter of an inch thick, was observed to extend for about 6 feet along a bedding plane in limestone. Pink-spar dolomite may be sparingly developed, without ore, in bedding veins, or cross-cutting veins, or even in replacement pockets in the limestone, but such occurrences are not conspicuous in the region as a whole.

When it is considered that the occurrence of chert or quartz is far from universal in deposits in other types of country rock, the fact that none of the Everton limestones are mineralized without accompanying silicification seems rather surprising at first. The explanation is perhaps to be found in the extreme susceptibility of this fine-grained limestone to replacement by silica. Innumerable examples have been observed of the selective replacement of limestone where dolomite and limestone are closely associated in ore deposits. Had only the dolomite been present, it is probable that very little evidence would have been preserved to show that the mineralizing solutions contained silica, for precipitation of crystalline quartz along channels of circulation is relatively inconspicuous even in extensively silicified beds. The inference to be drawn from the almost invariable association of chert with the sulphides (sphalerite and galena) where limestone is the country rock is that all the ore solutions carried silica, at least in their early stages, whether it was precipitated or not. Although most of the silica was precipitated early, enough was present in the solutions throughout the period of deposition of sphalerite to silicify any fresh limestone that may have been invaded; such silicification was not necessarily complete. The occurrence of pink-spar veins in unaltered limestone on the borders of ore deposits is rare and presumably results from the opening of new channels into the limestone at a relatively late stage in the mineralization, after the deposition of the silica and sphalerite.

The silicification of the limestone was generally accomplished without marked change in the volume of the rock, but in places it was accompanied by slumping that crumpled the bands of clay (beidellite) lying along the bedding of the original limestone. It is possible that in certain deposits where the ore bed appears as a soft sand with interstitial greenish clay, the lime may have been entirely removed by the ore solutions, leaving only the residual sand and clay.

After the limestone had been replaced by chert, the deposits produced in it were very similar in character to those in medium-grained dolomites. Pink spar and sphalerite, with the accessory gangue minerals, formed replacement veins along and across the bedding and irregular replacement masses chiefly centered along bedding planes. A greater proportion of the ore was probably deposited along the bedding planes. The intensity of the mineralization and the sizes of the mineral structures were comparable to those produced in medium-grained dolomites.

Perhaps the most striking characteristic of the jasperoid cherts, whether they replace limestone, dolomite, or sandstone (rarely), is the development in them of disseminated sphalerite and to a minor extent galena. These sulphides occur as scattered grains, with crystalline boundaries, embedded directly in the chert, without associated gangue. The grains range from pinhead size or smaller up to 1 inch in diameter, though the average of the sphalerite grains lies perhaps between one-eighth and one-half inch and that of the galena grains is somewhat larger. In a given deposit the size is likely to be rather uniform, the variation coming in different deposits. The distribution of the grains may be very sparse, or very dense, and they tend to be concentrated along or adjacent to bedding planes. In extreme cases the grains of sphalerite may be so close together as to coalesce into irregular replacement masses along the bedding. Ordinarily the disseminated ore is not of commercial grade, owing to the difficulties of mill recovery.

Besides the characteristic occurrence in chert, some disseminated sphalerite appears in the medium- and coarser-grained dolomites, and lesser amounts in the fine-grained dolomites, in sandstones, and in gray spar.

The simple chert deposits show a greater tendency toward blanket veins than the deposits in the dolomites, and the structural features that have localized the mineralization are in places rather obscure. A typical and fairly rich deposit is the Gloria mine, at Zinc. Here the worked-out stopes wind about irregularly, without any evidence of fracturing along their roofs.

Gray-spar replacement bodies occur as lenticular masses in the limestone and sandy limestone. They lie typically on the borders of a mineralized body, with which they actually or presumably connect. They represent one of the few recognized cases in which solutions connected with the mineralization have acted on limestone that escaped earlier dolomitization or silicification. The replacement advanced more or less as a wave upon homogeneous rock rather than through a network of fractures, so that inclusions of the replaced rock in the gray spar are rare. The apparent replacement of sandstone by gray spar is probably a replacement of the limy material between the sand grains, with concentration of the sand interstitially. Lateral gradations of such gray spar lenses into fairly pure sandstone are deceptive, owing to the great variability in the original lime content within the sandstones.

Mineralization in the gray spar has produced chiefly pink-spar veins and vugs, few of which carry ore and these only in very small quantity. The veins lie along and across the bedding and are usually wider than those developed in dolomite or in chert. Their low grade is probably due to the fact that they represent some of the last pink spar to crystallize. A little sphalerite is disseminated in gray spar, but the amount is rather meager.

DEPOSITS IN ST. JOE LIMESTONE MEMBER

Four deposits in Marion and Boone Counties—the Coker Hollow, Ben Harrison, Pigeon Roost, and Big Elephant—are at the horizon of the St. Joe limestone. They are similar in showing the ore minerals embedded, by replacement, directly in the silicified limestone, usually without associated pink spar, although at the Pigeon Roost a little pink spar is disseminated in the chert along with the ore minerals. The occurrence of calcite at the Ben Harrison was not observed in place. Brecciation by solution slumpage is more or less in evidence in the different deposits, and at the Coker Hollow mine, which has been the most productive of the four, it is the dominant structural feature. Indeed, if the others did not exist, the Coker Hollow deposit, because its exposed form is roughly pipe-shaped, could not be classed as a run but would have to be described as a breccia deposit produced by slumpage into an underlying cave. However, its close similarity to the other three deposits, which are in the form of runs, suggests that it is simply that part of a run on which solution was intensified to produce the slumpage breccia. Part of this breccia has apparently been let down from overlying beds of Boone chert.

The brecciation in the different deposits is not especially evident, as the limestone appears to have acted more or less plastically during the process. At the Coker Hollow mine, although the preexisting Boone chert has been conspicuously brecciated, the silicified limestone matrix in which it is embedded has the appearance of massiveness. In the other deposits the blocks that have been produced by the slumpage are usually large and so grade into one another that their boundaries are indeterminate. There are no angular edges and very few openings between blocks. Much of the obscureness of the brecciation is undoubtedly due to the silicification.

The solution effects are believed to have been contemporaneous with ore deposition, but this interpretation is not essential. In the absence of material that would form a relatively impervious matrix for the breccia, the solution slumpage might have preceded the introduction of the ore solutions.

DEPOSITS IN BOONE LIMESTONE AND CHERT

Important classes of ores that are developed in the Boone are described above as fault deposits and deposits in the St. Joe limestone member. The type to be treated here includes the rest of the Boone deposits, lying in the form of runs and blanket veins. All the commercially important occurrences are in Newton County.

As contrasted to those in the Everton, the breaks that define the runs in the Boone formation are more likely to be definite fractures that may or may not show small displacements. The ores commonly fill shatter cracks or replace the limestone along and adjacent to the fractures, favoring especially the horizons of bedding planes. A typical form of the replacement is a dissemination of sulphides, without gangue, in the mass of the limestone. The disseminated material may be fairly coarse grained, especially if it is galena, but much of the sphalerite is extremely fine grained. Pink spar is present in the larger pockets and veins of ore, and here and there it is disseminated in the limestone, but it is not so abundant as in the deposits in the Ordovician formations and may be completely absent. Gray spar has locally replaced the limestone and commonly carries disseminated sphalerite. Jasperoid has replaced a little of the limestone in certain deposits, although it nowhere attains the prominence that it shows in the Everton limestones. It usually carries disseminated sphalerite. Certain cherty masses at the Confederate and

Panther Creek mines are so heavily impregnated with finely disseminated sphalerite as to constitute commercial ore without the necessity of separating the sphalerite from the chert, even if it could be done.

Boone chert that accompanies the limestone generally carries the ore in simple shatter cracks. Owing to its greater porosity in sections that are only slightly broken up, it tends to carry the scattered ore in the low-grade blanket veins.

DEPOSITS IN THE BASAL CLAY OF THE BATESVILLE SANDSTONE

Four mines in the Ponca district carry galena in the Batesville sandstone, chiefly in the basal clay. These are the Brewer no. 1, Beechwood, Kilgore, and Ponca City. The first three were being worked in the fall of 1929, and the first two were accessible. The galena occurs as large crystalline nuggets, weighing several pounds, embedded in the sandy clay adjacent to the lines of mineralized fractures in the underlying limestone of the Boone formation. The clay bed is 1 foot or less thick, and the ore is developed over a width of several feet, the maximum observed width being about 20 feet at the Beechwood, although a width of 35 feet (between two fractures) is reported at the Kilgore. In addition to the runs and blanket veins in the basal clay, a small amount of ore appears in cracks in the fine-grained sandstone for 3 or 4 feet above the base of the Batesville. The only gangue mineral is calcite, which occurs sparingly in cracks chiefly in the sandstone above the basal clay.

ORIGIN OF THE ORES

Two strongly contrasting hypotheses have been advanced in the literature to explain the origin of the zinc-lead deposits of the Mississippi Valley. One postulates deposition by meteoric waters that leached disseminated mineral matter from one or another of the sedimentary formations and redeposited it in concentrated form, either after descending directly through overlying formations or after traveling for long distances under artesian pressure; the other, favored by the writer, postulates deposition by magmatic waters, which necessarily had traveled far from their deep-seated igneous source, as no igneous rocks that are closely related to the ore deposits are known in the region. Concentration by directly descending waters, as pointed out by Lindgren,[30] would require the waters to have passed through an impervious shale cover to reach the sites of deposition in many of the Mississippi Valley districts and would furthermore limit the column of rock that could be effectively

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[30] Lindgren, Waldemar, Mineral deposits, 4th ed., p. 440, 1933.

leached of its disseminated material to a few hundred feet at most, which seems inadequate to produce the rich deposits of certain of the districts. The hypothesis based on artesian circulation, most thoroughly developed by Siebenthal,[31] has much to commend it but it is believed to be less applicable to the deposits of northern Arkansas than the theory of magmatic origin. Preference for the latter interpretation is based on four independent lines of evidence—(1) the incompatibility of certain physiographic relations with the hypothesis based on artesian circulation; (2) the significance of an order of crystallization of the ore and gangue minerals; (3) the presence, though recognized in only one deposit each, of enargite and wulfenite, the first of which has generally been regarded as indicative of magmatic solutions and the second of which, although an oxidation product, contains the element molybdenum whose occurrences other

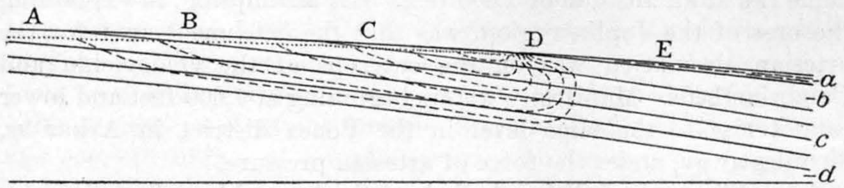

FIGURE 9.—Diagram showing a late stage in Ozark artesian circulation. A–E, Stages in erosion of Pennsylvanian shale. *a*, Pennsylvanian shale; *b*, Mississippian limestone; *c*, Ordovician and Cambrian rocks; *d*, pre-Cambrian rocks. (After C. E. Siebenthal.)

than in genetic connection with igneous rocks are rare and not entirely undisputed; (4) the similarity of the ores in composition to other ore deposits whose genetic connection with intrusive igneous rocks is generally recognized.

1. Siebenthal, writing on the Tri-State ores in particular, conceives them to have been dissolved from the gently dipping Cambrian and Ordovician sediments by waters that entered the outcrops of these strata high on the Ozark dome, and to have been deposited in and near the top of the Mississippian limestone on the borders of the dome by the rise of artesian waters to the zone of escape at the inner edge of the Pennsylvanian shale outcrop. The cause of precipitation was believed to have been the loss, at the zone of artesian escape, of the carbon dioxide, which held the metals and gangue minerals in solution as bicarbonates in the presence of hydrogen sulphide. Figure 9, modified after Siebenthal, shows the drainage conditions at a late stage in the erosion of the Pennsylvanian shale from the flanks of the Ozark dome. Artesian water, beginning at points A,

[31] Siebenthal, C. E., Origin of the zinc and lead deposits of the Joplin region: U.S. Geol. Survey Bull. 606, 1915.

B, and C, on the outcrops of strata below the Pennsylvanian shale, follows the courses of the dotted lines, rising to the surface at D, where, upon escape of carbon dioxide, the mineral matter in solution is precipitated. Especial stress is laid on the fact that the ores lie comparatively near the surface and near the inner edge of the overlapping Pennsylvanian shale.

The application of this mechanism on the south flank of the Ozark dome meets with many difficulties. The ore deposits of the Ponca district lie at a much higher altitude than those of the Joplin region, so that the hydrostatic head necessary to produce an artesian circulation does not exist. The ore at the Bennett mine lies at an altitude of 1,550 feet, and that at the Chimney Rock mine at 1,650 feet.[32] According to Siebenthal,[33] the contact between the Mississippian and the Ordovician and Cambrian strata on the top of the Ozark dome lies at an altitude of 1,600 feet. His assumption, in explaining the ores of the Joplin region, was that the catchment area for the artesian circulation was on the outcrops of the Ordovician and Cambrian beds. Manifestly waters beginning at 1,600 feet and lower cannot rise to the same level in the Ponca district in Arkansas, 80 miles away, under the force of artesian pressure.

A modification of Siebenthal's hypothesis would, at first thought, seem to remove this obvious difficulty to its application in Arkansas: if the catchment area for the artesian circulation were the original outcrop of the Mississippian limestone on top of the Ozark dome instead of the outcrops of underlying formations, then, on the assumption of a maximum thickness of 400 feet for the Mississippian,[34] the altitude of the intake area could originally have been as much as 2,000 feet, producing a maximum effective artesian head of 350 to 450 feet. There is, however, geomorphic evidence against this modification. The Buffalo River, flowing to the east, is the master stream of the Ponca district (see pl. 5), and there are no streams anywhere south of it that could have cut through the shales overlying the Boone formation earlier than it did. An artesian circulation that could concentrate the ores according to Siebenthal's hypothesis could not be set up until the shale had been cut by the Buffalo. Since that time the river has cut to a depth of 550 feet below the shale at the Bennett mine and 650 feet at the Chimney Rock mine. The valley of the Buffalo near Ponca is perhaps the most canyonlike of all of the stream valleys in the Boston Mountains. The river is

[32] Purdue, A. H., and Miser, H. D., U. S. Geol. Survey Geol. Atlas, Eureka Springs-Harrison folio (no. 202), areal-geology map, 1916.

[33] Siebenthal, C. E., op. cit., pl. 4.

[34] Moore, R. C., Early Mississippian formations in Missouri: Missouri Bur. Geology and Mines, 2d ser., vol. 21, pp. 107, 142, 1928.

sharply incised to depths of 1,300 feet below summit levels of the mountains less than a mile away. As there is no evidence to suggest any pause in the down-cutting of the stream, a relatively short time, in geologic terms, must have elapsed since the possible inception of an artesian circulation that could have deposited the ores at Ponca according to the mechanism presented by Siebenthal. Contrast the geomorphic setting at Ponca with that on top of the Ozark dome. Except for certain crystalline knobs in the St. Francis Mountains, the highest part of the Ozark uplift today is a structural plain developed on the resistant Boone formation and lying at an altitude of about 1,700 feet in Webster and Wright Counties, Mo. Possibly that part of the Ozarks that has been subjected to the greatest uplift may lie a short distance east of the Burlington escarpment in western Wright County; but when it is considered that the preservation of the structural plain on top of the dome is due to its position at the headwaters of the various Ozark drainage systems, it becomes evident that the amount of recession in the Burlington escarpment could not have been great during the time interval represented in the cutting of the lower gorge of the Buffalo River at Ponca, Ark., nor could the general surface of the plain have been lowered any significant amount by erosion in the same period. When the shale was first cut through at Ponca, the surface on top of the Ozark dome was much the same as today, and the assumption that the entire thickness of the Mississippian was present to afford additional artesian head is untenable.

The conclusion to be drawn from the geomorphic evidence is that 1,700 feet is the maximum altitude of limestone outcrops that could have served as a catchment area for artesian circulation through the Ponca district. Considering the imperfections of the hypothetical artesian system, this altitude seems too low to produce the effect required in the application of Siebenthal's theory to the ore deposits at Ponca.

The position of the White River across the course of supposed artesian drainage down the south flank of the Ozark dome is an added complication to the artesian theory. The river lies south of the catchment area for the artesian water and north of the area that contains most of the Arkansas ore deposits. (See pl. 5.) As it is the master stream of northern Arkansas and southern Missouri its main channel was presumably cut down ahead of tributary channels (Buffalo River and Crooked Creek drainage) on the south. The bed of the White River in Missouri north of the Ponca district is today from 100 to 400 feet lower than that of the Buffalo River at Ponca. Inasmuch as the Buffalo at Ponca is much nearer than the White

River in Missouri to the head of drainage, where change in gradient is rapid, it is reasonable to assume that, owing to recession of the gradient upstream, the Buffalo has cut the lower part of its gorge at a faster rate than the White River in Missouri. Hence, when the shale was first cut through at Ponca the channel of the White River was at a considerably lower altitude, and regardless of the hydrostatic head that might exist on the Ozark dome, only very exceptional conditions could cause an artesian circulation beneath the White River and up to the base of the shale on its south side.

To explain the high altitude of the ore deposits at Ponca by postulating a very recent differential uplift of the district relative to the Ozark dome would require the assumption of crustal movements for which there is no other evidence. As a matter of fact, the district lies along a structurally high zone which Siebenthal considered to date from premineral time and to have been effective in directing the artesian circulation along certain channels into the Joplin region.[35]

According to Siebenthal's hypothesis, the ores are deposited from the artesian solutions by the escape of carbon dioxide when the waters rise to the surface at the end of the artesian circuit. As circulation was supposedly set up as soon as the shale cover to the Boone was removed at any given locality, the ores should lie near the top of the Boone. Such is the case in the Joplin region, as pointed out by Siebenthal, but in Arkansas most of the deposits lie in the Everton, several hundred feet below the top of the Boone. Unless the escape of carbon dioxide can take place several hundred feet below the surface, the mechanism presented by Siebenthal for the precipitation of the ores does not appear to be applicable in Arkansas.

2. The existence of a fairly definite order of crystallization indicates an orderly change at the point of deposition either in the temperature (and to a slight extent, perhaps, in the pressure) or in the composition of the ore solution. A decreasing temperature at the point of deposition brings different constituents to the saturation point at different times and may also lead to instability of certain minerals below certain temperatures, so that they cease to be deposited. A changing composition produces mass-action effects in the solution that, in conjunction with a temperature gradient along the course followed by the solution, may easily produce a definite order of crystallization.

Insofar as a change in temperature at the point of deposition is applicable to the present case, it would favor an interpretation of magmatic origin rather than a meteoric origin. If a given point is within the range of deposition from a cooling magma, it should

[35] Siebenthal, C. E., op. cit., pp. 39, 199.

probably also be within the range of thermal effects from the magma and should be subject to a gradual cooling along with the magmatic waters that reach it. On the other hand, under conditions of artesian circulation, a given point in the zone of mineral deposition should remain at a constant or nearly constant temperature throughout the period of ore deposition. With the circulation as postulated in Siebenthal's hypothesis the point of deposition should always be near the surface and therefore at a uniformly cool temperature. With a different type of supposed artesian circulation, whereby the solutions penetrate to great depths along tilted bedding planes and then rise along cross fractures, precipitation might be induced anywhere along the ascent by loss of temperature gained in depth. A given point of deposition, if it lies fairly deep during the early stages of the artesian circulation, might conceivably decrease in temperature as a result of erosion of overlying sediments, which would bring it gradually nearer the surface. None of the Arkansas deposits that are exposed today, however, could have lain more than a few hundred feet below the surface when artesian circulation was set up. This statement is based on the assumption that artesian circulation, at least of the type that could leach important quantities of mineral matter from a disseminated state in the limestones and dolomites, could not have begun until erosion had removed the shales from the top of the Ozark dome. The highest altitude from which the solutions could start, as above pointed out, is below 2,000 feet. Hence the drainage levels in the mineral belt of northern Arkansas would have had to lie at a lower altitude than 2,000 feet for artesian waters to escape at the surface. The lowest deposits of the district, lying around 400 feet in altitude, would have been, at the most, 1,600 feet below the bottoms of drainage lines when the supposed artesian circulation began, under the assumption of ideal conditions, and probably much nearer to the surface in view of the imperfections of the postulated artesian system. The removal of the few hundred feet of sediments that might have been eroded from above a point of deposition during the period of mineralization is not believed to be adequate to produce an appreciable lowering in the temperature of the deposit during that period.

Insofar as a change in composition of the solution with time at the point of deposition is applicable to the present case, it would indicate more emphatically an origin by magmatic waters. Though other interpretations are possible, it is believed that an orderly change in composition of the solutions that reach a certain point can most logically be brought about by a change in temperature at the source or at some point toward the source from the point of deposition. Constituents that are precipitated near the source and are absent from the solution in its later travels during the early stages of mineralization become unstable at lower temperatures and under different chemical environments (which in turn are due directly or ultimately to change in temperature) and pass again into solution. Hence constituents that are absent from the ore solution at the point of deposition in the early stages of mineralization may be present at the same point during a later stage. While the changes in composition may be very complex, they should be orderly. In descriptions of ore deposits attention has frequently been called to the facts that a definite order of crystallization is common in deposits that are genetically related to cooling igneous intrusives, and that this order is roughly the same in different deposits. Furthermore, many mining camps show a mineralogic zoning in space around intrusives that is roughly the same, from the intrusives outward, as the order of crystallization. It seems significant that the "remote" deposits in such camps show a mineral composition and a paragenetic order of crystallization similar to the deposits of northern Arkansas.

Artesian solutions, inasmuch as they travel much the same course throughout the period of deposition, should, it seems, remain constant in composition during that period. Of course, accidental additions from extraneous sources will occur, but these will tend to destroy rather than promote any tendency toward any order of crystallization and need not be considered. It is conceivable that an orderly change in the character of the solution might be produced through impoverishment of certain constituents from the source rock, but it is impossible to see how this could affect the time relations between such minerals as pink spar (dolomite) and calcite.

In the discussion of paragenesis it was pointed out that certain deposits show departures from the normal order. Where such departures occur they are usually very definite for the deposit—for example, the occurrence of chalcopyrite between sphalerite and pink spar, instead of after both of them, at the Marguerite mine. Such reversals do not invalidate the deductions drawn from the working out of a paragenetic sequence: the presence of such a sequence is just as definite in these deposits as in the more normal ones. The reversals are probably due to a difference in the composition of the original solution as compared to other solutions that produced the normal paragenetic sequence. Such variations are to be expected of magmatic solutions.

3. The occurrences of enargite at the Governor Eagle mine and of wulfenite at the Shiras mine add two other elements—namely, arsenic and molybdenum—to the list of elements whose presence

has to be explained in theorizing on the origin of ores of the Mississippi Valley type. It is possible that these minerals may be present in similar small quantities in other deposits but have been overlooked. Fowler and Lyden [36] report 0.009 percent of arsenic in an average sample of zinc concentrate from the Picher-Miami district, Oklahoma, but the form in which the arsenic occurs is not known.[36a]

Arsenic has heretofore been considered an element that is characteristic of deposits of magmatic origin. Lindgren [37] includes it among the elements that occur in the various types of ore deposits genetically related to igneous rocks, but states (p. 471) that both arsenic and molybdenum are conspicuously absent from those lead-zinc ores whose origin is independent of igneous activity. E. T. Allen,[38] in a study of a large number of springs in the Yellowstone National Park, observed that the smaller, superficial springs, whose mineral constituents are derived by leaching from the adjacent igneous rocks, contain no arsenic, whereas the larger springs of the deeper circulation contain arsenic along with other magmatic elements, such as sulphur, carbon, boron, fluorine, and chlorine. Although he believes that practically all the water of these alkaline springs is of meteoric origin, he can account for the arsenic and associated elements in no other way than that they represent magmatic emanations appearing at the surface for the first time. He points out that all these elements are relatively volatile. The occurrence of arsenic at the Governor Eagle mine might be an exception to the general rule governing occurrences of this element, but it seems more logical to consider this occurrence one of several links that tie the northern Arkansas ores to magmatic sources.

Wulfenite is a common oxidation product in deposits of the Cordilleran region that contain both galena and molybdenite (MoS_2). Molybdenite is the only common primary mineral of molybdenum and is possibly the original source of this element at the Shiras mine, although it was not recognized in polished sections of the galena. The preponderant association of molybdenum with igneous rocks, especially with acidic igneous rocks, has been pointed out by Ball [39], but there are a few occurrences to which other than a direct igneous origin has been ascribed. Small amounts of molybdenum are as-

[36] Fowler, G. M., and Lyden, J. P., The ore deposits of the Tri-State district: Am. Inst. Min. Met. Eng. Trans., vol. 102, p. 234, 1932.

[36a] Since this was written enargite has been found to be rather common in the Picher-Miami district.

[37] Lindgren, Waldemar, Mineral deposits, 3d ed., pp. 518, 599, 718, 787, 841, etc., 1928.

[38] Oral communication.

[39] Ball, S. H., Molybdenite and its occurrences: Eng. and Min. Jour., vol. 104, pp. 333–338, 1917. See also Hess, F. L., Molybdenum deposits: U.S. Geol. Survey Bull. 761, 1924.

sociated with the ores of vanadium and uranium in Jurassic sandstone in southwestern Colorado, probably as a minor constituent of the mineral carnotite ($2UO_2.V_2O_5.K_2O.xH_2O$). Ilsemannite, a soluble sulphate of molybdenum, occurs in a bed of Eocene sandstone in northeastern Utah, miles from any known occurrence of igneous rock.[40] Although those who have studied these different deposits[41] differ as to the details of concentration of the mineral matter, all are agreed that the metallic constituents were derived from the weathering of an earlier granitic land mass and hence are not of magmatic origin in the restricted sense used in the present report. The famous cupriferous shale deposit of Mansfeld, in central Germany, contains a small quantity of molybdenum, detectable in chemical analyses,[42] but opinions on the origin of this deposit are controversial, some maintaining a sedimentary origin and others a magmatic origin. The examples given are representative of the occurrence of molybdenum in deposits that may have been formed by meteoric waters. They indicate that the amount of molybdenum concentrated by such waters is meager in comparison to that concentrated by waters of magmatic origin. Considered alone, the presence of wulfenite in northern Arkansas can be given no special significance, but taken in conjunction with other evidence here presented, it is believed to lend some support to the theory of magmatic origin of the ores.

No significance is attached at present to the occurrence of adularia in the jasperoid, as this mineral has been found in the sediments, where it is apparently unrelated to ore-forming processes.

4. Finally, the resemblance of the ores, as regards mineral composition, to zinc-lead ores that are definitely related to igneous rocks is close enough so that fewer facts seem to be violated in making this correlation than in assuming a very special and unique mode of origin for them, such as the artesian theory postulates. The following table compares the primary minerals of the Arkansas deposits with those characteristic of zinc-lead deposits within the epithermal and mesothermal zones as given by Lindgren.[43]

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[40] Hess, F. L., Ilsemannite at Ouray, Utah: U.S. Geol. Survey Bull. 750, pp. 1–16, 1925.

[41] Hillebrand, W. F., and Ransome, F. L., On carnotite and associated vanadiferous minerals in western Colorado: Am. Jour. Sci., 4th ser., vol. 10, pp. 120–144, 1900. Fleck, Herman, and Haldane, W. G., A study of the uranium and vanadium belts of southern Colorado: Colorado Bur. Mines Rept. for 1905–6, pp. 47–115, 1907. Hess, F. L., Notes on the vanadium deposits near Placerville, Colo.: U.S. Geol. Survey Bull. 530, pp. 142–156, 1913. Moore, R. B., and Kithil, K. L., A preliminary report on uranium, radium, and vanadium: U.S. Bur. Mines Bull. 70, 1913. Hess, F. L., A hypothesis for the origin of the carnotites of Colorado and Utah: Econ. Geology, vol. 9, pp. 675–688, 1914. Coffin, R. C., Radium, uranium, and vanadium deposits of southwestern Colorado: Colorado Geol. Survey Bull. 16, 1921. Hess, F. L., Ilsemannite at Ouray, Utah: U.S. Geol. Survey Bull. 750, pp. 1–16, 1925.

[42] Stelzner, A. W., and Bergeat, A., Die Erzlagerstätten, vol. 1, p. 395, 1904.

[43] Lindgren, Waldemar, Mineral deposits, 4th ed., pp. 445–446, 508, 530, 582–583, 1933.

Comparison of minerals in ore deposits of northern Arkansas with those of zinc-lead deposits of the epithermal and mesothermal zones in general

Mineral	Typical occurrences			Mineral	Typical occurrences		
	Northern Arkansas	Epithermal zone	Mesothermal zone		Northern Arkansas	Epithermal zone	Mesothermal zone
Ore minerals:				Gangue minerals:			
Sphalerite	×	×	×	Quartz	×	×	×
Galena	×	×	×	Jasperoid	×	--------	×
Chalcopyrite	[a] ×	×	×	Adularia	×	×	--------
Pyrite	[a] ×	×	×	Dolomite	[b] ×	×	×
Marcasite	[a] ×	×	--------	Calcite	×	×	×
Enargite	[a] ×	×	×	Ankerite	--------	--------	×
Arsenopyrite	--------	--------	×	Siderite	--------	--------	×
Tetrahedrite	--------	×	×	Fluorite	--------	×	×
Tennantite	--------	×	×	Barite	--------	×	×
Gold	--------	×	×	Rhodochrosite	--------	×	--------
Argentite	--------	×	--------	Rhodonite	--------	×	--------

[a] Small amounts.
[b] Pink spar.

It will be understood, of course, that the lists representing the epithermal and mesothermal zones are composite, including all the important minerals found in these zones throughout the world. Any one deposit of either zone may contain only a few of the minerals listed. The Arkansas list is not so extensive as that in most districts characterized by magmatic ores, nor are certain of the minerals as abundant. Still it does not seem that the absence or scarcity of a few minerals should call for a totally different origin of the Arkansas ores from the one now generally accepted to explain most of the metalliferous ore deposits of the world. There are certainly wide regional variations even among the ores that are generally accepted as of magmatic origin. The minerals of the Arkansas deposits are the same as those characteristic of the outer zones of magmatic ore deposits. The following table compares the mineralogy of the Arkansas deposits with that of the outer zones at Tintic, Utah, and Leadville, Colo., where the ores are admittedly of magmatic origin. The similarity in mineral composition of the ores and in crystal habit, shown under zone 3 of this table, suggests that the physical and chemical conditions at the time of deposition were essentially identical in all three places.

The evidence that has been cited in support of the theory of magmatic origin deals, among other things, with the presence in the ores of certain constituents that are most logically explained as derived directly from a magma and with certain orderly changes in mineralogy during the period of ore deposition that are believed to be due to a decreasing temperature at the point of deposition or to changes in the composition of solutions given off from a magma. This evidence in no way precludes the possibility that certain constituents

Comparison of minerals in ore deposits of northern Arkansas with those in deposits of the Tintic mining district, Utah, and the Leadville mining district, Colorado

Locality	Early stage (contact-metamorphic deposits)	Later stage (vein and replacement deposits)			
		Veins in and near central intrusive	Replacement deposits in limestone and dolomite, arranged in zones outward from intrusive center		
			Zone 1, near intrusive center	Zone 2, at moderate distance from intrusive center	Zone 3, remote from intrusive center
Tintic [a]	Spinel, enstatite (largely serpentinized), garnet, tridymite, little magnetite. Cut by veins of later stage.	Much pyrite; galena, enargite, dark-brown sphalerite, little chalcopyrite; quartz in well-developed crystals formed by replacement and cavity filling; barite.	Much enargite, with little pyrite, tetrahedrite, and famatinite; jasperoid, with few small quartz druses, much barite; gold $10 to $12 a ton, silver 20 ounces a ton.	Galena, sphalerite, and minor pyrite; abundant jasperoid, moderate barite, minute quartz crystals in scattered cavities, little dolomite and scalenohedral calcite in marginal places; silver 30 to 40 ounces a ton; very little gold with local exceptions.	Galena and sphalerite, scarce pyrite; dolomite spar, scalenohedral calcite, little quartz; silver only a few ounces to the ton.
Leadville [b]	Much serpentinized silicate, some wollastonite, tremolite, and epidote; magnetite, hematite, and also siderite, which is transitional into later stage. Cut by veins of quartz and pyrite with relatively high gold content that belong to later stage.	Only small veins found in the central intrusive area, but similar veins of quartz, pyrite, with local shoots of sphalerite, galena, and chalcopyrite, and relatively high gold content are abundant in adjoining siliceous rocks.	Pyrite, dark-brown sphalerite (marmatite), galena, rare bismuth-silver sulphides, chalcopyrite, and arsenopyrite; manganosiderite, quartz, rare barite (in marginal locations), siderite, ankerite, and white dolomite; silver content moderate but locally rich; very little gold with local exceptions.	Brown sphalerite, galena, pyrite, little chalcopyrite; quartz, jasperoid, barite; silver content moderate.	Light olive-green sphalerite, galena, variable but prevailingly scarce pyrite, negligible chalcopyrite; dolomite and calcite; quartz and jasperoid subordinate except in barren ledge; silver content low; gold content very low.
Northern Arkansas.	----------	----------	----------	----------	Dominantly rosin-colored but some black sphalerite, less galena, negligible pyrite, chalcopyrite, and enargite; jasperoid, quartz, pink-spar dolomite, scalenohedral and steeply rhombohedral calcite; silver content extremely low; no gold.

[a] Lindgren, Waldemar, and Loughlin, G. F., Geology and ore deposits of the Tintic mining district, Utah: U.S. Geol. Survey Prof. Paper 107, pp. 94, 127, 159, 1919.
[b] Data furnished in 1932 by G. F. Loughlin. See also Loughlin, G. F., and Behre, C. H., Jr., Zoning of ore deposits in and adjoining the Leadville district, Colo.: Econ. Geology, vol. 29, pp. 215–254, 1934.

of the ores, such as calcium and magnesium carbonates, have been abstracted from rocks that were traversed by the ore solutions after leaving the magma. Perhaps even much of the water of the depositing solutions may have been of meteoric origin. These later additions would greatly modify the composition of the ore solutions, but their general effect on the composition should be more or less constant throughout the period of ore deposition. The magmatic constituents of the solutions, or changes in these constituents, should persist and be revealed in the ore deposits, as we find to be the case. Insofar as a magmatic influence is indicated in mineralogic changes that can be ascribed to decreasing temperature at the point of deposition, these extramagmatic constituents would be affected by the falling temperature in the same way as the original constituents and should aid in recording this temperature effect of the cooling magma.

The runs and blanket veins along rather ill defined shattered zones within certain beds in the Arkansas field appear superficially to be very different from the lode deposits that are commonly thought to be characteristic of the magmatic ores, but this difference is due to structural differences in the sites of deposition and is nonessential in considering the more fundamental question of the source of the solutions. The Arkansas deposits bear a close resemblance structurally to the epithermal deposits described by Lindgren.[44] Special points of similarity are the shattered structure instead of well-defined fractures, the abundance of druses, and the existence of coarse crustification, at least insofar as sphalerite commonly lies along the borders of ore pockets with drusy pink-spar dolomite toward the centers. The structural evidence points to rather shallow depths of deposition for the Arkansas ores. Perhaps the better-defined faults and fissures in the Boone formation in Newton County may indicate somewhat greater depth of this region at the time of mineralization, which is not unlikely in view of the location of the region within the Boston Mountains, where the thick Carboniferous rocks have more recently been eroded from above the sites of the ore deposits.

Emmons [45] has presented the association of the Mississippi Valley ore deposits with faults as evidence for their magmatic origin. This association is rather pronounced in the Arkansas field, and of course the presence of faulted zones would offer favorable avenues for the upward movement of ore solutions from magmatic depths. On the other hand, the shattering adjacent to faults might prove equally advantageous for the rise of artesian solutions, or for the localiza-

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[44] Lindgren, Waldemar, Mineral deposits, 4th ed., p. 445, 1933.

[45] Emmons, W. H., The origin of the deposits of sulphide ores of the Mississippi Valley: Econ. Geology, vol. 24, pp. 221–271, 1929.

tion of deposits simply because of favorable structure. Hence as a means of distinguishing between ores of magmatic origin and ores of artesian origin the relation to faults is not believed to have much significance.

In summary, it is believed that the altitude of the ore deposits in the Ponca district as compared to the altitude of limestone and dolomite outcrops on the Ozark dome is unfavorable to any theory of concentration of the ore from these rocks by means of artesian circulation heading on the Ozark dome. The position of the White River across the course of such artesian circulation would also tend to prevent the rise of artesian water to the level of the Ponca deposits. The development of a paragenetic order of crystallization in the northern Arkansas ores, the presence of enargite and wulfenite, and the mineralogic similarity of the ores to those of other regions where a definite genetic relationship to intrusive igneous rocks can be shown are believed to favor the theory that the ores are of magmatic origin, although the constituents that make up the abundant pink-spar dolomite gangue may have been leached in part at least from the wall rocks traversed by the solutions after they left the magma. The deposits are believed to have formed relatively near the surface. While the vicinity of faults would undoubtedly be favorable for the rise of magmatic solutions from depth, the structural conditions produced by faulting would be equally favorable to ore deposition from any other source.

OXIDATION OF THE ORES

Northern Arkansas has been of little importance in the United States as a producer of sulphide ores, but it assumed a very high rank, especially during 1916 and 1917, as a producer of oxidized zinc ores. This was due largely to the purity of the product, which greatly simplified the metallurgical treatment necessary.

The minerals of the oxidized deposits have been described in detail. The commercially important ones are smithsonite and calamine, although cerusite attains some importance at the Bald Hill mine. Usually, however, galena remains unaltered in the oxidized deposits, even though the accompanying sphalerite may have been completely changed to carbonate or silicate.

Although some movement of the zinc ore occurred in solution during oxidation there has been no enrichment. Indeed, the gross effect has probably been one of impoverishment: if the zinc, in solution, is ever carried beyond the limits of the primary deposit it is soon dissipated and lost. The oxidized ore has formed in the openings vacated by the sulphides upon oxidation, or else in the unoccupied spaces in the adjacent vugs and cracks. Much of it was precipitated on unaffected or partly leached sulphide crystals, and the presence of sulphide kernels in the oxidized ore is almost universal.[46] Part of the oxidized zinc has also been fixed in the primary deposit by replacement of pink spar. Hence the oxidized deposits will show the same types of occurrence as the primary deposits from which they were derived, except for minor textural rearrangements that have tended to agglomerate the ore into larger masses of " free " ore that do not have to be milled and for a certain amount of decomposition of the country rock to red clay. Much of this decomposition has taken place since the oxidation of the ore, as shown by the occurrence in the clay of botryoidal masses of pure carbonate of the type that usually forms in open vugs.

The absence of replacement of the country rock beneath or down the dip from the original sulphide deposits is in marked contrast to the conditions in important oxidized deposits in the Cordilleran region. Perhaps the explanation is to be found chiefly in the abundance of calcium and magnesium bicarbonates, derived from the overlying country rock, in the waters that effect the alteration of the zinc sulphide; some of the zinc is also held in place by replacement of pink spar, or, more rarely, of the immediately adjacent limestone or dolomite.

Except for local occurrences of a little zinc carbonate or silicate along more open channels, the deposits below ground-water level are unoxidized. Many that lie well above the water table are likewise unoxidized or only partly oxidized. This is especially true of those in fine-grained dolomites, through which the movement of ground water is more or less inhibited. Under such conditions zinc sulphide may lie practically at the grass roots.

SPECIAL ECONOMIC APPLICATION OF GEOLOGY

The preceding pages of this report contain information whose application may be of considerable practical importance in prospecting, in the appraisal of properties, and in the development of ore bodies. It is proposed to summarize here the outstanding features of the ore deposits that have a direct economic bearing.

It has been shown that the most productive deposits occur in either the Everton or the Boone formation. In Sharp and Lawrence Counties the Smithville formation has proved somewhat less productive. The Powell dolomite is distinctly unfavorable except for

[46] One of the big commercial problems of the district has been the occurrence of these mixed ores, which are not amenable to separation by the jigging methods of concentration used in the field. General practice has been to keep the more " jacky " portions separate from the rest if the mineral is unevenly distributed in a mine. It is marketed as a mixed ore at a considerably lower price than the carbonate or silicate. Usually 1 percent of sulphur is allowed in the concentrates, but for more than that a penalty is imposed by the smelter.

two ledges, one lying 30 feet and the other 60 feet above its base, and even these ledges have been, on the whole, unpromising, owing to the irregular distribution of the ore pockets within them. The Cotter dolomite contains a few promising prospects but has nowhere yielded an important mine. The distribution of the different formations within the Yellville quadrangle is shown on plate 3. In using this map it should be borne in mind that the formations have been plotted on a very imperfect topographic base map (made in 1891) and that numerous errors appearing on this map will affect the distribution of the formations. In many parts of the area the formation that crops out in a certain fractional part of a land section can be determined by referring to the map, but this procedure can lead to incorrect conclusions where the map is inaccurate. The ability to recognize the different formations according to their characteristics, as presented in the section on stratigraphy, is preferable in determining what formation is present.[47]

It has been shown that the vicinity of a fault is favorable prospecting ground for ore deposits, but that, except where the rock on one side is Boone limestone or chert, the fault itself is likely to be barren. The structural features that are usually most favorable for the deposits are relatively insignificant: slight flexures, or even simple fractures that are limited to certain beds, may be all that are necessary to create optimum conditions for ore deposition. A monoclinal displacement of a few feet, taken up by shattering in the rock rather than by a clean break, is especially favorable. Although such features may occur in the rocks outside of faulted districts and may prove to be richly mineralized, the minor adjustments to stresses that are set up in the neighborhood of major faults have often been of the requisite type and amount to produce them most abundantly. Major faults, where they cut the Boone, are likely to be mineralized and should be prospected carefully before they are eliminated from consideration.

An understanding of the form in which most of the deposits occur—namely, as runs that are limited to certain beds in nearly horizontal strata—is of importance in deciding upon a plan of devel-

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[47]A rapid and convenient method for distinguishing between limestone and dolomite can be provided for a few cents. If commercial muriatic acid is diluted with two or three parts of water and a drop of this is applied to the rock in question, a limestone will effervesce or "fizz" vigorously, but a dolomite will react very sluggishly or not at all. If a dry place on the dolomite is then scratched back and forth several times with a knife so that some of the material is powdered along the scratch, a drop of acid will produce a "fizz" in this powder. In the experience of the writer a small rubber-stoppered iodine bottle, containing a glass rod in the stopper, makes an ideal container for the acid diluted as above. Such a bottle can be carried in a pocket where there is no danger of the cork coming out, and a drop can be applied with the glass rod as desired. If the acid spills on a person it is not especially harmful in the dilution recommended and can be washed off without any serious effects. The acid, even in dilute form, is very destructive to clothing and should be washed out as quickly as possible.

opment. It will be obvious that sinking a shaft on the outcrop of a mineral deposit is wasted effort unless there is evidence to show that the deposit is on a fault, or on some pronounced flexure that is likely to continue in depth. Usually the correct method of developing a run is by following the ore along the bedding. Nowhere is the age-old advice to " follow the ore " more applicable than in northern Arkansas. The structural features that determine the limits of ore deposition are relatively of such minor proportions that they may give out at any point, or they may change direction. Any plan of development that is based on projecting these structural features into unknown ground is liable to failure.

Certain estimates of ore reserves have been made in mining camps of northern Arkansas by comparing the area that has not been touched with the area of the underground workings. Such estimates are based on the assumption, contrary to evidence, that ore deposits in certain beds are of uniform tenor over considerable areas. An understanding of the nature of the runs and of the causes underlying their development will show that they are of moderate size and that the ground between adjacent runs is normally barren. There are probably many undeveloped prospects in the region that would prove to be of the same degree of richness as those which have been exploited and that, under economic conditions such as prevailed in 1916 and 1917, could be profitably worked. It will, however, be difficult to estimate, in advance of actual development, what such a deposit would yield. The roughness of the topography in northern Arkansas is in general unfavorable to the economical use of the portable churn drill, which has played so prominent a part in the prospecting and development of the Tri-State district of Missouri, Kansas, and Oklahoma.

MINES

The following descriptions of mining properties, with few exceptions, relate only to those visited by the writer. The attempt was made to examine all the properties in northern Arkansas that have produced ore or that show any promise of future production. Information on the existence, location, and worth of different prospects came from so many different sources, however, that no uniform basis on which to pass judgment in advance of examination could be worked out. The writer was necessarily guided by the knowledge and opinions of certain men interviewed as to what properties were worth visiting. Hence it must not be assumed that the properties described in the following pages are necessarily more valuable than others that are not described. Undoubtedly some have been overlooked that may have produced considerable ore. Some reported occurrences of ore that turned out to be nothing more than a " shine " have not been thought worthy of treatment in this report but, as a general rule, if any ore at all showed at a prospect that was visited, a description of the property is included. No attempt has been made to include information on prospects that are treated in Branner's or Adams' reports if they were not revisited by the writer.

Some of the information on production appearing in the descriptions of the different mining properties is reliable, but some is not. Very few detailed statistics have been kept in the region, so that many of the figures given express little more than the general order of magnitude of the production.

WASHINGTON AND BENTON COUNTIES

Low-grade deposits occur in Boone limestone and chert at several places in Washington and Benton Counties, but none of them have been commercially profitable.

Morrow.—This prospect is on the right bank of Fly Creek 700 or 800 feet below the town of Morrow, Washington County, in the SW¼SE¼ sec. 25, T. 14 N., R. 33 W. The ore is in the Boone formation, apparently near the top. The opening is a large pit 200 feet long, 40 to 50 feet wide, and 30 feet deep, dug on the edge of a flat immediately bordering the creek. As the surface surrounding the pit is only about 10 feet above the level of the creek, the lower part of the pit is full of water. The only natural exposures in the neighborhood are in the creek bed and reveal interbedded chert and limestone, horizontal and to all appearances unbroken. The ore minerals are galena and "jack", the latter grading from rosin jack to almost ruby jack. In their original type of occurrence these sulphides are scattered in pockets and small cracks through the chert and, to a less extent, through the limestone. The galena tends to occur in rather large chunks, but the jack is more granular, appearing as single crystals averaging one-eighth inch in size (maximum one-fourth inch) or as aggregates of such crystals. A little calcite associated with the ore is in the form of small rhombohedrons. Part of the ore is reported to have been taken from clay at the top of the flint, after the soil had been stripped. It is probable that most of this was lead ore.

The first work on this prospect is said to have been done somewhere around 1880, or perhaps as much as 5 years later than that, but serious development began in 1908. The property was worked to some extent during the period of high prices in the early years of the World War. In spite of the fact that a mill was erected to handle the ore, the output has been small, estimated at about 50 tons, half galena and half jack. The ore is too widely dispersed in the rock for the prospect to be developed commercially.

A 50-foot shaft, about 100 feet north of the open pit, contains a little galena, but it was of even lower grade than that in the open pit. Lead "shines" are reported in the creek between points a quarter of a mile above and a mile below the prospect.

Burr.—This prospect is in the NE¼SW¼ sec. 28, T. 16 N., R. 32 W., Washington County, a mile or so northeast of Rhea's Mill. The location is on the R. F. Ezell land, in a comparatively level old field that contains no outcrops. The ore bed is Boone chert. The developments consist of five or six old shafts spread over a diameter of 500 feet or so and sunk originally to a reported depth of about 70 feet, which is the depth of the mineral. The ore shown on the dumps consists of scattered galena crystals occurring in chert; it was not observed in the associated limestone. Some of the ore is said to have been taken out of loose clay, and one mass is reported to have weighed 400 pounds. The total production amounted to only 5 or 6 tons, made somewhere around 1905. The prospect is of low grade.

Roller.—In 1929 a shaft was put down in the Boone formation on the A. W. Roller property, in the SW¼NE¼ sec. 13, T. 21 N., R. 28 W., Benton County. When visited in November 1929 it had reached a depth of 50 feet. From a point 10 feet below the collar down, a little rosin jack occurs in fine-grained Boone limestone and in the chert. A little galena is also reported to have been found. The ore is reported to be richer along a vertical crevice, becoming leaner away from it. The shaft is located in fairly level farming country.

PONCA-BOXLEY DISTRICT

The Ponca-Boxley district lies in the valley of the Buffalo River in northwestern Newton County. Most of the deposits are in various tributary hollows on the northwest side of the river in the general neighborhood of Ponca, and they line up in a general northeast-southwest direction. The ores are chiefly zinc carbonate and galena. They occur together in the Boone chert and limestone, and galena occurs also in several deposits in the basal clay of the Batesville sandstone. Zinc silicate is present on one of the levels of the Ponca City property and at the Bennett mine. Many of the deposits in the Boone are localized along fractures or along insignificant faults. Some of the faults show horizontal slickensides, indicating that the movement was in a horizontal direction. The production of the district has been about 4,000 tons of concentrates, of which 1,500 tons was galena. Mining for lead was done on the Bennett property, which has been the most productive in the district, as early as the time of the Civil War.

Brewer.—This mine is in the SE¼NW¼ sec. 18, T. 16 N., R. 22 W., about 1 mile north of Ponca and only a short distance below the Ponca-Compton highway. It lies on the steep east slope of the east prong of Adds Creek near its head, about 250 feet above the level of the creek. The main tunnel goes northeast about 500 feet (an additional 400 feet is caved) into the hill and is driven on a mineralized fracture parallel to and only 5 feet or so southeast of a fault (fig. 10). The fault runs N. 45° E. and shows a downthrow on the southeast of about 60 feet. At 175 feet back from the portal of the tunnel a raise of 72 feet to the surface is used as a hoisting shaft. Near the end of the main tunnel two mineralized fractures have been followed by drifts—one drift, 80 feet from the end, going about N. 25° W. for 160 feet into Boone limestone of the upthrown block of the fault, and the other, at the end of the main tunnel, going about S. 25° E. at a horizon just below the base of the Batesville sandstone in the downthrown block. This second drift had been driven 220 feet when the mine was visited in November 1929 and was being extended at that time. The structure in both blocks, away from the immediate vicinity of the fault, approaches horizontality, but near the end of the drift on the northwest fracture the strata rise at an angle of 5° to 10°. Near the fault, on the downthrown side, the beds are dragged up steeply, so that the location of the fault is hard to place. According to reports the Batesville sandstone is only about 8 feet thick in the hoisting shaft, and its base lies about 20 feet above the floor of the tunnel beneath the shaft. About 150 feet farther back in the tunnel, where the displacement on the fault is apparently the greatest, the Batesville approaches within a few inches of the floor, but at the rear end it has risen again 15 feet or so.

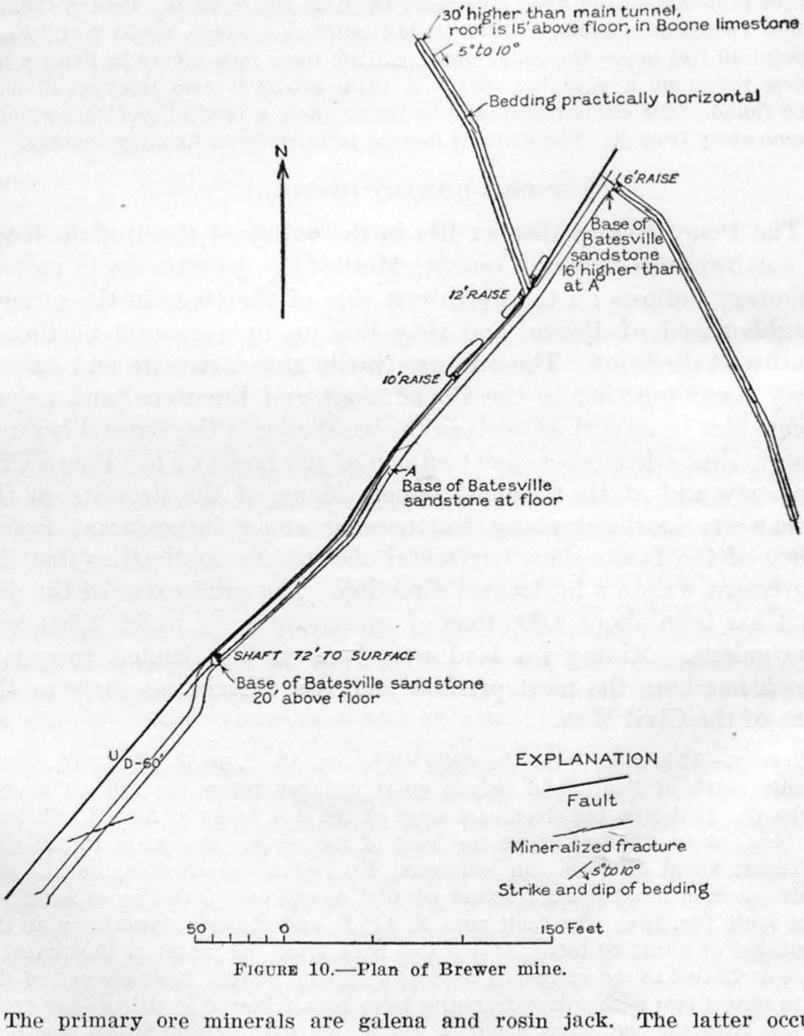

FIGURE 10.—Plan of Brewer mine.

The primary ore minerals are galena and rosin jack. The latter occurs only along the cross fracture running southeast, disseminated in Boone limestone within the first 5 feet below the base of the Batesville. The rock is mineralized adjacent to the fracture for 2 feet on each side. Most of the jack is in grains smaller than one-eighth inch but a few blebs measuring an inch or so occur. The galena, which is intimately associated with the jack, is in larger crystalline masses, averaging 1 to 2 inches in size. A little calcite is associated with the sulphide minerals in this occurrence. Above the level of the mixed sulphides is galena in greenish to buff sandy clay at the base of the Batesville.

The galena occurs in large crystalline nuggets, some of which weigh several pounds, replacing the clay over a width of 4 or 5 feet centered on the fracture. Although the main ore zone is only 1 foot or less thick, some galena occurs in fractures in the fine-grained Batesville sandstone as much as 2 or 3 feet above the contact. Where the rock, including the basal bed, is shattered, the galena may be accompanied by calcite. Pockets of gypsum appear in the basal ore-bearing clay of the Batesville but do not appear to be especially related to the ore.

A little galena has replaced the Batesville clay material along the fault in a series of small drifts just beneath the roof on the northwest wall of the main tunnel, but apparently the fault gouge was too impervious for the ore to develop in this occurrence to any great extent. The mineralization along the northwest fracture and along the fracture followed by the main tunnel was similar to that below the Batesville contact in the southeast fracture, except that part of the mineralized limestone in the main tunnel is silicified, and all of the jack has been oxidized to carbonate. Some of the carbonate is of the "pine bark" type and lies sheeted parallel to the wall of the fracture, adjacent to the barren limestone. The mineralized zone along this fracture is generally about 1 to 2 feet wide but in places widens to as much as 10 feet, although the ore minerals form only a small proportion of this zone. The richest ore occurs for a short distance below the base of the Batesville. According to reports, the fracture extended only about 160 feet back of the hoisting shaft, and thence to the cross fractures the tunnel was practically barren. All the ore has been mined out of the main tunnel fracture and the northwest fracture. Where the Batesville sandstone comes down to the floor of the main tunnel galena occurs in the basal clay and also in fractures in the overlying 3 or 4 feet of sandstone. This occurrence is closely adjacent to the fault. Galena is reported to have been taken out of the Batesville sandstone in the hoisting shaft.

The Brewer mine is reported to have produced around 600 tons of ore since 1916. Most of this was lead, the rest being zinc carbonate. Part of the ore was shipped as free nugget lead, and the rest was hauled to the creek below, where it was hand-jigged. The mine was being worked in a small way in November 1929.

Some production has also been obtained from other workings on the same fault but farther down the hill. The highest of these is about 35 feet below the Brewer tunnel and is reported to have yielded one galena mass weighing 1,750 pounds. Another level, 150 feet below the tunnel, produced gray crystalline carbonate and some turkey fat, but no lead, from the fault zone, the ore body being about 8 feet wide. A third level, 185 feet below the tunnel, produced turkey fat, also from the fault fissure.

Brewer No. 2.—This prospect is on the opposite (northeast) side of the spur from the workings just described. It lies in a steep gully near the top of the hill on the southwest side of a short but deeply cut tributary to the Buffalo River, in the NW¼NE¼ sec. 18, T. 16 N., R. 22 W.

The horizon is the top of the Boone formation from 0 to 15 feet below the overlying Batesville sandstone. The working is an open cut 70 feet long and 4 feet wide, passing into a 20-foot tunnel at the rear. The two walls of the cut are formed by slickensided fault surfaces, striking N. 6° W. and standing practically vertical. The more pronounced (east one) of the two faults shows a vertical displacement of a few inches, down on the east. The greater movement, however, was horizontal instead of vertical, as shown by the flutings on the slickensided surface, which dip south into the hill at angles from 0 to 20°. The ore is entirely galena and is either embedded directly in the limestone or associated in pockets with a little calcite.

Chimney Rock.—This mine is on the south side of a steep gully near the top of the ridge, a quarter of a mile or so northwest of the Brewer No. 2 workings. It lies in the same 40-acre tract, the NW¼NE¼ sec. 18, T. 16 N., R. 22 W. The workings consist of two tunnels into Boone limestone, immediately underlying the Batesville sandstone. The larger of these tunnels, beginning near the bed of the gully, is caved but is reported to have gone in about 170 feet and to have produced about 30 tons of lead concentrates during the early years of the World War. The smaller tunnel, whose portal lies 30 feet northeast of the portal of the other one, goes in S. 49° E. for about 70 feet along a small fault that shows a downthrow of 2 feet on the southwest at the rear end of the tunnel. The displacement on the fault decreases to practically zero at the portal. The only ore mineral observed at the time the tunnel was examined was a little galena associated with an onyx type of calcite, and occurring in the fault fracture in the base of the Batesville, near the portal. At 50 feet east of this tunnel another fault, striking N. 18° W. and nearly vertical, shows well-developed slickensided grooves that dip about 10° S. The downthrow on this fault is only 2 feet, on the west. A prospect drift on the fault, only 10 feet or so in length, does not reveal ore of any kind.

Kilgore.—This mine, in the SW¼ sec. 18, T. 16 N., R. 22 W., a few hundred feet east of south from the Brewer, was caved at the time it was visited in November 1929 but was being reopened. The folowing notes were furnished by Ike Kilgore and Ed Minicus.

The strata dip gently from the Brewer to the Kilgore, and the ore occurs at the same horizons in each—at the base of the Batesville sandstone and in immediately underlying Boone limestone. The main tunnel goes in 400 feet or so along a "break," running N. 38° E. (probably magnetic). From this tunnel at least three parallel fractures were worked to the northwest to distances of 100 to 200 feet, their direction being probably parallel to that of the southeast drift of the Brewer mine (S. 25° E.); indeed, Mr. Kilgore thinks that the central one of these three fractures is the same as the one in the Brewer. That part of the main tunnel in front of the cross fractures (about 300 feet) produced ore, but along the stretch where these fractures join the tunnel it was barren. All of this ore was taken from the limestone below the Batesville sandstone. The northwest fractures produced ore not only from the limestone but also from the base of the Batesville sandstone. One of the most productive deposits in the mine, however, was not in a fracture but occurred as a blanket vein of galena at the base of the Batesville, between two minor fractures parallel to the main (northeast) tunnel. These two fractures were about 35 feet apart and lay about 100 feet northwest of the main tunnel.

A large cave, about 50 by 75 feet in ground plan, was broken into below the ore horizon. It was lined with white calcite and contained lead ore on the floor beneath the cross fractures.

The ore produced by the Kilgore was both galena and zinc carbonate, with the latter probably exceeding in total production. One pocket of "white flour carbonate" is reported to have contained about 15 tons, assaying 46.8 percent of metallic zinc. This ore was never taken out of the mine. During the time that Mr. Kilgore worked the mine he took out about 500 tons of lead. The total production, including the zinc carbonate, would be around 1,000 tons.

Baker & McGrath.—This old-time working is at about the same altitude as the Kilgore but 200 or 300 feet along the hill to the northwest, toward the

Brewer. An open cut, about 200 feet long and 10 to 20 feet high on the upper side, passes into a tunnel at the north end. It is developed on a small fault running N. 5° E. The fault cuts into the hill from south to north at a low angle, and the west wall of the open cut has been in large part removed. The east wall exposes limestone, somewhat shattered, and contains embedded galena and red-brown jack, the latter in blebs from half an inch to an inch in size.

Bonanza.—This is an open cut in the Boone formation well down toward its base, on the upper side of the main highway leading down the hill to Adds Creek, in the NW¼NW¼ sec. 19, T. 16 N., R. 22 W. The production has been 70 or 80 tons of zinc carbonate, taken from a pocket in interstratified lime and flint, with the flint forming a high percentage of the whole. The ore was concentrated by hand jigging.

Ponca City.—These workings are in the SE¼SW¼ sec. 24, T. 16 N., R. 23 W., high on the southwest slope of Adds Creek and a little over a quarter of a mile west of Ponca. They consist of several tunnels, open cuts, and shafts at different levels.

At the top a 68-foot shaft, driven in 1928, begins in the Fayetteville shale and had reached the Boone formation when abandoned, but it produced no ore.

About 20 feet below the base of the Batesville sandstone two short tunnels were worked in 1928. The rock, at least near the portal, is very much decomposed, and as a result both tunnels had caved when examined in November 1929. The ore, to judge from the dump, consists of galena and zinc carbonate, embedded in limestone, and also in broken up shaly sandstone of the Batesville, indicating that either workings were carried up to that horizon within the mine or else some of the Batesville has been let down by faulting or by weathering. The occurrence of large blocks of the sandstone in clay at the portals suggests that the ore in the Batesville may have been taken from such blocks, let down into a crack in the underlying rock by weathering. The zinc carbonate is of several kinds—a brownish crusty type, the "pine bark" type, and the normal gray crystalline type. The production of these tunnels was only about 300 pounds of galena.

At a horizon 130 feet below the base of the Batesville two tunnels open on the same level with their portals about 30 feet apart. One begins in the bed of the steep draw along which all the Ponca City workings are located and goes S. 10° W. about 50 feet, into the hill; the other begins in the northwest wall of the draw, averages southwest in direction, and is 35 feet long. Fault slickensides show in the portal region of these tunnels over a width of about 15 feet. The strike of most of them is N. 5°–10° W. and the dip ranges from vertical to horizontal, a slickensided surface in one example bending from the one attitude to the other. Some of these surfaces are fluted horizontally, indicating that the movement was in a horizontal direction. An isolated slickenside, showing in the portal of the east tunnel, strikes N. 57° W., has a vertical dip, and shows horizontal flutings.

The country rock is Boone chert and limestone in about equal proportions and is shattered over a width of about 30 feet, centered on the slickensided zone. The ore occurs in the shattered chert, chiefly in the east tunnel, and consists largely of crystalline zinc silicate. The colors are white, black, and yellow; the yellow material may be cadmiferous(?). A little galena is associated with the zinc silicate, but it is not abundant enough to be of commercial importance. The production from these two tunnels is not definitely known, but it amounted to only a few tons.

An open cut on the northwest side of the draw, 30 feet below these two tunnels, is of interest in that it shows a slickensided surface striking N. 10° W., parallel to those in the tunnels above but lying some 50 feet east of their line of projection.

A tunnel 35 feet below the open cut and thus about 200 feet below the base of the Batesville sandstone bears S. 75° W., into the hill, going directly in below the open cut. This opening has produced about 80 or 90 tons of zinc carbonate ore.

Beechwood.—This mine is near the top of the hill on the northeast side of Clark Creek, about 1 mile southwest of Ponca. It is somewhere near the quarter corner between secs. 25 and 26, T. 16 N., R. 23 W. The altitude is around 1,600 feet. The main (west) workings consist of a 30-foot shaft sunk through the Batesville sandstone and 3 or 4 feet into Boone limestone; a drift, running N. 30° W. from the foot of the shaft along a fracture in Boone limestone, for a distance of 120 feet, gradually descending in the Boone over this stretch; and a cross drift at the north end of the other drift but 15 feet or so higher, at a horizon near the base of the Batesville, and running N. 80° W. along the line of a small fault. The maximum displacement on the fault is about 8 feet down on the south, but although the fault crosses the drift in the Boone below, it is not evident, owing apparently to recrystallization in the limestone. The fault decreases rapidly in throw to the west. The upper cross drift follows in part and is extended by a natural cave, lined with white stalactites of calcite. It extends 100 feet or more west from the junction with the lower drift. The dip of the basal Batesville at the foot of the shaft is east or slightly south of east, about 30°, but along the northwest drift off of the shaft it flattens to only 5° or so, slightly south of east.

The ore consists of galena and zinc carbonate. Both minerals occur to some extent, in association with a little pink spar, embedded in limestone along the fracture in the Boone, to a depth of 10 feet below the base of the Batesville. The more productive deposit, however, consists entirely of galena and occurs in a bed 6 inches or so thick along the Boone-Batesville contact on the downthrown side of the fault. It appears to be confined to a structural sag about 20 feet wide, adjacent to the fault, but is developed chiefly at the west end of the cross drift, where the throw on the fault is very small. The galena occurs in crystal nuggets as much as several inches across. In mining, it is taken up from the floor of low stopes dug in the base of the Batesville. By this method of working, as the Batesville is very much softer than the underlying Boone, very little shooting is required. Ore occurs in the sandstone up to a level 3 feet above the main blanket vein and also in the underlying limestone to a depth of 3 feet below it. These extensions are not so rich, however.

The total production up to November 6, 1929, was about 16 tons of galena, of which 15 tons was produced in 1929.

A second shaft on the Beechwood property is 300 feet east of the one described above. The workings from this shaft are reported to be on a fracture in the Boone running northeast. This deposit produced a little over a ton of galena in 1929.

Bennett.—This property lies high on the point of the ridge between the Buffalo River and Clark Creek, in the NE¼NW¼ sec. 35, T. 16 N., R. 23 W. The altitude is around 1,550 feet. Owing to the fact that the property was leased in very small lots, a large number of openings were made, most of them shafts (12 reported). The deepest one is said to be 146 feet deep, but most of them are from 30 to 60 feet. There are also one or two open cuts on the property. The horizon of the workings is at the top of the Boone, most of the shafts beginning in this formation, from 0 to 15 feet below the outcrop of the Batesville sandstone, but one of the larger shafts at the south end of the group begins a few feet above the base of the Batesville. Ore was obtained in all the shafts from the surface to their bottoms. The group of workings are enclosed in an area about 800 feet long and 100 feet wide, whose longer axis trends N. 10° E., across the nose of the hill. A large open cut at the north end of the group gives the clue to this alinement. Here the beds that are nearly horizontal on the west abruptly steepen in dip toward the east. Apparently the workings are localized on the axis of this abrupt flexure, where the rocks have been shattered to some extent by the bending. The drifts from the shafts extended along the direction of this axis.

The ore minerals are zinc carbonate, zinc silicate, and galena, the carbonate predominating. Some of the carbonate left on the various dumps is of a brownish to gray dry-bone type. Another type is black and porous and contains small specks of aurichalcite, indicating a little chalcopyrite in the primary jack. Still a third type is the usual crystalline gray carbonate that is so common in the northern Arkansas field. Some turkey-fat ore is reported to have been taken from the bottoms of several of the shafts. The ore minerals contain a little associated pink spar and calcite.

One or more shafts at the south end of the group produced lead in the days of the Civil War. A lead smelter is reported to have been erected in 1889 on Clark Creek below the Bennett mines to reduce the ore from these mines. Branner reports a production of 100 tons of zinc carbonate between 1889 and 1891. However, the big production from the property came between 1912 and 1917. During this period the mines shipped roughly 2,000 tons of concentrates and free ore, about 80 percent of which was zinc carbonate. Concentrating was done by means of hand jigs.

Peck.—These lead workings are in a bluff, 100 feet or so above creek level, on the south side of Edgmon Creek, a tributary that enters the Buffalo River from the west between 1 and 2 miles above Boxley. The property is in the NW¼SE¼ sec. 16, T. 15 N., R. 23 W. There are two tunnels about 100 feet apart both in the Boone formation a short distance below the Batesville sandstone. The west tunnel goes in about 100 feet at a horizon 30 feet below the base of the sandstone, following an ill-defined and rather crooked fracture, whose general trend is about south. The ore, which has been almost entirely mined out, was apparently confined to a width of only 2 or 3 feet along the fracture. The maximum height of the tunnel is 10 feet. A very little galena is embedded in the limestone of the tunnel walls at the back end of the tunnel.

The east tunnel goes in 70 feet S. 15° E., at a horizon 10 feet or so below the Batesville sandstone. Most of the country rock is limestone, but there is a 6-inch seam of primary chert 7 feet below the top of the formation, and the most valuable ore deposit occurred as a blanket vein of galena, reported to be 6 or 8 inches thick, immediately under this chert. A little galena also occurs, associated in part with calcite, in the limestone down to 2 feet below the chert layer, and galena is embedded rather sparingly in the top foot of Boone limestone. The width of the run is about 10 feet. Any fracture that may have controlled the site of deposition was of slight extent both horizontally and vertically, and all evidence of it was removed by the mining operations. Practically all the ore has been removed, but the edges of the blanket vein may still show a thickness of 1 or 2 inches in places along the wall.

These openings are old, having been worked in 1882 and 1883. A smelter, built on the creek below the mine, turned out some 40 tons of pig lead during this period of operation. Most of the ore is reported to have come from the east tunnel.

LITTLE BUFFALO RIVER DISTRICT

Several mines and prospects are located within the Little Buffalo drainage basin in Newton County. All are in Boone chert and limestone. The two most productive, the Panther Creek and Keys Gap, are opened on small faults. The output has been chiefly zinc carbonate and jack in nearly equal proportions, with some lead sulphide, and has amounted to about 3,200 tons of concentrates, most of which came from the Panther Creek mine. About 90 tons of the total production of the district has been galena concentrates.

Panther Creek.—This mine is in the NW¼NE¼ sec. 31, T. 16 N., R. 21 W., on a small tributary prong entering Panther Creek from the northwest. The main working is a 90-foot shaft, driven from a point 15 feet above the bed of the branch, on the southwest bank. The country rock is Boone limestone and chert, the shaft collar lying roughly 100 feet below the top of the formation. The shaft was put down on a small fault running N. 10° E., and drifts lead off along this fault at different levels from the shaft. Movement along the fault has been chiefly in a horizontal direction and has dropped the strata on the east only a few inches. The movement has shattered the adjacent limestone and chert, rendering conditions favorable for ore deposition. The width of the mineralized zone a short distance north of the shaft is about 5 feet, although most of the ore is confined to a width of only a foot or so. The fault crosses the branch about 100 feet north of the shaft, and on the north side of the branch it has been worked as an open cut, 50 feet long and 30 feet high, passing into a 30-foot tunnel at the rear end. The width of the ore zone is here about 8 feet. These workings are at the level of the branch bed. South of the shaft the fault has been worked as an open cut to a distance of 300 feet.

The ore is dark rosin jack, dark red-brown (almost ruby) jack, and carbonate. The gangue minerals are pink spar, calcite, and jasperoid chert. The ore occurs most abundantly as a filling of irregular fractures in both limestone and chert along the shattered zone adjacent to the fault and in bedding cracks out a little way from the fault. A mass of jack, weighing 5,200 pounds, is reported to have been taken from the open cut north of the branch bed and sent to the World's Fair at St. Louis in 1904. Lenticular bedding veins of jack with the associated gangue minerals occur in the walls of this cut. They average from 6 to 10 inches in thickness, but the horizontal extent of any one vein is not more than 5 feet. Most of these veins contain a fine groundmass of black secondary chert, in which the jack is thickly disseminated in very fine grains. Another type of ore is disseminated in rather coarse limestone, usually as small grains but locally in blebs as much as an inch or so across. A little associated galena shows the same type of occurrence. The gangue minerals in ore of this type are a rather pale pink spar and a little calcite, both of which have replaced the limestone irregularly. Brownish-gray or yellow zinc carbonate occurs as an alteration product of the jack in the various types of occurrences. Carbonate is not conspicuous on the dump, but according to reports it made up about half of the commercial production. One chunk is said to have weighed more than 4,500 pounds.

The Panther Creek mine is reported by Noah Goss, of Mull, to have produced about 3,000 tons of concentrates during the World War. Of this about 30 tons was galena and the rest was jack and zinc carbonate. The ore was milled a short distance down the hollow from the mine, and the concentrates were teamed to Harrison.

Keys Gap.—This mine is in T. 15 N., R. 22 W., probably in the NE¼ sec. 11. It lies high on the north slope of the Little Buffalo River. The horizon is in Boone limestone near the top of the formation. Most of the ore was taken out of a tunnel, now caved but reported to be about 200 feet long. The tunnel entered the hill on a line N. 15° W. but hit a fracture about 100 feet back, from which most of the ore was taken. This fracture runs N. 20° E. and has been prospected for several hundred feet to the southwest, two or three exploratory shafts lying fairly near to the main tunnel. A little brecciation in the limestone along the fracture indicates that some faulting has taken place, but the movement appears to have been slight. The horizon of the main tunnel is about 40 feet below the top of the Boone, but the workings extend up to the top of the formation, appearing on the surface as an open cut.

The ore consists of galena, zinc carbonate, and, according to reports, zinc silicate, although none of the silicate was identified on the dump. The galena occurs as imperfect cubes, as much as an inch or so in size, embedded in rather fine to coarse grained limestone along the fracture. This limestone is pocked with small cavities from which zinc sulphide has been leached, and here and there a little dark rosin jack, in grains one-eighth inch or less in size, is still preserved. Some of the galena and jack also appears in masses an inch or more across, embedded in broken-up chert that contains a limestone matrix. The carbonate was formed chiefly by replacement of the limestone, but occurs also as blue-gray crystalline material in small openings in the chert. A little pink spar was deposited in the limestone along with the primary sulphide minerals.

The production of the Keys Gap property has been about 180 tons of concentrates, of which about one-third has been galena and two-thirds zinc silicate as reported, although the silicate has contained an unknown proportion of zinc carbonate.

Jackpot.—This mine is in a bluff on the right side of the Little Buffalo River, 50 feet above water level, in the SE¼SW¼ sec. 22, T. 15 N., R. 22 W. The main working is a short tunnel, now caved, at a horizon in the Boone formation estimated to be 75 or 100 feet below the Batesville sandstone. The regional dip of the rocks is upstream (to the south) at a low angle (about 3°), but the mine is located on a small monocline that drops the beds a few feet on the east, flexing them over a width of 30 or 40 feet without faulting them. The ore on the dump is gray to drab zinc carbonate associated with pink spar in a coarsely crystalline gray dolomite (gray spar) or in Boone chert. A little of the original rosin jack occurs disseminated in ¼-inch grains in the gray spar. A peculiar feature of the mineralogy of this mine is the large amount of barren coarsely crystalline calcite that occurs in drusy pockets in the rock for 50 feet or so west of the monocline in the portal regions of the tunnel.

A second tunnel has been opened on the same side of the river, 30 feet above water, at a point 300 or 400 feet downstream. It is driven 120 feet on a fracture running S. 19° E. but is barren.

Lamar.—This mine is in the NW¼NW¼ sec. 33, T. 15 N., R. 22 W., on the left slope of a hollow tributary to the Little Buffalo River from the left. The horizon is in the Boone formation, 60 feet or so below its top. The main working is a tunnel 120 feet in length driven, toward its front, on a poorly developed watercourse that runs N. 25° W. The watercourse follows an obscure fracture and is filled with clay. Toward its rear the tunnel swings more to the west, and the fracture becomes still more obscure. Just within the portal a shaft goes down to a depth of 40 feet or so, dipping 75° or 80° E., along the watercourse. Another shaft has been sunk on the extension of the fracture from a point 60 feet higher on the hill, but whether mineral was struck in this shaft is not known. A tunnel on the same run between the main lower tunnel and this upper shaft is caved.

The ore within the main tunnel is zinc carbonate in various forms. One type is brownish and crusty and may contain specks of malachite. Another type, developed sparingly, is composed of gray concentric shells or plates, resembling pine bark. A third type has replaced the pink spar that accompanied original jack along the fracture.

The dump in front of the mine shows, in addition to the minerals mentioned, some zinc silicate and galena, the latter in crystals averaging between one-fourth and one-half inch.

UPPER CAVE CREEK DISTRICT

The upper Cave Creek district is in Newton County, about 6 or 8 miles south of the southwest corner of the Yellville quadrangle. It is localized along a pronounced structural break, the Confederate fault, on the headwaters of Haw Hollow, a tributary to Cave Creek from the east. The ore deposits appear on minor fractures in the Boone formation, on the northwest (upthrown) side of the fault. The ores have been chiefly zinc carbonate and lead sulphide, the former predominating. Although some of the earliest mining in northern Arkansas was done in this district, the greatest development took place during the period of high prices produced by the World War. The production of the district during this period, according to R. F. Truitt, of St. Joe, was about 3,100 tons of zinc carbonate and 1,200 tons of galena. The most productive mines of the district are the Bald Hill and Confederate.

Bald Hill.—This property lies in the SE¼NE¼ sec. 35, T. 15 N., R. 19 W., on the head of one prong of Haw Hollow, about 2 miles up from Cave Creek. Most of the mining has been done from shafts on the top and sides of a low spur whose surface is mantled with a thick coating of Boone chert debris, derived from the weathering of the ore-bearing beds. A deep shaft near the south base of this spur is 86 feet in depth and had just reached ground-water level at that depth. The altitude of its collar is about 1,080 feet.

The mineralized area is limited on the southeast by the Confederate fault, which in this region trends about N. 43° E. The throw on the fault increases from northeast to southwest; at the northeast end of the fault segment that is adjacent to the mines, the Boone lies against the upper Fayetteville, but at the southwest end, opposite the deep shaft, the Boone is in contact with the Pitkin. The amount of the displacement cannot be determined, as it is not known how far the Bald Hill ores lie below the top of the Boone. The minimum displacement opposite the deep shaft is estimated to be about 250 or 300 feet.

The developed ore farthest from the fault, including that on adjacent properties north of the Bald Hill mine, lies about 800 feet northwest of the fault.

The bedding of the Boone, as nearly as can be judged from reports on the mining developments, is nearly horizontal; the Pitkin opposite the deep shaft dips 20° S.

The ore deposits occur along minor fractures that, as a rule, strike about N. 10° W. One of the most productive runs, however (fracture *d*, fig. 11), showed a strike of N. 35° W., and the run on the lowest level of the deep shaft in fracture *a* trended east-west. The westernmost fracture from which ore has been mined at Bald Hill (*b*, fig. 11) shows, in a drift on one of the ore levels, a vertical displacement of 2 feet, down on the east. The vertical component, however, is small compared to the horizontal one, to judge from the low angle at which the flutings of the slickenside, exposed on the west wall of the drift, dip to the north. The east wall of the fault thus moved down and to the north relative to the west wall. It is probable that some or all of the other fractures that carry ore at Bald Hill show comparable dis-

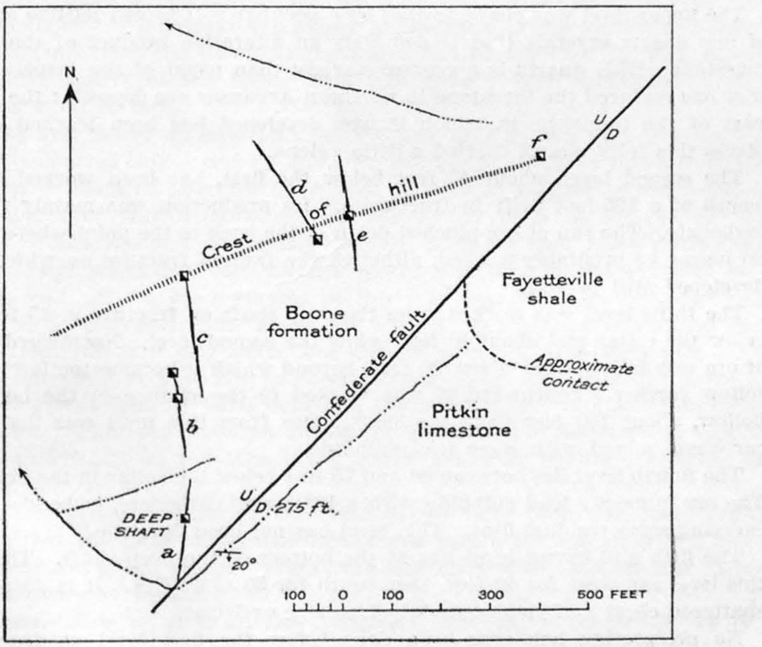

FIGURE 11.—Sketch map, more or less diagrammatic, of the fractures along the ore runs at Bald Hill. (See text.)

placements, but no others were exposed for observation at the time that the property was visited. Most of these fractures are marked by zones of vertical sheeting in the chert beds which they cut. Such sheeted zones show a superior resistance to weathering and tend to stand out on the weathered surface of the Boone. According to R. F. Truitt, of St. Joe, prospecting has been controlled largely by these sheeted siliceous reefs.

Ore at Bald Hill has been found at five separate levels. Each level, except the fifth, is developed in limestone and is capped by chert. The fifth and lowest level is in shattered chert. The highest level, from which most of the production has come, lies from 45 to 50 feet below the top of the hill and would outcrop on the sides of the hill were it not for the thick concealing mantle of Boone chert debris. All the fractures produced ore at this horizon except *a*, whose intersection with the horizon in question has been removed by erosion. This upper ore level was worked from shafts on the top and sides of the hill; from the foot of each shaft drifts were run north and south along the ore bodies, in places to the grass roots.

The ores taken from the upper level were lead sulphide, lead carbonate, and zinc carbonate. In general the lead sulphide and zinc carbonate were mixed together, but in fracture *d* the lead lay above the zinc, the ore run being 10 or 12 feet high. Fracture *c* produced only the carbonates of zinc and lead on the upper level. At the south end, where the ore lay close to the surface, it consisted of a high-grade crystalline "rice grain" lead carbonate. Farther north, where the ore was more deeply buried under the top of the hill, it consisted largely of a peculiar sheeted zinc carbonate called "pine bark ore" by the miners in allusion to a fancied resemblance to pine bark. This ore was very friable, and most of it was shoveled out, like sand.

The upper level was characterized by a peculiar soft brown feltlike aggregate of fine quartz crystals that is definitely an alteration product of the original limestone. This quartz is a coarser variety than usual of the jasperoid chert that has replaced the limestone in northern Arkansas ore deposits; the residual part of the limestone in which it was developed has been leached out. In places this felty quartz carried a little galena.

The second level, about 40 feet below the first, has been worked only the length of a 125-foot drift in fracture *b*. Its production was mainly free zinc carbonate. The run of ore pinched down at the back to the point where it could no longer be profitably worked, although the faulted fracture on which it was developed still persists.

The third level was worked from the deep shaft on fracture *a*, 45 feet or so below the collar and about 40 feet below the second level. Northward the run of ore was followed for about 80 feet, beyond which it became too low grade to follow farther. Southward it was worked to the surface in the bed of the hollow, about 150 feet from the shaft. Ore from this level was mainly zinc carbonate mixed with some lead sulphide.

The fourth level lies between 60 and 75 feet below the collar in the deep shaft. The ore is mostly lead sulphide with a little zinc carbonate, embedded in clay carrying some residual flint. This level has not been developed.

The fifth and lowest level lies at the bottom of the deep shaft. The ore on this level ran west for 40 feet, then south for 50 to 60 feet. It is developed in shattered chert and yielded mainly free zinc carbonate.

No prospecting has ever been done below the first level on fractures *c*, *d*, and *e*.

The cross-sectional dimensions of the different runs, as might be expected, were variable. The run on the third level (fracture *a*) was 6 to 10 feet wide and about 10 feet high. The run on the second level decreased from 10 feet in width and 20 feet in height at the front of the drift to 1½ feet in width and 10 feet in height at the back. The run on fracture *d* of the top level was especially wide and rich. It was wider at the top, where it carried galena, than at the bottom, where it carried smithsonite. The width ranged from 10 to 30 feet and averaged perhaps 20 feet; the height was 10 to 12 feet. The run on fracture *e* increased in one place to 30 feet in width and 20 feet in height; this was in lead carbonate. The other runs on the top level were smaller.

The only primary ore at Bald Hill occurs in the floor of the fifth level. A 6-foot exploratory shaft was sunk in the floor near the southernmost workings on the level, and material from this shaft was studied on the dump by the writer. The gangue rock is a coarse gray dolomite accompanied by considerable pink spar and carrying unaltered fragments of original Boone chert. The dolomite and pink spar have very plainly replaced the original limestone. The primary ore minerals are galena and rosin jack. According to R. F. Truitt, the galena was above the jack but this was determined from a very shallow cut (6 feet) and is very possibly due to removal of the jack from the very top of the primary ore by leaching; still, the two minerals were nowhere observed by the writer in the same hand specimen. The galena occurs in the pink spar and, according to Mr. Truitt, was also disseminated in the dolomite. In some of the rock removed, the individual masses of galena reached 3 or 4 inches in diameter; the average size, however, is less than an inch. In contrast to the galena, the jack occurs in very fine grains, thickly disseminated in the dolomite. Chalcopyrite occurs in very small quantities in the primary ore.

That other types of primary ore may have formerly been present is suggested by the occurrence of pink spar and galena in fractured primary chert in a specimen picked up from the dump at the south end of fracture *d*. The galena in the felty quartz of the upper level has already been mentioned in the discussion of that level.

Ore was first mined at Bald Hill in 1876 and 1877 by the Boston Mountain Mining Co. During this period an unknown amount of lead was taken from the northernmost shaft on fracture *b*, reduced in a little smelter on Cave Creek at the mouth of Haw Hollow, and hauled by ox team to Russellville for shipment. The greatest development of the property took place during the period of high prices produced by the World War, but as the property possessed no mill, all the ore marketed at this time was free ore. A small mill was put up in 1925 and from 100 to 150 tons of concentrates was milled and shipped from the mill dirt taken out earlier with the free carbonate. All of the development at Bald Hill has been carried on by very primitive methods. The drilling was done by hand drill and the hoisting by windlasses operated by man power. The ore produced during the last period of activity was hauled by team to Pindall, on the Missouri & North Arkansas Railway, 15 miles to the north.

Records of production during the boom period have been lost. Mr. Truitt estimates that the total production during this period for the Bald Hill tract was about 3,500 tons. The ore averaged about one-fourth lead ore and three-fourths zinc ore by weight.

Bierbaum.—This mine is in the NE¼NE¼ sec. 35, T. 15 N., R. 19 W., across the head of a hollow and 500 to 600 feet north of the Bald Hill workings. It produced about 130 tons of lead sulphide from a level that appears to be the same as the upper one at Bald Hill. This property was worked from a shaft.

Confederate.—The Confederate mine is three-quarters of a mile southwest of the Bald Hill, in the SE¼SW¼ sec. 35, T. 15 N., R. 19 W., on a low point between two headwater forks of Haw Hollow, at an altitude of 985 feet. It is in essentially horizontal Boone limestone and chert beds, about 500 feet west of the Confederate fault. The fault in this region is rather hard to locate precisely, on account of the low relief near the drainage head, but it has swung from the N. 43° E. course at the Bald Hill tract to a course that is about N. 15° E. Opposite the Confederate mine Pitkin limestone has been thrown against the Boone. The throw increases to the northeast so that a black shale overlying the Pitkin is in contact with the Boone.

The workings from which the commercial production has come consist of a series of shafts along a belt 20 to 25 feet wide and about 200 feet long, bearing N. 10° W. The ore runs were worked from lateral drifts along this belt, mainly at a depth of about 40 feet. The main shaft at the north end of the group was worked for lead by the Confederate forces in 1864. In 1876 and 1877 this shaft was extended to a reported depth of 160 feet by the Boston Mountain Mining Co., and drifts were run on one or more levels, but mainly on the 40-foot level, on the ore run indicated by the line of later shafts. The original shaft is reported to have carried lead to the very bottom. This ore was reduced in a small smelter at the mouth of Haw Hollow, and the pig lead was hauled by ox team to Russellville. None of the later shafts were more than 50 feet in depth. An elaborate mill was erected during the World War period as part of a big promotion scheme but was later torn down.

The ore minerals at the Confederate are chiefly galena, smithsonite, and rosin jack. The galena occurs either in clay or in seams in primary chert; it is accompanied by pyromorphite stains. Most of the smithsonite is of a gray opaque rock-like type that may have replaced dolomite or limestone. Additional evidence suggestive of the same thing is the development of the gray-rock carbonate as a cementing matrix for fragments of the primary chert. The jack, according to R. F. Truitt, occurred mainly in fine grains disseminated in dolomite (limestone?). In addition some of it appears in fine grains disseminated in black-banded jasperoid that has very plainly replaced the original limestone. All of the jack is reported to have come from the bottom of the Old Confederate shaft. Some of the zinc carbonate on the dump shows a little green malachite stain, indicating a trace of copper in the primary ore. A little pink spar lying loose on the dump shows that this gangue was developed with the primary ore.

The commercial ores were lead sulphide and zinc carbonate. During the period of activity induced by the high prices prevailing in the earlier stages of the World War, an estimated production of about 400 tons of zinc carbonate and 150 tons of lead sulphide was made from this tract. Part of the zinc carbonate, in the free form, had been piled out at the time the Old Confederate shaft was worked for lead during the days of the Boston Mountain Mining Co. The ore was hauled by wagon to Pindall, the nearest shipping point, 16 miles to the north.

Ragged Breeches.—This mine is in the NW¼NW¼ sec. 2, T. 14 N., R. 19 W. The shaft was sunk in a fairly flat area well above drainage levels to a reported depth of 40 feet. It is now caved in. This mine is in the Boone on the northwest side of the Confederate fault. During the World War it produced about 20 tons (another statement says 70 tons) of free zinc carbonate and about 15 tons of lead sulphide. The carbonate remaining on the dump is mainly of the dry-bone and "rock" types, but a little crystalline (botryoidal) ore is present.

Lost Mountain.—This mine is in sec. 3 T. 14 N., R. 19 W., on the ridge of a low divide between two prongs of Haw Hollow. It is in the Boone formation, and the ore produced was mixed with flint. Mining was done from a shaft probably 25 or 30 feet deep; drifting from the foot of the shaft was confined to a small radius. The production during the World War period was about 40 tons of free zinc carbonate and 15 tons of lead sulphide, the latter having been hand-jigged on the ground. The carbonate was noteworthy on account of its occurrence in pearl-gray botryoidal masses ("crystallized carbonate") of extreme purity, as much as 300 pounds in weight. Some of the carbonate is reported to have been turkey fat.

Turkey Fat.—This prospect is in sec. 3, T. 14 N., R. 19 W., just across a small hollow west of the Lost Mountain mine. The development consists of a small open cut in the Boone formation on the side of the hill. It is reported to have produced somewhat less than a carload (40 tons) of zinc carbonate, a large part of which was turkey fat.

MOUNT HERSEY-LOWER CAVE CREEK DISTRICT

The Mount Hersey-lower Cave Creek district lies in northeastern Newton County. The deposits occur in medium- and fine-grained dolomites in the Everton formation. The ore minerals are jack and zinc carbonate, occurring separately or mixed in the different deposits. The production from the district is known to have been about 250 tons (100 tons jack) but may have been somewhat greater.

Old Granby.—Working on this property began as early as 1875, when the Old Granby Mining Co. first put down a shaft. The property is in a field on the sloping divide between Davis Creek and Mill Branch, 700 to 800 feet north of Mount Hersey, in the NW¼ sec. 25, T. 16 N., R. 19 W. The workings consist of five or six old shafts, now caved, strung out in a roughly east-west line about 300 feet long. They are reported to have been 40 or 50 feet deep, but the ore was taken from a horizon above their bottoms. The shaft collars are in the Everton formation, about 100 feet above its base. The ore is gray crystalline and crusty zinc carbonate, associated with some pink spar, in shatter cracks in a medium-grained dolomite of the Everton formation. The production of the property is reported to have been about 150 tons of free carbonate ore.

Unnamed prospect.—A fairly promising prospect (name not known) is 50 feet above creek level in the low bluff on the left side of Davis Creek, perhaps half a mile above Mount Hersey, probably in the SE¼ sec. 23, T. 16 N., R. 19 W. It lies only a short distance below the road up Davis Creek. The opening is a rock cut, about 50 feet long along the contour of the steep hill and 15 feet high at the back. The ore is mixed rosin jack and carbonate and occurs associated with pink spar in cracks and replacement pockets throughout the depth of the back face of the cut but more especially in slightly brecciated rock in the lower 5 feet. The country rock is a medium-grained dolomite. The carbonate is of several types; the gray to purplish crystalline and honeycomb black types are most common, but there is a little turkey fat. Some of the carbonate has replaced pink spar in the druses. Several tons of ore has been piled up in the cut, considerably more in the carbonate pile than in the jack pile.

Yount.—This mine is 50 feet above low-water level of the Buffalo River, on its right bank about a mile below Mount Hersey, some distance above the mouth of Cave Creek. The workings consist of two or three open cuts over a distance of 200 feet, the largest one at the north being 50 or 60 feet long along the contour and 10 feet high at the back; a drift (now caved) from the back end of the main open cut; and a second drift, 50 feet long, in practically barren rock, 20 feet below the main workings. The horizon is near the base of the Everton formation. The ore on the productive level is mixed rosin jack and carbonate, the latter predominating, and occurs in association with pink spar in cracks in a medium-grained dolomite. The carbonate is largely of the gray crystalline type, but there is also considerable crusty black carbonate carrying a trace of malachite. The dolomite is overlain by a 1-foot sandstone ledge and underlain by 5 feet of quartzitic sandstone. The lower barren level is in fine-grained dolomite.

Several tons of fairly good mill carbonate is stacked on the dump. The mill, erected in the bluff below the level of the main workings, is now in ruins.

Belle of Wichita.—The opening on this property is a short curved tunnel, probably no more than 200 feet long, driven into the left bank of a small hollow that runs into Cave Creek from the east in the NW¼ sec. 12, T. 15 N.,

R. 19 W. The tunnel is 500 feet above the mouth of the hollow. It was full of water at the time it was visited. The horizon is in the Everton formation about 150 feet below the St. Peter sandstone. The ore fills shatter cracks in a fine- to medium-grained but mostly fine-grained sandy dolomite that grades above into dolomitic sandstone. The ore mineral is rosin jack with or without accompanying pink spar and minor amounts of calcite. A little pyrite occurs in the country rock adjacent to the mineralized cracks. Probably 100 tons of jack was milled on the property before 1908. The mill has since been completely destroyed.

MILL CREEK DISTRICT

The valley of Mill Creek, which is a branch of the Buffalo River heading a couple of miles north of Wilcockson, contains two mines, the Marble City and Canton, both of which are reported to have produced ore from the Everton formation. Only the Canton was visited by the writer, and the reader is referred to Branner's report for a description of the Marble City.

Canton.—The Canton mine is on the left bank of Mill Creek in the SE¼ sec. 6, T. 16 N., R. 20 W., half a mile above the junction of the creek with the Buffalo River. The openings are several open cuts and shallow shafts made almost at creek level. Bedrock does not crop out in the immediate vicinity, but the horizon appears to be in the Everton formation a short distance below the Newton sandstone. The ore is rosin jack, associated with a little pink spar, and occurs disseminated both in sandstone and in a sandy gray spar (coarse gray dolomite). A trace of chalcopyrite is associated with the jack, and zinc carbonate has formed to a minor extent as an oxidation product. It is reported that several carloads of jack concentrates have been shipped from this property.

DAVIS CREEK-HURRICANE BRANCH DISTRICT

Two very productive mines, the Spier and Big Hurricane, are located on the St. Joe fault in northeastern Newton County and northwestern Searcy County respectively. At each of these mines the fault has a displacement that is near 150 feet and brings the Boone into contact with the Everton formation. The known production of the district has been around 8,450 tons of zinc carbonate and silicate concentrates, the greater part of which was milled between 1914 and 1918.

Spier.—This mine is in the NE¼ sec. 9, T. 16 N., R. 19 W., on the left bank of a hollow a few hundred feet above (west of) its junction with Davis Creek. It is located on the St. Joe fault, which has brought rocks of the Everton formation on the north into contact with those of the Boone on the south. The developments consist of a huge open pit, 75 feet wide, 150 feet long (along the fault), and 50 feet deep; a shaft, extended from the bottom of the pit an additional 90 feet; and a second shaft (now caved) that goes down on the south side of the pit to a reported depth of 80 or 90 feet, from the bottom of which a drift 60 or 70 feet long extends into the rock under the pit. It is reported that a heavy flow of water was a serious problem in the exploitation of the mine at these lower depths. Water at present fills the lower 10 feet of the open pit.

The ore is zinc silicate in the upper levels but gives way to rosin jack below. It occurs embedded in the matrix of the fault breccia. This matrix, in fresh specimens that carry jack, is a clayey fine- to coarse-grained dolomite that may be sandy in places, especially toward the Everton side of the fault zone. Its composition and texture are streaky in detail. Vugs lined by pink spar are not uncommon in it. The jack occurs as small disseminated crystals and also in larger pockets and crosscutting veinlets, associated with the pink spar and occasionally with a little calcite and a trace of chalcopyrite. In the oxidized portion of the mine the dolomite and jack have been leached out, leaving only the porous spongy clay, with the silicate developed in the pores. The fragments of Boone chert in the breccia attain 2 feet in maximum size but are generally much smaller. In addition to fragments from the Boone and Everton, small flakes of laminated black shale of uncertain origin and also scattered blocks of quartzite, containing blackish "worm-bored" phosphatic pebbles of the type that characterizes the basal Boone, are present. Most of the fragments are not mineralized, but some of those composed of sandstone carry a little finely disseminated jack, or replacement blebs of pink spar. The Spier mine is reported to have produced about 1,000 tons of concentrates in 1914–16. There was, however, earlier production amounting to several carloads (1 carload=about 35 tons), part or all of which was made before 1905.

Big Hurricane.—This mine, the most productive in northern Arkansas, is located directly on the St. Joe fault in the head of Hurricane Branch, in sec. 7, T. 16 N., R. 18 W. The fault here throws the Boone formation down on the south until it is in contact with the top of the Everton formation. The throw on the fault is around 150 feet. The opening is a huge open cut (glory hole), about 300 feet long in an east-west direction, 20 to 60 feet wide, and originally 60 to 70 feet deep, though the bottom has been filled in 25 or 30 feet since work ceased. The depth given is along the north wall; the south wall, which has cut back into the hill, is about 35 feet higher. The cut is made directly in the bed of the hollow, lengthwise of its course, and while it is near the drainage head, considerable trouble was experienced during the working from filling in by wash during floods. Most of the ore was taken from a narrow zone along the north wall, near the line of the fault, and the last heading was on this line, going west. After a rather severe wash-in during the latest period of development, a shaft was put down at the west end through the sand and gravel to re-reach the heading, and some work was extended underground.

The top 20 feet of the north wall is formed by the lower part of the St. Peter sandstone. The beds of the underlying Everton formation consist of interbedded limestone, sandstone, medium-grained dolomite, and greenish-blue shale (one 6-inch seam). The rocks in this wall are remarkably unaffected either by the movement along the fault or by the mineralizing solutions. Some of the sandstone and limestone beds, however, have been replaced by pink spar and gray spar over parts of their outcrops, although there has been no zinc mineralization. The limestone of the Boone in the south wall has been shattered and shows a dip of 10° to 15° into the wall. Fairly large masses of pink spar have replaced the limestone on this side; masses of gray spar are less common and apparently are nearer to the mineralized area. The two types of coarsely crystalline dolomite may be intermottled. Although the main mineralization occurred along the fault, some ore was found a short distance back, in the shattered Boone limestone, but none of it is exposed at present.

The ore is chiefly zinc carbonate, but there is some silicate, and finely disseminated jack is reported to have occurred toward the east end of the workings.

Most of the zinc carbonate is said to have been crystalline, but much of it, as well as the silicate, is a drab or brown dry-bone type. Some of the carbonate is developed as a drab replacement product of the matrix of the fault breccia. The silicate is reported to have occurred chiefly at the surface, with the carbonate farther under cover.

The ore occurs in a matrix of the fault breccia. In less altered fragments, such as are reported to have carried the jack and much of the carbonate, this matrix is a clayey dolomite that appears to be irregularly cherty. It contains, in addition to the casts of disseminated jack, irregular replacement segregations of pink spar. Other types of the matrix appear to be more cherty. In much of the surface material at the west end of the pit the matrix is a soft drab claylike material that contains, in addition to the ore, scattered casts of dolomite, of about pinhead size or a little larger. Under the microscope the matrix is seen to be composed of clay (beidellite) and minutely crystalline quartz of the jasperoid type. It is apparently residual from the weathering of an earlier chert or cherty dolomite.

Records of the early output of the Big Hurricane mine are incomplete, but from 1903 to 1905 the production is reported to have been around 2,000 tons of concentrates, chiefly zinc carbonate; for 1907, 400 tons or more is reported; and for 1908, 525 tons. The production during the World War, according to records kept by R. W. Willett (1915) and by the J. C. Shepherd Mining Co., was as follows, in tons of concentrates:

1915	50
1916	1, 330
1917	3, 081
1918	52
	4, 513

This makes the reported total (1903–18) about 7,450 tons, which, except for the production in 1906, probably represents nearly the true total. An average assay of concentrates, according to the books of the J. C. Shepherd Co., shows 39 percent of zinc, 0.85 percent of sulphur, and 0.139 percent of cadmium. The mill, which was one of the largest and most efficient in the northern Arkansas field, made an average recovery of concentrates during 1917 of 13 percent. This mill is at present rapidly going to ruin.

ST. JOE DISTRICT

The mines and prospects in the St. Joe district, in northern Searcy County, are all related to the St. Joe and Tomahawk faults. The ores are in shattered Everton dolomite and sandstone on the north or upthrown side of the faults. The displacement on the St. Joe fault where it crosses Monkey Run is about 230 feet, and that on the Tomahawk fault at the Davy Crockett prospect is about 700 feet. The ore minerals of this district are jack and zinc carbonate, but all of the ore shipped has been jack. The known production of the district has been about 180 tons of concentrates, chiefly jack.

Garvin.—This prospect is on the east side of Monkey Run, 20 feet above the bottom of the hollow, in the northeast corner of sec. 18, T. 16 N., R. 17 W. An old shaft, now caved, was sunk in 1887 directly on the St. Joe fault, to water level at a depth of 20 feet. The north side of the fault here shows shattered and brecciated Everton dolomite and sandstone; the south side shows brecciated Plattin limestone. The ore is in the Everton and consists of zinc carbonate associated with pink spar filling cracks adjacent to the fault breccia but tending to avoid the breccia proper. The ore occurs in medium-grained gray dolomite, sandy dolomite, and dolomitic sandstone.

Dale.—This prospect is on top of the hill east of the Garvin prospect, in the northwest corner of section 17, T. 16 N., R. 17 W. A shaft, now caved, was sunk in 1887 directly on the St. Joe fault, to a depth of 90 feet. The shaft has Everton dolomite on one side and Boone chert on the other; most of the development work in the shaft was in the Everton, with the hard quartzitic fault breccia appearing along the south wall. The shaft, according to reports, showed zinc carbonate all the way down, some of it in blocks as large as 50 pounds. The carbonate is of a gray crystalline type, some of it being honeycomb. At the very bottom of the shaft the workings went from carbonate into jack. The ore on the dump hoisted from this level shows rosin jack associated with pink spar in sandy gray dolomite.

East of the Dale shaft, along the St. Joe fault, a few other small openings show a little zinc carbonate.

The St. Joe fault just east of the Dale shaft is marked by a resistant siliceous reef that stands out on the erosion surface. The reef is composed largely of quartzite that has been broken up and recemented. It shows a few pockets of opaque drab to whitish chert that may carry a few jack casts.

Excelsior.—This mine has been more extensively developed than any other in the St. Joe district. It is situated on the steep hillside east of Monkey Run, about 200 feet north of the St. Joe fault, in the southeast corner of section 7, T. 16 N., R. 17 W. The ore is in the Everton formation and has been developed over a vertical interval of 80 feet, between 160 and 240 feet below the base of the St. Peter. The main ore run parallels the St. Joe fault and is apparently localized on a minor fracture. On both sides of the fracture the wall rock, which consists of medium-grained gray dolomite and dolomitic sandstone, has been shattered and mineralized for varying distances. On the north side the rock removed in making the cut for the mill location was mineralized for a distance of 50 feet from the main run, and this rock, though of low grade, was nevertheless rich enough to run through the mill. Most of the ore now exposed on the face of this cut lies in small discontinuous veinlets parallel to the main ore run, but some of it is in horizontal or diagonal veinlets, and some shows a tendency to be disseminated, apparently by replacement of the country rock.

The developments consist of two shafts on the main ore run, the west one, 50 feet deep, at an altitude of 840 feet, and the east one, 70 feet away and 65 feet deep, at an altitude of 870 feet. The west shaft showed the ore run to be 4 feet wide at the surface but 20 feet wide at the bottom. The mine is well equipped with a mill and machinery that are being kept up somewhat better than those at most of the idle mines of the northern Arkansas field.

The ore minerals are jack and zinc carbonate. Jack prevails in the open cut in which the mill is erected, even to the surface, and also in the main run below the 20-foot level in the west shaft. It is rosin-colored, with a suggestion toward red (ruby jack). The carbonate occurs in the main lead to a depth of 20 feet in the west shaft. It is a high-grade crystalline mineral of a flesh-gray color. Both of the ore minerals are associated with pink spar, and here and there a little colorless calcite appears as a late primary crystallization. A very little chalcopyrite, in crystals the size of pin heads, is associated with the jack and pink spar, and pyrite occurs rather sparingly in the country rock adjacent to the upper shaft.

This mine has produced about 140 tons of concentrates, mostly jack, which ran 58 to 62 percent in metallic content.

Two prospect holes have been drilled north of the Excelsior run. The first is 100 feet north of the upper Excelsior shaft, and at the same level. Its depth is 175 feet, and it is reported to have shown jack over an interval of 107 feet, between 56 and 163 feet from the surface. The second hole was sunk from the same level as the first but 100 feet farther north. It went into jack ore at 42 feet and showed ore to the bottom, at a depth of 84 feet. A shaft sunk on this drill hole is reported to have just reached the ore when work had to be discontinued for lack of the necessary capital to develop further. The ore exposed on the dump shows jack associated with pink spar and fine drusy quartz in a medium-grained gray dolomite country rock. Some of the jack is in well-formed ⅛-inch crystals in open druses; some of it is also disseminated, without gangue, in the dolomite.

An interesting old watercourse, long abandoned, appears in this last shaft, just above the ore. It is 10 feet deep and at least 20 feet wide. Most of the pebbles in it are Boone chert, many of them much water-worn.

Campbell.—This prospect is on the east slope of the main branch of Monkey Run about half a mile above the Excelsior, in the SE¼ sec. 7, T. 16 N., R. 17 W. The altitude of the shaft collar, which is 50 feet above the bed of the hollow, is around 940 feet. The geologic horizon is in the Everton formation about 100 feet below the top. The development consists of a 50-foot shaft sunk on a minor east-west break, the exact displacement of which was not determined. The break is exposed in the creek bed below, and its position is marked on the slope near the shaft by a quartzitic reef, the presence of which led to the sinking of the shaft. Ore was present in the shaft from top to bottom but avoided the quartzite that forms the south wall of the shaft.

The dominant ore mineral is jack, associated with pink spar and fine drusy quartz in small irregular veinlets. Some of the jack and pink spar appear as well-formed crystals in druses. A little of the jack is disseminated in the dolomite. The jack is dominantly rosin-colored, but certain blotches are black (greenish in transmitted light), and others are lemon-colored. Near the surface the jack has been altered to carbonate. Pyrite is present but is spotty in distribution. The country rock is mainly medium-grained gray dolomite, some of which is sandy, but a little of the ore is in quartzitic sandstone.

Roaring Hollow.—This prospect consists of two or three small open cuts, at an altitude of 860 feet, in and just above the creek bed of Roaring Hollow, in the SE¼ sec. 8, T. 16 N., R. 17 W. The openings are in the Everton formation, about 400 feet north of the St. Joe fault. The rocks in the immediate vicinity show some contortion and brecciation, but the beds exposed downstream toward the fault are undisturbed except for a low-angle tilt away from the fault. The rock in which the ore occurs is dolomite of varying appearance, from medium to rather fine grained dark gray, through medium-grained gray to coarse-grained gray. A little of the ore is in quartzite. The ore zone is underlain by limestone between the openings and the fault. The ore mineral is jack, associated with abundant pink spar and a little chalcopyrite. Here and there it is disseminated in the dolomite, or even in the quartzitic sandstone.

Davy Crockett.—This prospect is on a tributary to Tomahawk Creek from the west, in the N½NE¼ sec. 9, T. 16 N. R. 17 W. The main working is a wide drift, practically at water level, that penetrates 25 feet into the hillside on the north side of the branch. At the portal this drift merges into a narrow open cut, extending along the side of the branch at right angles to the drift for 60 or 70 feet and 15 feet high at the back. The altitude is about 885 feet. The country rock consists of a series of Everton dolomites and sandstones at a horizon about 150 feet below the St. Peter sandstone ledge. The portal of the drift is just 180 feet north of the Tomahawk fault, which here throws Fayetteville shale against the Everton. The throw on the fault, directly opposite the prospect, is about 700 feet. The ore-bearing beds, however, are undisturbed except for a little minor shattering. Downstream from the prospect for several hundred feet the rocks exposed in the creek bed are brecciated but carry no ore.

The main ore bed is a gray dolomitic quartzite about 3 feet thick that lies just above the floor of the workings. This bed shows a richer mineralization on the back face of the open cut than it does within the drift, apparently owing to the fact that this face is developed along a minor fracture parallel to the Tomahawk fault. The ore is found in small discontinuous vertical and inclined cracks and locally in shattered zones that resemble breccias but that are not true breccias in the sense that the rock fragments have been rotated relative to one another. A fine-grained dark-gray dolomite, 4 feet thick, overlying the main ore bed, is mineralized to some extent. Above this a 4-foot quartzite bed that forms the roof of the drift and overlying beds of fine-grained dark-gray dolomite are not mineralized.

The ore mineral is a light-colored uniform rosin jack which may or may not be accompanied by pink spar. Drusy crystalline growths of pink spar are common; those of jack are less common. Fine drusy quartz lines the walls of the fractures, and chalcopyrite occurs in minute crystals on the jack crystals and less commonly on the pink-spar crystals. A little white calcite is present.

An open cut 25 feet long, 10 feet wide, and 15 feet deep at the back end lies 15 feet above the lower workings and a short distance upstream. The wall rock is rather fine-grained dark-gray dolomite which is variably sandy. It carries a little pyrite as fine crystals. The ore and the mode of occurrence are similar to those in the lower workings, but owing to the shallowness of the pit much of the original jack has been leached out or altered to carbonate. The carbonate appears as cellular black and gray masses, as finely botryoidal pearl-gray ("crystalline") masses, and as flesh-colored or blue-gray coatings on pink spar.

The Davy Crockett prospect has produced about 40 tons of jack concentrates, averaging about 40 percent of zinc. It formerly had a small mill opposite the workings.

TOMAHAWK CREEK DISTRICT

The drainage basin of Tomahawk Creek above the crossing of the Tomahawk fault contains several mines and prospects, the most productive one of which has been the Lucky Dog. The district lies partly in Marion County and partly in Searcy County. The deposits are on the north or upthrown side of the fault, but with the exception of the Electric mine none of them are especially close to it. All of them, however, are within 1½ miles of either the Tomahawk or the Section 35 fault. The displacement on the Tomahawk fault where it crosses the main creek is around 500 feet; the fault along this particular segment is split into two parts. All the ore deposits are in the Everton formation, in fine- to coarse-grained dolomites, dolomitic sandstones, and locally in thin silicified limestones. The ores comprise jack, zinc carbonate, zinc silicate, and, at the Tomahawk copper mine, malachite. The reported output of the district has amounted to about 900 tons of concentrates, 550 tons of which was jack.

Lockhart.—This mine is in the SE¼ sec. 33, T. 17 N., R. 17 W., on the southwest slope of a rounded knob on the north side of Tomahawk Creek. The mine altitude is 915 feet. The ore horizon is in the Everton formation about 120 feet below the St. Peter sandstone. The opening is a tunnel that goes a few hundred feet into the hill, but it was caved near the portal at the time the property was visited. The ore is chiefly well-crystallized zinc carbonate that occurs in a blanket vein where it has altered from rosin jack. The jack was originally disseminated in chert and cherty dolomite or else was embedded, in ¼-inch to 1-inch grains, in veins of pink spar that occur chiefly along the bedding of these same rock types. Some of the jack is still preserved. A very little chalcopyrite accompanies it. The mineralized chert, where it is exposed near the portal, is only 1 foot thick, and the overlying cherty dolomite shows a similar thickness. The rest of the overlying section for 20 feet includes fine-grained dolomite, limestone, and sandstone, all barren except for the lower 2 feet (dolomite and sandstone), which is cut by a few small veinlets of pink spar carrying a little jack. This mine shipped perhaps 70 or 80 tons of free carbonate ore during the World War.

Uncle Sam.—This prospect is at an altitude of 850 feet, 200 feet below the St. Peter sandstone, on the north slope of Tomahawk Creek, probably in the SW¼ sec. 34, T. 17 N., R. 17 W. The workings consist of two or three small open pits on the outcrop of a 4-foot ore-bearing bed and a shallow shaft to the same horizon from a point higher on the hill. The ore exposed in the cuts is crystalline gray zinc carbonate, with a little residual jack, in irregular replacement pockets in a medium-grained dolomite. The shaft is reported to have shown considerable jack. Pink spar is associated with the ore as gangue.

Copper.—This prospect is located on the south slope of Tomahawk Creek at an altitude of 900 feet, in the NW¼ sec. 3, T. 16 N., R. 17 W. The opening is an open cut, 40 feet into the hill, 20 feet wide, and 15 feet deep at the back. The horizon is in the Everton formation about 70 feet below the St. Peter sandstone. The ore-bearing bed is a 2-foot massive dolomitic sandstone bedded in a series of dense dolomites and dolomitic sandstones. Some ore is also developed in one of the adjacent fine-grained dolomites. The ore is rosin jack, associated with a very little pink spar, in haphazard cracks, lenses, and pockets in the ore bed. The jack masses are commonly 3 or 4 inches across and 1 inch or more thick. A trace of malachite and a little calcite are present in some of the pink-spar druses. Crystalline and honeycomb zinc carbonate are sparingly developed from the jack.

Red Zinc.—This mine lies high on the south slope of Tomahawk Creek, at an altitude of 980 feet, in the SE¼ sec. 34, T. 17 N., R. 17 W. The opening is a tunnel about 100 feet long with several branches at the rear end. The ore occurs in a thin blanket vein in a series of limestones and fine- to coarse-grained dolomites, all of which are more or less sandy. The ore was originally jack disseminated in or segregated in pockets along a bedding plane of a chert that has replaced one of the limestones. Pink spar is associated chiefly in the bedding veins or in crosscutting veinlets. The jack has been altered almost entirely to silicate, though a little of the secondary ore is carbonate. Tallow clay has been developed with the oxidized ores and also along vertical cracks that crosscut the different beds and evidently reach the surface. Although 3 feet or so of the limestone may be silicified, the rich silicate ore bed is confined to only 1 or 2 inches at the top of the silicified zone. The mine is reported by Sam Davis, of St. Joe, to have produced about 100 tons of free ore from a big pocket where evidently the mineralized bed increased abruptly in thickness for a short stretch.

Fullbright.—This property is in the NW¼ sec. 35, T. 17 N., R. 17 W. One of the prospects, at an altitude of 885 feet on the point between Dry Fork and the main Tomahawk Creek, has revealed good ore, although there is no assurance that the ore has any continuity. The horizon is in the Everton formation about 100 feet below the St. Peter sandstone. The beds dip at a gentle angle to the north. The ore mineral is jack associated with a little pink spar and fine drusy quartz in irregular cracks in a mixed sandstone and dolomite. Zinc carbonate is developed sparingly. The opening is an open cut 30 feet long, 10 to 15 feet wide, and 10 feet deep at the back. About 2 tons of mill ore was lying on the dump when the prospect was examined.

A second prospect is on the right bank of a small draw on the east side of Dry Fork, a quarter of a mile up from the main Tomahawk Creek, at an altitude of 775 feet. The horizon is in the Everton, 200 feet below the St. Peter sandstone. Two rather large open cuts have been made into the hill, but only the southern one has revealed any ore. The mineral is jack and occurs with or without associated pink spar in irregular pockets and crosscutting lenses in a fine-grained dolomite. The prospect is not a promising one.

San Juan.—This prospect lies in the bed of a tributary to Tomahawk Creek, probably in the NE¼ sec. 35, T. 17 N., R. 17 W. The workings consist of two or three small open pits and an old shaft, now filled in. The ore is jack, which occurs disseminated in dolomitic sandstone or else associated with pink spar in cracks in the sandstone and in medium- to fine-grained dolomite.

Cold Water.—This prospect is on the gently sloping nose between Coldwater Hollow and Tomahawk Creek, near the center of sec. 2, T. 16 N., R. 17 W., at an altitude of 750 feet. The horizon is in the Everton formation about 100 feet below the St. Peter sandstone. The opening is an irregular-shaped open pit, 100 feet long, 25 feet wide on the average, and about 10 feet deep The ore-bearing zone is 6 feet thick. It consists of medium-grained greenish dolomite in the lower half and greenish sandstone in the upper half. At the base of the dolomite some ore occurs in chert that has evidently replaced limestone, though the limestone is not exposed. The ore is mixed jack and zinc carbonate, associated with pink spar. The jack and pink spar were deposited as irregular crack fillings in the ore beds and to some extent also in the cavities in a brecciated phase of the dolomite. The carbonate, which has oxidized from the jack, appears as thin crystalline coatings and spongy black masses. A very little finely crystalline chalcopyrite accompanies the ore. The prospect is reported to have marketed about 60 tons of free carbonate ore.

Lucky Dog (*Eureka*).—This mine is a few hundred feet up from Tomahawk Creek on the north side of a short hollow tributary from the east, in the NE¼ sec. 2, T. 16 N., R. 17 W., just south of the Marion-Searcy County line. The altitude is 770 feet. The ore horizon is in the Everton formation 50 feet below the St. Joe limestone. The opening is a tunnel, 250 feet in length, whose sides have been stoped out irregularly up to a distance of 100 feet from the center line of the tunnel on the east side and to distances of 50 to 70 feet on the west side (fig. 12).

The Lucky Dog was an important producer during the World War. The ore is rosin jack and occurs associated with pink spar in several different types of rock. The mineralization was concentrated in a greenish sandy bed, 1½ feet thick where undisturbed, that grades laterally and in different parts of its thickness to sandy limestone. Wherever mineralized the sandstone has been altered to quartzite and the limestone to chert. The mineralization, including the silicification, was accompanied by solution, so that the thickness of this bed is subject to abrupt variation; in places is has been practically removed. As the sandstone was originally very limy, much of this variation may

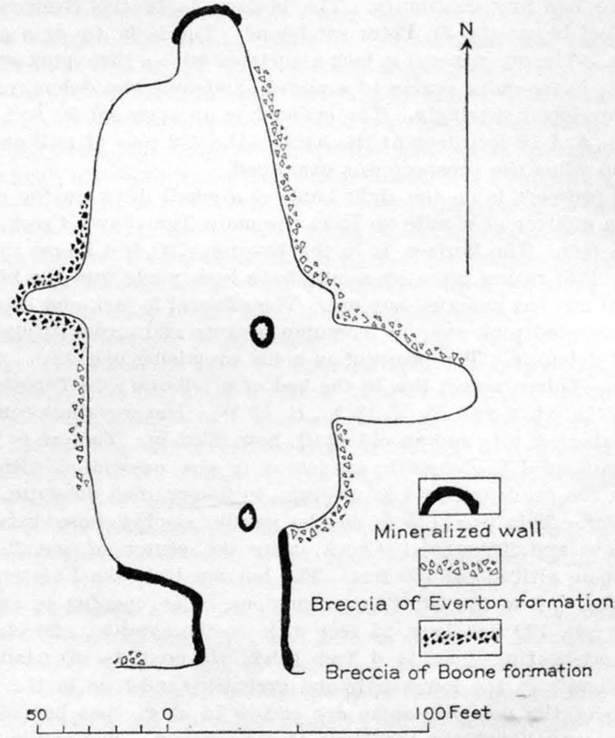

FIGURE 12.—Sketch plan of Lucky Dog mine

be due to the removal of the lime during mineralization. Solution pockets lined by drusy pink spar are conspicuous. The ore and gangue occur in the form of crosscutting and bedding veins, but more abundantly as irregular replacement masses in the sandstone, or chert, as the case may be, and along the bedding plane that separates this bed from the overlying bed. A little jack is also disseminated in both the sandstone and the chert.

Overlying the sandstone is a medium- to coarse-grained dolomite that is irregularly sandy. This dolomite likewise shows many evidences of solution in the form of open druses and contains considerable greenish clay, both interstitially and in bedding seams, evidently residual from such solution. It is shattered in many places and mineralized along the cracks by pink spar that locally carries jack. Some jack may occur in it as direct replacement masses in pockets, without accompanying pink spar, or the two minerals may be present together in irregular replacement masses. The latter type of occurrence is especially well developed in the richer parts of the mine, where the products of mineralization of the upper bed merge with those of the sandstone below, producing an ore face that may be 4 feet or more thick.

The rock below the sandstone, where not greatly disturbed, is dolomite that ranges in different beds from coarse to rather fine grained, the coarse texture predominating. The coarser dolomite may grade in places to limestone. The bed is invaded by numerous large lenses of mixed gray and pink spar that have replaced it along the bedding for distances of 8 or 10 feet, with thicknesses of 1 to 2 feet. Solution cavities as much as 2 or 3 feet across, lined by drusy pink spar, are conspicuous in such masses. Where the gray spar is contained in the medium-grained dolomite, it has probably replaced residual masses of the original limestone. A little jack is disseminated in the gray spar, but so far as commercial ore is concerned the stratum lying below the main ore bed is barren, unless the ore in the very back of the mine, mentioned below, is at this horizon.

The individual beds are very difficult to follow through the mine, owing to the great variability in texture to which certain beds of dolomite are subject, to the possibility of gradation from limestone to dolomite, to the unreliability of the sandstones as regards their persistence and uniformity over any distance, and especially to the presence of breccias in the mine. These breccias are very puzzling when considered in terms of origin. They are exposed on all the walls (see fig. 12) but are not continuous. Evidently they occur at about the same horizon in a series of beds that are not greatly broken by faulting, but they involve the few local key beds (sandstones) in such a way as to make correlations of the beds across them unreliable. In a 40-foot stretch on the east side the breccia is underlain by horizontally bedded unbroken limestone. The contact between the two types of rock is undulatory, showing a relief of 3 or 4 feet within a distance of 5 feet, but its average is essentially horizontal. At the southeast end of this limestone occurrence the breccia cuts down across it to the floor. There are one or two limestone "pinnacles" that project up into the breccia on the east wall, back of the main limestone exposure. At other places the breccias are underlain by a very coarse gray spar mixed with pink spar and containing rather large solution cavities lined with crystalline pink spar. This is the type of material that has commonly replaced massive limestone, and presumably a short distance below the level of the floor the limestone would be encountered.

In composition the greater number of the breccias show angular to rounded fragments of dark-gray or locally greenish medium-grained dolomite and quartzite, with a matrix of greenish clayey sand. The fragments, in general, make up the greater bulk, and adjacent ones may fit together in such a way as to show that there has been very little movement of the one relative to the other. The matrix is of just such a composition as would be obtained from the leaching of some of the sandy dolomite beds that overlie the zone occupied by the breccias, and the dolomite fragments are similar in composition to a bed that immediately overlies the ore-bearing beds in the section at the portal of the tunnel.

Certainly the final process that has operated in producing these breccias has been solution. Otherwise there is no way to get so sharp a division between unbroken limestone below and a breccia of dolomite fragments, that contains no limestone, above. Probably, to judge from the origin of so many other breccias in the northern Arkansas region by structural movement, the solution was here preceded by some shattering that opened the rock, providing channels for the water to circulate. The limestone would then dissolve out, giving the overlying dolomite a chance to slump. Solution through the shattered dolomite would dissolve some of it, leaving a residue of sand and greenish clay that would fill in the cracks in the shattered and partly brecciated dolomite.

On the west wall of the mine near the back the breccia shows a different composition. It is made up of blocks of Boone chert, some of which are 5 or 6 feet across, with a matrix of siliceous clay or sand. Along the borders with the Everton breccias the two types of fragments are mixed, but within the main mass the Boone is largely free from admixture with fragments from the lower horizon. On the surface slope outside the mine no fault that would account for such a displacement of the Boone, 50 feet or more below its normal position, can be located. There are no rock outcrops over an area 100 feet or so in diameter that overlies the underground position of the chert, and this area evidently represents a sink hole into which Boone chert has been dropped. This explanation is in harmony with the interpretation of the breccias in the Everton formation as essentially solution breccias.

That the brecciation of both the Everton and the Boone materials preceded the deposition of the ore is shown by the inclusion here and there in the breccias of pink spar and a little jack, in irregular replacement pockets or in cross-cutting drusy veinlets. On the whole the breccias, especially those of the Boone chert, are barren. Certain of the Everton breccias toward the front of the mine, where the rock has not been so thoroughly broken, carry ore in the interstitial cavities.

The mine has been worked out except at the very back end, where a run of ore is developed in a silicified dolomite breccia at a slightly lower level than the main stopes of the mine. Which bed of the portal section is involved in this breccia is not known, owing to the impossibility of tracing the beds back across the other breccias. The run is about 15 feet wide but only 2 or 3 feet thick. It pitches gently to the north along the dip of the beds at this particular point. Large solution caves, lined with crystalline pink spar and jack, have been developed in this ore run, probably during the mineralization. The largest one noted was 5 feet wide, 4 feet high, and at least 6 feet and perhaps more long. The original breccia here differed from most of the others in Everton dolomite in that the openings in it were not filled with sand and clay. Hence it could be penetrated by the ore solutions, which dissolved it out and intensified the brecciation by the resultant slumpage. The silicification, which occurred irregularly in the breccia, was an accompaniment of the mineralization.

In addition to the rosin jack and pink spar which are the chief minerals found at the mine, the usual trace of copper occurs in the primary ore as finely crystalline chalcopyrite. It has been altered in part to malachite and azurite. Zinc carbonate and silicate are developed very sparingly near the front of the mine, and fine drusy quartz has formed throughout the mine in cracks and pockets in the chert and quartzite. Feldspar (orthoclase and microcline) is a microscopic constituent of the chert.

The only prospect for future production at the Lucky Dog mine lies in the possibility that the ore run at the back of the mine will open up into a wider deposit.

On the opposite side of the hollow from the main mine a smaller deposit of ore has been opened up and worked out. It lies at the same altitude and probably at the same horizon, although the latter inference was not proved. The ore was jack and pink spar, occurring in irregular shatter cracks in a gray to greenish dolomite and also in chert that evidently has replaced limestone. The thickness of the ore bed is about 5 feet. A room considerably smaller than the main opening on the north side has been stoped out.

The greater part if not all of the production from the Lucky Dog mine was marketed in 1917, when 550 tons of jack concentrates were shipped.

Electric.—This mine is in the SE¼ sec. 1, T. 16 N., R. 17 W., on the left side and near the head of a hollow tributary to Tomahawk Creek from the north. The workings lie just north of the Tomahawk fault, which here has a throw of about 600 feet, bringing the lower part of the Fayetteville shale into contact with the top of the Everton formation. The ore horizon is near the top of the Everton. A shaft, now caved, begins at the base of the St. Peter sandstone, practically at the fault, and is reported to have gone to a depth of 36 feet, from which a drift was driven into the hill, under the St. Peter ledge, for about 100 feet. Other smaller drifts, the largest one 40 feet long, are driven from the side and bed of the hollow a short distance upstream but still within 100 feet of the fault.

The ore is mixed jack and carbonate. Much of the carbonate occurs as a lining to jack casts. The jack shows several different types of occurrence in the different openings. It may be disseminated in quartzitic sandstone, in coarse-grained dolomite (⅛- to ¾-inch grains), or in a cherty replacement product of limestone. More commonly it occurs associated with pink spar in cracks and replacement pockets in rocks of these same types, especially in the sandstone. Only one or two of the different types of ore beds were seen in place, so that observations on their thickness and extent are in general lacking. One of the chert beds, however, is 2 feet thick and lies between sandstones. A greenish clay mineral is prominent in seams and flakes in the cherty phases, interstitial to the grains in the dolomite phases, and along cracks into which it has evidently seeped in the sandstones.

The property has produced about 100 tons of concentrates, mostly carbonate. Part of this was free ore. The mill is at present in ruins.

Tomahawk.—This mine is in the SW¼ sec. 6, T. 16 N., R. 16 W., at the head of a steep draw tributary to Tomahawk Creek from the north. The horizon is at the very top of the Everton formation. Although the rocks below the level of the mine are well exposed, the overlying rocks have been deeply weathered and covered by chert debris from the Boone formation above, so that they do not crop out. The Everton strata dip gently to the south. The workings consist of several shafts, short tunnels, and open cuts scattered along a certain horizon over an outcrop length of about 400 feet. Only the workings in and just south of the head of the draw were productive.

The mineralized rock, in the few places where it is exposed, is chert resulting from the silicification of Everton limestone. It carries the casts of disseminated jack throughout its extent, though no zinc minerals were found, nor have any been reported. There is considerable pink spar in irregular replacement pockets in the chert, but without any associated ore in the exposed occurrences. The ore is malachite mixed with a greater percentage of brown iron ore. Where the iron ore has been exposed to the sun for a considerable time on the dump, its surface layer becomes red. None of the ore was observed in place, owing to the decomposed character of the ground, which has resulted in slumping and caving. A few blocks of massive pyrite, containing small irregular blebs of chalcopyrite, lie on the dump pile and show the nature of the original ore. Some of the pyrite has inclusions of sand grains, suggesting that the original ore may have replaced a sandstone or sandy chert. This interpretation is strengthened by the occurrence of the brown iron ore in the form of pockets in the chert.

The silicified mass is apparently thickest in the head of the draw (there is no drainage line above the level of the mine), and it decreases in thickness by rise of its base to the south, along the left side of the draw, over a distance of 300 feet. Although it carries jack casts throughout, the copper and iron minerals in it are restricted to the north end of this stretch. The decrease in the thickness of the chert to the west is more abrupt. The rocks encountered in a shaft 40 feet west of the head of the draw are unaltered Everton limestones and sandstones except for a very little chert that carries casts of jack.

The most productive opening up to 1930 was a 100-foot drift with a shaft at its portal, a short distance south of the head of the draw. Some of the ore masses taken out are reported to have been 5 or 6 feet across. In 1930 the property was worked with a steam shovel, but it has not been visited by the writer since this work was begun. The ore uncovered is reported to occur in scattered pockets at the base of the deep surface debris.

During the earliest period of exploitation, around 1900, a small smelter was built on the property, and about 18 pigs of metallic copper were turned out. Sam Davis, of St. Joe, reports that later work produced 40 or 50 tons of ore that was shipped out.

MAUMEE-WATER CREEK DISTRICT

Included in the general Maumee-Water Creek district, which lies partly in Marion County, partly in Searcy County, along the middle stretch of the county line, are several deposits within the drainage basins of Water Creek, Green Haw Hollow, and Mud Hollow (=Gulf Hollow), and also a couple of deposits along the Buffalo River near the mouth of Water Creek. There is no significant faulting with which the mineralization can be correlated, but the location of some of the deposits on the flanks or the rim of the Water Creek structural basin and on the Water Creek monocline suggests that structural movements connected with the development of these features may have had considerable to do with producing conditions favorable for deposition. The most productive mine of the district, the Sure Pop, is in an especially favorable location, on the northwest rim of the Water Creek basin where the rocks are tilted rather abruptly to the southeast (pl. 3, oversheet). The deposits of the district occur in the Everton, chiefly in fine- to medium-grained dolomites and in dolomitic sandstones. The production has been jack in some deposits and carbonate in others and has amounted to perhaps 3,500 tons of concentrates, most of which came from the Sure Pop. Perhaps a fifth of the total production of the district has been jack.

Christie.—This prospect is in the SE¼ sec. 19, T. 17 N., R. 16 W. The working was a 10-foot shaft in a garden on the left bank of Water Creek, but it has been completely filled in. The ore rock on the dump shows rosin jack, chiefly disseminated in a coarse-grained dolomite, in grains from one-eighth to three-fourths inch in size, but also to some extent associated with pink spar in replacement lenses. A little calcite and a trace of chalcopyrite are present. Black carbonate occurs as a minor oxidation product. A little ore is reported to have been sold from this prospect, but the amount could not have been greater than a few tons.

Water Creek lead prospect.—This prospect consists of two small open cuts lying on both sides of a small steep ravine that enters Water Creek from the south, probably near the northeast corner in sec. 28, T. 17 N., R. 16 W. The altitude is around 720 feet, about 30 feet above the bed of Water Creek. The horizon is 40 feet below the base of the St. Peter sandstone, which is here only 10 feet or so thick. The galena occurs as poorly formed cubes, half an inch in greatest dimension, disseminated in chert that has replaced limestone. The mineral-bearing zone is only 2 to 6 inches thick, and lies at the top of a 2-foot limestone member, immediately below a bed of medium-grained dolomite. Most of the galena is concentrated along certain planes in the chert that are further marked by a concentration of minute dolomite casts. The western of the two cuts contains small disseminated crystals of rosin jack in addition to the galena. This material is of too low grade to ever be of any commercial value but is of interest in being the only occurrence of lead known to the writer in the zinc districts south of Crooked Creek, outside of those in Newton County.

Sure Pop.—This property contains two tunnels, each of which has produced considerable ore. They are in the N½SE¼ sec. 34, T. 17 N., R. 16 W., on opposite sides of Water Creek, perhaps 1,000 feet above its junction with a prominent left branch. The altitude of both tunnels is 675 feet, which is about 50 feet above the creek bed. The horizon is in the Everton formation 30 feet below the St. Peter. For convenience the two tunnels will be described as tunnel 1 and tunnel 2.

1. The tunnel on the left bank goes into the hill for about 250 feet curving from S. 65° W. to S. 75° W. in this distance. From the end of this entry the main workings are developed as a series of irregular large rooms and hallways along a general westerly course for a distance of 200 to 300 feet farther.

The structural feature that has defined the mineralization is a low monoclinal flexure of very local extent whose crest runs about due west along the main line of underground workings, westward from the end of the entry drift. The monocline dips about 10° N. and deflects the beds only a few feet before they flatten out again. One of the ore-bearing beds, a medium-grained dolomite, is in places almost squeezed out along the axis of the monocline. Crossing the monocline are a number of obscure fractures bearing between N. 55° E. and N. 75° E. To judge from the way the mine rooms have been opened along these fractures leaving them exposed only in the roof they have apparently been lines of mineralization. Apparently the entry drift follows one of them.

The total thickness of the ore-bearing interval is about 6 feet. This interval contains three lithologic members—a very limy sandstone at the top (2 feet), a less limy one at the base (1 foot), and a medium-grained dolomite between them (3 feet). Here and there the upper limy sandstone grades into a limestone that carries fossil ostracodes, but where it carries ore the limy material has been either replaced by dolomite (rarely by chert) or else dissolved out, leaving a residual clay. The dolomite between the sandstones grades laterally into limestone on certain of the borders of the ore deposit, although the ore and dolomite are not exactly coextensive, for ore may occur in the top (limy sandstone) member beyond the limits of dolomitization in the member below. The ore zone is overlain first by 2 or 3 feet of sandstone and then by about 30 feet of fine- to medium-grained dolomite that extends to the base of the St. Peter; it is underlain by limestone.

The little ore that remains in the walls of the mine suggests that the top limy sandstone member was the chief ore bed; certainly it carries ore over a wider extent than the beds below it, and in a large proportion of the wall length it is the only member that carries any ore. The dolomite and lower sandstone were mineralized chiefly along the line of rupture that follows the crest of the anticline.

The ore is dominantly carbonate with some silicate and jack. The carbonate and silicate occur in the upper member of the ore interval practically to the exclusion of the sulphide. They are associated with pink-spar and gray-spar dolomite, which have replaced the country rock, and with various types of clay, ranging from a green variety to reddish-brown tallow clay. These clays are evidently residual from the solution of the limestone and pink spar. Some of the pink spar is brown from incipient alteration to clay. The ore is in large part rather intimately mixed with the clay and hard to distinguish, but locally it may appear in small open vugs or as a replacement product of pink spar. The carbonate is commonly brown or gray. The silicate is colorless where crystallized in vugs, but it also appears as opaque flesh-colored material that has replaced chert. Unaltered jack is of rare occurrence in the upper sandstone, though here and there it appears with pink spar, or disseminated in the more dolomitic phases of the member, or in phases that represent a silicification of limestone.

The lower sandstone exhibits features similar to the upper one but has not been so extensively altered and mineralized. In a very few places the top foot of the limestone underlying it has been altered to chert that contains disseminated jack casts, or else to a fine-grained red-brown dolomite.

The dolomite between the two sandstones carries practically all the jack. Along the crest of the monocline, where the disturbance has been greatest, the jack is associated with pink spar and a little calcite as irregular cavity fillings in the more or less squeezed and brecciated dolomite. The bedding has been obliterated in this zone. In certain places the ore and gangue have been preceded by a minor infiltration of sand. Rarely the jack occurs disseminated in chert that has replaced the dolomite. Away from the disturbed zone jack occurs only here and there in ¼-inch crosscutting veins of pink spar. Pink-spar veins occur rather uncommonly in the limestone beyond the boundaries of the dolomite, but no zinc mineral is present in any of them.

The jack is dominantly rosin-colored, but some of it shows spots of black.

Much of the dolomite throughout the mine is pale greenish. Examination with a hand lens shows this color to be due to a pale-greenish clay mineral (beidellite) that forms a matrix to the dolomite grains. This clay may be segregated in small flecks or pockets. It is apparently the same clay mineral that is found in the more leached parts of the upper ore-bearing sandstone, where in many places it forms the matrix of pink-spar masses. In a few places where the dolomite is thin it may be overlain by 3 or 4 inches of this green clay, indicating that some of the thinning that suggests squeezing may be due simply to solution of the dolomite.

A little calcite is associated with the pink spar in the different members of the ore zone, but it is not very prominent.

2. Tunnel 2, on the right side of Water Creek, lies at the same altitude and nearly the same horizon as tunnel 1, but about 600 feet farther downstream. It goes in straight for about 275 feet in a general easterly direction. Most of the ore has been taken from a zone only 2 feet thick that lies immediately under the roof. This zone has been cut back on each side to a maximum distance of 20 feet from the center of the tunnel, but the underlying barren limestone has been removed only along the center line of the tunnel to give a runway.

The ore is embedded in clay and is chiefly brown, black, and gray carbonate, with a little crystalline silicate. Much of the brown and all of the black carbonate represent the replacement of pink spar and jack, respectively. A little rosin jack is residual in the clay. A trace of malachite appears in the black carbonate. Pink spar occurs both in the ore zone and in a few 1-foot pockets in the limestone below, associated with calcite. Where the ore zone has not been so extensively oxidized, pink spar, with some interstitial green clay, makes up the greater part of it. In a small area near the front of the mine the original jack has remained unaltered. It occurs both as a thickly disseminated replacement product in chert, in the top foot or so of the limestone below the main ore horizon, and also in masses as much as 5 or 6 inches across, associated with a little pink spar, in the immediately overlying sandstone. In places the disseminated material becomes so thick as to form an almost solid lens of jack, a foot or so thick and 2 or 3 feet long. Most of this jack is rosin-colored, but a minor amount is black.

The ore in this tunnel lies apparently at a slightly lower horizon than that on the opposite side of the creek. It is overlain by 1 foot of sandstone, then by 5 feet of medium-grained gray to greenish dolomite, then 4 feet of dolomitic sandstone, the second foot of which is dolomite, and finally 37 feet (to the base of the St. Peter) consisting dominantly of dolomite but with 1½ feet of limestone about 3 feet below its top. The roof sandstone in tunnel 2 is tentatively correlated with the lower ore-bearing sandstone of tunnel 1. The overlying dolomite has been penetrated in several raises in tunnel 2, where it is seen to be crosscut by groups of pink-spar veins that apparently carried some ore, but the overlying sandstone, 4 feet thick, whose basal half carries the ore in tunnel 1, has not been prospected in tunnel 2.

The production of the Sure Pop, according to the records of the J. C. Shepherd Mining Co., was as follows, in tons of concentrates:

1915 (September–December)	195
1916	744
1917	315
	1,254

The mine was operated under lease for about a year prior to the time at which the above statistics began, and although the production was apparently not recorded in detail, a summarized statement giving statistics on the property, found in the books of the J. C. Shepherd Mining Co., gave a total production of 2,244 tons for the property, indicating a production of about 1,000 tons prior to September 1915. The ore marketed was carbonate with a little admixed silicate and averaged 41 percent of zinc and 0.11 percent of cadmium. It was very rarely penalized for sulphur. The output in 1915 and earlier came from tunnel 2. The mill, near the portal of tunnel 2, has been destroyed.

Red Bird.— This mine lies on the left hillslope of the left branch of Water Creek, perhaps a quarter of a mile above its junction with the right branch, probably in the NE¼ sec. 34, T. 17 N., R. 16 W. Its altitude is about 690 feet. The horizon is in the Everton formation about 40 feet below the St. Peter. The working is a curved tunnel, 350 feet long, with considerable development about halfway back, partly at a higher level, on the right side.

The ore-bearing beds consist of a series of sandstones, limestones, medium-grained dolomites, and beds of intermediate composition, about 15 feet in total thickness. The limestones are barren except where they are silicified. Certain of the dolomites grade laterally into limestone. A persistent member at the base of the series is an intraformational conglomerate, 6 to 12 inches thick, containing pebbles of limestone and chert in a sandstone or sandy limestone. The series is underlain by limestone and overlain chiefly by dolomite, more or less sandy, to the base of the St. Peter, although the top 5 feet is again limestone. The St. Peter lies about 25 feet above the uppermost ore-bearing bed.

Throughout the greater part of the mine the beds show very minor undulations, first one way and then another, without there being any very marked displacement of a given bed from a level plane. A little crushing has been produced locally, but it is not conspicuous. In that part of the mine from which most of the ore has been removed, however, on the right side about halfway back, rather intense brecciation has been produced by an abrupt upturning of the beds on that side. The main tunnel barely enters the brecciated zone at the base of the monoclinal dip and then leaves it by swinging away to the left. The monocline dips into the tunnel, about 15° SW. The workings have extended only a short distance away from the main tunnel, up the dip of the monocline, and only 80 feet or so along the base of the monocline, so that the extent of the structure is not known. The bedding has been largely destroyed by the brecciation along the foot of the monocline.

The breccia has not been mineralized to the extent that might have been expected—in fact, some of the most intensely broken dolomite, in which limy sand forms a good part of the filling material, contains little or no ore. The mineralization appears to have favored the rock that was simply shattered in place. The ore is carbonate and is associated with a comparatively large amount of pink spar. It occurs as fracture fillings and breccia fillings in the dolomite and sandstone. A minor amount of calcite and a trace of malachite occur in vugs in the pink spar, and a little fine drusy quartz appears on the walls of certain vugs not completely filled with pink spar. Much of the jack that was originally developed with the pink spar has been leached out, without the zinc having been reprecipitated as carbonate, but some of it is still present. It is dominantly rosin-colored, but considerable black also shows.

Away from the brecciated mass the mineralization has been slight. Pink-spar veinlets occur in the dolomites and sandstones, but without ore. A little jack is disseminated in silicified sandstone and in the silicified phases of the intraformational limestone conglomerate that occurs at the base of the ore series. Most of this disseminated ore has been altered to carbonate. Some of the limestone has been silicified in places for a few inches but without the development of ore.

The production, made in the early years of the World War, has been about 200 tons of concentrates.

Lone Star.—This prospect is in the bed of Myers Hollow, which is tributary to Water Creek from the right, in the S½SE¼ sec. 1, T. 16 N., R. 16 W., half a mile or more up from Water Creek.

The openings consisted originally of several drifts into the slopes on both sides of the stream bed. Those on the right, which produced the most ore, had caved at the time the property was visited. The main tunnel on the left goes in 140 feet and has a large stope worked out on the right near the back end and a curving lateral drift on the left. The beds in this drift dip about 10° NW. The ore bed is a greenish dolomitic sandstone, about 5 feet thick, whose top lies 17 feet below the St. Peter. It has been rather extensively replaced by gray spar (dolomite) with the development of a greenish clay interstitial to the gray-spar crystals. This replacement was concentrated along certain bands in the sandstone, probably the zones that were originally more limy. Most of the ore was confined to a thickness of 3 feet. The mineralized bed is underlain by fossiliferous limestone and overlain first by medium-grained dolomite (7 feet) and then limestone (10 feet) to the base of the St. Peter. A short distance up the hollow from the mine the limestone underlying the ore bed has been silicified but not mineralized.

The chief ore mineral is zinc silicate. It is accompanied by a little carbonate and considerable rosin jack. The original jack occurred either in veinlets of pink spar, which tend to lie parallel to the bedding or else disseminated in the gray spar. All the jack originally disseminated in gray spar has been altered to silicate. Aurichalcite in bluish scales is a minor constituent of the less oxidized ore.

This mine is reported to have produced about 200 tons of carbonate (probably in part or largely silicate) during the period of high prices in the early years of the World War.

Silver Run.—The Silver Run workings are in the bed of a hollow that drains southwestward into Water Creek. The property is in Searcy County just south of the Marion County line, in the N½NE¼ and the NE¼NW¼ sec. 6, T. 16 N., R. 15 W. The workings consist of an inclined tunnel (no. 1) on the right (north) side of the hollow, and two tunnels (nos. 2 and 3) and an open cut on the left side. Most of the production is reported to have come from the open cut (150 feet upstream from tunnel 1) and from tunnel 2 (100 feet above tunnel 1), on the left side of the hollow, but the latest workings have been made in tunnel 1. As the tunnels begin at the level of the bed of the hollow, they have to be pumped when being worked. The ore horizon is in the Everton formation 40 feet below the St. Peter sandstone. The beds dip at about 10° W.

The ore-bearing bed in tunnel 1 is a white to greenish sandstone which in places becomes gray and dolomitic. It is reported to be about 5 feet thick in the mine. The ore is rosin jack and occurs associated with pink spar in cracks and irregular replacement masses through the sandstone. Gray to greenish chert has replaced some of the sandstone and is evidently a product of the mineralization. It contains scattered microscopic grains of feldspar (adularia). Finely crystalline chalcopyrite appears in some of the pink spar and jack druses, and minute crystals of pyrite are disseminated in the chert and in the sandstone. Very small amounts of carbonate and silicate are present but are not commercially important. The carbonate occurs as black spongy masses derived from jack in place, or as flesh-colored coatings of pink spar, or as aggregates of fine flesh-colored rods.

The relations of the ore-bearing bed or beds on the south side to that on the north side are not clear, owing to poor outcrops and to the inaccessibility of the workings. Tunnel 2 is driven in a fine-grained dolomite. It was full of water at the time the property was examined. The only ore bed exposed in the open cut is a 5-foot greenish cherty sandstone, containing, chiefly in the upper 3 feet, veins of pink spar and rosin jack, with a little black carbonate. The zone between 1 and 2 feet above the base of the sandstone has been replaced to a large extent by gray spar, which contains some rather finely disseminated jack. This sandstone bed is at a higher level than tunnel 2, as it is underlain by a barren fine-grained dolomite that forms the roof of the tunnel portal. It is probably the same bed that carries the ore in tunnel 1. It is overlain by a chert that contains abundant greenish shale partings and that has been altered from a limestone. Above the chert, which is about 1 foot thick, is 12 feet of sandstone and dolomite that carries some jack and black carbonate in pink-spar veins, but this higher-level mineralization is perhaps of too low grade to have any value.

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Tunnel 3, 180 feet down the hollow from tunnel 1 and on the opposite (left) side, goes in only 20 or 30 feet. It is reported to have been rich near the portal but went blind toward the back.

The Silver Run property is reported to have produced about 250 tons of high-grade jack.

Bear Pen.—This is an undeveloped prospect some distance up from the junction of Bear Pen Hollow with Water Creek, in sec. 6, T. 16 N., R. 15 W. Bear Pen Hollow is the next tributary to Water Creek from the left below the mouth of the hollow that contains the Silver Run property. The working is a small open cut in the Everton formation, estimated 50 feet below the St. Peter, on the north (right) bank of the hollow, just upstream from a small fault that crosses the hollow in a west-northwesterly direction. The beds are somewhat broken up and dip moderately to the southwest, owing to drag along the fault. The country rock is a medium-grained gray dolomite; the ore is mixed rosin jack, silicate, and carbonate, rather sparingly scattered through pink spar that forms veins somewhat thicker than usual, crosscutting the dolomite. Much of the jack has been leached out, leaving only insignificant crusty masses of black carbonate and colorless crystalline silicate. Some of these masses contain a little malachite.

Commercial.—This prospect lies at an altitude of 755 feet near the top of the left bluff of the Buffalo River, in the SW¼NW¼ sec. 4, T. 16 N., R. 15 W., about half a mile below the mouth of Water Creek, at the upstream shoulder of a short draw that breaks the cliff at this locality. The horizon is in the Everton formation about 50 feet below the St. Peter. The ore-bearing beds consist of a series of silicified limestones with two sandstones, and one interbedded 8-foot fine-grained dolomite. Although the different rock types, including the sandstones, carry abundant pink spar in veins and irregular replacement pockets over an interval of 15 feet or more, the only beds that contain any considerable ore in addition are the dolomite and a 1-foot sandstone under it, lying at the base of the series. The ore was originally a rosin jack but has been largely converted to black and colorless crystalline silicate. A trace of malachite shows in the black silicate.

The silicified limestones that have been invaded by pink spar show considerable crumpling, which is apparently due to solution at the time of silicification. They also contain a large amount of green clay in fractures. The uppermost sandstone of the series has been extensively replaced by pink spar and gray spar.

The working is a tunnel 170 feet long, that rises through 14 feet of beds between the portal and the end, at the same time curving sharply to the left. It does not follow any apparent structure or any localization of ore. At the rear end it is above the main ore-bearing bed. The only condition that might suggest a structural control to the mineralization is a small but rather sharp sag in the beds about 50 feet upstream from the portal of the tunnel, but this structure is not cut within the tunnel.

Jackpot.—This mine is on the left bank of the Buffalo River, 15 feet above water level, in the W½SE¼ sec. 8, T. 16 N., R. 15 W., at an altitude of about 520 feet. The workings are below the level of high water of the Buffalo River. The property was originally worked as an open cut, but owing to the steepness of the bluff, the depth of the face at the back of the cut soon became disproportionately large as compared to the length, and further development was carried on by means of a drift on the richest ore zone, which is about 5 feet thick, at the bottom of the cut. Present workings, therefore, show an open cut, 60 feet long, 60 feet wide, and 50 feet deep, with a room leading back from the rear of the cut 70 feet farther.

The country rock is a medium to rather fine grained gray dolomite, variably sandy. Certain beds grade laterally into chert, and chert streaks occur in the mineralized dolomite, especially below pink-spar veinlets. In a few places chert also forms the matrix of dolomite breccias. The basal foot of the more richly mineralized zone is a silicified sandstone.

There appears to be a fracture zone at the front of the mine that runs about parallel to the face of the bluff (north-south). Along this zone the rock has been somewhat brecciated and tilted, and certain beds have been locally thinned by squeezing. At one place in the drift a slickenside can be traced for a short distance, running about parallel to the bedding. The dips adjacent to the disturbed zone are as much as 20° W., into the hill, but within a short distance from the front of the mine they flatten out. Where the rock has been most broken, some sand has filtered in to form the matrix of the breccia. Upward in the face of the open pit the brecciation decreases.

The ore is rosin jack mixed with pink spar and occurs in veinlets crosscutting the dolomite and silicified sandstone. A minor amount of finely crystalline pyrite accompanies the ore, commonly forming films along the borders of the pink-spar veinlets. A little calcite and chalcopyrite occur in some of the pink-spar vugs. The cherty phases of the country rock are commonly barren except for a little disseminated jack. The upper beds in the open cut contain chiefly pink spar, most of it drusy, with very little ore.

The Jackpot mine produced considerable ore (jack) in 1910 and during the World War, probably a few hundred tons, but no close estimates of the amount could be obtained. The mill has been demolished.

Turkey Fat.—This prospect is on the right side of the left prong of Green Haw Hollow, in the NE¼SW¼ sec. 11, T. 16 N., R. 16 W. The openings lie just under the St. Peter sandstone, which is here perhaps 100 feet or more above the bed of the hollow. The main working apparently started in as a tunnel, but after going in about 10 feet changed to a shallow shaft, about 15 feet deep. The ore-bearing rock is medium-grained gray dolomite and sandstone, the latter locally replaced by gray spar. The different types have a greenish tinge due to an interstitial greenish clay mineral, and the dolomite contains blebs of this clay. The ore is a high-grade rosin jack and occurs associated with pink spar in numerous irregular cracks and pockets through both the sandstone and the dolomite. Here and there it is also disseminated in rather fine blebs in the sandstone or in the gray spar. Finely crystalline (pinhead size) pyrite occurs along the borders between the dolomite and pink spar and also scattered through both the dolomite and the sandstone. Chalcopyrite (altered to aurichalcite) is present in small amounts, and some of the crystals reach the unusual size of a quarter of an inch. Calcite is a minor constituent.

A second opening, at the same horizon a short distance up the hollow, shows a little silicate and carbonate associated with pink spar and calcite. The working is an old shaft, about 30 feet deep, sunk in a deeply weathered slope on which there are no outcrops. The ore-bearing rock is sandstone.

North Star.—This property lies near the head of a left-hand tributary of the right prong of Green Haw Hollow, probably in the SW¼ sec. 11, T. 16 N., R. 16 W. The workings consist of several shallow shafts, drifts, and open cuts in the left side of the hollow over an outcrop length of 700 or 800 feet. The horizon is in the Everton formation, the different openings lying between 15 and 55 feet below the St. Peter sandstone, but the main workings are about

45 feet below it. The ore-bearing rock grades from dolomitic sandstone into medium and fine grained dolomite. In places a coarse gray spar, with interstitial green clay, has replaced some of the sandy beds. The ore is rosin jack and occurs associated with pink spar in cracks and irregular replacement masses. It may also be disseminated in the gray spar, in individual blebs ranging from a fraction of an inch to almost an inch in size. Some of the jack has been altered to coarsely crystalline silicate or to gray or black honeycomb carbonate. A trace of malachite shows in some of the black carbonate masses, and a little calcite appears in a few places associated with the pink spar.

During the early part of the World War a small mill was in operation on the property and some ore was milled out, but the total production was not more than 50 or 60 tons of jack.

Evening Star.—This prospect lies high on the south side of Green Haw Hollow opposite the mouth of the hollow containing the North Star, in the N½ sec. 14, T. 16 N., R. 16 W. The workings consist of several small open cuts in the Everton formation 35 feet below the St. Peter sandstone. The ore-bearing bed is about 10 feet thick and ranges from medium- or fine-grained dolomite to fine-grained dolomitic sandstone. Most of the ore occurs in the sandstone. The bed is underlain by limestone. The ore is rosin jack with some carbonate and is associated with pink spar and a little calcite in crosscutting veinlets. A trace of malachite is present, and in places fine crystalline pyrite shows along the boundary between the country rock and the pink spar of a veinlet.

Maumee.—This property includes several workings, all lying on the left prong of Green Haw Hollow which is traversed by the road from Maumee to Marshall. The workings are in the NE¼ and the N½SE¼ sec. 11, T. 16 N., R. 16 W. Most of the openings have produced carbonate, but one of the main workings, a shaft just below the road, on the right-hand side of the creek bed, produced jack. The altitude of the shaft collar is 615 feet; the horizon is in the Everton formation 130 feet below the St. Peter. This shaft is now caved. It was originally sunk on the basis of the record of 17 drill holes put down along the hollow over a length of 1,900 feet, the lowermost hole 800 feet downstream from the site of the shaft. Ten of the drill holes are bunched within 400 feet of the shaft. All of the drill logs reported ore except two, one of which lies on the east side of the hollow, about 350 feet east of the shaft. The ore occurs on about the same level in all the holes. According to the drillers' logs, the ore run ranges in thickness from 8 to 40 feet and in tenor from 3 to 10 percent of jack. The drill records show a mineralized area of about 10 acres. The drill hole penetrating the richest ore lies practically in the bed of the branch, 250 feet east-southeast from the shaft. This hole is 120 feet deep and contains ore in the bottom 40 feet, the richest ore (reported by the driller as carrying 10 percent or more of jack) occurring in the upper half of this ore zone. Workings from the shaft are on this level. Most of the drill logs show the ore to be only a few feet below a saccharoidal sandstone that is 4 to 6 feet thick. A few of the drill logs show low-grade ore at higher levels but these higher runs are apparently not persistent.

The shaft is 130 feet deep. From its foot, workings extend eastward toward the richest drill hole for 250 feet, terminating in a room about 100 feet long from east to west, 50 feet wide, and 12 feet high. O. M. Bilharz, in a private report, states that about 4,000 tons of rock was taken from this room, producing 180 tons of jack concentrates. The recovery was therefore 4½ percent. Bilharz estimates that the mine would run 6 percent concentrates, the lower recovery obtained being due to the inefficiency of the mill.

The ore is rosin jack and occurs associated with pink spar in seams and shatter cracks, chiefly in a fine-grained, dark-gray dolomite, to a less extent in a medium-grained dolomite or in a greenish sandstone. According to Bilharz, the south wall of the underground workings is brecciated over a distance of about 150 feet. Some of this breccia that appears on the dump is cemented by gray chert which may carry a little disseminated jack.

A 70-foot tunnel driven into the hill, 15 feet vertically above the shaft collar, is absolutely barren. Near the top of the hill considerable open-cut work has been done at a horizon 30 feet below the St. Peter and over an outcrop length of 150 feet. The largest cut is about 70 feet in diameter. Although practically no ore now shows in this series of cuts, they are reported to have produced considerable carbonate. The ore zone is in limestone and greenish clayey sandstone; the overlying interval to the base of the St. Peter is largely medium-grained dolomite, with some sandstone. The original ore occurred in pink-spar lenses in the sandstone and also disseminated in a coarse gray spar that had replaced the limestone.

Another group of diggings is located up the hollow almost half a mile above the Maumee shaft and a quarter of a mile below a small fault that runs east and west across the hollow. The openings are near and on the top of a low ridge spur on the left side of the hollow. A shaft, estimated to be 50 feet deep, is on the top of the ridge, with its collar at an altitude of 750 feet, 20 feet below the St. Peter sandstone. The rock taken from this shaft shows the ore to occur chiefly in pink spar and gray spar that have replaced sandstone or less commonly medium-grained dolomite. The ore minerals are embedded in lenses or veinlets of pink spar. The original sulphide ore was rosin jack, but it has been largely converted to carbonate of various types, or to silicate. Much of it, however, was leached out completely, leaving only the jack casts. A trace of malachite accompanies the black carbonate, and a little calcite is associated with the pink spar.

Open cuts over an area about 100 feet in diameter on the side of the spur, 15 feet or so below the collar of the shaft, show a bed of gray spar, about 3 feet thick, containing a little carbonate apparently derived from disseminated jack. This bed is overlain by about 10 feet of sandstone and underlain by medium-grained dolomite. Both the sandstone and the dolomite contain pink spar that carries some carbonate. These beds are possibly the ones from which the ore was taken in the shaft. They also lie at about the same interval below the St. Peter and show the same lithologic types and sequence as the high-level workings at the Maumee shaft. The horizon is probably the same.

The production of the Maumee property is not known. Production from the shaft began in 1907, and 150 tons of jack concentrates are reported to have been shipped in 1910. During the World War free carbonate was shipped from the property, but no jack is reported.

Mud Hollow.—The Mud Hollow property contains two workings some distance apart. One prospect is on the north bank of a small tributary to Mud Hollow from the east, only a few hundred feet up from Mud Hollow, in the NW¼ sec. 15, T. 16 N., R. 16 W. The developments consist of a winding tunnel, 80 feet long, with an open cut at its portal, 25 feet long along the outcrop. The horizon is in the Everton formation, 25 feet below the St. Peter. The ore-bearing beds show the following sequence:

3. Fine-grained gray dolomite.
2. Sandy dolomite, 1½ feet.
1. Gray spar, with pink-spar druses, 1½ feet.

In the open cut the ore occurs in the two lower members and the basal part of the upper one; the tunnel is apparently barren of mineral, though it shows pink-spar veins in the different beds. The ore taken from the open cut is rosin jack associated with pink spar in irregular cracks.

The other prospect on the property is on the east bank of Mud Hollow only a few feet above the bed of the creek and perhaps 1,000 feet upstream from the lower prospect. The working here is a short drift, 25 feet into the hill. It is at the same horizon as the lower prospect and shows much the same lithology. The mineralized face is 5 feet thick; the upper 2 feet is fine to medium-grained dolomite, poorly mineralized, and the lower 3 feet is sandy dolomite, the lowest foot or so of which is replaced by gray spar. Most of the ore occurs in the lower 3 feet. The ore mineral is light rosin jack. It occurs in veins of pink spar as much as 2 inches thick, which may parallel or crosscut the bedding. A small amount is disseminated in the gray spar. Fine crystals of chalcopyrite are commonly attached to the crystal faces of jack where these have formed free in open druses in the veins. Zinc carbonate, altered from the jack, is of very minor occurrence.

Hazeldell.—The Hazeldell prospect is in the angle between Mud Hollow and a tributary that comes in from the right, about 500 feet above the upper Mud Hollow prospect, in the E½NE¼ sec. 16, T. 16 N., R. 16 W. The opening is a shaft, reported to be about 25 feet deep, with a slight amount of drifting from its bottom. The shaft collar is about 15 feet above the water level at the bed of the tributary hollow. The shaft collar is 5 feet below the St. Peter, so that the ore horizon is undoubtedly the same as that in the two Mud Hollow prospects.

The ore is rosin jack and occurs associated with pink spar, in cracks in a medium to rather fine grained gray dolomite, some of which is very sandy. The cracks contain numerous open druses in which the jack and pink spar are well crystallized. Minute crystals of chalcopyrite are rather commonly plastered onto the surfaces of the jack crystals. Calcite occurs as white, opaque, poorly formed crystals (rhombs, average one sixteenth of an inch in size) that resemble those of pink spar in general shape. Fine drusy quartz is a minor constituent in some of the druses. A little finely crystalline pyrite without any associated minerals occurs in certain cracks in the dolomite. Besides the more usual occurrence of the ore in cracks, jack occurs to a minor extent disseminated in a rather fine gray spar.

It is reported that one carload of ore was shipped from this mine to Joplin, where it was milled.

KIMBALL CREEK-ROCK CREEK DISTRICT

The Kimball Creek-Rock Creek district is in northern Searcy County on the east side of the Buffalo River. The deposits on the Kimball Creek side have been commercially productive; those on Rock Creek have never been developed beyond the prospect stage. The ores of the district occur in various lithologic phases of the Everton formation. The only fault within the district is a small one on Rock Creek showing a displacement of 30 feet. The ores are carbonate and jack. Reliable estimates on the production of the district are lacking, but probably 2,000 tons of concentrates, predominantly carbonate, represents a fair figure.

Churchhill.—This mine is in the creek bed of the right fork of Kimball Creek a few hundred feet above its junction with the left fork, in the S½NW¼ sec. 10, T. 16 N., R. 15 W. The working is an open cut, 50 feet along the creek, 30 feet wide, and 20 feet high at the back, on the right-hand side of the creek. A tunnel originally led back into the hill from the back of the open cut, but it was caved at the time examined. The altitude is about 560 feet; the horizon is in the Everton formation 300 feet below the St. Peter. The mineralization occurred on a small local monocline, striking N. 18° E. and dipping 23° E., whose crest is at the lower end of the pit. The beds flatten out again 100 feet or so above (east of) the cut. The ore is rosin jack associated with pink spar in veinlets and shatter cracks in a fine-grained dolomite. Locally this shattered material grades into a dolomite breccia in which the ore and gangue form the matrix. Very little ore remains in the walls of the cut or in the portal regions of the tunnel. A rather large mill was erected on the property, and considerable ore was milled out. Much of the ore milled here, however, came from the Evening Star mine.

Evening Star.—This mine is on the right side of Kimball Creek near its head, in the N½SE¼ sec. 10, T. 16 N., R. 15 W. The horizon is in the Everton formation 40 feet below the St. Peter. The strata show gentle warpings in various directions, in places as much as 10° or 15° from the horizontal, but there is no evident break of any kind. The tunnel runs N. 70° E. into the hill for about 300 feet but is very irregular in detail and shows numerous branches, pillars, and stoped-out rooms. Most of the workings appear to have followed zones of weathering, probably along original fracture zones that determined the emplacement of the primary ore. The main line of the tunnel appears to follow an ill-defined shallow synclinal axis over part of its course, along which some shattering had occurred.

Most of the ore is concentrated in a 2-foot soft porous sandstone that contains much greenish clay, but ore extends down to a distance of 3 feet into the underlying ostracodal limestone, the top foot of which is especially well mineralized. This limestone, where mineralized, has been converted to coarse dolomite (gray spar) with a greenish clay matrix. The ore zone is capped by a fine-grained dolomite that forms the roof of the workings. This dolomite is barren except where its lower 5 feet has been brecciated.

The ore marketed was chiefly zinc carbonate, but there is some jack. The jack occurred originally in pink spar that forms thick veins and replacement pockets in the sandstone and gray spar or that locally forms the filling of dolomite breccias along the lower part of the roof dolomite. Some jack is also disseminated in the gray spar and to a less extent in the sandstone. Chalcopyrite and calcite are uncommon gangue minerals in the vugs, and small streaks of pyrite occur in the clayey sand. Gypsum is a minor secondary product. Brown tallow clay has formed abundantly as an accompaniment of the oxidized ore.

The present walls are very lean, though probably the ore taken out along the main runs was much richer. Some jack appears in the working face, a few feet wide, at the back of the tunnel, but it shows no relation to any fracturing that might tend to continue it into the hill.

The production of the Evening Star, made chiefly during the early years of the World War, is not known exactly, but reports place it at about 1,000 tons of carbonate. Most of the milled ore was trammed several hundred feet around the hill to the north and then lowered to the Churchhill mill, where it was concentrated.

Mays & Redwine.—This mine is on the left side of Kimball Creek just below the waterfall over the St. Peter sandstone rim and a few hundred feet upstream from the Evening Star, in the S½SE¼ sec. 10, T. 16 N., R. 15 W. The horizon is immediately below the St. Peter, but owing to the severe alteration and weathering to which the deposit has been subjected the exact contact between this sandstone and the underlying Everton formation, which contains some interbedded sandstone, is impossible to fix. The opening is a high tunnel, perhaps 300 feet long, that runs roughly parallel to the face of the ledge and has connections with the outside at both ends. Practically all the ore has been mined out. The walls show a mixture of pink spar, coarse-grained gray dolomite (gray spar), and greenish clay. This material has apparently replaced certain limestone beds completely, with considerable solution slumpage, and elsewhere has crosscut and partly replaced a bed 3 to 4 feet thick, of fine-grained dolomite that lies just below the sandstone series. Veins of pink spar and veinlets of greenish clay also extend up into sandstone that may be a top sandstone of the Everton or the basal part of the St. Peter. The only ore observed was a little zinc carbonate in certain of the pink-spar veins. Apparently the ore body was sharply limited. A large amount of reddish clay has formed as an alteration product in the more porous beds and has obscured the geologic relations.

No reliable figures on the production of this property are obtainable. One estimate of 100 carloads (about 3,000 tons) of concentrates is certainly too large; the total is probably less than 1,000 tons. The mill in which the ore was concentrated stands on the right bank of the hollow, only a short distance from the Evening Star portal. What little jack there was in the ore was marketed as an impurity in the carbonate.

Ruby.—On Rock Creek, in the northeast corner of T. 16 N., R. 15 W., there are several small prospects, some of which have been named. The Ruby shaft was drilled to a reported depth of 80 feet in the bed of the creek in the E½ sec. 11 but is now filled by creek gravel. The altitude of the shaft collar is 685 feet; its stratigraphic horizon is in the Everton formation 20 feet below the St. Peter sandstone. The shaft is about 400 feet above a small east-west fault that shows a downthrow on the north of about 30 feet. The dip of the beds for several thousand feet upstream from the fault is several degrees downstream (to the north). The rock on the dump shows two types of ore—(1) rosin jack disseminated in gray spar and less commonly in medium-grained dolomite, and (2) rosin jack associated with pink spar in cracks and replacement masses in a medium-grained partly sandy dolomite. Much of the disseminated jack in type 1 is rather fine grained, but some of the blebs in the gray spar are as much as half an inch in size. The gray spar contains numerous segregations of pink spar. It also contains sand admixed in such a way as to suggest that the gray spar may have replaced an original bed of sandstone. The jack masses in type 2 attain 2 inches in size. Minute crystals of chalcopyrite are associated with the jack in this type.

A quarter of a mile or more above the Ruby shaft, at the first main forks of Rock Creek, 2 or 3 other prospect openings have been made at a horizon in the Everton formation about 40 feet below the St. Peter. One of them, a short distance up the left fork, shows pink spar and rosin jack with some carbonate in a fine- to medium-grained dolomite breccia. In another one on the right side of the forks the jack is disseminated in a gray spar. The dip of the strata in this general locality is perhaps 10° downstream.

Winchester.—This prospect is located in the E½ sec. 11, T. 16 N., R. 15 W., on the right bank of the left prong of Rock Creek, 1,500 feet above the main forks. The opening is an old shaft (or tunnel?), now filled, whose collar is 5 feet above the bed of the creek and 25 feet below the St. Peter sandstone. The ore is rosin jack and occurs associated with pink spar, filling irregular cracks in medium- to fine-grained dolomite which is in part sandy. Much of the dolomite has a greenish tinge due to contained flecks of a clay mineral. A little of the jack is disseminated in sandstone.

Dollar.—This prospect lies perhaps half a mile or more up a steep tributary of Rock Creek from the left, in the SE¼ sec. 3, T. 16 N., R. 15 W. The working is an old-time shaft, now caved, whose collar lies about 20 feet below the St. Peter. The altitude of the shaft collar is around 650 feet, which is about 5 feet above the bed of the hollow. The strata in the neighborhood of the shaft dip perceptibly to the north at an estimated angle of 5°; this dip is maintained at least as far as Rock Creek. The ore on the dump is rosin jack associated with pink spar and occurs in sandstone and also in medium and fine grained dolomite. A little of the jack has been altered to gray and black carbonate.

PANTHER CREEK-INGRAM CREEK DISTRICT

Panther Creek is on the west side of the Buffalo River, and Ingram Creek is on the east side; both are in southern Marion County. The deposits are few and scattered so that the district is not a very compact unit. The deposits occur in the Everton formation. The ore minerals are chiefly jack and zinc carbonate. Production from the district has not been great.

Sauers.—This prospect is on the right slope of Ingram Creek near its mouth, in the SE¼ sec. 26, T. 17 N., R. 15 W. The developments consist of two or three short tunnels, the longest one entering the hill only 100 feet or so. The horizon is in the Everton formation 250 feet below the St. Peter sandstone. The country rock is dolomite, which in places is somewhat sandy. Most of the dolomite is rather fine grained, but the main ore-bearing bed, which is about 3 feet thick, grades in texture toward medium grain. It contains indefinite chert bands along the bedding. The underlying bed, 1 foot thick, is chert, apparently derived from the silicification of a dolomite instead of a limestone. This bed also carries ore. The chief ore horizon of the prospect, however, is along the contact between these two beds.

The strata dip in general to the northeast, into the hill, at angles as great as 4° or 5°, but the dip is irregular in both amount and direction. There has been considerable squeezing of the ore-bearing chert bed, and some local brecciation of the fine-grained dolomite that underlies it. The breccia consists of blocks a foot or so in size, but the blocks have not been greatly rotated, showing that they were produced essentially in place by only slight movement.

The ore is mixed rosin jack and zinc carbonate, associated with pink spar, and occurs in cracks in the dolomite or in cracks and irregular pockets in the chert. The carbonate includes both gray and black varieties. A little chalcopyrite and calcite are very minor constituents. The pink spar is much more abundant than the ore minerals and forms the matrix to the dolomite breccias, with little or no accompanying ore. A very small amount of the jack is disseminated in the chert.

Big Bell.—This mine lies on the right side of Panther Creek at the big bend in sec. 29, T. 17 N., R. 15 W. The horizon is in the Everton formation immediately under the St. Peter sandstone. The opening is a tunnel about 140 feet long, of which the last 40 feet opens out into a room 40 feet in diameter and about 15 feet high. East of the workings the strata dip to the west at an angle of several degrees, but at the mine the dip flattens almost to horizontality.

The ore-bearing rock is chiefly bedded chert that contains conspicuous seams of greenish clay; there is also interbedded quartzite, containing much less ore. The chert, where it has locally replaced the quartzite and perhaps elsewhere, contains microscopic grains of feldspar (orthoclase and microcline). In the room at the back of the mine, 15 feet of strata are mineralized, though unevenly, owing to the alternation of chert with relatively barren quartzite. The original jack was disseminated in the chert, being concentrated along certain bedding planes to fairly rich sheets an inch or two thick, also embedded in pink-spar veins that line the chert and quartzite, chiefly along but also across the bedding. Large jack crystals were formed on the roofs of certain solution cavities in chert, with very little associated pink spar. Most of the jack has been leached out or oxidized to black carbonate, and some of the pink spar has been replaced by carbonate. Traces of malachite occur in the black carbonate. Tallow clay has developed conspicuously during the oxidation. The ore zone is underlain by fine-grained dolomite, which is barren except for a few pink-spar veinlets that may contain a little jack.

A large mill on the property is now in ruins.

In the spring of 1927 the Eagle-Picher Lead Co. drilled a prospect hole, beginning on top of the St. Peter sandstone ledge south of the mine. This hole went through the St. Peter (35 feet) and to an additional depth of 125 feet into the Everton formation. No evidence of mineralization of any kind was struck in the hole.

Big Find.—This prospect lies west of the Big Bell, up a small hollow that is tributary to Panther Creek. The workings are two tunnels on the left bank, 5 feet above the creek bed, one 35 feet long, and the other, 50 feet to the west, caved near the portal. The horizon is in the Everton formation 30 feet below the St. Peter.

The country rock is interbedded chert and quartzite. In the west tunnel there has been a flexure displacement of a foot or so, down on the east, which has led to shattering of the beds. The ore is mixed jack and carbonate and occurs associated with pink spar in the shattered rock, partly as a primary replacement. A little jack is disseminated in the chert. Chalcopyrite is present as a minor gangue mineral, and zinc silicate is subordinate to carbonate as an oxidation product. The carbonate includes both black and crystalline gray types. In the east tunnel the pink spar and jack occur chiefly in bedding veins in undisturbed chert; the material is of low grade owing to the great predominance of the pink spar. The chert here shows gradations into barren limestone.

Little Star.—This prospect lies in the bed of Panther Creek, a short distance below the waterfall over the St. Peter sandstone, in sec. 20, T. 17 N., R. 15 W. The main drift, which is 100 feet or more long, enters the left bank at an angle upstream and is at present half full of water. The horizon is about 30 feet below the St. Peter sandstone. There is also an old filled shaft almost in the bed of the creek opposite the tunnel, and a second filled shaft just under the St. Peter rim on the right side of the creek. The dip of the strata is at a slight angle upstream.

The ore-bearing rocks are a porous sandstone and a very coarse-grained dolomite (gray spar) that contains interstitial greenish clay. The sandstone and dolomite may be curiously intermottled in places. The ore is mixed rosin and black jack and occurs disseminated in both types of rock and also, in association with much pink spar, in crosscutting and bedding veins and irregular replacement pockets. A trace of chalcopyrite accompanies the jack. A little oxidation to zinc carbonate has taken place. The ore bed is overlain by 1 foot of quartzite, and then by fine- to medium-grained dolomite (17 feet) and limestone (10 feet).

RUSH CREEK DISTRICT

The Rush district, as the term has heretofore been understood, is a rather compact area extending from the Beulah mine and the town of Rush on the northwest to the Silver Hollow mine on the southeast, a distance of about 2 miles. The district, as thus restricted, includes the lower part of the Rush Creek Valley, the lower part of the Clabber Creek Valley, and the contiguous portions of the Buffalo River Valley. It is shown on plate 4.

Outside of the district proper there are several scattered deposits in the Rush Creek drainage basin above the town of Rush, and for the sake of completeness these deposits are included with the Rush Creek district in the present report. They occur at various horizons and in various types of rock in the Everton formation. Some are only prospects; others have produced ore. The Climax mine is the only one of them that is very closely connected with a fault.

The ore deposits of the restricted Rush district are related to the Rush Creek, Monte Cristo, and Silver Hollow faults but lie in ore runs in the vicinity of the faults rather than on the faults. The Edith-Yellow Rose deposit and the Red Cloud deposit are on the extended line of the Rush Creek fault, but beyond the point where it shows any significant displacement. The deposits of the district, except the Beulah, occur chiefly in limestone and medium-grained dolomite in the Everton formation. The Red Cloud, Lonnie Boy, Leader, Philadelphia, Monte Cristo (upper ore zone), Capps, the upper level of the McIntosh, the uppermost level of the Morning Star (at the top of the open pit), and probably the Edith and Yellow Rose all lie at the same stratigraphic horizon—namely, in a discontinuously dolomitized limestone whose top is about 160 feet below the St. Peter sandstone. The top of the mineralized stratum also lies from 36 to 44 feet below the base of a sandstone ledge that ranges in thickness between 2 and 5 feet and averages about 4 feet. This sandstone serves as a convenient key horizon for the Rush district. The ore shipped from the district has been preponderantly carbonate, but all the deposits carry more or less unoxidized jack, and this was the chief product of the Beulah, of the earlier workings at the White Eagle, and of the later workings in the Silver Hollow and Philadelphia mines. Statistics on the production of the district are incomplete, but an estimate of 26,000 tons of concentrates, based on partial statistics, is believed to be conservative.

Perhaps a quarter of this has been jack. Outlying mines in more distant parts of the Rush Creek drainage system account for an additional 450 tons or so of carbonate and 80 tons of jack. The Rush Creek district has thus produced far more than any other in northern Arkansas.

In the following detailed descriptions the outlying properties in the upper Rush Creek drainage basin are taken up first.

Morgan.—The J. M. Morgan prospect is in the SE¼NE¼ sec. 18, T. 17 N., R. 15 W., near the head of the largest hollow tributary to Rush Creek from the south. The ore horizon is in the Everton formation, about 20 feet below the St. Peter sandstone. The workings consist of a shaft sunk directly in the bed of the hollow; a drift, barely below the bed of the hollow, running upstream from the shaft along the strike of the bedding; and a gentle incline, about 50 feet long, running from a point near the top of the shaft into the left bank of the hollow and passing into a natural cave at the rear end. The local dip at the portals is 5°–10° SW. (upstream); within the left bank, as shown in the incline, the dip is 5°–10° NW. (away from the hollow). The ore bed is about 4 feet thick and consisted originally of alternating sandstone and limestone, but before ore deposition it was silicified to chert. It is underlain by limestone and overlain by a fine-grained gray dolomite that becomes medium-grained 4 feet higher.

The ore is a high-grade "free" zinc silicate that has been derived by oxidation from rosin jack. A little black jack is mixed with the residual rosin jack. The jack was originally both disseminated in the chert and concentrated along seams in association with pink spar, which occurs abundantly in the ore bed as a gangue. During the oxidation of the jack the pink spar in the same seams was usually dissolved out or altered to a reddish clay of greatly reduced volume, leaving the silicate considerably enriched. Much of the pink spar that was not so intimately mixed with the jack has been altered to a brown material, a small part of which is a form of zinc silicate that has replaced the original pink spar. Calcite occurs in small amounts as a gangue, and some of the black silicate carries green copper stains.

No ore has been shipped from the property, but a pile of high-grade silicate, estimated at about 10 tons, lies on the dump awaiting shipment.

Mattie May.—This mine is at the head of a short east branch of a large hollow tributary to Rush Creek, probably in the SW¼ sec. 8, T. 17 N., R. 15 W. It lies only a short distance northwest of the main road in to Rush, at an altitude of 895 feet. The horizon is in the Everton formation about 25 feet below the St. Peter sandstone, although the St. Peter does not crop out at the mine. The working is a drift into the hill, about 250 feet long.

The ore occurs in a zone of limestones, sandy limestones, and sandstones that occupy an interval of 8 or 9 feet within a series of medium-grained dolomites. The ore is further restricted to certain beds within this interval, most of it being confined to two beds, originally sandy limestones, that are separated by 2 feet of more or less barren sandstone. The lower bed is about 1 foot thick and the upper one 2 or 3 feet thick; neither is sharply set off in its composition or bedding from the adjacent sediments. Only the upper bed carries ore at the back end of the drift. The limy phases of the ore-bearing beds have been more or less replaced irregularly by medium-grained dolomite. Silicification accompanied ore deposition, altering the ore beds to chert or, where the original rock was dolomite, to a mottled cherty dolomite. A greenish-clay alteration product is present in the mineralized beds and also interstitially in the dolomites both above and below.

The ore occurs in a run, not more than 30 feet in width, that follows the line of an insignificant monoclinal flexure. The zone of most intense mineralization is only 5 feet or so wide. At a point 150 feet from the portal the walls of the tunnel show some brecciation, with the addition of certain dolomite and quartzite fragments from a slightly higher level than the adjacent beds, but considering the mine as a whole the beds are very little disturbed. The ore consists of carbonate and mixed rosin and black jack. It occurs disseminated in the chert or associated with abundant pink spar in bedding veins or irregular replacement pockets along the bedding, or as a matrix to the breccia mentioned. A very small amount of pyrite accompanies the ore in the breccia. The sandstone between the two ore-bearing beds contains crosscutting veinlets and small replacing blebs of pink spar, but without accompanying ore. Most of the carbonate was taken from the front end of the tunnel and from the open cut at its portal. Part of it had replaced pink spar in druses. Brown tallow clay was formed in the oxidized ore, segregating chiefly in the pink-spar druses. The production from the back end of the tunnel has been more largely jack.

The ore bed in places gives way to gray spar containing irregular segregations of pink spar. Such masses of mixed gray and pink spar are commonly coextensive in the two ore-bearing beds and tend to appear on the borders of the mineralized mass. They are usually barren.

About 100 tons of concentrates have been milled on the Mattie May property since the mill was put in, around 1918, but it is reported that 350 or 400 tons of ore was taken out as free carbonate ore before that time. Masses of high-grade carbonate ore weighing 300 to 400 pounds were sometimes encountered during this earlier period. Some of the ore taken from the portal region of the mine is reported to have been turkey fat. Practically all of the commercial production, according to reports, has been carbonate running less than 1 percent of sulphur and as much as 45 percent of metallic zinc.

Anglo-American.—This property is low on the right side of a large hollow tributary to Rush Creek from the south, a short distance above the mouth of the branch containing the Mattie May mine. It is probably in the SW¼ sec. 8, though possibly in the SE¼ sec. 7, T. 17 N., R. 15 W. The horizon is in the Everton formation 150 feet or more below the St. Peter sandstone.

The opening is a drift with three or four branches that go back 300 to 400 feet. The workings follow weathered clay-filled crevices and consequently show great variability in the width and height of their cross sections from place to place. At the portal the country rock is limestone, in part sandy, but underground the limestone has been replaced by chert or gray spar. In places the rock has been brecciated or shows evidences of local tilting, but such masses are not especially ore bearing. The relations are greatly obscured by the large amount of clay wash over the walls. Abundant pink spar has developed as irregular replacement masses and as bedding and cross-cutting veinlets in both the bedded chert and the gray spar, but it is singularly barren of ore. The only ore noted was a little jack disseminated in chert or developed in the various occurrences of pink spar, with calcite and a trace of chalcopyrite as additional minor gangue minerals.

It is reported that very little if any ore was ever marketed from this mine.

Cobert.—This prospect is on the left slope of Rush Creek, about a quarter of a mile above its junction with Cold Water Hollow, in the E½ sec. 12, T. 17 N., R. 16 W. The opening is a small irregularly fingering tunnel whose back face is probably 200 feet from the outcrop. The horizon is in the Everton formation 60 feet below the St. Joe limestone. The opening follows a clay crevice in sandstone and limy sandstone that overlies limestone. The original mineralization apparently occurred in the sandy phases and was narrowly confined to a fracture, but all the ore has been taken out. A little showing on the dump is zinc silicate, with some jack, and associated pink spar. The mine is reported to have been unprofitable.

Climax.—This mine is in a hollow tributary to the left prong of Rush Creek from the south, in the SW¼NE¼ sec. 1, T. 17 N., R. 16 W. The altitude is 810 feet. The workings consist of one or two caved shafts on the left bank and a short curving tunnel, now full of water, that goes into the right bank from the bed of the hollow. These workings lie 40 feet below the St. Peter sandstone, 200 feet south and on the upthrown side of the Climax fault. The throw on the fault is here about 80 feet. The strata dip into the fault at an angle of about 10°–15°.

The ore is mixed black and rosin jack and occurs in cracks and replacement pockets in a sandy coarse-grained dolomite (locally sandstone), in association with pink spar, calcite, and a trace of chalcopyrite. Some jack is also disseminated in chert, in blebs generally half an inch or less in size, though some reach 1 inch. This chert has evidently replaced the dolomite. It contains numerous greenish streaks, colored by one of the clay minerals.

The small mill that was once present on the property has been burned down. The complete production of the mine was not ascertained, but it is reported to have produced 40 tons of concentrates prior to 1907 and about 40 tons more in 1916.

Beulah.—This mine is on the right bank of Clabber Creek in the NW¼SW¼ sec. 3, T. 17 N., R. 15 W. (pl. 4). The main working is a tunnel driven from the back of an open cut at an altitude of 548 feet, about 18 or 20 feet above the level of the creek. A shaft has been sunk from a point 12 feet or so above the creek, about 500 feet southeast of the portal of the tunnel. These workings are on or near the axis of a flat syncline that trends northwest and pitches at a low angle to the southeast. The horizon of the tunnel is in the Everton formation about 40 feet above its base. The shaft penetrates to a somewhat deeper horizon, as its collar is at about the stratigraphic level of the tunnel workings.

Most of the ore was taken from the open cut in front of the tunnel and from a large room, about 60 feet in diameter, just inside the entrance of the tunnel. A drift running 80 feet southward from the back of this room is in tight barren rock, but another one running 100 feet southwestward contains considerable ore along its walls. Both of these drifts formerly ended in raises to the surface, but the raises are now caved.

The ore-bearing rock is a fine-grained gray dolomite, which becomes medium grained in a few places. The ore is chiefly rosin jack, in masses that may be several inches across, associated with considerable pink spar and a little calcite and fine drusy quartz. A trace of chalcopyrite appears as minute crystals. The ore occurs in cracks and shatter zones in the dolomite along localized zones of very slight flexure. The structural deformation is very slight and is undulatory in different directions, although the general dip is to the southeast, down the plunge of the synclinal axis on which the mine is located. One mineralized shatter zone on the west wall is on the axis of a very small monoclinal flexure, exposed in cross section, that displaces the beds only a foot or two in a distance of a few feet. The small structural features that determine the actual position of the shattering cannot usually be worked out, owing to their slight extent and their flatness, but all are evidently mere details of expression of the larger synclinal structure, to which, in a broader way, the shattering can be ascribed. Owing to the irregularity in the shattering, the thickness of the ore varies in different places, certain stoped-out masses appearing to have been 7 or 8 feet thick.

A small amount of the jack has been oxidized to a dark brownish-gray crystalline carbonate, which commonly forms a coating on exposed surfaces of jack crystals. Carbonate has also replaced pink spar. A trace of aurichalcite appears in a few vugs as thin pale-green scales on pink spar.

The dump of the shaft shows a larger proportion of the ore in medium-grained partly sandy dolomite than at the tunnel, although the type of occurrence and the mineralogy of the ore and gangue are much the same. No carbonates were observed, however. An additional feature is the presence of chert, containing some disseminated jack, that has replaced the dolomite either next to the ore cracks or along bedding planes.

The Beulah property produced about 500 tons of jack between 1901 and 1903. It was formerly equipped with a mill. Core drilling on the property is reported to have revealed ore in each of five holes, and the maximum depth of ore was 250 feet.

Morning Star and Ben Carney.—These two mines, lying adjacent to each other, are at present owned by the same company and will be described together, as the developments are continuous from the one to the other. They lie on the northeast slope of Rush Creek above the town of Rush, in the NW¼ sec. 10, T. 17 N., R. 15 W. They are opened on a fracture running about N. 60° W., parallel to the face of the hill, and apparently belonging to the system that is better displayed in the Capps workings, only a short distance to the southeast. The Morning Star mine is a huge open cut, 400 feet long, 100 feet wide at the top, and 40 to 50 feet deep. At its southeast end the Ben Carney tunnel extends for about 600 feet toward the Capps workings. At present the underground workings of the Ben Carney and Capps are only about 400 feet apart. The Carney workings are not accessible, owing to cave-ins, and the ore-bearing rock has been almost completely removed from the Morning Star pit, leaving the barren limestone walls. According to Branner's report, the fracture on which the Morning Star deposit is located showed a displacement at one place of about 3½ feet, down on the southwest, but so much rock has been removed since Branner visited the property that evidence of this fault no longer remains. On the northeast side of the pit several short tunnels have been driven northeastward into the hill from the bottom of the open pit, but most of these have been in barren limestone. One, however, is in chert that contains thin lenses of mixed black and rosin jack along the bedding and also considerable disseminated jack. The gangue is drusy quartz, developed along the bedding. Some of the jack is altered to black carbonate that contains a trace of malachite. Open cuts along the hill northwest of the main Morning Star pit show disseminated jack in silicified limestone.

The floor of the Morning Star open pit is in limestone considerably below the level of the bed that carries the ore at the Capps mine. Near the exit of the pit the limy sandstone that caps this ore bed crops out at the top of the pit, 55 feet above its floor. The ore bed here carries considerable zinc carbonate. Some of the last work done on the property, in the fall of 1927, was at this level. The deposit is not well exposed but, except for more thorough oxidation, is probably similar to that at the Capps mine described in considerable detail on pages 202–205.

The Morning Star has been famous in the past for the large masses of free botryoidal carbonate obtained from it. These were found in the decomposed clay along the line of the fracture and undoubtedly represent the richer mineralization along the line of the run. Much of this carbonate was turkey fat. A remarkable specimen, weighing 12,750 pounds, took a prize at the Chicago World's Fair in 1893. This specimen was hauled by team from the mine to Buffalo City, on the White River, whence it was freighted by barge to the railroad at Batesville. Another interesting specimen of a different type, in the collection of the late C. E. Siebenthal, shows gray carbonate that has replaced a large scalenohedron of calcite, 4 inches long.

The Morning Star mine was the first zinc property developed west of Sharp and Lawrence Counties. Prospecting began in 1880; the first prospectors were John Wolfer, Bob Stultzer, and J. H. McCabe. After spending several months developing the ore, whose metallic nature was as yet unknown to them, they had an assay made which reported the ore to be zinc carbonate but which also erroneously reported it to carry $8 a ton in silver. Two smeltermen were accordingly brought in and detailed to build a small rock smelter in which the silver ore could be reduced; this was in 1882. The first run of the smelter produced a spectacular display of zinc-oxide fumes about the stack, but the expected silver did not collect in the sand molds at the bottom of the furnace. The discouraged miners offered to trade their prospect, with the smelter thrown in, for a box of canned oysters worth $2.50, but the offer was rejected.[48] The remains of the old smelter still stand in the lane just east of the Morning Star Hotel at Rush.

The complete production of the Morning Star is not known but has been rather large. For the long productive period prior to 1915 the only figures that happen to be available are for 1907 and 1908, when 231 tons and 200 tons respectively of concentrates were produced. According to smelter settlement sheets in the files of the Morning Star Mining Co., the production from September 1915 to the end of 1917 was 370 tons of free ore and concentrates (97 tons in 1915, 162 in 1916, 110 in 1917). This ore was carbonate, rarely carrying more than 1 to 3 percent of sulphur. During the same period the Ben Carney produced 1,357 tons of carbonate (422 tons in 1915, 548 in 1916, 387 in 1917), but it also, like the Morning Star, produced much ore earlier than this. Both mines, but especially the Morning Star, have produced some jack in addition to the carbonate. Since 1917, the Morning Star, Ben Carney, and Capps mines have been worked by the Morning Star Mining Co., and no attempt has been made to record the production of each mine separately. In 1918, 53 tons of concentrates were marketed by the company; in 1927, 205 tons; and in 1928, 160 tons. Perhaps two-thirds of this total production came from the Morning Star and Carney mines.

Capps.—This mine is on the northeast slope of Rush Creek, halfway up the hill, a little less than half a mile below the town of Rush, in the SE¼NW¼ sec. 10, T. 17 N., R. 15 W. The horizon is in the Everton formation 170 feet below the St. Peter sandstone. The formation here is composed of alternating limestones and dolomites, some partly sandy, with a minor amount of sandstone. The working is an irregular-shaped tunnel with several interconnecting branches that tend to follow a northwesterly direction from the portal—the direction of the obscure fractures that have governed the emplacement of the ore (fig. 13).

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[48] This historical summary is condensed from two papers—Ruhl, Otto, Past and present of zinc mining in Arkansas: Min. and Eng. World, vol. 35, p. 376, 1911; Shiras, Tom, Early days in North Arkansas zinc district: Eng. and Min. Jour., vol. 110, p. 165, 1920.

The greater part of the ore was taken from a bed 5 to 10 feet thick which in different places and also in the same working face varies between dolomite, chert, and limestone. The dolomite is in large part medium-grained, but there is some fine-grained dolomite that may be banded in the other or else may form more massive beds. The chert is in places banded with the medium-grained dolomite on a fine scale: not uncommonly the separate bands are as thin as a quarter of an inch. In other parts of the mine the ore-bearing interval may be almost entirely massive chert or massive dolomite, or there may be blocks and lenses of unaltered limestone. In the southeast side of the underground workings, but probably across the McIntosh property line, the bed changes

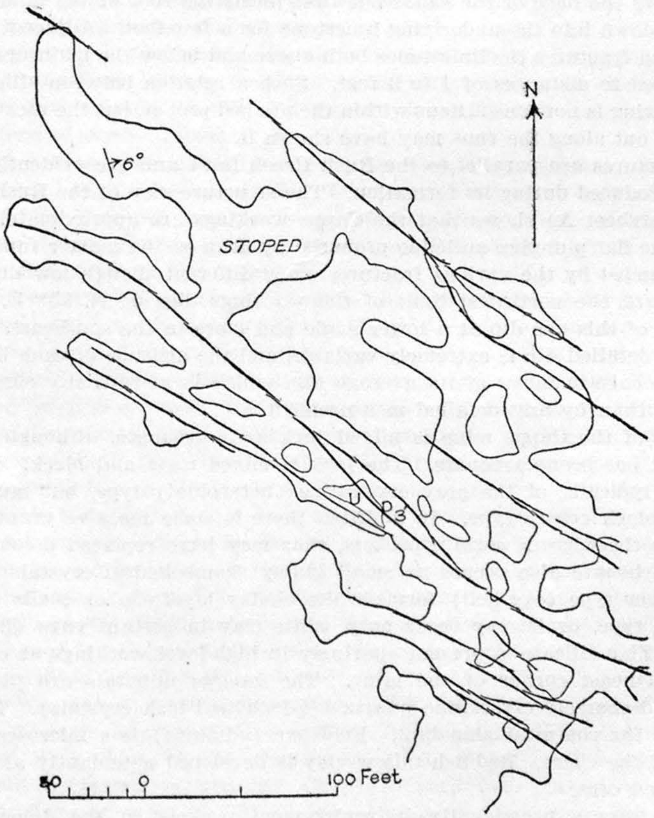

FIGURE 13.—Plan of Capps mine, showing stopes and fractures.

laterally to barren limestone. Throughout the mine the ore bed is both underlain and overlain by limestone. The overlying bed is only 1 to 2 feet thick and is capped by a very limy sandstone, 1 foot or so thick, that commonly forms the roof of the underground workings.

Although some mineralization has occurred nearly everywhere in the ore-bearing bed wherever its composition is dolomite or chert, most of the commercial production was taken from the runs developed along obscure fractures in a northwesterly direction. These fractures generally show no displacement and are visible chiefly along the roofs of the drifts as obscure shatter zones along which the bedding has been destroyed. Here and there the fracture shows in the roof as a series of parallel veins over a width of 2 or 3 feet, each vein less than an inch wide. One fracture zone (see fig. 13) shows a displacement of about 3 feet, down on the north, with accompanying brecciation. Another one, in the northeast corner of the workings, is apparently related to a breccia 8 feet wide that crosscuts the beds here at a steep angle, striking approximately with the main fracture system and dipping steeply to the north. Both of these breccias are mineralized to some extent, but the commercially important ore lies along other fractures that show no evident displacement. Although most of the ore is confined to the main ore bed, mineralization along the fractures extended up into overlying beds as far as 15 feet, though generally not more than 5 feet above the base of the sandstone that forms the roof of the mine, and in one place down into the underlying limestone for a few feet. Adjacent to these mineralized fractures the limestones both above and below the main ore horizon are silicified to distances of 1 to 3 feet. Such a relation between silicification and fracturing is not conspicuous within the ore bed proper, but the rock removed in stoping out along the runs may have shown it.

The fractures are parallel to the Rush Creek fault and are evidently due to stresses produced during its formation. The structure map of the Rush district (pl. 4, oversheet A) shows that the Capps workings are approximately at the crest of the flat plunging anticline produced by drag on the master fault. The blocks bounded by the various fractures show different though low dips. One block toward the northwest limit of the workings dips 6° N. 75° E. Blocks southwest of this one dip at a lower angle and more to the southeast. On the whole the detailed dip is extremely variable, and the attitude of each block can be defined only in terms of its average dip, which is more easily obtained by inspection than by any detailed measurement.

The ore of the Capps mine is mixed jack and carbonate, although most of the output has been carbonate. The jack is mixed rosin and black. The carbonate is typically of the gray crystalline (botryoidal) type, but much of it is of the black crusty type. In addition there is some massive granular carbonate, on the edge of certain pockets, that may have replaced dolomite, and a little carbonate also occurs as small glassy rhombohedral crystals in vugs. Still another type (eggshell) forms white chalky layers in or shells over the botryoidal type, or it may occur as a white clay in certain vugs (flour carbonate). Zinc silicate is present sparingly in high-level workings at one place in the northeast corner of the mine. The gangue minerals are pink spar, calcite, and coarsely crystalline quartz (¼-inch to 1-inch crystals). The pink spar is by far the most abundant. Feldspar (adularia) is a microscopic constituent of the chert. Reddish tallow clay is developed abundantly along with the oxidized ores.

The ore occurs prominently in replacement pockets in the dolomite and chert, especially in the dolomite. Some of the pockets are drusy and have the shape of solution channels. Much of the ore is also in bedding veins, associated with pink spar, or in similar crosscutting veins. The chert contains disseminated jack, though irregularly, generally in blebs that average around a quarter of an inch in size. This disseminated ore shows no relation to the fractures and is generally of too low grade to work. However, a stope has been driven on mineralized rock of this type at the very back (northwest) end of the mine, and much of the ore, though of low grade, was milled. The dolomite, even where interbanded on a fine scale with chert that carries disseminated jack, carries none itself in this form, except very rarely. Small amounts of ore and associated gangue occur in veinlets in sandstone above the main ore-bearing bed.

The Capps mine was opened up in August 1915. Ore was trammed around the hill to the northwest for a little more than a quarter of a mile and milled at the Morning Star mill. According to smelter settlement sheets in the files of the Morning Star Mining Co., the production from September 1915 to the end of 1917 was 120 tons of concentrates in 1915 (September–December), 430 tons in 1916, and 650 tons in 1917, a total of 1,200 tons. This ore rarely carried more than 2 percent of sulphur, and a large part of it ran less than 1 percent, thus avoiding the penalty. At the same time, premiums on carload lots for 2 or 3 percent of zinc in excess of the 40 percent basis were not unusual, even when the sulphur ran less than 1 percent. Cadmium was not generally reported in the smelter assays, but one carload lot contained 0.204 percent of cadmium, according to the smelter report.

The Capps was the last producing mine in the Rush district, being worked by the Morning Star Mining Co. at irregular intervals up to the spring of 1928, when it was finally closed. Production since 1917 has amounted to perhaps 140 tons of concentrates.

McIntosh.—This mine lies adjacent to the Capps, southeast of it, in the SW¼NE¼ sec. 10, T. 17 N., R. 15 W. The two are connected by underground workings. The McIntosh has two levels, 30 feet apart. Each of these levels has a portal to the outside, and the two are connected by a winze that goes down near the portal of the upper one.

The connection with the Capps is made through the upper level, which is at the same stratigraphic horizon as the Capps (p. 203). The mineralization was very similar, although somewhat less extensive. The medium-grained dolomite which is rather widespread in the Capps and which was most richly mineralized is present near the upper portal and extends northwestward, parallel to the surface of the hill, toward the Capps portal, but in a drift directly into the hill from the McIntosh portal the ore-bearing bed changes from dolomite to barren limestone, 65 feet from the portal. The development of the mine is thus limited to a zone near the outcrop of this bed. Furthermore, the amount of dolomite in the ore bed decreases toward the Capps, and some of the ground between the two mines is limestone, incompletely replaced along the bedding by chert that contains only a small amount of disseminated ore. The thickness of the mineralized zone is also somewhat less in the McIntosh upper level than in the Capps, averaging only 4 or 5 feet, though in places reaching 7 or 8 feet.

The ore was taken from northwest-southeast runs, on the same fracture system as those in the Capps. One of these fractures, running N. 45° W. and dipping 60° SW., shows a displacement of 4 feet, down on the south. The displacement decreases toward the Capps to zero near the property line. Another fracture, running N. 73° W. and dipping 75° N., drops the beds on the north 1½ feet where it crosses the drift in barren limestone, 100 feet northeast of the portal, but there has been no mineralization in this place. As this break accords with the main fracture system of the two mines and was probably formed at the same time as the others, it appears that the character of the rock rather than the presence of a break is more influential in controlling ore deposition. The blocks between the fractures strike N. 70° 80° W. and dip about 10° N.

The lower level is developed in medium-grained dolomite and chert at a horizon that, under the Capps workings, is occupied by limestone. Gradations to limestone show in the McIntosh workings. The ore, as in the upper workings, is concentrated along fractures, one of which, striking N. 45° W., shows a drop of a few inches on the south and is probably the same as the fracture in the upper workings mentioned above.

A good part of the McIntosh ore was taken from a large open cut, 150 feet wide, 100 feet into the hill, and 50 feet deep at the back, at the level of the lower portal and extending up to and above the horizon of the upper level. The back of this cut shows considerable evidence of brecciation in the rock along a line parallel to the main fracture system of the hill, and probably the mineralization in the cut was localized along this fracture.

The McIntosh ore is mixed jack and carbonate of the same type as in the Capps. The ore may be disseminated in chert or dolomite, or it may occur in bedding and crosscutting veinlets and in irregular replacement pockets, associated with abundant pink spar, in these same rock types. The richer ore is in dolomite rather than in chert. A small amount occurs with abundant pink-spar gangue, in dolomite breccias produced by small structural movements.

Besides pink spar, which is the principal gangue, calcite and quartz are common. Some of the quartz occurs in crystals as much as 2 inches across. Malachite appears sparingly in the black form of the zinc carbonate.

Production during the early part of 1915 amounted to 100 tons of concentrates. Later, during the period that the mine was operated by the J. C. Shepherd Mining Co., it produced 148 tons of concentrates in 1915 (4 months) and 169 tons in 1916—a total of 417 tons for the 2 years. Most of this was carbonate carrying around 40 percent of zinc, but a large part of it was penalized for sulphur up to 3 or 4 percent (due to excess jack). The ore was milled on the bank of Rush Creek, immediately below the mine, and was sold on a basis of 40 percent zinc.

White Eagle.—The White Eagle mine and mill are situated in a field on the left bank of the Buffalo River just below the mouth of Rush Creek, in the NW¼SW¼ sec. 11, T. 17 N., R. 15 W. The main working is a shaft at the base of Rush Mountain and at the back edge of the alluvial flat, about 40 feet above low-water level of the Buffalo. It is reported to be about 65 feet deep and to have workings from its foot that extend southeastward 400 feet or more to some point near but below the level of the river. Development has been hindered by excessive ground water. In addition to the shaft, tunnel workings have been made into the hill about 100 feet above the collar of the shaft, but all the drifts were short (maximum 60 to 70 feet), and the productive ones are now caved. The deposits are in the Everton formation, the ore horizon in the bottom of the shaft being about 225 feet below the St. Peter. This is the lowest developed horizon in the Rush district except for the Beulah and lower Silver Hollow runs. The tunnel workings on the hill above the shaft are about 85 feet below the St. Peter. The shaft is practically on the axis of the shallow syncline on which the Beulah and Lonnie Boy are situated.

The ore from the shaft, to judge from the rock on the dump, is largely mixed rosin and black jack and occurs in masses as much as several inches across, banded in chert, silicified sandstone, and partly silicified medium-grained dolomite. A little jack is also disseminated in the chert. The ore is associated with drusy quartz and a little pink spar. Some of the jack in the sandstone has been oxidized to a high-grade crystalline carbonate, both gray and flesh-colored. The ore run is reported to be 4 to 6 feet thick. Some of the upper tunnel workings are barren, but one on the flat nose of the hill shows considerable gray crystalline carbonate and a little black carbonate, in silicified sandstone. Some of the original jack is preserved, either disseminated or bedded in the cherty sandstone; it is mixed rosin and black.

The White Eagle is an old-time mine, having been worked as early as 1896, but the main shaft was idle during the period from 1914 to 1917, when most of the northern Arkansas mines yielded their greatest production. Owing to the long period over which the property has been intermittently worked, the total production is not known. The commercial product of the shaft has always been jack. J. C. Branner reports that the property had produced 500 tons of ore (shipping grade) before 1900, and Alex C. Hull, in the Manufacturers' Record for August 30, 1906, reports 850 tons to that date. In 1915 and 1916 the upper tunnel workings yielded about 275 tons of carbonate concentrates. It is probable that these figures approximate the total production for the mine.

Edith and Yellow Rose.—These ore deposits are geologically one and the same, only the accidental position of a property line causing them to be worked as two separate properties. They are on the left bank of the Buffalo River, 60 feet above low water, about a quarter of a mile above the mouth of Rush Creek. The Edith is in the extreme southeast corner of sec. 10 and the adjacent southwest corner of sec. 11, T. 17 N., R. 15 W.; the Yellow Rose is in the northeast corner of sec. 15 and the northwest corner of sec. 14. Considerable litigation occurred as to the exact position of the section corner; the line was finally re-run and the corner established at a point about 100 feet southwest of the Edith shaft.

The locality of the mines is one of deep rock decay, with no surface outcrops. The horizon is in the Everton formation about 160 feet below the St. Peter. The workings are directly in the line of projection of the two terminal prongs of the Rush Creek fault, but whether displacement on these two prongs persists as far south as the workings is not known. If such a displacement does occur it must be small, but the localization of the ore deposit is evidently due to the shattering produced near the ends of these faults. The underground workings were inaccessible at the time the property was visited, but a map by Charles LeVasseur shows four fractures traversing the underground workings in a northwesterly direction, which is the direction of the extended prongs of the Rush Creek fault.

The workings on the Edith property consisted of a shaft, 50 feet deep to the base of the ore zone, and numerous underground workings, chiefly large irregular rooms, extending 400 feet northwest, and 150 to 180 feet north and northeast from the shaft. On the east, two drifts were cut through to the surface. The Yellow Rose workings, to the south, were continuous with those of the Edith, but as they lay nearer to the surface the deposit was worked in large part as a big open cut. The ore-bearing bed was a large blanket bed containing ore runs and is reported to have been about 15 feet thick.

The ore is gray crystalline zinc carbonate and occurs chiefly in a chert derived from the silicification of limestone or dolomite but also in silicified sandstone (quartzite). A little of the carbonate is turkey fat; another type, present in small amounts, is made up of small flesh-colored rods. The original sulphide from which the carbonate was derived appears to have been disseminated in the chert, but some of the rock on the dump shows rosin jack disseminated in a medium-grained partly silicified dolomite. This dolomite contains pink spar along the parting planes. Pink spar and a little calcite are associated with some of the ore in the chert. Chalcopyrite is present in traces.

Both the Edith and Yellow Rose had mills. According to Charles LeVasseur, the Edith produced about 2,400 tons of concentrates in 1915, 1916, and 1917. The Yellow Rose, according to statistics kept by the company, produced about 2,150 tons in 1915–17.

Red Cloud.—This mine is on the southeast bank of the Buffalo River, a quarter of a mile above the mouth of Rush Creek, in the NW¼ sec. 14, T. 17 N., R. 15 W. The opening is a large irregular-shaped tunnel whose separate drifts and stopes occupy an area 800 feet long from north to south and 500 feet wide from east to west (fig. 14). There are four openings to the surface on the north and west sides. The tunnel is developed on a certain bed rather than on a certain level, with the consequence that its floor shows numerous inclines that reflect in a general way the structure of the rocks. The two southern portals are 25 feet higher than the two at the north, which in turn are 87 feet above the level of the river.

The horizon is in the Everton formation, 150 feet below the St. Peter sandstone. Most of the workings are in a limestone altered to medium and coarse grained dolomite and to chert, just below 2 or 3 feet of impure sandstone. This sandstone is marked through part of the mine by breccia fragments of fine-grained dolomite and chert (the chert having in all probability been limestone originally), as much as 3 or 4 inches in size. Six inches below the top of the sandstone is a 10-inch bed of medium-grained dolomite. If this bedded sandstone, with its dolomite seam, is distinguished from certain "solution sandstones" that are prominently developed in parts of the mine and that represent the insoluble residues of sandy dolomites, it becomes a convenient key bed for working out the structure of the mine. Overlying the sandstone is at least 20 feet, and perhaps more, of fine-grained dark-gray dolomite, slightly coarser-grained in its basal 4 feet. The rock for several tens of feet below the mine workings is largely limestone.

The mine is directly in line with the Rush Creek fault, and it is interesting to note that the structural trends in the mine are from northwest to southeast, parallel to that fault. Four small faults show in the mine, and three of these not only strike parallel with the main Rush fault but show a similar displacement, down on the southwest. The greatest displacement noted is about 10 feet. One of these faults is extended to the southeast by a noticeable flexure rather than an actual displacement, and the beds southwest of the flexure dip to the south at angles between 10° and 20°. A monoclinal flexure that strikes somewhat more westerly than these faults but that drops the beds in the opposite (northeast) direction a total of about 15 feet is present near the northeast boundary of the workings. This flexure brecciates the country rock, and probably some of the displacement shown on it is taken up by faulting. It is evidently the local expression of the small east-west fault that shows in the St. Peter sandstone on both sides of the Buffalo River (pl. 4).

The whole eastern boundary of the workings is formed by a barren breccia of fine-grained dolomite blocks, with some sandstone blocks, in a matrix of sandstone that is nearly everywhere calcareous or dolomitic. This breccia is very irregular in ground plan, and its base, at least in places, slopes in, to judge from the relations between exposures in certain pillars and in the adjacent walls of the workings. This breccia is believed to have been formed by solution slumpage, due to the circulation of ground water through rock previously shattered by structural movement. Although it is barren in the sense that it contains no commercial ore, it does contain a few veinlets of pink spar that may in places carry a little jack, and it may also show local veinlets of chert with disseminated jack. It is thus earlier than some of the mineralization and is believed to be earlier than all of it.

Very little ore has been left in the walls of the workings, but the locations of the more richly mineralized stopes were pointed out by Mr. Jesse James, of Rush, and have been plotted on figure 14. The mineralization is seen to have

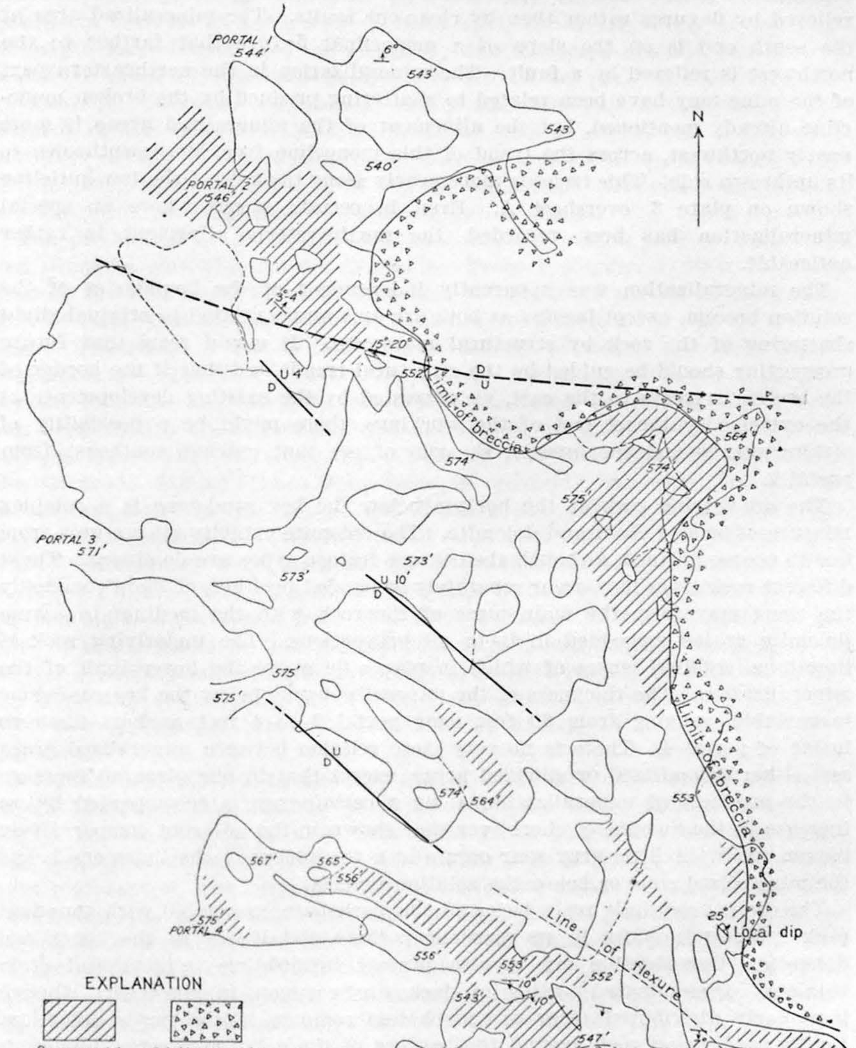

FIGURE 14.—Plan of Red Cloud mine.

followed in general the northwesterly trends shown by most of the other structural features and to have occurred chiefly where stresses have been relieved by flexures rather than by clean-cut faults. The mineralized area at the south end is on the slope of a monoclinal flexure that farther to the northwest is relieved by a fault. The mineralization in the northeastern part of the mine may have been related to shattering producd by the broken monocline already mentioned, but the alinement of the mineralized areas is more nearly northwest, across the trend of this monocline from its downthrown to its upthrown side. This trend is more nearly along the axis of the low anticline shown on plate 3, oversheet A. Even in certain stopes where no special mineralization has been recorded, the northwesterly alinement is rather noticeable.

The mineralization was apparently independent of the boundaries of the solution breccia, except insofar as both are apparently related to original slight shattering of the rock by structural movement. It would seem that future prospecting should be guided by the structural trends and that if the border of the breccia retreats to the east, as suggested by the existing developments at the extreme southeast end of the workings, there might be a possibility of picking up, beyond the breccia, the run of ore that extends southeast from portal 2.

The ore-bearing rock at the horizon below the key sandstone is a complex mixture of bedded chert and dolomite. The dolomite exhibits all textures from fine to coarse grained, although the coarser-grained types are dominant. These different rock types may occur separately or banded together, or more commonly the chert may form the main mass of the rock with the medium to coarse dolomite grains embedded in it in all proportions. The underlying rock is limestone, residual lenses of which in places lie above the lower limit of the mineralization. The thickness of the mineralized zone below the key sandstone is variable, ranging from 30 feet near portal 2 to 4 feet a short distance inside of portal 4. There is no very close relation between mineralized areas and either dolomitized or silicified areas, except that in one place an increase in the products of mineralization along a certain run is accompanied by an increase in the amount of chert over that shown in the adjacent comparatively barren walls. A little gray spar occurs in a few places in the limestone below the mineralized zone or below the solution breccia.

The ore is essentially rosin jack and zinc carbonate, associated with abundant pink spar, and occurs in replacement pockets and lenses in the chert and dolomite. Considerable ore is also present in bedding veinlets and cross veinlets. Disseminated grains of jack are common in the chert, though irregularly distributed; they are much less common in the purer dolomites. In the ore-bearing rock around the borders of the solution breccia, numerous large open solution channels, lined with drusy pink spar but generally without ore, are fairly common, the largest one noted being 5 feet wide and 2 to 4 feet high, with an undetermined length. In a few places the key sandstone carries a little ore in cross veinlets or in replacement pockets.

At the very back (south) end of the mine, owing to the dip of the strata, the key sandstone dips under the floor, and the overlying fine-grained dolomite, for several feet above the sandstone, is mineralized by the filling of shatter cracks (fig. 14).

The jack is dominantly rosin-colored, with a little intermixed black jack. The carbonate, besides the usual crystalline and porous black types, may be a white or flesh-colored variety that has replaced pink spar, or, locally, it may have directly replaced the fine-grained dolomite above the key sandstone, and in that case it may be hard to distinguish except by weight. Accessory minerals in addition to the abundant pink spar are transparent to pale-amber calcite, in crystals as much as 6 inches across, which may occur in ore vugs or in the large barren solution channels; fine to coarse grained quartz; and scattered small crystals of chalcopyrite, altered in part to malachite and aurichalcite. Feldspar (orthoclase, rarely microcline) is a microscopic constituent of the chert and of the interstitial clay in certain of the solution breccias. Pyrite is conspicuous in a few places as small replacement lenses in the fine-grained dolomite or in the key sandstone. Gypsum and epsomite are alteration products close to oxidizing pyrite masses.

The production of the Red Cloud mine has been made over a long time, and complete statistics are not available. From September 1, 1909, to March 1, 1913, the Red Cloud Zinc Co., according to detailed statistics in the possession of Capt. Charles LeVasseur, of Yellville, produced 2,681 tons of concentrates, consisting of mixed jack and carbonate, in which the jack usually predominated. The mill recovery during this period ran between 4 and 4½ percent concentrates; the mine recovery (concentrates per ton of rock mined) ran between 3½ and 4 percent. No figures are available on the production between March 1913 and June 1915. Between late June 1915 and March 1916 the Gertrude Mining Co. (Zimmerman & Scofield), according to smelter settlement sheets in the files of the Morning Star Mining Co., shipped 828 tons of concentrates from the Red Cloud mine (642 tons in 1915, 186 in 1916). These concentrates were marketed as carbonate, carload lots running 36 to 40 percent of zinc, 1 to 8 (generally less than 6) percent of sulphur, and some of them up to 5 percent of iron. The J. C. Shepherd Mining Co. took out 401 tons of concentrates in 1916, beginning March 1, and 30 tons in 1917. Most of this product was carbonate, averaging around 40 percent of zinc but carrying a penalty for sulphur, up to 6 or 7 percent, due to admixed jack. The mill recovery during 1916 is reported to have been 10 to 12 percent concentrates.

Between September 1915 and the end of July 1917 considerable ore from Silver Hollow, a few hundred yards up from the Silver Hollow mine, was milled at the Red Cloud mill. The land from which this ore was taken was usually identified as that of the Buffalo Zinc & Copper Co. Its ownership and control was largely if not entirely the same as that of the Red Cloud, but the production was kept separately. It produced 334 tons of carbonate concentrates during the time that Zimmerman & Scofield had charge of the Red Cloud (232 tons in 1915, 102 in 1916) and 335 tons under J. C. Shepherd's management (287 tons in 1916, 48 in 1917). The workings are caved and were not examined in detail by the writer.

Lonnie Boy.—The Lonnie Boy prospect is on the southeast side of the Buffalo River directly opposite the mouth of Rush Creek, in the SE¼SW¼ sec. 11, T. 17 N., R. 15 W. The workings consist of two tunnels, about 100 feet apart, extending southeast into the hill at a level only 12 feet or so above the low-water stage of the Buffalo. They are therefore subject to inundation at times of high water and have been largely filled with flood sand. The upstream tunnel goes in about 250 feet. Its first 100 feet was the only working accessible at the time the property was examined.

The geologic horizon is in the Everton formation 170 feet below the St. Peter sandstone. The openings lie on or near the axis of the shallow syncline on which the Beulah mine is also located. The portals of the two tunnels are in a massive chert breccia zone that parallels the face of the hill but apparently does not extend back into the hill any distance, as the rocks back of the portals, both outside and inside the tunnels, are not very greatly disturbed. This chert breccia resulted from silicification along a zone of brecciation that was produced by some slight structural movement. It contains very little mineral (zinc carbonate) but is iron-stained, presumably from pyrite.

Within the upstream tunnel the beds are practically undisturbed except for an obscure fracture on the roof at the rear end of a short lateral drift about 100 feet from the portal (fig. 15). The ore-bearing strata consist largely of chert and quartzite, whose mutual relations are rather obscure. Much of the chert is evidently derived from the silicification of a dolomite or possibly a limestone, but some of it appears to be derived from sandstone, perhaps a more limy facies than the sandstone that is altered to quartzite. In addition to these siliceous types medium-grained dolomite that is banded with chert carries a little of the ore. The ore-bearing interval is only 3 feet thick and is underlain by limestone.

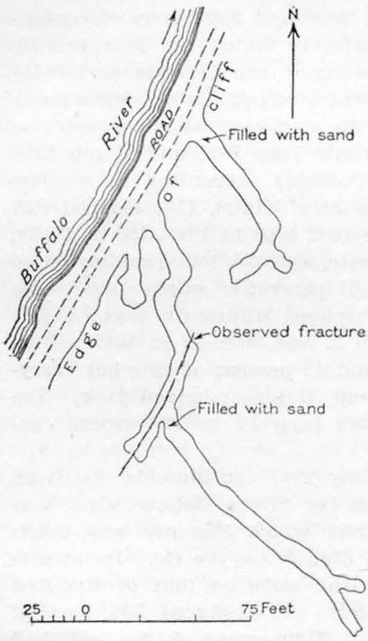

FIGURE 15.—Plan of Lonnie Boy mine.

The ore is chiefly a high-grade rosin jack and occurs in pockets and irregular cracks in the different types of country rock. Some of the masses reach a foot or so in size. A little jack is also disseminated in the chert. Part of the jack is oxidized to black silicate and to various types of carbonate: black, honeycomb, black and gray crystalline, and turkey fat are all common, although the gray crystalline type is most abundant. Pink spar accompanies the ore in the dolomite but is not so common in the chert. Drusy quartz, some of it in crystals as much as half an inch in size, is a common accompaniment of the ore in the chert. A trace of finely crystalline chalcopyrite occurs with the jack and, on weathering, appears as small malachite specks in the black carbonate and silicate.

The Lonnie Boy has been very little developed but is a promising prospect. About 150 tons of ore has been taken out, most of which was free carbonate and silicate. A small crusher that was formerly on the property has been washed away.

Leader.—This mine is in the NE¼NW¼ sec. 11, T. 17 N., R. 15 W., on the north slope of Leader Hollow about 500 feet above its junction with Clabber Creek. The property joins the Philadelphia on the east.

The horizon is in the Everton formation about 160 feet below the St. Peter sandstone. The workings consist of two short tunnels and several open cuts. The western tunnel is driven west diagonally into the hill for 125 feet and is essentially parallel to and about 150 feet south of the Monte Cristo fault, which here shows a displacement of about 20 feet. The beds in the mine are nearly horizontal and unbroken on the north side, toward the fault, but the south side shows an abrupt flexure, along a line roughly parallel to the drift, that drops the beds 2 or 3 feet down on the south. This break is parallel to the Monte Cristo fault, and the displacement is in the same direction. The shattered and partly brecciated rock along it has been silicified and carries most of the ore. The rock in the portal and in the north wall of the tunnel, although less broken, is nevertheless silicified and contains some ore, the maximum thickness of the ore-bearing zone being about 4 feet, with most of the mineral concentrated in the top 1 foot. Where the original rock is preserved at one point on the north wall, about 50 feet from the portal, it consists of limestone and limy sandstone, but the chert that elsewhere has replaced it contains a high percentage of fine- to medium-grained dolomite, either interbanded with the chert or else peppered through it as individual crystals. The chert has in such rock replaced dolomite or else has selectively replaced the limestone of a partly dolomitized bed. The more sandy beds have altered to quartzite. The ore-bearing bed is overlain by 6 inches of sandstone and underlain by sandy limestone.

The chief ore mineral showing is rosin jack, which occurs with very little associated gangue material, banded or disseminated in the bedded chert or filling the cavities of the chert breccia. The cavity walls in the chert commonly take the form of fine drusy quartz surfaces. A very small amount of pink spar occurs in scattered cavities in the chert, but compared to that in most of the other prospects in the Everton formation, the amount is negligible. Traces of malachite show in the more spongy carbonate.

The eastern tunnel runs N. 70° W. for 60 feet and is 50 feet closer to the Monte Cristo fault. It lies at the same horizon as the western tunnel, but the walls show more dolomite and less chert. The original ore was evidently deposited along a similar structural break, as much of the rock is brecciated. The rock has been more strongly weathered than in the other tunnel, and the ore was more dominantly carbonate.

Most of the ore marketed from the Leader property was gray crystalline carbonate, some of it turkey fat. Several carloads are reported to have been sold before 1905. According to the records of the J. C. Shepherd Mining Co., the production of zinc carbonate concentrates, averaging a little more than 40 percent of zinc, was 175 tons in 1915, 415 tons in 1916, and 36 tons in 1917, a total of 626 tons. The ore during this later period of operation was trammed around the hill and milled at the Philadelphia mill.

Philadelphia.—This mine, one of the most productive in the Rush district, is on the left hill slope of Clabber Creek, 160 feet above the creek bed, about half a mile from the Buffalo River, in the NW¼NW¼ sec. 11, T. 17 N., R. 15 W. The horizon is in the Everton formation 160 feet below the St. Peter sandstone. The chief working is a tunnel that goes about 1,200 feet into the hill along the line of a small monoclinal flexure, running N. 55° E., that drops the beds 6 feet on the southeast. The shattering and local brecciation of the rock along this flexure, over a width of 10 to 20 feet, has determined the site of ore deposition. A few cross fractures extend out on the northwest side, more or less at right angles to the monoclinal axis, and have been mineralized to distances of 70 feet. About halfway in, the tunnel swings more to the north, and the structure becomes obscured, but the shattered zone persists and is irregularly mineralized to the end. The width of the shattered and partly brecciated zone at the rear is somewhat greater, some ore faces being 30 feet wide.

The ore occurs chiefly in chert that has replaced limestone. This chert is limited chiefly to the mineralized zone along the monoclinal axis and is thus evidently closely related to the mineralization. A little of the limestone was previously replaced along the bedding by medium-grained dolomite, and the chert in this phase takes the form of replacement bands along the bedding, leaving a large percentage of the dolomite. The main ore-bearing zone is about 6 feet thick. Some mineralization also appears in the silicification product of a 5-foot limy sandstone above the main ore bed, and especially in the more limy phase of this upper bed (really a sandy limestone) that occupies the interval from 1 to 3 feet above its base. In places where the shattering along the monocline has been a little more intense, the sandstone of the upper bed has disintegrated and settled into the underlying beds along cracks. At the rear end of the mine some of the sulphide ore occurs in medium-grained dolomite whose horizon is uncertain, owing to the obscuring of the structure by shattering. Some of this dolomite may overlie the 5-foot sandy bed.

The chief ore mineral that has been commercially important is a gray crystalline carbonate, derived from mixed rosin and black jack (the former predominating), but at the rear end of the tunnel the carbonate gives way to rosin jack. Most of the carbonate has been mined out, but a considerable reserve of the jack remains. The jack, as exposed in a working face 30 feet wide and 6 to 12 feet high near the rear of the mine, occurs thickly disseminated in the chert, also as rather large replacement pockets in the chert, and in cracks in the overlying silicified sand. Some also occurs as replacement pockets in dolomite that probably overlies the sand. The gangue minerals are pink spar, calcite, and quartz, but they are not abundant and are irregularly distributed, being commonly absent entirely. Some of the calcite crystals are as much as 1 foot in size, but these are not accompanied by ore. A little finely crystalline chalcopyrite is associated with the jack.

The carbonate nearer the front of the mine includes some yellow turkey fat, and specimens were taken out during the period of production in which turkey fat formed the cores of large stalactites that consisted otherwise and dominantly of gray carbonate. (See p. 114 for partial analyses of these stalactites.) Some of the carbonate has replaced pink spar. Green copper stains are conspicuous in the more spongy carbonate. A little flour carbonate occurs in certain pockets in this portion of the mine.

The Philadelphia was equipped with a mill, which is now in ruins. According to records kept by R. W. Willett, of Yellville, and by the J. C. Shepherd Mining Co., its production during the World War period of high prices was 1,065 tons of concentrates in 1915, 1,066 tons in 1916, and 1,120 tons in 1917, a total of 3,251 tons. There was some production in 1911 and 1912 by an earlier company, but the amount is not known, although it was rather large. Much of this was mixed jack and carbonate, the jack predominating. All the ore produced by the J. C. Shepherd Mining Co. was marketed as carbonate on a basis of 40 percent zinc, determined by assay. The greater part of it contained less than 1 percent of sulphur, but some carload lots ran as high as 8 percent and were presumably heavily penalized for this constituent. On the other hand, other carload lots were remarkable for their combination of high zinc content with low sulphur content. A 30-ton shipment in July 1915 assayed 47.6 percent of zinc and less than 1 percent of sulphur. Cadmium is present in the ore, one reported assay, presumably of a carload of ore, showing a content of 0.231 percent. The recovery of the mill, based on an average over 11 months, was 15.6 percent of concentrates, which is equivalent to 6.2 percent of zinc, on the assumption that the concentrates averaged 40 percent of zinc.

Monte Cristo.—This mine is on the steep right slope of Clabber Creek, 70 feet above creek level, in the SE¼NE¼ sec. 10, T. 17 N., R. 15 W. The horizon is in the Everton formation 160 feet below the St. Peter sandstone. The tunnel begins just south of the Monte Cristo fault, which here has a throw of 25 feet, and goes south into the downthrown block for about 800 feet.

The ore occurs in a fairly straight run and is concentrated at two levels about 16 feet apart. The ore-bearing rock is limestone, slightly sandy in places, that has been altered to chert wherever it has been mineralized. It is slightly dolomitic in places, especially in the top few feet, but the dolomitization is not believed to be related in any way to the mineralization. The overlying rock is a 2-foot bed of limy sandstone. The upper ore-bearing level is 4 to 6 feet thick and lies immediately below this roof sandstone. The lower level, which is not very sharply defined, is concentrated for a few feet above and below a 6-inch bed of intraformational conglomerate that is bedded in the limestone 16 feet below the roof sandstone. This conglomerate, composed of small limestone pebbles embedded in limy sandstone, makes a very convenient key bed in an otherwise homogeneous limestone sequence and was traced throughout the greater part of the mine. There is 9 feet of limestone under this key bed, and then, in the only place where 2 feet or so of lower beds are exposed, medium-grained dolomite. Although most of the ore is concentrated at the two levels mentioned, the whole limestone interval has been mineralized at some place or another. One of the richest masses of ore that is left in the walls occupies a 4-foot interval between the two main ore levels over a length of 75 feet near the back end of the tunnel. There are also numerous stretches in the mine where the zones that normally carry the ore are themselves barren, at least in the present walls. This is especially true of the lower ore zone toward the back of the mine.

The main level in the tunnel is driven on the lower ore zone, and the tunnel, throughout the greater part of the mine, is rarely more than 10 feet wide at this level. The upper level is worked, near the front, as a separate mine level, but elsewhere it is worked as a high-level bench on the east side of the tunnel, extending perhaps 30 or 40 feet in places from the main drift. Near the front of the mine, where the run is evidently somewhat wider than farther back, a large high room has been stoped out over an interval that includes both ore levels. The entrance to the lower level is a small-bore drift through barren medium- to fine-grained dolomite, which may represent a lateral variation of the lower part of the limestone or may be the dolomite that underlies the limestone and that has been raised here a few feet above its normal position. Some crumpling and obscure brecciation in and at the back end of this entry tunnel, where it enters the large room, add weight to the second suggestion, though no definite faulting has been demonstrated.

The original ore mineral is rosin jack that contains a minor percentage of dark-colored jack scattered through it in spots. The greater production of the mine, however, has been carbonate, derived from the alteration of the jack. Most of it is crystalline and shows various colors—white, pearl-gray, flesh color, brown, yellow (turkey fat), and red (sealing wax). The gray type is most abundant. At many places carbonate is developed in stalactitic growths in open vugs. A little has also replaced or coated pink spar. The pink spar accompanies the jack as a gangue mineral, though rather sparingly compared to its usual abundance in the ore deposits of the Rush district. Additional gangue minerals of common occurrence are quartz and calcite; the quartz in places forms crystals from a quarter of an inch to 1 inch in size, lining vugs in the chert. Some of these vugs may run for as much as 8 feet along the bedding, though they are generally only a few inches to a foot high. A stalagmitic form of calcite, peculiar to this mine, is very prominent and has been mistaken for zinc carbonate, but it is translucent white and has a different luster. Of the minor gangue minerals chalcopyrite is widespread, generally associated with the jack, but is in such small scattered crystals as to be of no commercial importance. Crystalline gypsum has formed in a few places as an alteration product, and one small patch of aragonite a few inches across, associated with zinc carbonate, was picked up on the dump. Pyrite has replaced chert in and adjacent to the large stoped-out room near the front of the mine but is not present elsewhere.

The commercially important ore occurs as replacement masses, commonly lens-shaped along the bedding in the chert. There is also considerable disseminated jack in the chert, some of it in crystal blebs as much as 1 inch across, though generally much finer. This disseminated ore is of no commercial value but grades into the replacement pockets and lenses of commercial ore simply by increase in the amount of disseminated jack until the intervening chert has been largely replaced. The jack, carbonate, and pink spar may also occur on the walls of quartz-lined vugs, either on top of the quartz or under it. There is a little ore throughout the mine in bedding veins and crosscutting veinlets, in association with pink spar.

Most of the mine has been worked out except at the very back end, where the ore run, developed over a width of about 15 feet, chiefly at the higher level, shows low-grade ore of the open-vug type.

The production of the Monte Cristo according to figures kept by the J. C. Shepherd Mining Co. was 331 tons of concentrates in 1916; 1,417 tons in 1917; and 223 tons in 1918, a total of 1,971 tons. The production earlier than 1916 is not known but was small in comparison to the above figures. The mine was connected by aerial tram to the Philadelphia mill, where all the ore was concentrated. The average mill recovery from Monte Cristo ore during 1917 was 18.6 percent of concentrates, averaging 40 percent of zinc. Although the ore was sold as carbonate, smelter assays show that many of the cars were contaminated by jack, with a consequent penalty for sulphur.

A 300-foot tunnel on Monte Cristo property on the Rush Creek side of Rush Mountain produced 125 tons of free carbonate in 1916 and 1917. Some mill dirt from this tunnel was run through the McIntosh mill.

Silver Hollow.—This mine, one of the largest in the Rush district, is in the bluff on the right side of the Buffalo River about 2 miles southeast of Rush, in the NW¼NW¼ sec. 13, T. 17 N., R. 15 W. The ore occurs at two horizons in the Everton formation—the upper one 200 feet below the St. Peter sandstone, the lower one 50 feet lower. The Everton is here made up of limestone and medium-grained dolomite, with some sandstone. The strata near the face of the bluff in the immediate vicinity of the mine are somewhat disturbed by crushing and perhaps by solution slumpage, but within the hill the structure becomes more uniform, with an even dip of 3° or 4° to the south or southwest, into the hill. Although no evidence of faulting can be observed at the mine, the much lower altitude of the St. Peter sandstone on the north side of the river, opposite the mine, suggests that a roughly east-west fault, with a downthrow of about 200 feet on the north, is concealed somewhere within the river bed or alluvial bottom just north of the mine. (See pp. 101–102 and pl. 4.)

The opening on the lower level is a long tunnel whose portal lies 20 feet above low water in the river (fig. 16). There are really three entries on this level, over a width of about 150 feet, but they all coalesce within 300 feet from the face of the hill. At 400 feet from the portal the dip of the beds carries the floor of the tunnel down to the water level of the Buffalo River, and the back part of the mine is below water level. The back end of the mine, more than 1,000 feet from the portal, is reported to be 40 feet lower than the portal. A short distance south of the present water line in the tunnel drifts were driven east and west on ore along a cross fracture. The drift to the

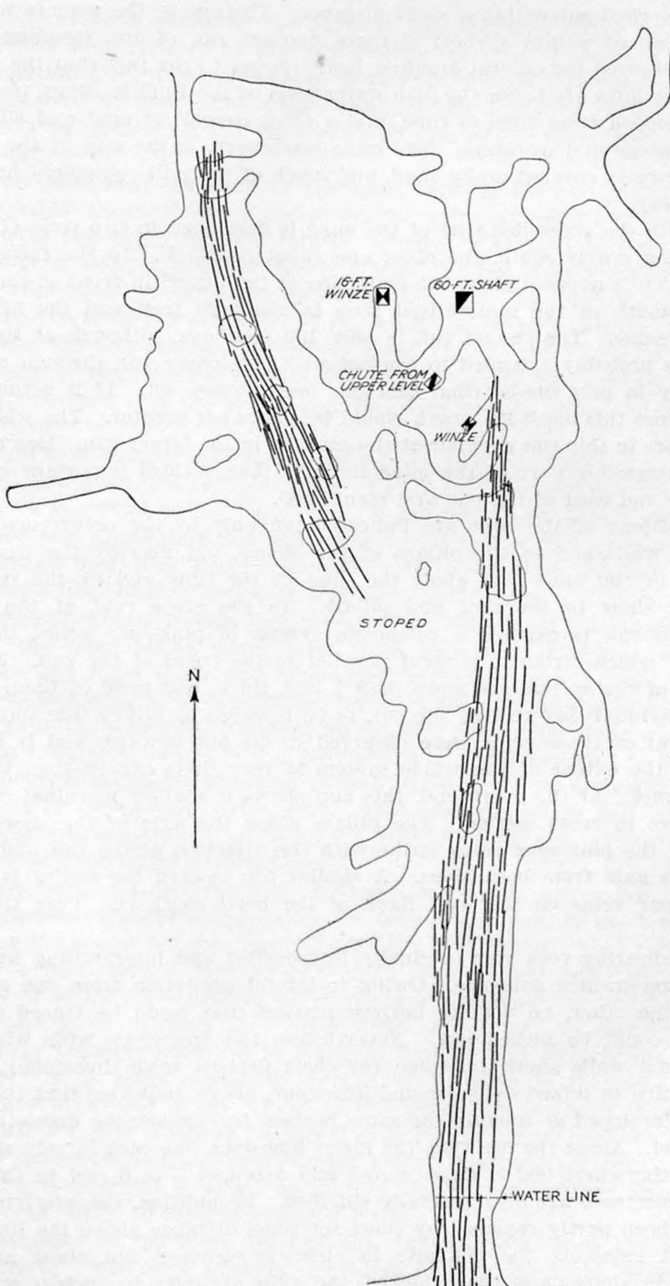

FIGURE 16.—Plan of Silver Hollow mine, lower level. The lines indicating ore runs show diagrammatically the average direction of the fractures.

east was worked out within a short distance. The one to the west is reported to have reached within a short distance another run of ore, trending south, which it followed for several hundred feet. Owing to the fact that the portals of the lower level are below the high-water level of the Buffalo River, the workings are flooded from time to time, and a thick deposit of mud and silt coats all the underground workings. The mine machinery, in the mill at the portal, has been largely covered up by sand, and much of the mill equipment has been washed away.

The ore in the accessible part of the mine is developed in two runs (fig. 16), one trending nearly south, the other one about S. 25° E. In the former, 300 feet of which is exposed along the main line of the tunnel in front of the water line, the width of the mineralized zone is about 20 feet, and the height is about the same. The second run is only 160 feet long, although at its south end it was probably extended to connect with the longer run through a block, presumably in part ore-bearing, that has been stoped out. If it actually extended across this block its length would be somewhat greater. The width and height of ore in this run were about the same as in the larger run. Descriptions of the inaccessible part of the mine indicate that a third important run lies parallel to and west of the one first mentioned.

The positions of the runs are indicated not only by the occurrence of ore along the walls and in the pillars of the stopes, but also by the weathered character of the mine roof along the lines of the runs and by the vein systems that show in the roof and pillars. In the stope roof of the longer north-south run is exposed a composite system of pink-spar veins, the individuals of which strike in general parallel to the trend of the run. None of the veins of the system are more than 1 inch thick, and none of them extend far as individuals before they die out, to be replaced by others that have come in. Several of these veins were observed to die out upward, and it is probable that the extent of the whole system is very little higher than the roof of the tunnel. At the north end, this run shows a shallow synclinal sag of a foot or two in cross section. The pillars along the axis of the shorter run show that the pink-spar veins strike with the direction of the run and dip in toward its axis from both sides. A similar dip toward the center is shown by pink-spar veins on the west flank of the north-south run, near its north end.

The ore-bearing rock was originally interbedded and intergrading limestone and medium-grained dolomite. Owing to lateral gradation from one of these types to the other, no definite horizon marker that could be traced through the mine could be picked out. Nevertheless the frequency with which the underground walls show limestone (or chert derived from limestone), below, and dolomite, or mixed dolomite and limestone, above, indicates that the workings are developed at roughly the same horizon throughout the accessible part of the level. Along the ore runs the lower limestone has been largely silicified. The resulting chert bed is dark-colored and averages 3 to 6 feet in thickness. Higher limestones are also generally silicified. In addition, the overlying dolomite has been partly replaced by chert for some distance above the limestone. The chert crosscuts the dolomite in clear-cut veinlets, but these are very irregular in shape, and they thicken and thin abruptly in such a way that they can be explained only as replacement masses, though the replacement process probably began along cracks. The final result of such replacement is a mottling of dolomite and chert that resembles a breccia. In a few places the dolomite blocks are definitely tilted, though on the whole they tend to preserve approximately their original attitude. It is suggested that this incipient brecciation shown by the dolomite was produced either by structural stresses that were relieved by shattering along the lines of the runs or else by slight solution along lines previously weakened by such structural shattering. The same type of brecciation where solution has definitely played a part is exposed in an unsilicified and unmineralized part of the mine, just within the east portal.

A large block near the front of the mine, between the two portals farthest apart, reveals dolomite with a minor amount of interbanded and intermottled chert in the few drifts that cut into it. Though it is possible that this block may be at a slightly different horizon from the bed that elsewhere is ore-bearing, the more probable interpretation seems to be that it represents a lateral variation of the ore bed. Three winzes were sunk within this block; no information was obtained on two of them, but the third one, 60 feet deep, is reported to have shown a little ore in the bottom but nowhere else. It appears therefore that the ore-bearing bed does not lie below the mine level in this block.

Around the borders of the mineralized masses, as a rule adjacent to unaltered limestone, are numerous isolated lenses of gray spar, in beds that may be 3 or 4 feet thick and 25 or 30 feet long, along the ore face. Such lenses were formed by replacement of the limestone and are generally barren, though rarely a little disseminated jack may appear in them. Many of them contain replacing pockets and veins of pink spar that may carry a little ore.

The ore is dominantly rosin jack, with a little intermixed black jack. In the part of the mine above water level some high-grade blue-gray crystalline carbonate and some black and honeycomb carbonate have altered from the jack, but, according to Frank Miller, formerly foreman at the mine, the production from the rear and at present inaccessible part of the mine was entirely jack, and the last workings in this part of the mine are reported to be in good jack ore. Pink spar is an abundant gangue. Less abundant are calcite, quartz, and traces of pyrite and chalcopyrite. Feldspar (orthoclase and microcline) is a microscopic constituent of the chert. Reddish, buff, and white tallow clay accompanies some of the oxidized ores.

The ore, with its accompanying gangue material, is segregated chiefly in large replacement pockets or in more or less open druses, in the lower chert, and along the border between chert and overlying dolomite. Such pockets may be 3 or 4 feet wide, 1 foot or more high, and several feet long. Certain channels of similar dimensions, or of perhaps somewhat greater height, are open druses lined by pink spar, with little or no ore. In addition to the replacement pockets much ore is found in bedding and crosscutting veins in the chert. Such veins commonly reach 1 or 2 inches in thickness and are partly of replacement origin. Part of the chert also contains disseminated jack, but much of it is barren. Chert that occurs at higher horizons along the ore runs is also ore-bearing, though these higher levels are not very persistent. The dolomite contains a small amount of ore in crosscutting and bedding veinlets, and rarely in the disseminated form.

Developments on the upper level of the Silver Hollow mine are somewhat less extensive. The main working is a large room at the front, about 60 feet in diameter and 50 feet high, from the back end of which a tunnel extends about 200 feet southward into the hill (fig. 17). This tunnel follows a certain bed, 5 to 7 feet thick, that ranges from limestone to chert and in a few places to medium to coarse grained dolomite. The bed is capped by a limy sandstone which forms a convenient key bed for the level, and is underlain by medium- to fine-grained dolomite, which is only a few feet thick and is in turn underlain by limestone.

The key sandstone can be followed, unbroken, from the rear of the tunnel around the walls of the large room at the front to the borders of a mineralized breccia at the very front of the room, near the outcrop. The ore was taken from this breccia, which formerly occupied the volume of the room. The present remnants show a width from northwest to southeast of about 40 feet and a height of about 50 feet, this cross section being triangular in shape. The original length was evidently about 80 feet. The base of the breccia apparently lies not far below the level of the present floor of the workings, for along the northeast side of the pit in the large room, the limestone passes unbroken beneath the breccia. The structure of the breccia is synclinal, with rather sharp boundaries, along which some slight normal faulting (maximum displacement 4 or 5 feet) has occurred along with the slumping. The breccia is made up of dolomite, sandstone, and chert blocks with a matrix of chert and ore, although the exact constitution is obscured by later alterations during oxidation. The origin of the structure is not evident, owing to incomplete exposures. The general shape suggests a settling along a zone of solution, but the amount of such settling has not been great, as the shattered key sandstone can be traced part way across the breccia. It seems probable that the original shattering was produced during structural movement along the line of the postulated fault to the north of the mine, and this shattering may have been later modified by solution slumpage.

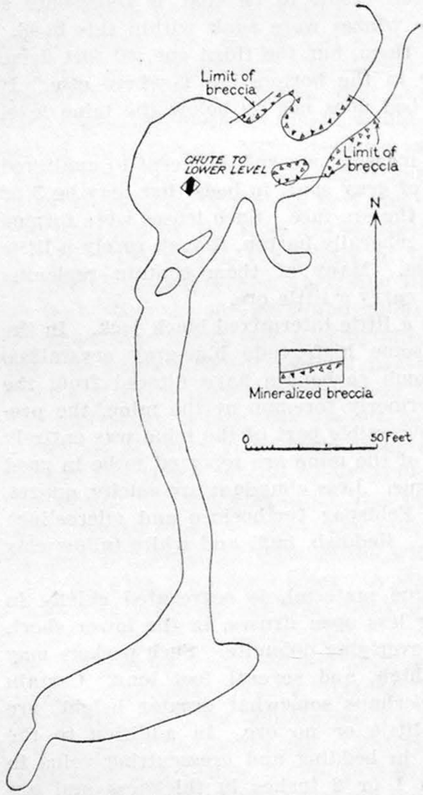

FIGURE 17.—Plan of Silver Hollow mine, upper level

The ore, which has been almost entirely removed, was mixed rosin jack and zinc carbonate, with a little black jack. It occurs interstitially in the breccia in association with pyritic chert and drusy quartz; the ore may or may not completely fill the quartz-lined vugs. The pyrite occurs as microscopic crystals disseminated thickly in the chert, coloring it black in fresh samples. A small amount of pyrite is also developed in the dolomite and sandstone blocks, but on the whole these are comparatively free from it. The oxidation of the pyrite has produced a spongy limonitic mass in which the original structure of the breccia is either destroyed or else obscured by staining. Many of the dolomite blocks have been entirely leached out, leaving only a red clay, which, however, may preserve the original bedding of the blocks. The jack, on the other hand, may be preserved, with its quartz shell, in rather highly decayed rock. Oxidation products of the pyrite, which occur as efflorescences on the walls of the mine, are copiapite, gypsum, and an unidentified mineral, essentially an iron-zinc sulphate, which appears as a white powder. The abundance of pyrite on this level is unique so far as northern Arkansas ore deposits are concerned and considerably impaired the value of the ore.

The mineralization in the tunnel back of the main room has been negligible, although a little jack and carbonate are disseminated in the chert or else associated with pink spar and some calcite in pockets and veinlets in the chert and to a less extent in the key sandstone. Some of the carbonate has replaced pink spar. A trace of chalcopyrite shows in some of the vugs, and pyrite of the same type that is developed so abundantly in the breccia is concentrated in small bedding lenses haphazardly in the chert.

The Silver Hollow mine has produced over a long period, Branner[49] having reported a production of 100 tons before 1900. A large output was made between 1900 and August 1907, when the mine was shut down temporarily. Several newspaper accounts following the shutdown and crediting the mine with a total production to that date of 3,000 to 4,000 tons of concentrates are doubtless somewhat exaggerated. Between 1907 and the beginning of the World War, very little ore was produced, but in 1915–17 the Silver Hollow was again a steady producer of jack concentrates. According to the late R. W. Willett, of Yellville, the production in 1915 was 150 tons; according to Charles LeVasseur, of Yellville, the production in 1916 was about 675 tons; according to J. H. Hand, of Yellville, the production in 1917 was 90 tons.

Eagle Picher drill holes.—In the spring of 1927 the Eagle Picher Lead Co. drilled several prospect holes along the Rush Creek fault, near Rush. Unfortunately none of these holes were located accurately on the Rush Creek map (pl. 4). Hole 1, drilled to a depth of 204 feet, was "due south of the Capps tunnel and about 50 feet south of the bank of Rush Creek." The boiler for the drill was set up on the south (downthrown) side of the fault, and the well log indicates that the hole was drilled on the same side, although it could not have been more than 150 feet from the fault. (See pl. 4.) The hole began about 20 feet below the base of the St. Peter and was barren. Hole 2, drilled to a depth of 182 feet, was on McIntosh mine property, in the NW¼SE¼ sec. 10, T. 17 N., R. 15 W., on the left bank of Rush Creek a short distance below the McIntosh mill. It was within 200 feet of the fault, on the north (upthrown) side, and began at a horizon about 100 feet above the base of the Everton. This hole was likewise barren. Hole 3 was drilled a short distance upstream from hole 2, but no log of it is available. Hole 4, on the opposite side of Rush Creek from hole 3, was drilled 60 feet and was barren. A fifth hole, drilled to a depth of 92 feet, was on the Edith property. The log of this hole reports 1.65 percent of jack in "brown water flint" at a depth of 40 to 45 feet, somewhere in the Everton formation.

CEDAR CREEK-BOAT CREEK-COW CREEK DISTRICT

The district including Cedar, Boat, and Cow Creeks lies in southeastern Marion County north of the Buffalo River and includes not only the drainage basins of the streams mentioned but also the Buffalo River Valley and tributaries on its north side between Boat Creek and Cow Creek. The larger part of the district is east of the

[49] Branner, J. C., The zinc and lead region of north Arkansas: Arkansas Geol. Survey Ann. Rept. for 1892, vol. 5, p. 210, 1900.

Yellville quadrangle. The deposits lie at different horizons in the Everton formation and occur in various types of limestone and dolomite country rock. A few of the deposits on the Cow Creek side and also the Omeara mine, on the Buffalo River, have been commercially productive. The output of the district has been largely jack, with some carbonate and a little silicate. Several hundred tons of concentrates have been marketed, but reliable figures on some of the principal producers are lacking.

Bonnie Blue.—This small prospect is an open cut, 20 feet across and 7 feet deep, on the point of a long but gently sloping nose between two western tributaries of Cedar Creek. It is probably in the E½ sec. 36, T. 18 N., R. 15 W. The horizon is in the upper half of the Everton formation. The ore bed occurs between fine-grained magnesian limestone above and limestone below and is a silicified limestone, with some quartzite. The ore is rosin jack and occurs disseminated or in irregular replacement chunks 2 inches or more across, in the chert and quartzite. A little pink spar accompanies it in places. A minor amount of oxidation to carbonate has occurred.

Carbonate Point.—This prospect is in the SW¼ sec. 6, T. 17 N., R. 14 W., on a point between Cedar Creek and a small tributary from the west, at an altitude of around 540 feet. The geologic horizon is near the middle of the Everton formation. There are several openings, but none of them are very extensive. One is an open-cut trench into the hill, with a 50- to 60-foot shaft at the back. The walls of the trench are in medium-grained dolomite, in part slightly sandy, that carries a little zinc carbonate associated with pink spar in thin veinlets. The rock is decomposed except at the very rear. Ore on the dump pile of this opening shows some rosin jack in dolomite, reported to have come from a drift along a fracture, 30 feet below the collar of the shaft. A little of the dolomite contains disseminated jack, or it is replaced by chert with disseminated jack. About 200 feet south of this opening are a shallow shaft and open pit, revealing essentially the same type of ore except that the oxidation to carbonate has been more complete. The carbonate is blue-gray and crusty in appearance. According to records kept by R. W. Willett, of Yellville, 6 tons of free carbonate ore was taken from the prospect in 1915; this is probably the total production.

Lucky Dutchman.—This is the mine that supplied the ore rock for the Moark mill, on the same property. The workings are in the NW¼ sec. 7, T. 17 N., R. 14 W., on the west bank of Cedar Creek at an altitude of 480 feet, a short distance up from the Buffalo River and about 40 feet higher. There are five or six openings strung along the foot of the hill for a distance of 500 feet or so. The southernmost one, evidently the main one, is a tunnel. This tunnel forks at the portal, the two prongs going in at a slightly divergent angle some 60 or 70 feet. In the portal region the country rock comprises medium to rather coarse grained dolomite, irregularly cherty dolomite, and chert. A little jack occurs, either associated with abundant pink spar in irregular lenses along the bedding lines or else disseminated in the cherty phases. The mineralized interval is 7 feet or more thick. At the back end of the right prong of the tunnel the wall rock has changed completely to barren limestone. Only 1 or 2 feet of mineralized rock remains in the left prong, where, however, the ore is somewhat richer than at the portal, though it is still of low grade. A shaft at the portal of the tunnel has been filled within 10 feet of the surface by waste rock from the workings.

The other workings along the hill are evidently at the same horizon, though the bed cannot be traced, owing to the lack of exposures. These workings are mostly open trench cuts into the hill, with short drifts from the rear in perhaps one or two of them. The type of country rock and the mineralization are similar to those already described at the south tunnel, except that in a few places jack is disseminated in dolomite that has not been noticeably silicified, although in such places silicification has occurred in the closely adjacent rock. One or two of the central openings, in which no chert is developed, contain only pink spar in the medium- to coarse-grained dolomite, without any accompanying ore. Evidently the jack accompanies the chert rather than the pink spar. A small amount of carbonate shows in one or two of the openings, chiefly as a coating of pink spar, and a trace of malachite occurs as small specks on the surfaces of pink-spar crystals, where it has altered directly from chalcopyrite.

It is reported that not enough ore was obtained from the Lucky Dutchman mine to bed the jigs of the Moark mill.

Boat Creek.—This prospect is on the northwest bank of Boat Creek, at an altitude of 480 feet, 40 feet above the level of the Buffalo River, near the center of sec. 7, T. 17 N., R. 14 W. The ore horizon is in the Everton formation, 200 feet or so below the St. Peter sandstone. The ore deposit is localized on a small monoclinal flexure, showing a dip, over a width of 100 feet or so, of 10°-12° S. The beds on the up side of the flexure show a very gentle dip to the north. The opening is a gently inclined drift, 100 feet long, on the monocline near its crest. The country rock is dolomite, ranging in texture from coarse to fine. Partial to complete silicification accompanied the mineralization. The ore is jack and occurs disseminated in the siliceous phases, or else associated with pink spar in bedding lenses, crosscutting veins, and irregular pockets in the different types of country rock. The jack is mixed rosin and black. A little calcite and a trace of finely crystalline chalcopyrite are developed in some of the pink-spar vugs. Toward the surface a small amount of zinc carbonate has formed, but the prospect is essentially a jack deposit.

George Washington.—This prospect is on the left side of Boat Creek near its mouth, at an altitude of 550 feet, 100 feet or so above the level of the Buffalo River. It is in the SW¼ sec. 7, T. 17 N., R. 14 W. The opening is a shallow open cut about 100 feet in length along the hill. The ore-bearing rock is Everton dolomite, more or less sandy, that ranges in texture from coarse to rather fine grained, averaging medium-grained. It is only 2 or 3 feet thick. Much of this dolomite has a bluish-green tinge due to the presence of a clay mineral developed either interstitially or else in blebs or along seams. The dolomite has been shattered and in places brecciated, so that blocks from the overlying beds appear intermingled with the more abundant blocks of the main ore bed. The ore is rosin jack and occurs associated with pink spar in the shatter cracks and interstitially to the brecciated blocks; the mineralization was everywhere accompanied by some solution and replacement of the adjacent dolomite blocks. A trace of chalcopyrite occurs along with the jack, and calcite is a minor gangue mineral. Fine granular pyrite is present very sparingly in the country-rock dolomite or along the contact of the dolomite with pink spar. A finer-grained bed at the top of the mineralized interval shows some irregular replacement of the country rock dolomite by chert containing disseminated jack.

A small mill was built on this property at the time it was worked, but no ore was produced. It is reported that the jack used for bedding the jigs was obtained from a shaft in the bed of a hollow that comes into Boat Creek from the south 600 to 700 feet above the prospect.

The shaft mentioned above is about 20 feet lower in altitude than the George Washington prospect. The ore is rosin jack associated with pink spar in cracks in a medium-grained dolomite or dolomitic sandstone. A few small crystals of chalcopyrite are plastered on the jack crystals in the open vugs, and pyrite in small quantities occurs in the dolomite. The deposit is thus very similar to that at the George Washington and is possibly at the same horizon.

Omeara.—This property is on the left slope of the Buffalo River between a quarter and half a mile below the mouth of Boat Creek, in the NW¼ NW¼ sec. 18, T. 17 N., R. 14 W. The workings are 5 or 6 short tunnels, as much as 150 feet long, that extend along a quarter-mile stretch at a horizon in the Everton formation 0 to 20 feet below the St. Peter sandstone. Usually the ore-bearing zone is only 10 feet or less thick. The strata dip at a low angle to the south. Although there is no break in the bedding, the strata show local contortions within the workings. The ore-bearing rock is chiefly a silicified limestone with a little interbedded quartzite and medium-grained dolomite. The lower limit of the silicification is indefinite as it extended down in places for several feet into the underlying limestone. The silicified rock and associated ore are not continuous along the outcrop, there being stretches between the openings that are barren limestone. The ore is chiefly black carbonate and gray carbonate, with some turkey fat, silicate, and residual jack. It occurs associated with pink spar and a minor amount of calcite in bedded and crosscutting veinlets and in irregular pockets along the bedding. The usual trace of chalcopyrite accompanied the original ore, and much of the black carbonate shows small inclusions of malachite and aurichalcite. A little gypsum has been developed as an alteration product. A whitish botryoidal (hailstone) form of calcite occurs as a late product of crystallization in many of the vugs and is followed by a little aragonite. In some of the openings farthest south, a little of the original jack was disseminated in the chert.

The Omeara property is reported to have produced several carloads of carbonate ore. Of this, two cars (60 to 70 tons) consisted of free ore. The rest was milled on the property.

Sam Hill.—This prospect is high on the hill on the south side of Boat Creek, at an altitude of 780 feet, in the SE¼ sec. 7, T. 17 N., R. 14 W. The opening is a slightly curving 70-foot tunnel in the Everton formation, 20 feet below the St. Peter sandstone. The mineralization was localized along a sharp monoclinal flexure that drops the beds on the north 2 or 3 feet, producing a narrow breccia zone. The ore occurs in the breccia developed in a medium to rather fine grained dolomite that is more or less sandy. It was originally jack with pink spar, but most of it has been leached out or altered to carbonate. A little gypsum was formed in some of the vugs during this alteration. Crusts of fine drusy quartz coat the blocks of the breccia, their formation having evidently preceded the deposition of the primary ore. The rock showing beneath the dolomite that carries the ore in the south wall of the tunnel and for 100 feet or so on both sides of the portal is limestone, incompletely silicified in a zone as much as 3 feet thick. The resulting chert originally contained disseminated jack and segregated drusy pink spar. Most of the jack has been leached out. This prospect has produced perhaps 30 or 40 tons of zinc carbonate, hand-picked.

Dixie Girl.—This mine is in the S½SW¼ sec. 8, T. 17 N., R. 14 W., in a hollow that is tributary to Boat Creek from the south. The horizon is in the Everton formation 10 to 20 feet below the St. Peter sandstone. There are two tunnels at the first main fork of the hollow, at an altitude of about 800 feet.

Both were caved at the time the property was visited. The western one, on the left side of the left prong of the hollow, practically at the level of its bed, is reported to have gone S. 80° W. 200 feet or so into the hill. Its portal is in limestone, sandy limestone, and fine- to medium-grained dolomite; the dolomite lies above the limestone and contains pink spar and a little jack in thin veins. At 30 feet from the portal the tunnel enters a barren breccia, composed of blocks of the same material that makes up the portal section, with a matrix of limy sandstone. This breccia apparently lies in a zone transverse to the course of the tunnel and parallel to the face of the hill. Although it has the appearance of a fault breccia, there is no observable displacement in the sandstone above other than a small displacement on a block, 200 feet long, that lies parallel to the face of the hill. This block has the appearance of a landslide block that has broken off parallel to the face of the sandstone ledge. This would explain the absence of mineral in the breccia, as the mineralization preceded the formation of the present topography by a long time, and any land-slip movement would have taken place after the present topography was formed. Decay has been extensive along the breccia zone, with the development of considerable clay. The tunnel is reported to have gone through 75 feet of this boulder ground, requiring heavy timbering. At the back end it was again in mineralized ground. The ore from this tunnel was jack, but the production was small.

The second tunnel is located around the point, on the left side of the right-hand hollow. It is reported to be 100 feet long and to present a 7-foot ore-bearing face at the rear end, though of course, as elsewhere in the northern Arkansas zinc field, only a small part of this face is mineral (jack).

Although a large mill was built on the Dixie Girl property, the production was not more than 40 or 50 tons.

Phoenix.—This prospect lies at an altitude of 930 feet on the left slope of Jake Hollow, which is a southern headwater tributary of Boat Creek. The horizon is in the Everton formation 40 feet or so below the St. Peter sandstone. The ore ledge is poorly exposed but appears to be about 10 feet thick. The openings consist of one or two short tunnels, now caved. The ore is carbonate and occurs in various forms, as dry bone, as black honeycomb, or as a coating over pink spar. The original rosin jack, from which the carbonate was derived, was disseminated in chert, in dolomitic sandstone, or in coarse dolomite, or else it occurred, in association with pink spar, as irregular segregated bodies or crack fillings in the same rock types and also in medium- to fine-grained dolomite. To judge from the numerous casts of jack masses preserved by hollow shells of carbonate, some of the original jack in these segregated bodies appeared in rather large masses. A few tons of free ore lies on the dump, but no ore has been marketed from this prospect.

Good Luck.—The several openings on this property lie on the left side of Rough Hollow, probably in the NW¼ sec. 20, T. 17 N., R. 14 W. They are 20 feet below the St. Peter sandstone. There are four or five short tunnels that enter the hill for distances as great as 160 feet, over an outcrop length of about 350 feet. The beds dip at a gentle angle to the south or southwest. The mineralized bed is at the top of a series of limestones and sandy limestones that lie beneath a fine-grained dolomite. The ore bed is generally not more than 2 or 3 feet thick, though in a few places it reaches 5 feet. It has been silicified to chert, part of which is greenish. The ore, which is not plentiful, is jack or carbonate, disseminated in the chert or occurring sparingly in bedding veinlets and irregular pockets of pink spar. The limestone bed immediately below, which normally is highly fossiliferous (ostracodes) is locally replaced as a whole by pink spar, more rarely by gray spar, without ore. The dolomite above contains a very small amount of jack in crosscutting pink-spar veinlets. The immediate capping of the ore bed is a 6-inch sandstone seam. This prospect is very unpromising.

Mary Agnes.—This prospect lies high on the point between the two main forks of Brush Creek, in the W½ sec. 16, T. 17 N., R. 14 W. The horizon is in the Everton formation 25 feet below the St. Peter sandstone. The tunnel is 60 feet long. The ore bed is a chert that has replaced limestone, but whereas the chert extends from the level of the mine clear up to the base of the St. Peter, only 4 or 5 feet of it is mineralized. Owing to the large amount of clay material in the chert, it is blue-green. Some quartzite is bedded in the chert. The original rosin jack was disseminated in the chert and quartzite or occurred in bedding veins and pockets in association with pink spar. Much of it has been oxidized to carbonate, which may appear in the black form or else as a replacement product of pink spar. Subordinate calcite and a trace of chalcopyrite accompanied the original ore.

Sixteen mine.—This property is a direct continuation of the Mary Agnes, its tunnel opening a little more than 100 feet farther west. The mineralization is the same, but the underground workings are somewhat more extensive, there being a many-branched tunnel with numerous stoped-out rooms. Gray spar has here and there replaced the chert in the neighborhood of pink-spar pockets or more extensively replaced the limestone under the ore bed. This property is reported to have produced about $6,000 worth of free carbonate during the World War.

Chickasaw.—This mine is on the south side of the south prong of Cow Creek near its head, probably in the SW¼ sec. 10, T. 17 N., R. 14 W. The mine is in the bed of a small gulch about 600 feet up from the mill site on the main south prong, at an altitude of 770 feet. The development consists of an open cut up the bed of the gulch, 200 feet long, 40 to 50 feet wide and 15 to 20 feet deep. Near the front a large room, 40 feet in diameter, extends off to the west. The country rock is chiefly a fine-grained dark-gray dolomite, but it includes a little medium-grained dolomite, sandy chert, and quartzite. The average local dip of the strata is at a low angle to the north, but the beds have been somewhat shattered and contorted, producing small local dips in varying directions at varying angles. Although part of the rock is brecciated, there is no definite fault break of any extent in the rock.

The ore is rosin jack in association with pink spar, and it occurs filling the shatter cracks and the interstices in the breccia. Minor gangue minerals are calcite, fine drusy quartz, and scattered minute crystals of chalcopyrite. Finely crystalline pyrite occurs sparingly in cracks in the dolomite or along the border between the dolomite and pink spar.

The jack that at present shows in the walls of the cut is subordinate in amount compared to the pink spar and is very erratically distributed. It is estimated to average not more than 1 or 2 percent by weight of the rock that would have to be milled to recover it. The deposit has not been exhausted, for the same ore minerals in presumably the same gangue rock are exposed in a small cut 500 feet toward the mill from the main workings. It is possible that streaks richer than the material showing in the walls of the cut may be encountered in the intervening block, although there is no way of predicting it. The size of the chat pile indicates that a large amount of rock was run through the mill at the time the property was being exploited, during the period of high metal prices that prevailed in the early years of the World War. The complete production is not known, but about 40 tons of concentrates were shipped in the fall of 1916.

Groundhog.—This prospect is in the SW¼ sec. 10, T. 17 N., R. 14 W., high on the south side of the south prong of Cow Creek. There are three openings at a horizon in the Everton formation between 10 and 15 feet below the St. Peter sandstone. Of these, the two outside ones, about 200 feet apart, are tunnels less than 100 feet long, in barren limestone. The third one, about halfway between the other two, is a rather small open cut, from the back of which a tunnel, now caved, enters the hill for a short distance. The walls of the open cut show a silicified limestone (chert) containing disseminated casts of jack. The ore on the dump pile from this cut is largely zinc silicate, with a little black carbonate, both minerals derived from the jack that was originally in the chert. A small amount of residual jack on the dump pile appears to have been developed originally as rather large replacement masses along the bedding of the chert. The mine is reported to have produced about 200 tons of free carbonate (probably, in part at least, silicate), mostly in 1916.

Bonanza.—This, the most productive mine on Cow Creek, is on the south side of the south prong, perhaps 40 or 50 feet above the level of the creek, in the NW¼SE¼ sec. 10, T. 17 N., R. 14 W. The altitude is around 630 feet. The workings are a large open pit, 100 feet in diameter and 40 to 50 feet deep at the back, with underground workings going off from it at different levels on the back side. There are reported to be other underground workings at lower levels. Most of the ore is said to have come from ground just southeast of the pit and within a distance of 50 feet from it. All the openings, including the pit, were worked through a shaft, 100 feet deep, that is sunk from the east rim of the pit.

The mineralized rock is dominantly a fine-grained dark-gray dolomite, with a little medium-grained dolomite irregularly distributed through it. Limestone 2 feet thick, showing chiefly in one of the higher-level tunnels at the back of the pit, is largely altered to chert.

The ore mineral is rosin jack, and it occurs, in association with pink spar, in crosscutting veinlets and irregular pockets in almost any conceivable attitude. Ore shows throughout the pit but is thicker in certain more shattered blocks than in others. A little chert accompanies the ore, either as a haphazard, indefinite replacement product in the dolomite, or as a border on the lower sides of veins and vugs. Fine drusy quartz and chalcopyrite are minor gangue minerals.

A very large amount of rock has been milled at the Bonanza mine, and it has been a rather persistent producer since 1890, though the exact output is not known. Random years for which figures happen to be available are 1908, with an output of 180 tons of jack concentrates (R. W. Willett); 1915, with an output of 87 tons (Willett); and 1917, with an output of 135 tons (J. H. Hand).

Foxden.—This prospect lies at an altitude of 640 feet on the south slope of Cow Creek, a mile up from the Buffalo River. The horizon is in the Everton formation 200 feet or so below the St. Peter sandstone. The tunnel is forked, the two prongs going in at a small angle to each other for a distance of 300 feet. The west prong has a small stoped-out room on a lean showing of ore. The ore zone lies at the base of a series of fine-grained dolomites and is immediately overlain by a 6-inch seam of sandstone. The ore bed is 3 feet or more thick and is variable in composition, between limestone, medium to coarse dolomite, and chert. The dolomite has replaced the limestone irregularly, and the chert has replaced both irregularly. The ore is confined almost wholly to the top foot of the ore-bearing bed, appearing chiefly in chert, less commonly in dolomite, and nowhere in limestone. Rosin jack, containing a little black jack, is the ore mineral, and it occurs disseminated in the chert and dolomite or, more abundantly, in association with pink spar in bedding veins. A trace of chalcopyrite accompanies the jack. This mine appears unpromising, although during the World War a small mill was built on the property and some ore was concentrated.

Dry Bone.—This prospect is opposite the Foxden and at the same altitude, on the point between the two main forks of Cow Creek, in the SW¼SE¼ and the SE¼SW¼ sec. 3, T. 17 N., R. 14 W. It lies along the contact between a dolomite series above and limestone below and is possibly at the same horizon as the Foxden. The opening is an open cut, 10 feet or more deep and 50 feet in diameter. The ore consists of mixed zinc carbonate and rosin jack, associated with pink spar, and occurs in bedding veins and cracks in medium and fine grained dolomite. A small amount of chert accompanies the ore, chiefly as a border to the veins. Fine drusy quartz and finely crystalline chalcopyrite are minor gangue minerals.

Prince Fred.—Three prospects were examined on this property, all lying on the slopes of a high hill at the end of the ridge between Cow Creek and Moreland Creek. One prospect is on the southeast slope of the hill at an altitude of 850 feet, in the NW¼NW¼ sec. 2, T. 17 N., R. 14 W. The horizon is in the Everton formation 250 feet or so below the St. Peter sandstone. The mineralization was localized in a breccia of fine-grained dolomite and subordinate dolomitic sandstone. Evidently the breccia was produced by slight structural movement along a line parallel to the face of the hill. The workings consist of two short tunnels that lead back from open cuts, the west tunnel going in 60 feet or so and the east one only 10 feet. The block between the two tunnels has been partly worked by blasting off back to a face along the line of the breccia. The tunnels begin in the breccia, but as the longer one was filled with water at the time of visit, whether or not it had passed through the breccia was not ascertained. The ore is rosin jack with intermixed black jack and pink spar. It occurs filling the cavities in the breccia.

A second prospect is situated at an altitude of 1,040 feet on the northwest slope of the hill (Moreland Creek side), in the NE¼NE¼ sec. 3, T. 17 N., R. 14 W. It lies only 50 feet or so below the St. Peter sandstone. The opening is a Y-shaped open cut, 10 feet deep, 40 feet wide at the back, and 30 feet long (into the hill). The ore-bearing interval is about 10 feet thick and consists dominantly of fine-grained dolomite, with a little medium-grained dolomite and still less dolomitic sandstone. The ore is rosin jack and occurs associated with pink spar in crosscutting cracks and bedding seams. A trace of chalcopyrite accompanies the ore, and finely crystalline pyrite is developed sparingly in the sandy phases of the ore-bearing rock and also bordering the pink-spar veins in the dolomite.

The third prospect, a small open cut, lies a short distance west of the second, almost in the saddle between Cow and Moreland Creeks. It is 30 or 40 feet lower stratigraphically than the second but is on the whole very similar as to country rock, mineralogy, and type of mineralization. The jack and pink spar are accompanied by a little calcite, and the jack is partly altered to carbonate.

WARNER CREEK-HALLS MOUNTAIN DISTRICT

Halls Mountain lies east of Yellville and south of Crooked Creek, in eastern Marion County. It is drained on the south by Clabber and Blue John Creeks and on the east by Warner Creek and its tributary, Williams Branch (east of the Yellville quadrangle). The deposits of this district occur in strata of the Everton formation, which dip gently to the south throughout most of the district. All the deposits lie within the Yellville quadrangle except the Lion Hill. The production from the district has included both jack and carbonate and has not been very large.

Lion Hill.—This mine lies high on the right slope of a short tributary to Warner Creek from the south, in sec. 28 (possibly 29), T. 18 N., R. 14 W. The horizon is in the Everton formation 215 feet above its base. The productive workings consist of a rock cut, 100 feet along the contour of the hill, 50 feet into the hill, and 25 feet high, from the back of which mining has been extended underground, producing a stoped-out room 100 feet or so in diameter. In addition to these main workings three or four tunnels have been driven at the same level within a distance of 300 feet to the east, but all are barren.

In the productive workings the ore-bearing rocks are dolomite, chiefly fine-grained but in part medium-grained. Certain zones are sandy and in extreme cases may be classed as sandstone. The rocks have been shattered along the ill-defined axis of a gentle synclinal flexure that is exposed in cross section on the back face of the open cut. Some breccia has been produced, in which the fragments are fine-grained dolomite and the matrix sand. The ore is jack and pink spar filling the shatter cracks in the less disturbed parts. Minor gangue minerals are calcite, finely crystalline quartz, chalcopyrite, and pyrite. Finely crystalline pyrite occurs not only in the vein material but also along the border between the dolomite and vein material and in small cracks in the dolomite and sandstone gangue rock. The thickness of rock that has been mineralized, as exposed in the workings, is about 10 feet. In the front wall of the underground workings fairly rich ore extends to a distance of 30 feet east from the axis of the syncline, beyond which the ore becomes of low grade, although some of the rock that has been stoped out may have been rich to a somewhat greater distance. The present east wall of the mine, however, is practically barren. In this wall limestone is exposed under the dolomite. The limestone has been in part replaced by large masses of barren pink spar and elsewhere by chert that carries a little disseminated jack. Bedding veins of pink spar in the chert are barren. On the edge of the richer mineralized area, a little fairly high grade ore is developed in a bedding lens between chert below and dolomite above.

The mill, now in ruins, is at the foot of the hill on which the openings are situated. The production from the property was made at a fairly early date, and the amount has not been ascertained. A little ore was also taken out in 1916.

Big Elephant.—This prospect lies on an eastward-facing slope within the drainage basin of Williams branch (tributary to Warner Creek), probably in sec. 18, T. 18 N., R. 14 W. The horizon is in the Everton formation 140 feet below the St. Joe limestone. That part of the formation in the neighborhood of the prospect consists of a series of interbedded dolomites, limestones, and sandstones, named in the order of their abundance. The openings consist of 3 irregular open cuts, the largest 20 by 20 by 10 feet. Ore occurs in 2 beds, with a 10-foot barren interval between them.

The lower ore bed is chert, more or less dolomitic or sandy, that grades laterally into cherty dolomite. This bed is about 5 feet thick. The ore is mixed jack and carbonate. Minor gangue minerals are finely crystalline quartz, calcite, and a trace of chalcopyrite. The carbonate includes both the blue-gray crystalline type and the black sooty type that has altered in place from the jack. A trace of turkey fat is also present. The jack was originally disseminated in the chert, or else deposited in association with pink spar, in bedding veinlets, irregular cracks and replacement masses in both the chert and the dolomite. Solution vugs in the dolomite, as much as 2 or 3 feet across, are lined with pink spar with a little jack.

The upper ore bed consists of medium-grained dolomite and subordinate sandstone. The ore is chiefly carbonate and pink spar and occurs in the brecciated dolomite and also in replacement pockets in the sandstone where that rock has been disturbed by the brecciation.

Several wagon loads of carbonate ore were hauled away from this prospect during the World War, but the amount is not known.

Ike Emery.—This prospect is on the left side of a steep ravine tributary to the head of Warner Creek from the northwest, in the SW¼ sec. 13, T. 18 N., R. 15 W. The horizon is in the Everton formation about 175 feet below the St. Joe limestone. The opening is a 60-foot tunnel, with a raise to the surface at the back end. At the portal there is a small structural flexure, down on the east (back) side, but a short distance within the tunnel the beds flatten out. The only mineralized rock that shows at present is at the back side. The bottom 15 feet or so of the raise penetrates silicified limestone that originally carried disseminated jack, but most of the jack has leached out. The tunnel lies at the base of the silicified zone, in limestone, partly sandy, that contains discontinuous lenses of chert. The limestone is partly dolomitic. The ore occurs both disseminated in the chert and also in association with a little pink spar, in irregular cracks and replacement pockets in both the chert and dolomitic limestone. The prospect is not very promising.

Cane Spring.—This mine is on the right slope of the headwater of Warner Creek, a few hundred feet below the Ike Emery, in the SW¼SW¼ sec. 13, T. 18 N., R. 15 W., at an altitude of 940 feet. The horizon is in the Everton formation about 120 feet below the St. Joe limestone. The tunnel goes in 200 feet and has a 15-foot winze about halfway back, from the bottom of which a lateral drift goes off at right angles to the line of the main tunnel for about 20 feet. The main tunnel follows a clay-filled solution channel on a joint in limestone. In one or two places the limestone has been silicified, with the development of disseminated jack, but the jack has been entirely leached out. It is reported that the tunnel produced some black silicate, chiefly from the front half, but all the ore has been removed. A little silicate and carbonate occur in chert on the dump.

Besides the main tunnel, smaller openings on the property show a little ore. A small tunnel 40 feet lower in altitude and about 100 feet farther downstream (south) shows pink-spar veins that carry a little jack and silicate, bedded in a cherty replacement product of limestone. Hydrozincite and aurichalcite are minor alteration products. Still farther downstream but on a level with the main tunnel, pink spar and jack occur in cracks in a medium-grained dolomite. This dolomite is stratigraphically higher than the limestone of the main tunnel but lies at the same level, owing to the dip, which is at a low angle to the south. In an open cut below the main tunnel there is considerable onyx, developed apparently by late crystallization unrelated to the ores.

Summit Home.—This prospect is barely on the south side of the dividing ridge between Crooked Creek and the head of Blue John Creek, in the E½ sec. 15, T. 18 N., R. 15 W., at an altitude of 1,025 feet. The horizon is in the Everton formation 90 feet below the St. Joe limestone. The developments consist of several rather extensive open cuts, of which the largest is rather irregular in shape, 40 feet long parallel to the surface contour, 20 feet wide, and 10 feet deep.

The ore-bearing rock is fine to medium grained dolomite, grading into dolomitic sandstone, and also, toward the south side of the workings, chert, banded by curved and distorted bands of medium-grained dolomite. In the wall of one of the pits at the mouth of which this mineralized chert is conspicuous, 3 or 4 feet of limestone, containing bands of medium-grained dolomite, is bedded below a massive dolomite and is evidently the original rock from which the banded chert was derived.

The ore is mixed jack and carbonate and occurs, in association with pink spar, in crosscutting veins and irregular replacement pockets in the ore-bearing rocks. Where the mineralized rock is chert, the jack may also be disseminated in it or occur with pink spar in bedding veins. The ore also occurs rather abundantly in dolomite breccias—in fact, the most extensive workings are in breccias. Some of these breccias occupy the whole vertical extent of open-cut walls that are 10 feet high and show a horizontal extent of at least 15 feet. No fault has been definitely located that would account for this brecciation.

In addition to the main ore minerals, finely crystalline quartz, chalcopyrite, and aragonite are uncommon gangue minerals. Finely crystalline pyrite occurs sparingly in the dolomite but not in the ore veins.

Ohio.—The Ohio mine is in the W½ sec. 15, T. 18 N., R. 15 W., near the top of the hill 1½ miles southwest of Rea Valley (Onset). The opening is a wide, irregularly stoped-out tunnel that penetrates the hill in a general westerly direction for about 300 feet. The maximum width of the workings is about 100 feet. A 30-foot shaft is located in the bed of the tunnel, some distance back from the portal.

The tunnel is localized on a small monoclinal flexure that drops the beds on the north a distance of 4 or 5 feet. Most of the shattering and subsequent mineralization occurred on the north or downthrown side. The primary mineralization produced jack and pink spar, but oxidation of the jack to carbonate has been extensive in certain parts of the mine. According to Frank Miller, the ground foreman during the last run of the mine, the ore stoped out toward the rear was largely carbonate, and the back face of the mine is in carbonate ore. An intermediate block was mixed jack and carbonate, and ore stoped from the front was largely jack.

Owing to the accumulation of a pond at the back end of the tunnel, only the tunnel wall in the jack-bearing block was accessible at the time the property was examined. The mineralized beds consist of a silicified dolomitic sandstone, 2 feet thick, overlain by fine-grained sandy dolomite and underlain by medium-grained dolomite. The jack and pink spar occur in the cavities of breccias produced in these rocks or in shatter cracks where deformation has not been so intense. Ore is especially concentrated in the sandstone, where the jack masses in places are 5 or 6 inches in longest dimension. The underlying dolomite includes some ore in replacement pockets. Mr. Miller reports that much of the jack taken from the mine occurred in association with pink spar on the walls of large solution pockets in this dolomite. Some jack is also disseminated in the dolomite. The sandstone is traversed by a few thin veins of chert that carry disseminated jack, and the underlying dolomite is banded with chert. This dolomite grades into limestone near the portal, and the limestone has been in part replaced by chert that carries both disseminated jack and bedding veinlets and irregular replacement masses of pink spar with some jack.

The gangue minerals that accompany the jack and pink spar in the various types of ore occurrences are calcite, chalcopyrite, and gypsum. The zinc carbonate that has been formed by alteration from the jack is mostly of the blue-gray crystalline type, but some is the yellow turkey-fat variety.

The production of the mine, about 175 tons of concentrates, was made chiefly in 1922–23, although there was a small output in 1916. The ore was milled on the property.

Highup.—Two openings were examined on this property, both well up on the east slope of the head of Blue John Creek, in the NE¼ sec. 16, T. 18 N., R. 15 W. One is a shaft 50 or 60 feet deep now full of water. The ore is reported to have come from a 10-foot bed at the bottom. The ore-bearing rock is medium to coarse grained dolomite, in part sandy, of the Everton formation. The ore is mixed rosin and black jack and occurs disseminated in the dolomite in grains from one-eighth to one-half inch in size or else is associated with pink spar and a little fine drusy quartz in replacement veins along the bedding or less commonly in cracks across the bedding. In the bedding veins the jack masses are tabular and several inches in diameter, though only an inch or a fraction of an inch thick. A little carbonate has formed from the jack. In the ore-bearing beds secondary chert was formed as a matrix to the dolomite grains during the mineralization. The ore was not observed in place here, but considering the amount that has been taken out of a small opening the prospect would seem to warrant further exploration.

The second opening is several hundred feet southwest of the first. It is 35 feet lower in altitude, but owing to the southward dip of the strata in this region may be at about the same geologic horizon. The opening is an 80-foot open cut that passes into a tunnel. The tunnel goes in 75 feet, to a point where a rather large room has been stoped out, and a raise has been driven here to the surface. Two short drifts extend back into the hill from this room. The country rock is fine to medium grained dolomite, with a little dolomitic sandstone. It has been brecciated and the open spaces filled by pink spar and some jack. Not all of the brecciated rock has been mineralized, however. Much of the space between the breccia fragments is filled with sandy clay. The rock underlying at least some of the barren breccia is limestone, but crumpled in such a way as to have destroyed the bedding. The brecciation appears to have been produced by two or three small sharp flexures that displace the rock only 1 or 2 feet each. About 40 feet above the level of the tunnel and 100 feet southeast of it, practically in line with the workings, the breccia seen in the tunnel is exposed in a shallow surface cut, where it likewise carries a little jack and pink spar.

The breccias in the main mine are traversed by several irregular solution channels, 1 foot or more in maximum diameter, that are lined with crystalline pink spar. In some of the smaller ore pockets a little calcite and a trace of chalcopyrite are developed as gangue minerals. Some silicification accompanied the mineralization in places, and the resulting chert may carry a little disseminated jack.

Reynolds.—This mine is located on the right side of the head of Blue John Creek, a short distance back on the gentle slope from the bed of the hollow, in sec. 16, T. 18 N., R. 15 W., at an altitude of 860 feet. The strata in the vicinity dip a few degrees to the south. The opening is a large open cut 100 feet long, 30 feet wide, and 30 to 40 feet high at the back. From the back of the cut a gently rising tunnel extends the workings 40 or 50 feet farther. The workings follow a small break in the rock that has displaced the strata perhaps a foot or so, though the effect was accomplished by bending and crumpling of the strata over a width of several feet rather than through a clean break. The ore-bearing rocks are largely medium-grained dolomite, with an interbedded sandstone seam here and there. A little of the dolomite has a greenish tinge due to the presence of interstitial greenish clay, but most of it is light gray. The ore is jack associated with pink spar and a little fine drusy quartz in irregular veinlets and replacement pockets in the dolomite along the crumpled zone. The pink spar extends back farther from the main line of the break than the jack. A minor amount of carbonate has been formed by alteration from the jack, though it is possible that the body of ore taken out, being somewhat more open than what remains in the wall, may have contained a higher percentage of carbonate. There was originally a mill on the bank of the hollow, but it is now in ruins. The mine has evidently been worked blind.

Great Eastern.—This prospect is in sec. 8, T. 18 N., R. 15 W., near the center of the south line. It is near the head and on the left side of a short hollow that drains north to Crooked Creek. The horizon is in the Everton formation 140 feet below the St. Joe limestone. The developments consist of a cut in the steep hillside, 50 feet along the hill, 30 feet into it, and 20 feet high at the back, with a curving tunnel going back 70 or 80 feet from the back side. The back 30 or 40 feet of this tunnel is in barren limestone. The mineralization near the front was evidently due to a structural flexure, showing above the portal, that drops the rocks on the north a distance of 2 or 3 feet. The ore is jack accompanied by pink spar. It occurs either in replacement pockets and bedding veins in a silicified limestone, 2 to 3 feet thick, or else in a brecciated fine to medium grained dolomite, not more than 3 feet thick, that overlies the chert. The deposit is of low grade owing to the great preponderance of the pink spar over the jack.

Willett.—This mine is on the steep north slope of Halls Mountain, east of Yellville, in the SE¼ sec. 12, T. 18 N., R. 16 W. The horizon is in the Everton formation 185 feet above its base. Most of the country rock is medium-grained dolomite, but the ore-bearing bed, 2½ feet thick, is chert that appears to have replaced the dolomite. Most of the ore is concentrated in the upper foot of chert. Immediately capping the ore-bearing chert is a 6-inch bed of cherty sandstone, and 5 feet higher is the base of a thick bed of limestone; the intervening rocks are alternating dolomite and limestone. A tunnel has been driven on the ore bed for 150 feet into the hill.

The ore mineral is largely zinc carbonate, either the black type or a crystalline gray type or a flesh-colored variety that has replaced pink spar. It was derived by oxidation from rosin jack, a little of which remains. Some of the carbonate masses, both black and gray crystalline, are in large pockets, as much as several inches across. The original jack occurred either in such pockets associated with pink spar or else disseminated in the chert. Pink spar occurs in both the ore-bearing chert and the underlying dolomite as horizontal veinlets and irregular pockets, but much of it in the ore bed has weathered to a red clay that is mixed with the ore. A little of the black carbonate shows green copper stains in traces.

Gentle changes in dip occur within the mine, and the ore may be related to the minor sags. A few obscure fractures of small extent appear within the roof, but there is no apparent enrichment in the walls where these fractures reach them.

The Willett mine produced carbonate ore during several years of the World War period, about 200 tons having been reported for 1915, 1916, and 1917.

Dyson.—This mine lies on the southwest slope of a high ridge overlooking Clabber Creek, in the SE¼ sec. 30, T. 18 N., R. 15 W. The horizon is in the

Everton formation 160 feet above its base. The developments consist of a large open cut, 100 feet in diameter and 30 feet deep at the back, with several short tunnels leading off from it, the longest one about 100 feet long. The tunnels are barren. A few shallow surface gouges lie south of the main cut.

The ore-bearing rock is medium-grained dolomite that dips at a low angle into the hill. It is broken up by veins and irregular vugs of pink spar that cross it haphazardly. Locally, movement in the rock has resulted in brecciation; these more disturbed areas show especially in the walls of the open pit, though also in one of the south tunnels. Within the main tunnel the dolomite is underlain by limestone, but toward the portal this limestone has been converted in large part to dolomite, though irregularly so. Within the open cut what appears to be the same bed is again, in part, limestone.

The ore that shows on the dump is of low grade, consisting chiefly of pink spar showing some slight replacement by zinc carbonate. It was evidently taken from the open cut. The original jack, a little of which remains on the dump, was mixed black and rosin-colored. It was disseminated in silicified phases of the dolomite or else occurred sparingly with the abundant pink spar in cracks. The small amount of carbonate formed by direct alteration from this jack, without being transported any great distance, is black or gray and crystalline. A trace of chalcopyrite occurs in a few places in pink-spar vugs.

GREASY CREEK-HAMPTON CREEK-CLEAR CREEK DISTRICT

The Phillips mine, on a prong of Mill Creek southwest of Yellville, is included in the district embracing Greasy, Hampton, and Clear Creeks, which lies in west-central Marion County, south of Crooked Creek. The mineral deposits of the district occur in the Everton formation, except for one deposit in the Boone. The Potts mine, with a production of 100 tons of jack in 1916, and the Marguerite, with a reported production of 200 tons of carbonate in 1916, have been the chief productive properties. The ore at the Potts mine occurs in a dolomitic sandstone; elsewhere in the district the mineralization was limited to medium- and coarse-grained dolomite.

Phillips.—This mine is in the SW¼ sec. 20, T. 18 N., R. 16 W., on a west prong of Mill Creek. The workings consist of an open cut in the bed of the creek and a shaft on the adjacent bank between two small prongs of the creek. The shaft was full of water when visited but is evidently not very deep. The geologic horizon is in the Everton formation about 50 feet above its base. The ore-bearing rock is medium to rather coarse grained massive dolomite, but where mineralized it has been banded along the bedding by chert. The ore mineral is chiefly rosin jack and occurs associated with pink spar, a little calcite, and a trace of chalcopyrite in irregular cracks and replacement pockets in the dolomite. Pyrite is sparingly developed in small replacement blebs in the dolomite and also along the boundaries between the dolomite and ore. A small amount of zinc carbonate has been formed by oxidation of the jack.

The mill site is about 300 feet below the workings; the mill, however, has been removed. The production of the mine is not known, but it was not very great.

Wolf.—A prospect opened up by L. D. Wolf on the west side of Greasy Creek, in the first hollow south of the Yellville-Eros road crossing, shows considerable jack, with some carbonate, occurring with pink spar in cracks in a medium- to coarse-grained dolomite. The opening is a small open cut in the Everton formation 60 feet below the St. Joe limestone. The ore that has been uncovered warrants further prospecting.

Blankenship.—This prospect is on the fairly gentle west slope of the ridge between Greasy and Hampton Creeks, at an altitude of 880 feet, probably in the SW¼ sec. 16, T. 18 N., R. 17 W. The ore horizon is near the middle of the Everton formation which is here about 200 feet thick. The workings consist of several old-time open cuts and shafts and a 50-foot drift, all scattered over a diameter of about 200 feet.

The ore occurs in a rather coarse grained dolomite at the base of a series between 50 and 75 feet thick composed of similar dolomites. In the drift it is 6 or 7 feet thick and is immediately overlain by a 4-foot sandstone, which is locally ore-bearing. The underlying rock is limestone. The strata dip gently to the west.

The ore consisted originally of mixed black and rosin jack, associated with pink spar and a little calcite, but a large part of the jack has been oxidized to carbonate or less commonly to coarsely crystalline silicate. The carbonate may be of the black porous type, derived directly from the jack, but more commonly it is gray and crystalline, grading in places to turkey fat. Still another type of carbonate is a flesh-colored variety that has replaced pink spar. A trace of chalcopyrite appears as minute blebs in the jack. The ore and gangue minerals have replaced the country rock along irregular shatter cracks, but some of the jack occurs also as disseminated grains, half an inch in maximum size, in the dolomite.

Getzendener.—Two prospects were visited on the Getzendener land, both in the SE¼ sec. 21, T. 18 N., R. 17 W. One lies in the forks of a flat hollow tributary to Hampton Creek from the east, a quarter to half a mile from the main creek, at an altitude of 840 feet. The horizon is in the Everton formation 65 feet above its base. The opening is an open cut, 10 feet wide, 60 feet long, and 10 feet deep at the back. The ore is of very low grade and consists of jack with a little carbonate associated with pink spar in cracks in a medium- to fine-grained dolomite. The ore-bearing bed is 8 feet thick and is capped by 3 feet of sandstone.

The second prospect lies at about the same altitude and horizon, on the rounded point just below the mouth of the tributary hollow. The workings are several old shafts on a soil-covered sandy slope in the edge of a woods. The ore-bearing rock and mineralization are the same as at the other prospect, although a little more mineral is visible on the dumps.

Marguerite.—This property lies just east of the Boone County line in Marion County, probably in the SW¼NW¼ sec. 34, T. 18 N., R. 18 W., near the top of a low bluff on the right side of Clear Creek. The horizon is in the Everton formation about 150 feet below the St. Joe limestone. The workings consist of about six short tunnels into the hill over a distance of 300 feet, at an altitude of 900 feet. The longest tunnel is perhaps a little more than 100 feet long. The ore-bearing stratum is capped by a zone of alternating quartzite and chert, the latter representing silicified limestone. The chert is more abundant than the quartzite and contains casts of disseminated jack. The ore bed is a medium-grained dolomite that is decidedly brecciated in places, the interstices between the breccia fragments being filled with ore and gangue. The ore mineral is rosin jack that shows considerable alteration to silicate and carbonate; the carbonate includes a little hydrozincite. The chief gangue mineral is pink spar, which is far more abundant than the ore. A trace of chalcopyrite accompanies the jack and on oxidation is altered to aurichalcite. The production from the mine is reported to have been about 200 tons of free carbonate, marketed in 1916. Ore shows in only the three southernmost tunnels.

Potts.—This mine, worked by the Clear Creek Mining Co., is at an altitude of 840 feet, well up on the right slope of Kings Branch at its junction with Clear Creek, in the NW¼ sec. 27, T. 18 N., R. 18 W. The working is an open cut, 50 feet in diameter, 20 feet deep at the front, and 35 feet deep at the back. This cut was made in one side of a shallow draw, so that the lower 15 feet is at present full of water. The horizon is in the Everton formation 70 feet below the St. Joe limestone. The ore is mixed rosin and black jack, with some zinc carbonate, and occurs associated with abundant pink spar and a little finely crystalline quartz in irregular replacement pockets that are commonly elongated along the bedding, and also in cracks, in a rather coarse grained sandstone. The sandstone is dolomitic and in places grades into a medium-grained sandy dolomite. The individual jack masses may be as much as 4 or 5 inches across. A trace of chalcopyrite accompanies the jack. The carbonate may be black noncrystalline or pearl-gray crystalline. The black variety commonly carries a trace of malachite or aurichalcite. Feldspar (orthoclase and microcline) is a microscopic constituent of the small amount of interstitial chert in the more dolomitic rock. The ore bed is overlain by 20 feet of unaltered limestone, and this by a 4-foot ledge of sandstone.

The mill, now more or less in ruins, is on the bank of Clear Creek at the mouth of Kings Branch, about 700 feet from the mine. The Potts mine marketed about 100 tons of jack concentrates in 1916. The deposit is of somewhat higher grade than many of the others of the district, although there is no way of telling how extensive the deposit is, as it is not related to any evident structural feature.

Unnamed prospect.—On the left side of a hollow tributary to Clear Creek from the west, in sec. 20, T. 18 N., R. 18 W., is a prospect of interest in that the mineralization occurred in the Boone limestone, far from the other occurrences of ore in this formation, which lie in Newton County. The opening is a small open cut, lying at least 40 feet and probably considerably more above the base of the Boone. The original rock is a coarse-grained very light gray marble containing a little fossiliferous chert. This marble has been shattered and invaded by secondary chert, which has replaced the original limestone wholly or in part. Where the silicification has not been complete the marble has been recrystallized to a finer-grained, grayer cherty limestone. The ore mineral is chiefly rosin jack, with a little black jack mixed in, and is disseminated in the replaced or recrystallized parts of the marble. Pyrite, in very fine blebs, occurs sparingly in the same phases that carry the jack. Pink spar occurs in irregular replacement pockets in the mineralized rock but is not itself ore-bearing.

The primary Boone chert, carrying abundant crinoid stems, is unaffected by the mineralization, and much of it remains as residual masses in the secondary chert. The fact that many of these residuals are very angular fragments is further evidence, in addition to the angular shape of many of the marble fragments, that the rock was shattered before being mineralized. In places two or more adjacent fragments of primary chert are very plainly parts of an originally unbroken mass.

Maxwell.—This prospect, opened up by Joseph Migliori, is near the center of sec. 15, T. 18 N., R. 18 W., on the left bank of Clear Creek just below the mouth of a rather large hollow. There are several shafts, inclines, and open cuts in a sandy abandoned field that slopes toward the creek. All the workings are caved in. The horizon is in the Everton formation, probably 30 or 40 feet above the base. The country rock is a coarse-grained dolomite, grading in places toward medium grain. A few residual streaks of limestone appear along the bedding of the dolomite, and in the mineralized beds these are silicified to chert. The ore is rosin jack associated with pink spar and a little calcite in replacement pockets and irregular veins in the dolomite. The jack forms granular aggregates 2 inches or more in greatest diameter. Disseminated jack may also appear in the dolomite and in some of the chert bands. Zinc carbonate and silicate are developed as alteration products of the jack but are subordinate to it. Some of the carbonate masses include a few small specks of malachite, indicating a trace of copper in the primary ore.

The production of the property has been practically nil. The mill was set too close to Clear Creek and was washed away in a flood.

On the right side of the tributary hollow, 500 feet up from Clear Creek, the dumps of a couple of demolished shafts, probably on the same property, show much the same type of mineralization as at the main group of workings except that possibly there is more jack relative to the pink spar. Some of the jack masses are 5 or 6 inches across and 1 inch thick. A little ore appears in sandstone in addition to that in the dolomite.

HARRISON DISTRICT

There are several mines and prospects east of Harrison, along Crooked and Hussar Creeks, in Boone County. Not all of them have been visited. The mineralized zone is usually in the Everton formation; at the Denison shafts, however, it is apparently the †Black Ledge of the Powell. The ore is jack at some mines and carbonate at others. The production for the district has probably been less than 1,000 tons of concentrates.

Starkey.—These workings lie in the NE¼SE¼ sec. 9, T. 18 N., R. 19 W., in an old field on the left slope of a flat hollow that is tributory to Hussar Creek from the south. The workings are a series of irregular open cuts, none of them more than 10 feet deep, scattered over a distance of 600 feet or so along the slope, at an altitude of about 950 feet. There are also a few shallow shafts. The ore-bearing rock is a medium- to coarse-grained dolomite in the Everton formation; it grades in places into chert. The primary ore is rosin jack that occurs chiefly along cracks and bedding planes and in replacement pockets, in association with pink spar, but also to some extent disseminated in both the dolomite and chert. Most of it, however, has been oxidized to a gray to flesh-colored crystalline carbonate, or locally to turkey fat or to the fine flesh-colored rod type of carbonate. Some of the flesh-colored carbonate replaces pink spar.

Some free carbonate has been shipped from the Starkey property, and about 100 tons was shipped from the Bowie land, a short distance from the Starkey workings. The Bowie workings were overlooked by the writer, but the ore is reported to be similar to that at the Starkey.

Halliday.—This mine is in sec. 4, T. 18 N., R. 19 W., on the south bank of Crooked Creek. The opening is a shaft whose collar is 20 feet above the level of the creek. The chief ore-bearing rock is a medium-grained dolomite, sandy in places, that is locally silicified to chert. This rock is apparently at the very base of the Everton formation. A little of the ore, to judge from the rock on the dump of the shaft, is in the Powell dolomite, which crops out in the creek bed just north of the shaft and is undoubtedly penetrated a short distance below the collar of the shaft. The ore is mixed rosin and black jack, the former predominating. It occurs associated with pink spar and some calcite in cracks and bedding veinlets. A little chalcopyrite accompanies the ore. The mill on the property has burned down.

Denison.—Openings on this property are on a gentle slope on the south side of Crooked Creek, in the W½SE¼ sec. 6, T. 18 N., R. 19 W. The workings consist of four or five shafts, whose collars lie 10 to 30 feet above the level of the creek. They are opened in the Powell dolomite, and apparently the ore was derived from the †Black Ledge. The ore zone is reported to be 8 feet thick and to lie about 35 feet below the shaft collars. A mill was built on the property, but the ore run was of too low grade (reported 3 to 4 percent jack) to be successfully operated. Specimens of ore from this horizon show rosin jack, associated with fine drusy quartz, in vugs in a massive, rather fine grained dolomite. Fine cubes of pyrite also line some of these vugs.

In addition to the ore that was derived from the Powell, the waste dump at the mill shows numerous blocks that came from workings in the Everton formation. The source of these Everton blocks was not ascertained. The base of the Everton south of the mill site is 110 feet above the level of the creek. The Everton blocks show rosin jack disseminated in chert and also associated with pink spar in cracks and replacement pockets in chert, sandstone, and medium- to coarse-grained dolomite. Much of the jack has oxidized to various types of carbonate—gray, flesh-colored crystalline, rod, black, etc. The black carbonate has specks of malachite.

The Denison property is reported to have produced 70 to 100 tons of ore in 1899, but whether this ore was taken from the shafts or from some horizon in the Everton is not known.

North Star.—This mine is on the steep right bank of Crooked Creek in the NW¼SE¼ sec. 1, T. 18 N., R. 20 W., 3 miles east of Harrison. In a stretch of several hundred feet along the creek there are several irregular-shaped tunnels driven into the hill, most of them about 60 feet above the level of the creek. One of the more productive tunnels is caved. The ore horizon is in the Everton formation, but not all of the tunnels are at exactly the same horizon. Most of them lie just below a 10-foot bed of sandstone, but the tunnel that is caved lies 20 feet below it. The ore-bearing rock is chert that contains lenses of medium-grained dolomite and in places a little sandstone. Part of the chert may have replaced dolomite, but most of it has replaced limestone, into which it grades laterally. The chert is especially characterized by thin seams and partings, more or less broken up, of a greenish clay mineral. Most of the workings show a mineralized face 8 or 9 feet high.

The ore is chiefly rosin jack with a little admixed black jack. It occurs disseminated in the chert and also, in association with pink spar, in cracks and replacement pockets in the chert, dolomite, and sandstone that make up the ore bed. Considerable carbonate of various types has been derived by alteration from the jack, and it is possible that carbonate may have formed a higher proportion in the ore that has been taken out. Most of the carbonate is of the gray to flesh-colored crystalline type, but there is some flesh-colored rod carbonate and some black carbonate. The black variety contains specks of malachite and aurichalcite. Some of the zinc carbonate replaces pink spar. Zinc silicate is reported as one of the oxidation products but was not observed in the accessible workings or on the dumps.

The North Star produced 350 to 400 tons of concentrates, chiefly jack, during the World War. The ore was milled on the bank of the creek below the workings, but the mill has been washed away.

ZINC DISTRICT

The Zinc district lies chiefly in eastern Boone County; the Tarkiln mine, however, is across the county line in Marion County. The deposits are located in the valleys and tributary valleys of Sugar Orchard and Tarkiln Creeks. The ore is in the Everton formation except at the Coker Hollow mine, where the mineralization affected also the overlying St. Joe limestone. Characteristic of the Zinc district is the prominence of silicified limestone as a carrier for the ore. Medium- to coarse-grained dolomites, however, contain the ore at several of the mines and prospects, and at the Jackpot and Tarkiln mines part of the ore occurs in shattered fine-grained dolomite. Most of the oxidized ore is silicate instead of carbonate. Jack is the product of a few of the mines but has been subordinate to the silicate in the district as a whole. Many of the ore deposits in the chert are blanket veins in which the runs are poorly defined. There are no faults to which the ore deposits can be related. The district has produced 8,500 tons or more of concentrates and thus vies with the Davis Creek-Hurricane Branch district as the second most productive district in northern Arkansas. Of the total output not more than 100 tons or so has been jack; an additional 1,200 tons is reported to have been marketed as mixed jack and silicate.

Van Vorhees.—This property lies on the left side of a west tributary of Sugar Orchard Creek, almost on the point between the two and 120 feet or so above the bed of the tributary. It is probably in the SE¼SE¼ sec. 29, T. 19 N., R. 18 W. The developments consist of several tunnels over a stretch of 300 feet or so along the hill at a horizon in the Everton formation just below the St. Joe limestone. The country rock comprises interbedded coarse dolomite, limestone, and sandstone, the limestone showing lateral gradations into dolomite in a few places. The ore is in the dolomite and is confined chiefly to an interval 1 to 2 feet in thickness that lies at the base of a certain bed and generally immediately above limestone. The ore is mixed rosin jack and gray to flesh-colored crystalline carbonate and occurs either disseminated in the dolomite or else associated with pink spar and a little coarsely crystalline calcite in veinlets and irregular pockets. The calcite may include small crystals of chalcopyrite. A small amount of the zinc carbonate is the yellow turkey-fat variety. A little of the carbonate has replaced the pink spar.

Virginia J.—This prospect is in a hollow that drains into a tributary of Sugar Orchard Creek in the NW¼SE¼ sec. 29, T. 19 N., R. 18 W. The opening is an open cut, 50 feet in diameter and 3 to 10 feet deep, in the bed of the hollow at an altitude of about 1,035 feet. The ore is rosin jack, associated with pink spar, and occurs in irregular solution druses and cracks in a coarse-grained dolomite of the Everton formation. The jack crystals have numerous minute crystals of chalcopyrite on their free surfaces and in places are bordered, along their irregular contacts with the dolomite, by thin films of finely crystalline pyrite. The ore bed is 2½ feet thick and is underlain by limestone and overlain by 2 feet of cherty sandstone that may contain a little ore. Above the sandstone comes another bed of dolomite very similar to the one that contains the ore except that it is barren. This property did not produce during the period of activity brought on by the World War.

Madison.—The Madison mine is on the right bank of a hollow tributary from the south to Tom Young Hollow, in the N½NE¼ sec. 30, T. 19 N., R. 18 W. The ore horizon is in the Everton formation 20 to 50 feet below its top. The main developments consist of two tunnels, one 15 feet above the other; the lower one is 250 feet long, but the upper one is caved, so that its length was not determined. It is reported that one of the tunnels broke into a natural cave, carrying some ore in its floor and explored for a reported distance of three-quarters of a mile. The ore deposit in the developed workings is apparently localized along an obscure fracture that runs in a general southeast direction, although the workings within the lower tunnel extend irregularly into the walls away from the fracture, and the main gangway does not follow the fracture very closely. In a few places the dolomite forming the wall rock is definitely brecciated, with or without the invasion of interstitial sand from some outside source.

The ore-bearing rock in the lower tunnel is a medium to rather coarse grained dolomite that grades in places into limestone and that may carry unaltered blocks of limestone within it. The bed averages about 5 feet in thickness and is capped by 15 inches of sandstone, slightly mineralized in spots. The ore in the portal of the upper tunnel, extending for 15 feet above the floor, is in quartzite and dolomite. Part of the dolomite shows a greenish cast, owing to the development of a greenish clay mineral between the grains of dolomite. Away from the mine the dolomite may grade into limestone. The rock between the two mine levels is comparatively barren, but where exposed it does not differ greatly in character or in type of mineralization from the rocks that carry the ore. Above the ore-bearing rocks of the upper level comes 20 feet of sandstone that forms the top of the Everton.

Silicification accompanied the mineralization, and the resulting chert occurs as bands, with vaguely defined boundaries, along the bedding lines of the dolomite, or where the silicification has been more intense the chert may increase in amount and even replace the dolomite completely. Much of the chert contains disseminated jack or its casts, but some of that between the two mine levels is practically barren.

The primary ore mineral was rosin jack, with a small amount of black jack, and it occurred disseminated in the chert, in blebs a quarter to half an inch in diameter, or disseminated in the dolomite, or as a crack or irregular vug filling, in association with pink spar, in the dolomite. The greater part of it, however, has been oxidized to silicate, the jack being preserved only in certain well-protected blocks. Black forms of the silicate contain spots of malachite, showing that a trace of copper was deposited along with the zinc in the primary ore. Zinc carbonate occurs as a coating of pink-spar crystals, but it is on the whole rare.

An unusual feature that shows at one place in this mine is the presence of *Cryptozoon* remains (see p. 31) preserved during the dolomitization and accentuated by the subsequent introduction of chert, with its disseminated ore, along the bedding lines.

The Madison mine has produced a considerable amount of ore, milled on the property, but the tonnage was not ascertained, though it probably has exceeded 500 tons. Several carloads are reported to have been shipped before 1907.

Frisco.—This mine is in the NW¼SE¼ sec. 17, T. 19 N., R. 18 W. There are tunnels and open cuts on the property on both sides of Mill Branch just below the mouth of Coon Hollow and about 50 feet above water level, at an altitude of about 950 feet. The geologic horizon is in the Everton formation

15 feet or so above the base, but the beds that are mineralized cannot be identified as the same on both sides of the creek (other than by their similar position), owing to the lack of any bed with sufficiently constant characters to permit its recognition as a key bed on both sides. This is attributable largely to the variations in texture to which the dolomite in a given bed is subject and to frequent lateral gradations from limestone into dolomite or chert in the same bed.

The main opening on the west side of the creek is a tunnel, now largely caved but reported to have been originally about 150 feet long. The country rock consists of alternating medium-grained dolomite, limestone, and chert. The ore in the tunnel is reported to have followed a fracture, running west into the hill, and to have been limited to a thickness of about 10 feet of beds, pinching out at the top. At 10 feet south of the portal of the tunnel a fracture is exposed running S. 85° W., along which, to a distance of 1 foot or more on each side, the limestone has been silicified to chert and this impregnated with jack. It is possible that this is the reported fracture onto which the tunnel swings after entering the hill.

The original ore, to judge from the rock on the dump, was jack, disseminated in the chert beds or else appearing as larger chunks bedded in the chert, but it has been entirely oxidized to silicate and carbonate. The silicate, which predominates, is rather finely crystalline. The carbonate is of several types, but the most abundant is the gray to flesh-colored crystalline variety that is characteristic of the northern Arkansas field. Less abundant types appear as fine opaque flesh-colored rods and as gray to blackish honeycomb masses, several inches in maximum size, and formed as a direct alteration product from the larger chunks of jack. A large amount of tallow clay was formed during the oxidation, chiefly from the chert beds, and at one place the tunnel is reported to have passed through about 30 feet of clay along its course. If any of the ore was developed in the dolomites, it is not evident from a careful examination of the dump. Pink spar occurs in a few small cracks in the associated dolomite but it was not observed to carry ore.

A series of open cuts at the same level, extending for 200 feet south of the tunnel, yielded both silicate and carbonate, derived from disseminated jack in chert. The mineralization was therefore not confined to the fracture in the main tunnel, but the ore was probably much richer there.

The main tunnel on the east side of the creek goes 300 to 400 feet into the hill along an irregular course and follows no apparent fracture. The ore zone is limited to a chert bed, 1 foot or less thick, and the lower few inches of an overlying bed of medium-grained dolomite. Unaltered limestone lies below the chert. The original rosin jack, of which a little remains, was disseminated in the chert, or embedded in the chert in masses as much as 1 or 2 inches in size, associated with a little pink spar, or banded along the bedding of the overlying dolomite, in lenses as much as 2 inches thick. Most of it has been altered to colorless crystalline silicate, but a little has been altered to black silicate, which may contain a few specks of malachite. Crystalline carbonate was formed to a very minor extent. Silicate has also formed as an opaque flesh-brown replacement product of chert adjacent to the ore pockets. The rest of the enclosing chert was in part altered to tallow clay during the oxidation, and some of the clay is white instead of the more usual reddish brown. A few masses of pink spar with a little associated calcite, underlying the chert bed, have been altered to a "brown spar" during the oxidation.

At a small opening 250 feet north of the main Frisco tunnel on the east side crystalline gray carbonate and silicate both occur in the casts of disseminated jack in a thin-bedded chert about 4 feet higher than the ore horizon at the Frisco. This opening may be on the Bollinger tract, which lies between the Frisco and the Gloria.

The production of the Frisco property is reported by Lon Brown, of Zinc, to have been about 500 tons, chiefly from 1912 to 1917. The ore was concentrated at a mill below the tunnel, on the west side of the creek.

Gloria.—This property is adjacent to the Frisco on the east side of Mill Branch, probably in the SE¼NE¼ sec. 17, T. 19 N., R. 18 W. The horizon is in the Everton formation, the base of the mineralized zone lying about 10 feet above the base of the formation.

The main tunnel, which is 600 feet northeast of the Frisco tunnel, is a network of winding, branching, and interconnecting drifts that penetrate the hill to a maximum distance of about 400 feet. The ore-bearing bed is a silicified limestone, 8 or 9 feet thick, underlying a rather coarse-grained dolomite. It seems to be the same bed as that in the Frisco on the east side of the creek, except that a greater thickness of the limestone underlying the dolomite was silicified and mineralized. Although workings within the tunnel extend up in places into the dolomite and overlying beds to a height of 25 feet above the floor, these higher levels are apparently rather lean. The original ore mineral was rosin jack, bedded in or crosscutting the chert along cracks, but it has been largely converted to both colorless crystalline and black silicate. Some residual jack occurs in the black silicate but is not abundant. Silicate also occurs as a flesh-colored to brown replacement product of the enclosing chert adjacent to the ore pockets. The presence of a little copper in the primary ore is indicated by specks of malachite in the black silicate and by little clusters of aurichalcite globules in cracks with the crystalline silicate. Pink spar was not observed in the main ore bed, but that it was formerly present is shown by the occurrence of silicate pseudomorphic after it. It occurs in seams and irregular pockets in the overlying dolomite, but without any associated ore. A large amount of tallow clay, both orange-colored and white, was formed in the chert during the oxidation, and as a consequence the mine is very muddy. A large spring runs the whole length of the main tunnel.

Besides the main Gloria tunnel there are numerous other minor openings at about the same level on both sides of the creek. In a cut a short distance south of the main tunnel, on the same side of the creek, silicate, much of which is black, is banded in the 4 feet of weathered dolomite overlying the chert zone of the main tunnel. North of the main tunnel the chert zone is practically unmineralized. Several cuts over a distance of a few hundred feet reveal only barren limestone at this level. A cut about 100 feet south of the Gloria mill, which lies north of the main tunnel, shows a little jack and carbonate associated with pink spar in medium- to coarse-grained dolomite, but the horizon was not determined. An opening just back of the mill, 550 feet northeast of the Gloria tunnel, reveals a zone, 1 foot thick, of chert containing disseminated rosin jack and pink spar, which lies between barren limestone below and medium- to rather coarse-grained dolomite above. The dolomite is largely barren except for a little carbonate associated with pink spar in pockets at one place. The ore in this opening appears to be at the same geologic horizon as that in the Gloria tunnel and in the Frisco.

About 100 feet north of the mill an open cut, reported to have produced 100 tons of free carbonate, has part of the ore developed in bedding cracks and crosscutting veinlets in a fine-grained dolomite, 10 feet thick, whose base is 30 feet above the base of the Everton. This dolomite overlies the beds that carry the ore farther south and appears to be the same as the similarly mineralized rock in the Jackpot. Perhaps the greater production from this cut, however, came from replacement pockets in the underlying medium-grained dolomite along a disturbed zone at the entrance to the open cut. The mineral is rosin jack, in part altered to carbonate, and is associated with pink spar.

The northernmost working on the east side of the creek lies 700 feet north of the mill and is a tunnel 100 feet into the hill. The ore shows chiefly in the heading. It consists of rosin jack disseminated or forming small pockets along the bedding in a dolomitic chert, which was derived by silicification from a dolomitic limestone. The chert carries numerous replacement vugs of pink spar, but these vugs do not contain ore. In much of the material appearing on the dump the jack has been oxidized to carbonate or less commonly to silicate. The carbonate is of various types, gray crystalline, black crystalline, and matted aggregates of fine flesh-colored rods all being common. Some of the carbonate is pseudomorphic after pink spar. Scattered specks of malachite show in the black carbonate.

The openings on the west side of the creek consist of open cuts and short tunnels at an altitude 15 feet or so higher than the workings on the east side, but as there are no natural outcrops, the geologic horizon is not determinable. The ore minerals are silicate and carbonate of zinc, altered from disseminated jack in chert. Some of this chert forms the matrix to a breccia of fine-grained dolomite fragments. A small amount of malachite accompanies the oxidized zinc ores.

The production of the Gloria group of workings has been about 1,750 tons of concentrates, according to Lon Brown, of Zinc. This was made chiefly during the period of war production, from 1914 to 1918.

Jackpot.—This mine lies in the NW¼ sec. 16, T. 19 N., R. 18 W., on the east side of Mill Branch, above the Gloria workings but a few hundred feet up a small tributary hollow. The main opening is a tunnel from the back end of an open cut, at the level of the bottom of the hollow and on its south side. It was full of water at the time of visit, but according to reports there are two or three forks, none of them longer than 100 feet or so. The open cut in front is 200 feet in length (along the hollow), 100 feet wide, and 15 feet deep. A second tunnel, now caved, went into the north wall of the hollow opposite the mouth of the first tunnel. It curved to the northeast after entering the hill and was 150 to 175 feet long. A third and rather short tunnel went northeast into the hill 100 feet or so upstream from the second one. It was not very productive.

The ore in the portal regions of the two main tunnels is largely rosin jack, associated with a little pink spar and calcite and a very little finely crystalline malachite. It occurs over a thickness of 15 feet in cracks and shattered zones that locally grade into breccias, in a fine-grained dolomite. This dolomite lies a short distance above the chert zone that carries the ore in the main Gloria tunnel and in the Frisco tunnel, but the exact distance was not determinable. It is underlain by 4 feet of cherty sandstone, somewhat brecciated and containing fragments of fine-grained dolomite and scattered pockets of jack, pink spar, and calcite.

Although the beds of the region as a whole lie nearly flat, there are numerous local structural disturbances within the mine that produce dips in various directions of as much as 10° or 15°. The shattering that has resulted in ore deposition is concentrated wherever there is an abrupt change in dip. In a few places the shattered dolomite contains a matrix of fine white sandstone instead of ore minerals.

It is reported that both the north and the south tunnels went into silicate ores at their rear ends. The south tunnel, according to W. A. McCurry, of

Zinc, dropped to an underlying chert zone and produced silicate ore very similar to that of the Gloria. Some of the rock on the dump shows ore of this type. Part of the original jack, from which the silicate was derived, is preserved in this rock. It is mixed rosin and black jack and occurs in replacement pockets that may attain several inches in size.

The production of the Jackpot during the early years of the World War was about 500 tons of concentrates. Of this about 100 tons was jack, and the rest was mixed jack and silicate, marketed as such.

Almy.—This mine is in the NW¼NE¼ sec. 17, T. 19 N., R. 18 W., on both sides of a small hollow that drains into Mill Branch from the northwest. The altitude is 980 feet. The workings consist of two tunnels, one on each side of the hollow, at about the level of its bed. The tunnel on the north side forks about 100 feet from the portal, and both forks were full of water at the time the property was examined. The tunnel on the south side is reported to have been about 175 feet long but is now caved. It produced most of the Almy output.

The horizon is in the Everton formation 60 feet above its base and about 40 feet below the St. Joe. The rock forming the tunnel walls and extending 30 feet higher in the section outside the tunnels is chert and cherty sandstone, interbedded with and grading into limestone and limy sandstone. A small amount of medium-grained dolomite is interbedded at the horizon of the tunnels, and part of the chert is dolomitic. The top 10 feet of the Everton is sandstone. In the portal region of the north tunnel the strata dip to the north and northwest irregularly at angles of 5° or less, but these dips appear to be local in their development.

The ore is zinc silicate. It is oxidized from mixed black and rosin jack that was once developed through the whole thickness of chert but more abundantly in certain bands than others. The jack was either disseminated or else filled seams and pockets in the chert. A little zinc carbonate accompanies the silicate. Pink spar occurs in cracks in the dolomitic chert but is not associated with ore.

A prospect shaft on the north side of the mouth of the hollow and two small open cuts on the south side, opposite, have revealed mineral in a fine-grained dolomite about 20 feet lower than the horizon at the main Almy workings. The mineralization is similar to that at the Jackpot, a few hundred feet away, and the horizon is probably the same. The ore is essentially jack associated with pink spar and fills cracks in the dolomite. The jack is rosin-colored on the north side, mixed rosin and black on the south side. It is partly altered to gray crystalline carbonate on the south side, and part of this carbonate has replaced the pink spar and preserved its crystalline form. Minor accessory minerals associated with the jack on the north side are calcite, fine drusy quartz, chalcopyrite, and pyrite.

The Almy is an old-time mine that produced ore at least as early as 1902, perhaps earlier. Several carloads are reported to have been taken out before 1907. The total production is not known. During the war period from 1914 to 1917 the Almy produced about 400 tons of silicate concentrates, milled on the property.

Coon Hollow.—These workings lie in Coon Hollow a quarter of a mile or more above its junction, from the northwest, with Mill Branch. The property is probably in the SE¼NW¼ sec. 17, T. 19 N., R. 18 W. The workings consist chiefly of a series of short tunnels into the hill on both sides of the hollow, over a distance of about 500 feet along its course. The longest tunnel is reported to be about 250 feet long. These tunnels lie at an altitude of 950 feet, from 10 to 15 feet above the bed of the hollow. There is also a 30-foot shaft on the west side of the hollow, 400 feet upstream from the group of tunnels. It lies 20 feet above the bed of the hollow, at an altitude of 985 feet. One drift from its base goes west about 75 feet, and two others go northwest and southwest respectively to a distance of 40 or 50 feet. Most of the Coon Hollow workings are now caved.

The deposit worked through the tunnels is an ore-bearing bed (blanket vein) in the Everton formation, 15 feet above its base. Its thickness ranges from a few inches to 10 feet. The exact horizon of the bed worked from the shaft is not determinable, but it is at about the same altitude as the ore bed at the tunnels, and the ore is similar in character. The ore consists chiefly of zinc silicate with some carbonate, especially at the north end of the group of tunnels, both derived from the oxidation of disseminated rosin jack in chert. To a lesser extent the original jack occurs in medium-grained dolomite, in cracks, bedding veins, and irregular replacement pockets. Some of the dolomite is lined along the bedding planes with chert, which may carry disseminated jack. A little of the material on one of the dumps shows a breccia of fine-grained dolomite with a matrix of chert containing disseminated jack. Only a small percentage of the original sulphide remains.

The jack is associated with a little pink spar, especially where it occurs in dolomite. Much of the silicate is black and may contain small specks of copper carbonate (malachite). The zinc carbonate is of various types, but the gray and flesh-colored crystalline material are the most common. Some of the carbonate consists of a felted aggregate of fine flesh-colored rods, and some of it has replaced pink spar and preserved the crystalline form of that mineral. A very small amount of turkey fat is present.

The production of the Coon Hollow group is estimated by Lon Brown, of Zinc, to have been about 1,750 tons of concentrates, consisting of silicate and carbonate, produced chiefly between 1914 and 1918. A small mill erected near the site of the shaft concentrated chiefly ore from the shaft, but the greater production of the Coon Hollow property came from the tunnels.

A few hundred feet below the main Coon Hollow workings mineral shows in small prospect pits on both sides of the hollow at about the same level, though lack of outcrops prevents determination of the geologic horizon. On the left side, 1,000 feet upstream from the mouth of the hollow, rosin jack occurs in medium-grained dolomite, both disseminated and associated with pink spar along bedding lines. On the right-hand side, 200 feet downstream from the deposit just mentioned, crystalline carbonate and silicate occur in chert containing casts of disseminated jack. In addition, carbonate and rosin jack are here developed in medium-grained dolomite in association with pink spar.

Boggs.—These workings lie on the left side of Sugar Orchard Creek, 100 feet or so above the creek, about a mile above Zinc. The Boggs holdings are in the SE¼NE¼ sec. 18, T. 19 N., R. 18 W., but as the section line parallels the face of the hill and lies only a short distance above the level of the workings, most of the tunnels pass into Coon Hollow property in sec. 17 after entering the hill a short distance. The horizon worked is in the Everton formation 20 to 30 feet above its base. The workings consist of numerous tunnels 100 to 200 feet long and open cuts strung along the hill over a distance of a quarter of a mile. Most of the tunnels are caved. The ore-bearing bed is a dolomitic chert, derived from a dolomitic limestone, but in places it grades into a cherty medium-grained dolomite. Exposures are very poor, but in one place at the south end of the group of tunnels the ore bed is 4 feet thick.

The original ore mineral was rosin jack, disseminated or forming veins along the bedding in the chert or occupying irregular pockets in the dolomite. At the south end of the workings some black jack was mixed with the rosin. Most of the jack has been oxidized to zinc silicate and carbonate, predominantly the silicate, and these products form the ore. The silicate is of various types, some being finely crystalline and flesh-colored, but most of it is dark-colored or even black. The carbonate is chiefly of the crystalline type and may be gray, pinkish, or yellow (turkey fat); some is black, and a small percentage of it is of the fine flesh-colored rod type. The proportion of carbonate relative to silicate increases toward the south end of the group of openings. Small specks of malachite are included in the black varieties of both the silicate and carbonate. That some pink spar originally accompanied the ore in the chert is shown by the occurrence of a little zinc carbonate pseudomorphic after it, but none of the original mineral is preserved. Fine drusy quartz occurs in the chert in association with the ore. A greenish clay mineral is commonly developed along parting planes in the chert or forms the matrix of the dolomite.

The production from the Boggs tract during the period of high prices in the early part of the World War was about 150 tons of silicate and carbonate concentrates.

Minnie Lee.—This property lies on the right side of Sugar Orchard Creek a mile or so above Zinc, opposite the Boggs tract. It is in the W½NE¼ and the NW¼SE¼ sec. 18, T. 19 N., R. 18 W. The main tunnel is probably in the middle one of the three 40-acre tracts. It is 200 feet long, is rather sinuous, and enters the hill at a horizon 15 feet above the base of the Everton formation, at an altitude of 990 feet. A shorter south prong of the tunnel was unproductive. The ore occurs over an interval of 6 or 7 feet, in medium-grained dolomite, fine-grained dolomite, and chert. The following is a section of the ore-bearing beds, no. 1 lying at the bottom of the section:

Section of ore-bearing beds at Minnie Lee mine

	Feet
6. Medium-grained dolomite.	
5. Chert, derived from limestone	1
4. Medium-grained dolomite	½
3. Fine-grained dolomite	1½
2. Medium-grained dolomite; boundary with overlying bed very indefinite	1–2
1. Chert, grading in places into barren limestone.	

Ore is developed in the basal 2 or 3 feet of no. 6 and in the underlying members, down to and including the top 2 feet of no. 1, but most of it is concentrated in bed 2 and the top foot of bed 1, over an interval of 2 or 3 feet. In the other beds the mineralization was local, extensive stretches being barren. The ore is chiefly colorless (crystalline) and black zinc silicate, the latter containing a few residual masses of rosin jack and numerous small specks of malachite. Pink spar accompanies the silicate in varying amounts in the dolomites, being especially prominent in the fine-grained dolomite (bed 3), where it is commonly unaccompanied by any other mineral. A little brownish-gray crystalline zinc carbonate occurs in this bed in addition to the silicate. In the two main ore beds mentioned the silicate occurs in horizontal and cross-cutting seams 1 inch in maximum thickness that may extend for several feet along the walls of the tunnel. In the fine-grained dolomite (bed 3) the ore is found more in irregular pockets. The mine shows a large amount of reddish clay, especially at the top of the lower chert bed.

Several hundred feet north of the main tunnel another tunnel near the head of a shallow hollow yielded zinc silicate from a chert bed, probably from the same horizon as in the main tunnel. Most of this ore was mined near the portal.

The production from the Minnie Lee tract during the early years of the World War was about 250 tons. Of this amount about 70 tons came from the last-mentioned opening north of the main tunnel.

Swansea Hollow.—In Swansea Hollow, half a mile or so above its junction with Sugar Orchard Creek, some prospecting has been done by means of a shaft sunk in the left bank of the hollow a few feet above its bed, probably in the northwest corner of sec. 17, T. 19 N., R. 18 W., although as the working plots near the section corner, it may be in one of the three adjacent sections. The shaft begins in the Everton formation about 15 feet below the St. Joe limestone and was at one time 30 to 35 feet deep. The ore is mixed rosin jack (containing a little black jack in the larger masses) and zinc silicate and shows several different types of occurrence, being disseminated or occupying vugs in chert or occupying irregular cracks and pockets in medium-grained dolomite or in cherty sandstone. Probably the different types came from different beds in the shaft. The silicate is dominant and is developed only in the cherty phases. It is reported to occur in a 3-to 4-foot bed at the bottom of the shaft. The jack in the dolomite and cherty sandstone is accompanied by a little pink spar and calcite and in the chert by finely crystalline quartz. A small amount of chalcopyrite is present in the jack, and a very little zinc carbonate is formed directly on the jack crystals in some of the chert vugs. This property produced a few tons, concentrated by hand jigging.

Rhodes-Manchester.—This mine is in the NE¼SE¼ sec. 7, T. 19 N., R. 18 W., on the steep left slope of Sugar Orchard Creek, about 2 miles above Zinc, at an altitude of 985 feet. The main working is a tunnel 430 feet long, very irregular in ground pattern and with a second opening to the surface to the south of the main portal. Another tunnel opens 60 feet north of the first and goes 200 feet into the hill. The horizon is in the Everton formation 20 feet above its base. The structure within the mine is gently undulating on a small scale. A fracture running N. 60° W. is followed for about 100 feet by the main tunnel in its middle course; another fracture at the rear end of this tunnel runs N. 85° E. These breaks show no displacement but evidently were favorable zones for ore deposition.

The ore is chiefly zinc silicate, but some gray crystalline zinc carbonate occurs in places, especially at the rear end of the main tunnel and along the walls of its south entrance. Most of the ore mined was free and required no milling. It occurred in a bed a foot or so thick and was associated with considerable tallow clay. The original ore, a little of which remains, was rosin and black jack, chiefly the former, associated with pink spar, and occurred in a bed as much as 4 feet thick that ranges in different places from medium-grained dolomite to chert. Intermediate phases show the dolomite banded by the chert, which may or may not be dolomitic. The rich oxidized ore was derived from only the richest foot or so at the top of the mineralized bed. In places the lower part of the ore-bearing zone and the underlying barren dolomite, with which it is continuous, grade laterally into barren limestone. The rock capping the ore zone is dolomite. The ore minerals appear in veins and pockets along the bedding, some of the pockets 2 feet or so in diameter, though only a few inches in thickness. Where the country rock is chert the original jack was also disseminated in it. Traces of malachite appear in the black silicate.

The production of the Rhodes-Manchester mine during the period of the World War was about 1,500 tons. In addition to the free ore some of the rock was milled on the property.

Three or four chunks of galena, the largest weighing 10 or 15 pounds, were blasted out of Powell "cotton rock" below the mine in excavating a place for the mill.

Mason.—This property is in the NW¼SE¼ sec. 7, T. 19 N., R. 18 W., on the opposite side of Sugar Orchard Creek from the Rhodes mine. The altitude is 990 feet, and the geologic horizon appears to be the same as at the Rhodes, though lack of exposures prevents confirmation of this inference. The openings consist of several short tunnels, now caved. The ore is zinc silicate, with a little carbonate, associated with pink spar in chert. The chert is partly dolomitic. The silicate, where it is black, contains small blebs of malachite. The Mason workings have produced 30 to 40 tons of ore.

Oswego.—This mine lies in the bed of Mineral Hollow about a mile up from its junction with Sugar Orchard Creek, probably in the SE¼ sec. 12, T. 19 N., R. 19 W. The opening is a shaft, 18 to 20 feet deep, from which a short inclined tunnel runs off to the south. The ore horizon is in the Everton formation, perhaps 30 feet above its base, though the base is first exposed some distance down the hollow. The ore-bearing rock is medium- to rather coarse-grained dolomite containing a small amount of chert. The ore is mixed jack and zinc silicate but is reported to have been marketed as silicate. It occurs in large replacement masses, as much as a foot in diameter, in the dolomite or in clay altered from the dolomite. The jack is mixed rosin and black, but more dominantly the former, and contains small inclusions of chalcopyrite. A little zinc carbonate occurs with the silicate. The production from this opening during the World War period was about 70 tons.

Coker Hollow.—The Coker Hollow mine is in the bed of a hollow that is tributary to Tarkiln Creek from the west. It lies in the SE¼NE¼ sec. 16, T. 19 N., R. 18 W. Unlike most of the other mines in Marion and Boone Counties, which are developed entirely in the Everton formation, this mine contained part of its ore in the St. Joe limestone member of the Boone formation.

All of the productive ground was worked from a shaft 110 feet deep. The shaft begins at the top of the St. Joe and at its bottom is reported to be in a fine-grained dolomite of the Everton, similar to the one that carries the ore in the Jackpot mine. Drifts and stopes were made on three levels from the shaft. On the lowest level, 10 feet above the base of the shaft, a drift was driven to the south but was unproductive. On the 55-foot level, a curved drift averaging less than 15 feet in width was driven first to the north, then swinging to the west and finally to the southwest. This drift is reported to have been in the Everton formation a short distance below the St. Joe limestone. The uppermost level was 35 feet below the collar of the shaft, entirely in the St. Joe limestone. It was worked as a circular stope clear up to the surface, and later some 10 feet or more of ore was taken up from the floor. The resultant opening is a large glory hole about 40 feet in diameter and 40 or 45 feet deep. It lies west of the shaft and within the block enclosed by the curved drift on the middle level.

The ore is mixed jack and zinc silicate, in about equal proportions. In the upper level it occurs in masses several inches in maximum size but averaging 1 or 2 inches, in the matrix of a peculiar chert breccia that forms a pipelike body in the St. Joe. In that part of the breccia that still remains on the east wall of the glory hole the fragments of the breccia are primary

Boone chert that have come down from some higher level; the matrix is a soft drab chert (probably somewhat weathered in its present form) that contains scattered casts of crinoid stems. Evidently the matrix was originally a limestone that behaved more or less plastically under the stresses that brecciated the more brittle chert. The block making up the pipe is believed to have been brecciated by the slumpage due to solution of the underlying beds. In the oxidized phases of the ore considerable tallow clay occurs as a filler in the breccia, evidently from the alteration of the original chert matrix.

The jack of the primary ore is mixed black and rosin colored, the former predominating. It contains rather abundant inclusions of chalcopyrite, which, in the oxidized phases of the ore body, have changed to the green copper carbonate, malachite.

The ore from the lower horizons, in the Everton formation, was not observed in place, but material on the dump shows mixed black and rosin jack, partly altered to silicate, in cracks in quartzite, and also considerable silicate derived from the oxidation of disseminated jack in chert that has replaced limestone. A small amount of zinc carbonate accompanies the silicate in both of these occurrences.

The production of the Coker Hollow mine has been about 800 tons of mixed jack and silicate concentrates, beginning as early as 1911.

Tarkiln.—This property is in the SE¼ sec. 10, T. 19 N., R. 18 W., on the east slope of Tarkiln Creek. The developments consist of several short tunnels driven in the Everton limestone 20 feet or less below the St. Joe limestone; a shaft beginning 40 feet below the St. Joe and apparently penetrating to the Powell dolomite; and several shafts lying a quarter of a mile or so up a hollow that comes in from the northeast at the main workings. These last-named workings were not visited.

The country rock at the highest horizon, just below the St. Joe, is chiefly limestone and limy sandstone, but where mineralized it has been silicified to a blanket bed of chert with some cherty sandstone, 6 feet or so in maximum thickness. The original jack was mixed black and rosin and was disseminated in the chert, but most of the ore taken from this level has been zinc silicate derived from the jack. Small specks of malachite are common in the black phases of the silicate. A small amount of carbonate is associated with the silicate. Considerable red-brown clay developed in the chert during the oxidation. In a few places the original limestone grades into a rather coarse-grained dolomite, and where this rock was mineralized pink spar occurs as a lining to the druses.

A mill was erected on the property several years before the World War, but all the ore recovered by milling is reported to have come from the shafts up the side hollow and to have been jack instead of silicate. The chat pile shows that it occurred in a fine-grained dolomite, probably as a filling in shatter cracks, to judge from the usual type of occurrence in this rock in other mines and prospects in northern Arkansas.

The production of the Tarkiln mine has been about 150 tons, most of it being free silicate ore. Most of the production was made several years prior to the World War.

DODD CITY DISTRICT

The Dodd City district includes the region around the headwaters of Little Sugar Orchard Creek and the south headwaters of East Sugarloaf Creek. It lies between the Boone-Marion County line and a north-south line through Dodd City. The district as thus defined is not a very compact unit, but the ore deposits contained within it are fairly similar. Two deposits, the Ben Harrison and Pigeon Roost, occur in the St. Joe limestone. The Black Bear, a low-grade deposit, occurs at some horizon in the Cotter formation. The rest of the deposits are in the Everton formation, in various types of country rock. The ores comprise jack, zinc carbonate, zinc silicate, and lead sulphide. The Sugarloaf fault, with a displacement of 100 feet, crosses the district from northwest to southeast, and several of the deposits lie fairly close to it. The production of the district is imperfectly known but has probably not exceeded 5,000 tons of concentrates. Perhaps 200 tons of this has been galena.

Governor Eagle.—This mine is on the right bank of a west headwater fork of Little Sugar Orchard Creek, in the NW¼ sec. 7, T. 19 N., R. 17 W. The workings consist of three shafts, 85, 112, and 105 feet deep. The horizon of the shaft collars is in the Everton formation about 10 feet below the St. Joe limestone. The ore is reported to have been taken from one of the earlier shafts, but the ore run pitched eastward so steeply that the third shaft was sunk in an attempt to reach it at a lower level. The run is reported to be about 20 feet thick and to carry about 3 percent of ore. The ore occurs in fine- to coarse-grained dolomite, as a filling of cracks and irregular replacement pockets, but also, in the coarse-grained dolomite, as a filling of breccia. The ore minerals are rosin jack and zinc silicate; some of the jack masses are 6 inches or more across. The gangue minerals are pink spar, quartz, and calcite. Small amounts of chalcopyrite and enargite (see p. 110) are present. The mine produced about 70 tons of jack concentrates in 1915 and 60 tons in 1916. The mill on the property is now in ruins.

Susquehanna.—This property is in the E½ sec. 8, T. 19 N., R. 17 W. The main opening is a shaft, now caved, on the left bank of a small hollow that is tributary to Little Sugar Orchard Creek from the east. The collar of the shaft is in the Everton formation 35 feet below the St. Joe limestone. The depth of the shaft is reported to be about 70 feet, which would place its foot near or at the base of the Everton. The ore run, lying at the bottom of the shaft, is reported to be 13 feet thick and 20 to 50 feet wide and to run in a north-south direction. It was followed northward by a drift from the bottom of the shaft. The ore-bearing rock is fine- to medium-grained dolomite, in part sandy; there is also some chert. The ore is mostly rosin jack associated with pink spar, finely crystalline quartz, and some calcite, in cracks and replacement pockets in the dolomite, but some of it forms replacement pockets in the chert. A little galena is also disseminated in quartzite, apparently from a different level. Zinc carbonate is present but of minor importance; it is flesh-colored and crystalline. Minute crystals of pyrite and chalcopyrite occur in the vein material. Some silicate ore is reported to have been taken from the more open ground in the run.

A second shaft is 15 feet higher, on the opposite side of the tributary hollow and 200 feet north of the main shaft. Very little ore shows on its dump, but there is some disseminated jack along bands in chert, much of which is dolomitic. The shaft is reported to reach the ore run that is opened up in the first shaft and to have a drift running southward from its foot. The two shafts were not connected, however.

The production from the property was made prior to 1908. The total output is not known, but 100 tons of jack concentrates were produced in 1907. The mill has been completely removed.

Nakomis.—This property is in the S½SW¼ sec. 32, T. 20 N., R. 17 W., 1 mile northwest of Dodd City. It has been developed at two localities, about 1,000 feet apart.

The largest working at the upper locality is a deep open cut, 80 feet long and 30 feet wide, in the bed of a headwater prong of East Sugarloaf Creek. The pit is elongated N. 60° W., crossways of the hollow. The cut is now filled with water and is rapidly filling with sand and gravel. The altitude of the outlet of the present pond is 990 feet. In addition to this cut, a 150-foot shaft has been covered up by the waste dump. It produced a little ore from about the 110-foot level.

The open cut is in a fine-grained gray magnesian limestone in the Everton formation. The exposures are very poor in the vicinity, but the cut appears to follow some sort of a structural break, probably the Sugarloaf fault. On the lower (northeast) side of the pit, just above the level of the pond, a breccia of limestone fragments in very limy sandstone is exposed. The relation of this breccia to the magnesian limestone of the southwest side is not apparent. The waste-rock dump shows several types of breccia in addition to the dominant unbrecciated magnesian limestone. Examples were noted of fine-grained gray dolomite (magnesian limestone) fragments in quartzite, limestone in medium-grained gray slightly sandy dolomite, and limestone in quartzite. About 20 feet upstream from the upper (southwest) rim of the pit, a medium-grained dolomite that forms the top layer along the rim of the pit abuts directly against a blue limestone. The limestone is silicified for 2 or 3 feet from the contact and contains disseminated jack for 2 or 3 inches from the contact. This plainly records a small fault, but the amount of the displacement and the direction of movement cannot be determined from the meager outcrop. The movement was probably small, as there has been no brecciation here.

The ore of the upper Nakomis is chiefly mottled rosin and black jack. It occurs in shatter cracks in the dolomite of the pit and also, at least in one place, disseminated in the dolomite for a few inches adjacent to such a crack. A minor amount of the jack on the dump is disseminated in quartzite and associated with a cherty replacement product of the quartzite, but this may have come from a deeper level in the 150-foot shaft. The ore does not occur in the more severely brecciated blocks. Some of the cracks in the dolomite contain gray chert with disseminated jack. Common gangues are calcite and fine drusy quartz. Pink spar in druses with jack and fine quartz is rather rare; it was noted only in a block of medium-grained dolomite on the waste dump that may have come from a lower horizon than that in the pit. Pyrite and chalcopyrite in minute grains are accessories of the ore, and in addition the pyrite may be embedded in the matrix of some of the breccias. Oxidation has not been extensive, but a little zinc carbonate occurs.

On the west side of the hollow, in line with the elongation of the pit and for several hundred feet upstream from the workings, the surface limestone and sandstone have been silicified with the development of a little jack, now largely leached out, but none of this is rich enough to be commercially valuable.

The mill that formerly stood at this upper Nakomis site was burned down. The mine has not been worked since 1907.

The lower Nakomis working is a shaft on the west side of the branch, about 1,000 feet below the upper working. This is known as the no. 4 shaft. It was put down to a depth of about 175 feet on a drill hole. Some drifting was done at the 45-foot level on a run of ore reported to be 10 feet thick and 40 feet wide and to trend in a north-northeast direction. From calculation, the shaft reaches the base of the Everton formation at 55 feet and at the bottom is within 30 feet of the base of the Powell. It is reported that the drill hole showed mixed jack and galena ore between the 300- and 330-foot levels. This would be around 100 feet below the top of the Cotter.

The ore-bearing rock on the dump, presumably taken from the level of the drift, is fine- to medium-grained gray dolomite. The jack occurs in cracks that are lined with fine drusy quartz, some of the cracks being evidently enlarged by solution. Chalcopyrite, pink spar, and calcite are minor constituents.

This shaft was equipped with a mill, which is now in ruins. Its production has been practically nil.

Markle.—This mine is in the bed of the middle fork of Markle Hollow, in the NW¼ SE¼ sec. 31, T. 20 N., R. 17 W., at an altitude of 955 feet. It was originally a shaft sunk in the creek bed to a depth of 75 feet but was later enlarged to an open cut in the upper part, the final pit being 100 feet long, 60 feet wide, and perhaps 20 or 30 feet deep. During the period of its operation the stream flowing in the hollow at times of heavy rains had to be flumed across the workings. Since the mine was abandoned the creek has completely filled the shaft, and is rapidly filling the open cut to the level of the outlet, with sand and gravel. The geologic horizon of the exposed workings is the upper part of the Everton formation, the present outlet of the open pit being 25 feet below the St. Joe limestone. At this level the beds are chert (silicified limestone) and some quartzite, part of which has been replaced by chert. The character of the rock from lower levels in the shaft is not revealed, but it is apparent that the whole underlying thickness of the Everton was penetrated. It is reported that ore occurred in the shaft to the bottom but was concentrated at different levels, with barren rock between.

The mine follows a minor anticlinal flexure that runs about north and south. The beds dip away from the pit at a low angle around the north end of the fold. There has been some brecciation along the flexure and some ill-defined longitudinal fracturing parallel to its axis.

The commercially important minerals are jack and zinc carbonate. The original jack was in part disseminated in the chert and quartzite, from which it has largely been leached, leaving only the casts, but the occurrence that was of greater commercial value was, according to reports, in the form of lenses and irregular masses along the bedding planes (and in breccias?). The carbonate was rather intimately mixed with the jack in the same modes of occurrence. A little of it is reported to have been turkey fat. Some showing on the dump is in the form of ⅛-inch flesh-colored rods with blunt ends. Some galena occurs at the north side of the pit at the higher levels, disseminated in chert. A little zinc silicate and crystalline lead carbonate and stains of pyromorphite appear on the waste dump. The only common gangue mineral is fine drusy quartz, which lines the bedding seams and cracks in the chert. A little fine pyrite is disseminated in the chert. Red clay is a common development along the bedding planes of the chert where the ores have been oxidized.

Much of the Markle ore was free ore, but this generally had to be hand picked to separate the jack from the carbonate. Even then the carbonate, as marketed, contained a rather large percentage of jack. A small concentrating mill was erected during the war period of production. The total production of this mine has been estimated by W. A. McCurry, of Zinc, at about

1,400 tons of concentrates. About 640 tons were produced under the management of Markle & McCurry in 1914, 1915, and 1916.

Pigeon Roost.—This working is on the north bank of Pigeon Roost Hollow, 10 feet above the creek bed, about a quarter of a mile up from East Sugarloaf Creek, in the N½SE¼ sec. 32, T. 20 N., R. 17 W., at an altitude of 995 feet. The opening is an open cut about 50 feet wide along the creek and 20 feet high at the back side. The ore-bearing rock is a chert resulting from the complete silicification of the St. Joe limestone. The horizon is only 10 feet or so above the base of that formation. Although the St. Joe ledge crops out on both sides of the mine, there are no natural exposures within the 200-foot stretch that contains the mine. Most of the chert has weathered until it is fairly soft and light drab.

In the bed of the creek opposite the mine, 10 feet lower, is an outcrop of the same type of chert that carries the ore. This mass is very plainly at the horizon of the St. Joe-Everton contact, for its lower part shows the thinner bedding of the limestone of the Everton formation and carries some quartzite. Only 5 to 10 feet of beds are represented. The St. Joe part of this mass contains a few galena casts. The outcrop is only 50 feet long (transverse to the direction of the creek) and perhaps 20 feet wide; it deflects the main stream channel at right angles around its upstream side. The structure has been obscured by the silicification, but the beds appear to be nearly horizontal, with local rather steep dips into the mass from the upper side. There are also evidently some crumpling and obscure brecciation in places.

A similar chert mass, derived entirely from the Everton, is exposed on the opposite side of the valley floor from the mine, upstream from the first mass. Its bedding is roughly horizontal. There are no outcrops within 100 feet of this mass, and the St. Joe ledge fails to crop out above it. Upstream, beyond 100 feet, the limestone at the top of the Everton dips gently into it.

Evidently these three chert outcrops (that in the mine and the two masses just described) mark a zone of silicification that crosses the hollow here. They are not in line, which indicates that the zone may have considerable width, perhaps 100 feet. There does not appear to have been any faulting, as the St. Joe ledge both upstream and downstream is undisturbed. There may have been some slumpage during silicification, however, as suggested by the crumpled condition of one of the chert masses. It could not have been great, because the Everton appears in both of the creek masses. The outcrops in this zone are too few to tell anything very definite.

The ore is mixed galena and lead carbonate, containing stains of pyromorphite. The galena occurs disseminated as crystals as much as 2 inches across in the chert. The carbonate may be an earthy black or gray mass, or it may be white and crystalline. It generally occupies the cast of the galena crystal from which it has been derived, and much of the earthy carbonate has an unaltered core of galena. Lead carbonate also occurs to a minor extent as a flesh-colored replacement product of small dolomite crystals (average one-sixteenth inch) that occur disseminated in the chert more thickly along certain bands than others, without showing any very close relation to the galena. The greater part of the dolomite has weathered out, leaving only the casts.

Pilot Rock.—This property is in the S½NW¼ sec. 32, T. 20 N., R. 17 W., on East Sugarloaf Creek at the mouth of Pigeon Roost hollow. The main shaft collar is at an altitude of 970 feet, 40 feet or so above the bed of the hollow. The shaft is about 75 feet deep. The main ore run is reported to be a blanket vein 7 or 8 feet thick and to lie 35 to 40 feet below the shaft collar, which would put it in the Everton formation 45 to 50 feet below the top. The ore at this level was originally worked from a tunnel in the side of the hill. The shaft was later sunk through the tunnel in an attempt to reach an ore level, revealed in a drill hole, about 100 feet below the shaft collar, but the project was abandoned before the ore was reached, on account of excessive ground water.

To judge from the waste rock on the dump, the zinc ore occurs in chert that has replaced limestone, and to a minor extent in silicified sandstone. Jack casts appear in a good part of the chert that shows on the dump, and some jack still persists in pockets along the bedding planes. A somewhat higher percentage of this jack than usual is dark-colored. Most of the commercial ore was a gray crystalline zinc carbonate occurring along the bedding planes of the chert. A little zinc silicate is associated with the carbonate. Some galena was produced at this mine, but it is reported to have come from a higher level than the zinc. The galena on the dump is commonly attached to the free bedding planes of sandstone, into which it may be slightly embedded. Most of the galena is reported to have lain below sandstone. Galena is also disseminated in chert. The occurrence of a little copper in the primary mineralization is indicated by the presence of small green-stained pseudomorphs of limonite after chalcopyrite, coated on chert, and by the presence of green stains in masses of black carbonate.

The greater production of the Pilot Rock mine was hand-picked free ore, some of which is reported to have been shipped as early as 1886. In 1908–9 hand jigs were installed and about 6 carloads of concentrates were shipped, a large part of which was milled from the waste rock of former operations. The total production of the mine is estimated at about 800 tons of concentrates according to A. M. Goatley, of Rush.

Copperhead.—This opening is on the left side of the head of East Sugarloaf Creek a short distance below the Pilot Rock. The workings consist of an old drift, now caved, at an altitude of 955 feet, 10 or 20 feet above the bed of the hollow, and a caved shaft above, sunk in 1910, slightly off the line of the drift. The drift is in the Everton formation 35 feet below the St. Joe limestone. The ore-bearing rock is silicified limestone that carries disseminated jack and galena. Although galena was not found on the dump, it is reported to have been the chief output of this mine.

North Pole.—This mine is in the SW¼ sec. 29, T. 20 N., R. 17 W. The opening is on a gently sloping point, rather high on the east side of East Sugarloaf Creek, at an altitude of 1,000 feet. The workings consist of an open cut perhaps 50 feet across, at the St. Joe-Everton contact, and a shaft 20 feet higher, a short distance on the southeast. Owing to the presence of a small fault through the south side of the open cut, with a throw of about 20 feet, down on the north, the shaft is developed entirely in the Everton formation, beginning about 5 feet below the St. Joe. The rock on the dump of the shaft shows chert derived from the replacement of limestone and carrying disseminated dark-colored jack in crystals 1 or 2 inches in maximum size. Some of the jack has been altered to gray and black carbonate, and some to gray and black silicate. The black carbonate is accompanied by a little malachite stain.

Although there is no mineral showing at present in the lower pit, it is reported by Drew Markle, of Dodd City, to have produced about 50 tons of carbonate and 600 pounds of copper carbonate, most of the latter being in one chunk. The St. Joe limestone next to the fault has been crumpled into large pillowlike blocks 3 to 4 feet across, tilted somewhat at various angles but still showing some relation to horizontality. Along the fault contact the St. Joe and Everton formations are so interkneaded that a definite fault plane does not exist. The

St. Joe has been bleached to a pale gray color throughout most of the pit. In spite of these changes, the fossils in both the St. Joe and the underlying Everton have been preserved. At the north edge of the pit, where crumpling is not so pronounced, both formations have been silicified, but the exposed beds show no mineralization.

Edna Bee.—This mine is in the SE¼NW¼ sec. 29, T. 20 N., R. 17 W., at an altitude of 980 feet, well up on the left-side hill of East Sugarloaf Creek, opposite the mouth of Chapman Hollow. The horizon is in the Everton formation about 35 feet below the St. Joe limestone. The ore-bearing bed is a limestone about 10 feet or more thick, overlain to the top of the Everton by alternating sandstone and limestone. The developments consist of an open cut, 100 feet long, 30 feet wide, and about 30 feet high at the back, from the end of which a tunnel has been driven 150 feet into the hill, curving sharply to the right about two-thirds of the way back. There is also a shaft in the portal of the tunnel. The walls of the tunnel are limestone with a little chert showing in a few places, especially toward the portal and near the top of the breast. This chert was formed by replacement of the limestone during mineralization and is the ore-bearing rock. More of it is present in the open cut than in the tunnel. The silicification appears to have been limited to a rather narrow zone, as the tunnel is only about 15 feet wide, and most of the chert has been removed. No definite fracture can be determined, although the rock on the right side of the portal shows some crumpling. A short distance back in the drift the limestone beds are unbroken in the walls and across the roof except by the numerous irregular clay seams and pockets produced under present-day weathering conditions. Some of these pockets contain fragments of Boone chert that have come down 70 or 80 feet from above. It is a noticeable feature that the chert beds tend to decompose before the limestone, probably owing to their greater permeability. Considerable tallow clay is developed in the chert pockets, some of the purest being banded as lenses in the decomposed chert.

The ore marketed is reported to have consisted of jack, zinc carbonate, zinc silicate, and a little galena. The mine has been almost completely worked out, but some of the ore appears on the various dumps and in the portal walls. The jack is rather dark in color and occurs in pockets in the chert, 3 to 4 inches in maximum diameter, and also disseminated in the chert in crystals, many of which measure 1 to 2 inches, an uncommonly large size for this type of occurrence. Much of the chert, however, is barren. Much of the silicate is black, having evidently been derived from jack in place; the free surfaces of such masses are commonly gray and crystalline. The Edna Bee is reported by W. A. McCurry to have produced about 120 tons of free ore during the World War.

Ben Harrison.—This property is in the SW¼ sec. 25, T. 20 N., R. 18 W., on the west side but near the end of a long spur extending northward between two headwater branches of East Sugarloaf Creek. The openings are in the St. Joe limestone near the top of the hill. The nature of the ore run or runs could not be determined, owing to the lack of exposures of the ore rock in place. Although surface exposures are not good enough to prove definitely that no faulting has occurred in the vicinity, no evidence was found of any displacement.

An ore run was intersected in a small-bore drift that enters the hill at an altitude of 1,075 feet, 10 feet above the base of the St. Joe, but this drift has caved in front of the ore, so that the ore is no longer accessible. According to T. J. Lawhon, of Monarch, the ore was intersected a short distance back of the cave. It occurred along an irregular "channel" that showed no evidence of having developed along a definite fracture. The "channel" varied abruptly in size. One big pocket was 6 by 6 feet in cross section and contained cubes of galena, 6 inches or so across, embedded in flint. When the ore was taken out of the pocket, all the flint underlying it was removed. Back of this pocket the "channel", consisting of flint and ore, narrowed down and was followed back to a clay-filled crevice at the rear of the tunnel, where a shaft was put down for about 30 feet into the underlying Everton formation. This crevice also carried lead embedded in the clay, though not in such large masses as in the "channel" followed by the drift. This crevice was followed by a drift for about 30 feet. Another prong of the main tunnel, bearing more eastward, headed toward the foot of an old-time shaft that was worked about 1900.

Other workings occur on the hill above the tunnel. An old-time shaft, lying slightly north of east from the tunnel portal and 45 feet higher on the hill, and a shallow open cut above the tunnel, presumably over the mineralized stretch in the tunnel, both show ore on the dump, but a more recent shaft on the hill 60 feet above the tunnel and more in line with it, is barren. It begins in the Boone above the St. Joe limestone member.

Material lying on the dump of the tunnel shows the general nature of the mineralization. Silicification of the limestone has accompanied ore deposition. The primary ore minerals are galena (dominant) and jack, disseminated in the resulting chert. The crystals of galena that remain on the dump average half an inch to an inch in size; those of jack average somewhat smaller, though a few reach 1 inch. The jack is mostly rather dark in color. Some of the larger jack crystals carry chalcopyrite embedded within them. Drusy quartz is common along the bedding planes of the chert, and coarsely crystalline calcite, reported to have come from the clay-filled crevice at the back of the tunnel, is also common on the dump of the tunnel. A little finely crystalline pyrite appears in a few places in quartz-lined druses. Much of the jack has been altered to silicate and less commonly to carbonate. A little malachite occurs in the silicate, and pyromorphite is present in the ore-bearing rock as a stain.

Some of the ore-bearing chert on the dump is plainly derived from the Everton formation, and blocks of sandstone carrying pockets of zinc silicate and crystals of galena, the latter embedded in drusy quartz, came from the same source.

The mine produced only 20 tons or so during the World War but is reported to have produced much more around 1900.

Bill Parks.—This is an old drift, now caved, on the east side of the first hollow east of the Ben Harrison. It lies 30 or 40 feet above the bed of the hollow, at an altitude of 1,030 feet. The ore-bearing rock is a chert (silicified limestone) about 2 feet thick, that lies 20 feet above the base of the Everton. It is overlain by 8 feet of fine-grained or locally medium-grained dolomite, capped by sandstone, and is underlain by limestone; in places the limestone has been converted to medium-grained dolomite. The ore is chiefly galena, which is disseminated in the chert as crystals 1 inch or more in maximum size. Most of it lies adjacent to bedding planes. A little jack accompanies the galena, also disseminated in the chert. Some of the jack has been altered to carbonate. Quartz, in rather coarse crystals (one-fourth to three-fourths inch), is a rather conspicuous gangue.

This prospect has not produced ore in commercial quantities.

Broome County.—This opening is in the NE¼NE¼ sec. 35, T. 20 N., R. 18 W., on the west side of and 120 feet above a headwater tributary of East Sugarloaf Creek. The working consists of an open cut, 200 feet along the side of the hill, 100 feet wide at the maximum, and 20 feet deep at the back side. The altitude is 1,120 feet. The ore occurs in the cracks of a shattered and somewhat brecciated fine-grained gray dolomite, 20 feet or so thick, whose horizon is 20 to 40 feet above the base of the Everton formation. This is evidently the same bed that carries the ore at the Iola. It is underlain by medium-grained gray dolomite, with a little sandstone, and overlain by poorly exposed limestone and sandstone.

The cut follows a poorly defined and discontinuous zone of brecciation at least 15 feet wide, that runs about N. 30° W. That the breccia was formed practically in place by structural movement is indicated by the absence of fragments other than the dolomite of the surrounding rock and by the upward flexing of the beds accompanied by shattering for a short distance adjacent to the breccia near the center of the pit. The beds show no displacement of any consequence. Some sand has filtered into the breccia, presumably from above. Where this sand forms the matrix of the breccia the mineralization was rather scant, although here and there a little ore occurs in veinlets in the sand along the margins of the breccia. Most of the ore is in breccia that has not been filled with sand and in shattered rock adjacent to the breccia proper. The zone of shattering extends southward beyond the workings for perhaps 200 feet. A few small open cuts on it show a little scattered mineralization, but evidently the rock is not rich enough to work.

The north end of the Broome County workings lies 200 to 300 feet south of the Sugarloaf fault. The fault probably does not extend much farther west, as the displacement has decreased from southeast to northwest till it is almost nil on the east side of the hollow below the Broome County mill. A siliceous reef marking the line of the fault is, however, well developed here in the Everton formation and also appears in the strata of the Powell on the west side of the hollow.

The ore was apparently spotty in distribution. The chief mineral is rosin jack, but a considerable percentage of it has been altered to gray crystalline carbonate, which generally coats the jack. Carbonate is said to have predominated in the ore that has been taken out. A little of the carbonate is yellow (turkey fat). A very little finely crystalline chalcopyrite occurs on some of the jack crystals, and galena, though not abundant enough to have any commercial importance, is occasionally found in separate cracks. The chief gangue is fine drusy quartz that lines nearly all the cracks. Locally, instead of quartz, the silica deposited in the cracks takes the form of chert, which may carry disseminated jack. Gypsum is an uncommon alteration product.

The Broome County mine was equipped with a large mill, situated in the hollow below, but the production of the mine is not known. According to notes kept by W. R. Willett, of Yellville, 70 tons of jack concentrates were produced in 1915; according to J. H. Hand, of Yellville, 30 tons of concentrates (probably mixed carbonate and jack) were produced in 1917.

Salina.—The Salina mine is in the SE¼NW¼ sec. 36, T. 20 N., R. 18 W., on the east side of the same hollow that contains the Broome County mine but 1,000 feet or so up the hollow from that mine. Its altitude is about 1,100 feet, and that of the branch bed 20 or 30 feet lower. The main workings are in a fine-grained gray dolomite about 15 feet thick, near the bottom of the Everton formation, evidently the same as at the Broome County and Iola.

There are two main openings, the more productive one (no. 2) an open cut 60 feet long, with a tunnel at its back end going 120 feet into the hill. Most of the ore was taken from the open cut and from a cross drift, 75 feet long, at the end of the tunnel. The latter ore body was originally located in a drill hole that shows at the south end of the cross drift. A second opening (no. 1) lies at about the same level, 200 feet up the hollow. This is an open cut, 60 or 70 feet across, with a tunnel in 30 feet or so from the back end. In addition to these main openings, some prospect work in open pits (no. 3) at a slightly higher level (1,130 feet), 400 to 500 feet to the north (downstream), shows ore of about the same type as that worked in the main cuts. These pits are possibly at a higher geologic horizon than nos. 1 and 2. It is reported that a drill hole put down in this neighborhood struck ore at about the level of that in no. 2.

A drill hole sunk near the site of the mill is reported to have penetrated 8 or 9 feet of ore at a level 125 feet below the level of openings 1 and 2. This horizon would be near the †Black Ledge of the Powell dolomite.

The upper ore-bearing bed, of openings 1 and 2, is irregularly crumpled, shattered, and brecciated. However, no definite fault can be made out, and probably none exists. The beds in opening 1 show a monoclinal rise in the direction of no. 2, of about 10 feet in 40 feet, the width of the monocline. The underlying quartzitic sandstone is broken up along this stretch and shows a broken contact with the dolomite. The rock surrounding the entrance to the tunnel in opening 2 is decidedly brecciated. The matrix of the dolomite blocks may be clayey sand or a bluish-white clayey substance of uncertain origin, possibly feldspathic and cherty in composition. This spot is reported to have carried considerable ore, but little of it remains. The rock exposed adjacent to this in the front part of the tunnel is broken and invaded by sand, but the enclosed blocks of dolomite preserve approximately their original orientation and are practically in place. This stretch is not mineralized. In the back of the tunnel the beds show dips of several degrees in various directions, and the dolomite is shattered but without being brecciated or invaded by sand. This phase carries ore. The rocks of the north prospect openings (no. 3) show some warping and are shattered and brecciated. In the Salina, as in numerous other mines of the northern Arkansas district, the most severely brecciated rock that has been invaded by sandstone is not mineralized, whereas less brecciated rock adjacent contains deposits of ore.

The primary ore mineral is jack, which occurs both in the brecciated and shattered dolomite and, in opening 1, in the brecciated sandstone immediately underlying the dolomite. Some of the jack masses in this sandstone or along the sandstone dolomite boundary are a foot across. The jack is accompanied by a little chalcopyrite and galena. Part of the jack, especially in the open cut of opening 2, has been oxidized to carbonate, some of which is yellow (turkey fat). The gangue products are calcite, fine drusy quartz, less commonly chert, and rarely pink spar. The chert occurs as veinlets or bordering ore-bearing cracks in both the dolomite and the sandstone under the dolomite. Much of it carries disseminated jack, and in one of the north prospect pits it contains very finely disseminated pyrite.

The occurrence of abundant feldspar (orthoclase and microcline) as a microscopic constituent of certain rocks at the Salina mine (see p. 113) presents a number of puzzling features. The dolomite in opening 1 contains a 4-foot bed of opaque white feldspathic rock, exposed in the tunnel, which is driven along an insignificant anticlinal flexure. Below this feldspathic bed the dolomite has been slightly crumpled and invaded by the same feldspathic material, the relation apparently being one of replacement, although the crushed and recrystallized dolomite may include certain blebs of the feldspar rock that resemble fragments of an earlier rock. Neither the 4-foot bed nor the underlying breccia shows any evidence of mineralization. On the northwest side of open pit 1 a white opaque chert is developed in a slightly mineralized breccia of dolomite and quartzite, where it occurs both as "fragments" (real or apparent; see below) and as a replacement product that contains disseminated jack. Although this chert was not examined microscopically, it closely resembles the feldspathic rock and shows the same type of occurrence, so that it is believed to be the same. Still another occurrence of similar material is exposed in the tunnel of opening 2, where an opaque whitish to gray chert has irregularly replaced a 1-foot bed of dolomite that is somewhat coarser-grained than the rest of the dolomite of the mine. This chert carries a little mineral along cracks.

If all of the opaque white chert that occurs at the Salina mine is feldspathic in composition, as some of it certainly is, this feldspar rock shows conflicting relations. Some of it accompanies the ore and has definitely replaced the earlier rock. Some of it, on the other hand, looks as if it may have been formed at an earlier date and been brecciated, while in a rather plastic state, at some time preceding the mineralization. If, however, it is admitted that the feldspar and associated jasperoid quartz could have replaced the earlier rock (dolomite or brecciated sandstone) to form, in a few places, rather sharply defined segregated masses that simulate fragments, then the whole occurrence becomes explainable as a result of replacement of the country rock during the mineralization. The writer is at present inclined toward this view, but more complete investigation at the Salina mine is desirable.

The Salina has produced several carloads of ore, two of which were milled at the Markle mill. Its greatest production came in 1915, 1916, and 1917.

Iola.—This mine is on one of the headwaters of East Sugarloaf Creek, in the SE¼ sec. 35, T. 20 N., R. 18 W. The main working is a tunnel into the hill on the south side of the hollow, about 10 feet above the bed of the branch, at an altitude of 1,110 feet. The length of this tunnel is about 550 feet. Its width is variable, owing to the irregular development of rooms on the east side; perhaps 30 or 40 feet would be an average width of the ore body, but in places the ground that has been worked is 100 feet in width. In addition to the main tunnel, a couple of prospect shafts have been sunk on the north side of the branch a short distance above the main tunnel, and considerable open-cut work has been done at an altitude of 1,120 feet on the north side about 200 feet below the main tunnel.

The geologic relations at the Iola (fig. 18) are complicated by the lack of exposures at critical places. The ore-bearing rock is a fractured fine-grained gray dolomite, about 15 feet thick, that lies near the base of the Everton formation. At the mouth of the main tunnel this bed dips 30°–40° E., but exposures within the mine show that only a few feet to the east of the portal the dip changes to a more nearly horizontal attitude. On the west side of the tunnel some distance back from the portal a lateral incline has been run up the dip (here 15°–20° NE.) for 40 or 50 feet and is connected through to the surface by a raise. The beds along the roof of this incline are nowhere faulted, but along the floor considerable fracturing and some brecciation have taken place, along with some invasion by sand, but without mineralization. In the main tunnel immediately back of this incline, where essentially the same structural conditions prevail, the breccia below the unbroken roof is heavily mineralized for 50 feet or so along the wall. Here the breccia is underlain by a sandstone and limestone mass which has been thrust into the overlying beds, acting as a rigid block in the brecciation without itself being brecciated. The boundary between this mass and the dolomite breccia breaks irregularly across the bedding of the mass. (See fig. 19.) Although a little sand occurs interstitially in the dolomite breccia, sandstone does not appear as breccia fragments, and the limestone is not represented at all in the breccia unless possibly by a few kaolinized fragments of doubtful origin. The unbrecciated character of the underlying mass and the absence of limestone in the breccia suggest at first that the breccia might be due to the collapse of a solution cavern, but the unbroken condition of the roof, considering the fact that it would have had to settle at least 5 or 6 feet according to this interpretation, and the rapid gradation in intensity of brecciation from the contact outward (see fig. 19) both point to an origin by structural movement. On the floor sloping downward from the face shown in figure 19 to the main gangway a breccia of dolomite and limestone fragments in sandstone and limy sandstone is exposed, although the

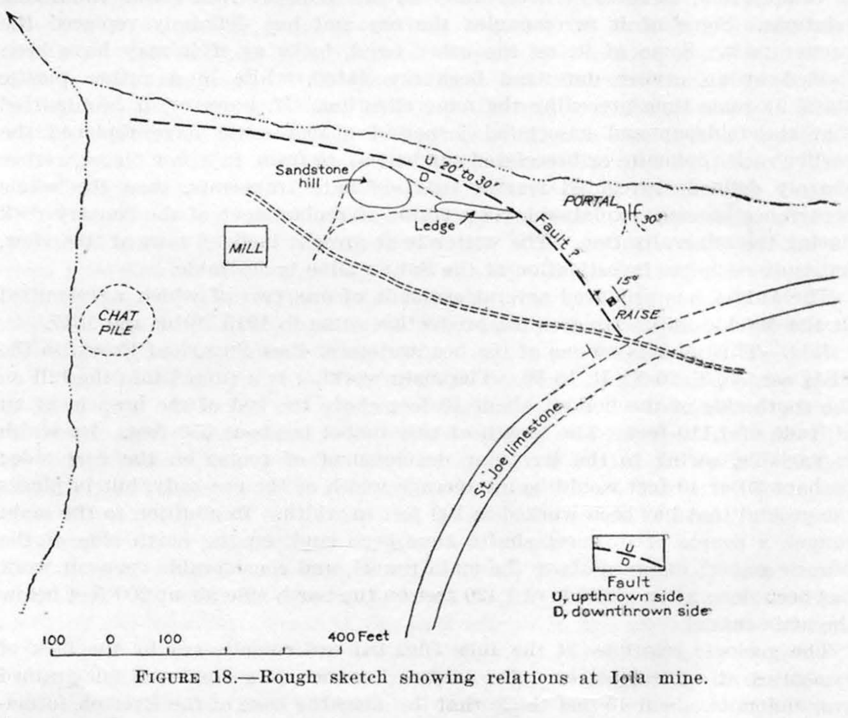

FIGURE 18.—Rough sketch showing relations at Iola mine.

limestone fragments are not very angular, evidently owing to later solution. This is plainly a part of the fault breccia in which the limestone has entered as fragments. The direction of movement is almost if not quite parallel to the bedding.

At the very back of the mine appears another instance of the thrusting of bedded sandstone and limestone below into dolomite above, with brecciation of the dolomite, and to some extent of the other beds. Mineralization here has been very meager.

According to the writer's interpretation, the brecciation was caused by horizontal movement between the beds during the formation of a rather sharp but small and possibly faulted anticline, whose axis lies just southwest of the raise from the lateral underground incline to the surface. The only outcrop along the line of this supposed axis is in a small open cut a short distance to the west of the portal of the main tunnel; it shows the ore-bearing bed decidedly brecciated. The southwest limb of the anticline is well exposed

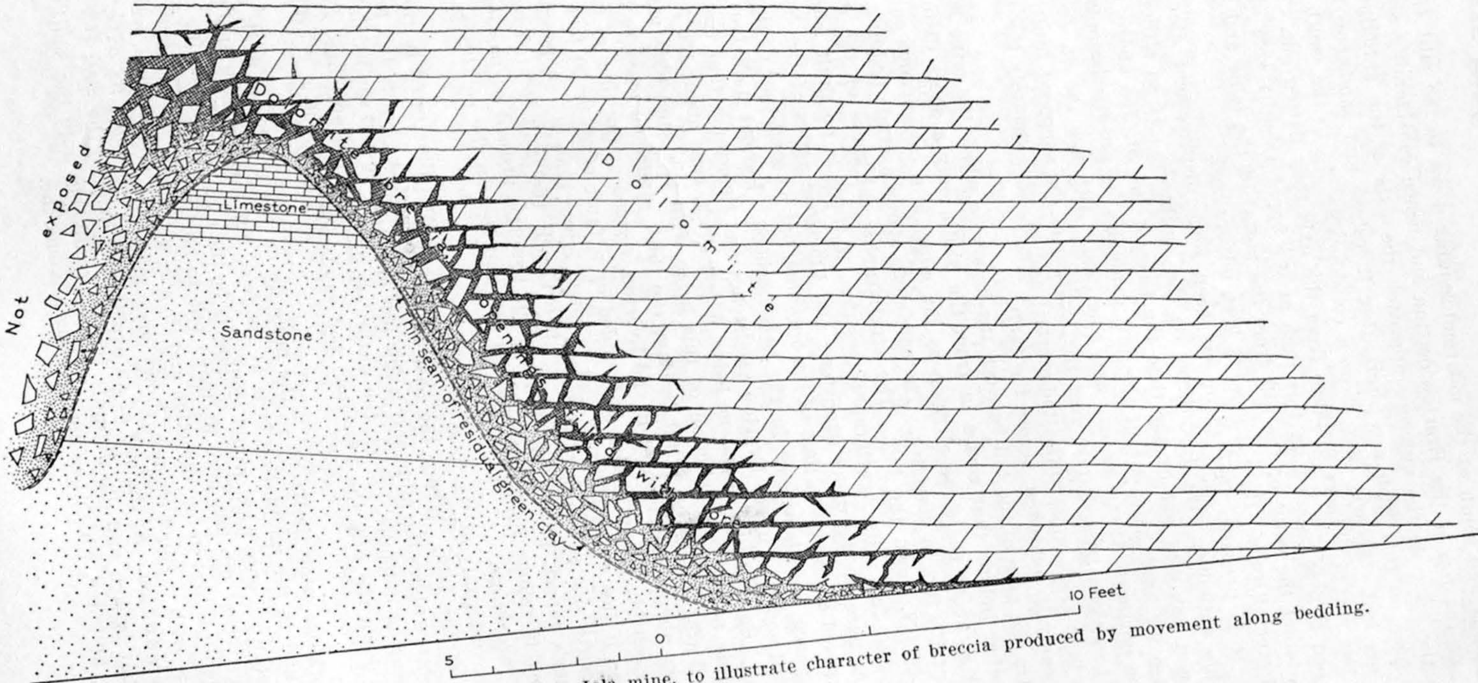

FIGURE 19.—Diagrammatic sketch of wall in Iola mine, to illustrate character of breccia produced by movement along bedding.

along and south of the old road leading down to the mill (fig. 18), but only at the top of the Everton section and hence considerably above the level of the mine do the outcrops approach the axis of the anticline. The exposed beds on this limb are alternating limestone and sandstone that overlie the ore bed. At first they show a considerable dip to the south and southwest, but within a short distance from the axis they flatten out. The ore-bearing bed is first exposed on this limb at the upper (south) side of the chat pile, around the point of the hill from the portal of the mine and at a somewhat lower altitude. Here it has not been mineralized.

It is probable that there has been some displacement along the axis of this anticline, with downthrow on the southwest. If so either the displacement has died out by the time the base of the St. Joe above is reached, or else we have here one of the few examples of pre-Mississippian faulting in the northern Arkansas lead and zinc field. Although the St. Joe limestone is not exposed immediately over the location of the supposed fault, it is present on both sides, apparently undisturbed and in approximately the right attitude to carry it, unbroken, across the fault.

On the nose of the hill between the hollow in which the mine is located and another hollow that comes in from the south, only a short distance west of and at about the same altitude as the mine, is a conspicuous sandstone hill, about 100 feet in diameter. The sandstone shows a crude bedding, which dips 15°–20° N. down the hill. The stratigraphic thickness of the sandstone is about 30 feet. Its stratigraphic position, if there is no fault south of it, is at the base of the upper sandstone and limestone series of the Everton that is exposed on the south limb of the anticline, but no sandstone of this thickness is exposed anywhere else in the neighborhood. Beyond a 50-foot concealed interval south of it are Everton sandstones and limestones that trend directly into it. East of it a sandstone ledge, 5 feet thick, runs about 150 feet toward the mine portal; the junction of this ledge with the sandstone mass is not exposed (fig. 18). The writer believes the thick sandstone mass to be a local and very abrupt development in the Everton, formed at the time of sedimentation. Probably its north side is bounded by a fault of 20 or 30 feet displacement, as it lies at an altitude that is much lower than its supposed horizon on the north side of the hollow. This is evidently the fault located by Purdue (Branner's report, p. 83), but if the fault persists, instead of passing on up the creek it swings southeast into the hill and lies on the southwest side of the mine workings.

The unconformity at the base of the St. Joe is well illustrated in the neighborhood of the Iola. Where the base of the formation crosses the hollow a short distance above the mine only a few feet of limestone and sandstone overlie the ore-bearing dolomite, but on the southwest flank of the anticline, south of the road down the hill, the limestone and sandstone make up a considerable thickness.

The workings near the front of the mine lie on the northeast flank of the anticline and in the undulating beds at its foot, but farther back the tunnel swings southward onto what would ordinarily be the axis of the anticline except that the northeast dip has here flattened out to horizontality. The beds here show gentle dips, first in one direction and then in another. One small syncline, 50 feet wide with a 4-foot closure, shows some brecciation along its axis, with richer mineralization. At the end of an exploratory drift to the west the beds are somewhat broken and dip abruptly down, presumably onto the southwest flank of the anticline, which has here become a monocline.

The ore occurs partly in a true breccia in the dolomite, as already mentioned, but perhaps more of it was originally deposited in rock that was simply shattered without being brecciated. The primary ore mineral is rosin jack, which in places is mottled with black jack. A little galena appears generally in separate cracks from those carrying jack but locally in the same cracks, where it is possibly of later crystallization than the jack. It is reported that one mass of galena weighing 1,200 pounds was taken from a drainage trench a little below the mine level, at the portal of the main tunnel, and other masses up to 400 or 500 pounds were found at the same vicinity and horizon. The chief gangue mineral is white crystalline calcite. Fine drusy quartz is common as the original lining of the cracks. A few of the cracks are filled or lined on the lower side with gray chert, which may or may not carry disseminated jack. In many places this chert can be explained only as due to replacement of the country-rock dolomite and not to filling of a preexisting opening. At one place near the front the limestone along its broken contact with the overlying dolomite breccia has been silicified with the development of a little disseminated jack, but this is exceptional. A little finely crystallized (one-eighth inch or less) pink spar was seen in a few places lining cracks on the dump of one of the shafts, but was not noted in the tunnel. A very little chalcopyrite appears in the main tunnel.

The ore-bearing dolomite, especially the lower part, is heavily charged with organic matter in the main tunnel. In places this has seeped out and has been deposited as small black semisolid globular masses in the cracks in close association with the ore. The deposition of this bitumen preceded that of the calcite, but apparently, though the evidence is not absolutely conclusive, followed the deposition of the jack.

Where surface waters have had access to the ore body near its outcrop and along certain fractures well back from the outcrop, the jack has been altered to carbonate. This has not been extensive enough, however, to be commercially important. A very little zinc silicate appears in the dolomite of a drift toward the back of the mine. This drift further discloses orange-red tallow clay in horizontal and vertical seams in the dolomite. The ore exposed in shattered and brecciated dolomite in the open cut on the north side of the hollow has been largely converted to carbonate. Besides the normal gray crystalline and honeycomb types, some of this appears as fine flesh-colored crusts, made up in part of very fine rods.

Complete figures are not available on the production of the Iola, as the mine has been worked over a long period and by several different operators. An estimate of 800 tons of concentrates, based on known production or lack of production for certain years, reliably estimated production for other years, and an assumed production for two widely separated years, is believed to approximate the true total. Most of the output has been jack, but in 1916 a few carloads of carbonate are reported to have been taken out, presumably from the open cuts on the north side of the hollow.

Tallow Clay.—This claim is in the E½SW¼ sec. 35, T. 20 N., R. 18 W., in the first hollow from the south below the one that contains the Iola chat pile. The workings are all on the west side of the hollow and consist of several old shafts, an old drift, and an open cut, all scattered over a diameter of 200 feet. The geologic horizon is the lower part of the Everton formation. The primary ore was jack, disseminated in a silicified limestone (chert), but the greater part of it has been oxidized to carbonate and silicate. No galena was found on the dump, but a little white chalky anglesite and stains of pyromorphite point to its former presence. The presence of a small amount of copper is indicated by green malachite stains in the oxidized ores. Finely crystalline pyrite occurs in places in more or less open cracks in the chert, evidently one product of the original mineralization. Surface weathering at this locality has obliterated all outcrops and has developed considerable red clay as an alteration product of the chert.

Washington Lead Co.—This mine is on the point of a ridge between two headwater prongs of East Sugarloaf Creek, in the SW¼NW¼ sec. 35, T. 20 N., R. 18 W., at an altitude of about 1,115 feet. The ore horizon is in the Everton formation about 15 feet below the St. Joe. All the workings are now caved, but originally a drift went into the hill for about 200 feet, from the end of which a raise, 45 feet high, was driven through to the surface on top of the ridge. In the open cut at the portal of the drift a shaft was sunk to a reported depth of 30 feet but was barren.

The ore is reported to have been entirely galena. One nugget, taken from the open cut near the portal, weighed 1,800 pounds and was shipped to the World's Fair at St. Louis in 1904. The average nugget size was, of course, much smaller. The ore, as originally deposited, occurs in quartzite and in brecciated fine-grained magnesian limestone which has been invaded to some extent interstitially by sandstone. Cubic galena casts 1 or 2 inches in maximum size are embedded in some of the quartzite on the dump, but more generally the galena occurs in preexisting cracks. A little fine drusy quartz accompanies the lead in the quartzite. Calcite is a fairly common gangue throughout. A stain of pyromorphite occurs in places as a secondary alteration product. Much of the lead that has been taken out occurred in residual clay, produced from the original country-rock dolomite by weathering.

About 200 feet southwest of the main tunnel is a smaller one at the same level; the ore on the dump is galena disseminated chiefly as well-formed cubes in a cherty replacement product of limestone.

The greater part of the production from the mine, amounting to about 75 tons of free lead ore, was made between 1910 and 1915.

Black Bear.—The developments here consist of a shaft about 85 feet deep, sunk in the bed of a hollow tributary to East Sugarloaf Creek in the NW¼NW¼ sec. 27, T. 20 N., R. 18 W. The altitude is about 875 feet. It is reported that drifts were run north, south, east, and west from the bottom of the shaft, about 80 feet in each direction. The horizon is in the Cotter formation, the shaft collar lying about 125 feet below its top. The ore is jack and occurs as rather fine crystals in cracks in a fine-grained dolomite. Although this property at one time had a mill on it (built in 1907–8), the ore proved to be of very low grade, and no production was ever made.

It is reported that the wash below the Black Bear shaft yields a varying supply of galena nuggets, of unknown source, after each period of heavy rains.

WEST SUGARLOAF CREEK-MALDEN CREEK DISTRICT

The district embracing the headwaters of West Sugarloaf and Malden Creeks lies in northeastern Boone County. The deposits occur in the †Black Ledge of the Powell dolomite, and in a similar bed, not quite so thick, lying about 30 feet lower in the Powell. The Bryan & Snyder prospect and one level of the Elixir are opened in beds of the Cotter dolomite. The ores of the district are jack and carbonate. The production has been probably not more than 200 or 300 tons, chiefly carbonate.

Elixir.—This property is in the NE¼ sec. 36, T. 20 N., R. 19 W., in Elixir Springs Hollow, one of the small headwater tributaries of West Sugarloaf Creek. The workings are near and on the north (upthrown) side of a small fault that shows a displacement of about 50 feet on the hill to the west. The fault bears slightly north of east. Beds at two horizons have been worked for mineral. The lower one is somewhere in the Cotter and was worked through a shaft on the left bank of the hollow, 10 feet above its bed. The collar of the shaft is at the Powell-Cotter contact, at an altitude of 990 feet, but the depth of the shaft was not learned. The ore as exposed on the dump is very lean and consists of thin seams of galena, occupying cracks in a fine-grained dolomite that contains a few small solution pockets lined with fine drusy quartz. It is reported that much of the galena taken out of the shaft was found in the form of free masses embedded in red clay. A 160-foot churn-drill hole near the shaft and a similar drill hole 500 feet upstream are reported by B. J. Rosewater, of Eureka Springs, to have shown rosin jack below the galena.

The upper horizon of the Elixir is in the Powell dolomite 35 feet above its base. The ore bed is worked through a series of five or six small, irregularly branching tunnels that are located for 400 or 500 feet down the hollow from the shaft, on the same side of the hollow. These tunnels penetrate the hill to distances of 200 to 300 feet. The ore bed is 5 feet thick and is a medium-grained dolomite that contains solution cavities lined with fine drusy quartz. A little greenish chert occurring in the dolomite is not evidently related to the mineralization. The ore is chiefly gray and flesh-colored crystalline zinc carbonate, with some black carbonate and a little black and colorless crystalline silicate. A little jack, residual in the carbonate, is rosin-colored. A trace of copper in the ore appears in the jack as chalcopyrite and in the black carbonate as malachite. The ore minerals occupy irregular solution pockets scattered sporadically in the dolomite. These workings are reported to have produced about 75 tons of free carbonate during the early part of the World War.

Bailey.—The main workings on this property are a series of shallow open cuts over a diameter of 200 feet, on the right bank of the right one of a group of hollows that converge to form West Sugarloaf Creek about a mile below Elixir Springs. The cuts lie at an altitude of 970 feet, perhaps 15 or 20 feet above the bed of the hollow, in sec. 30, T. 20 N., R. 18 W., near the middle of the south line. The ore horizon is in the Powell dolomite, apparently in the same bed that carries the ore in the upper workings on the Elixir property. The ore bed is medium-grained massive dolomite that contains solution cavities lined with fine drusy quartz. The ore is jack (mixed rosin and black) and zinc carbonate, in about equal proportions. The carbonate is chiefly of the gray crystalline type which commonly contains unaltered kernels of the jack. Other forms of carbonate, appearing in subordinate amounts, are the gray honeycomb type, the fine opaque flesh-colored rod type, and turkey fat. The ore occurs in irregularly distributed solution pockets, ranging from several inches to a foot in longest dimension. Greenish chert lenses are scattered through the dolomite and are especially prone to occur bordering the jack masses, particularly on the lower sides. A small amount of pyrite developed with the ore tends to occupy the borders between the jack and chert.

Less extensive workings at the same horizon on the opposite side of the hollow produced chiefly zinc carbonate.

The Bailey workings have produced 40 or 50 tons of high-grade ore. They are somewhat richer in appearance than most of the other workings in the Powell that show the same type of ore occurrence.

Rock and Ore.—This property is in a hollow that enters West Sugarloaf Creek from the left a short distance below the point where Elixir Springs Hollow, draining northeast, joins several other hollows to form the head of West Sugarloaf Creek, which flows northwest. The property is probably in the SE¼ sec. 25, T. 20 N., R. 19 W. The workings are in the †Black Ledge 60 feet above the base of the Powell, on both sides of the hollow, at an altitude of 975 feet. On the right side a tunnel enters the hill to a distance of 90 feet, with a raise to the surface 55 feet back. Two small open cuts have been made 360 and 460 feet upstream from this tunnel. On the left side of the hollow two closely adjacent open cuts, both about 8 feet wide, have been made into the hill to distances of 20 and 30 feet. The best ore shows in the ore piles on this side, though the exposed walls of the open cuts are of low grade.

The ore-bearing ledge is 8 to 10 feet thick and consists of medium-grained massive dolomite, very porous from abundant small solution cavities that are lined by fine drusy quartz. The ledge on the left side of the hollow is broken by a system of joints running N. 15° W., but these do not appear to be related in any way to the mineralization. The ore is chiefly gray crystalline or honeycomb zinc carbonate and occurs as a filling of scattered solution pockets in the ledge. A little mixed black and rosin jack is residual in the carbonate. At the farthest upstream cut on the right side of the hollow the residual jack is red-brown. Thin shells of eggshell carbonate coat some of the gray carbonate masses on the left side of the hollow.

Empire.—The Empire opening is on a hillside facing northwest, overlooking a headwater prong of West Sugarloaf Creek. It lies in the SE¼SE¼ sec. 26, T. 20 N., R. 19 W. The opening is an open cut, about 40 feet in diameter, in the †Black Ledge, which is here about 55 feet above the base of the Powell dolomite. Part of the ore also occurs in a "cotton rock" (fine-grained dolomite) immediately underlying the †Black Ledge. The ore consists of gray and flesh-colored crystalline zinc carbonate and gray honeycomb zinc carbonate and occurs as irregular replacement masses in the dolomite. A little residual red-brown jack is present. Perhaps the most distinctive feature of this deposit is the large amount of pyrite that occurs finely scattered through segregated bodies of chert at the "cotton rock" horizon. The pyrite is so finely divided as to color the chert black. Upon weathering, a conspicuous limonite stain develops and may invade the adjacent "cotton rock", coloring it buff. Perhaps the greater part of the chert that forms segregations in this bed, however, is nonpyritic and greenish. Some of this chert forms the matrix to a fine-grained dolomite breccia, but it was not observed in place.

Willis.—This property lies in the NW¼NW¼ sec. 22, T. 20 N., R. 19 W., at the south end of an outlying hill between two prongs of West Sugarloaf Creek. This hill is composed of Powell dolomite and is capped by Boone limestone and chert. The ore deposit is in a 3-foot ledge of dolomite, lying in the Powell 25 feet above its base. It has been worked over an outcrop length between 200 and 300 feet by a series of tunnels and open cuts. One tunnel, at the west end of the group, is 70 feet long and is preceded at its portal by an open cut 70 feet long and 15 feet wide. The most extensively worked opening is a tunnel lying 200 feet east of the one just mentioned, but it was full of water at the time the property was examined.

The ore-bearing bed is medium to rather fine grained and contains numerous solution cavities lined by fine drusy quartz, as well as scattered lenses of greenish chert. The ore is mixed black and rosin jack and zinc carbonate. It occurs in scattered solution pockets through the rock. The carbonate is dominantly of the gray crystalline type, but some is of the gray honeycomb type, some is black, and some consists of an aggregation of fine opaque salmon-colored rods. The ore is associated in places with rather coarsely crystalline calcite, and a little malachite is speckled through the black zinc carbonate. The main, easternmost tunnel is reported to have produced more jack than carbonate. The production has not been very great.

Bryan & Snyder.—On this property, which is probably in the SW¼SE¼ sec. 21, T. 20 N., R. 19 W., though possibly in the next 40-acre tract to the north, three short tunnels have been driven from the level of the branch bed into the east bank of a small branch that drains northward into one of the west prongs of West Sugarloaf Creek. The tunnels are only 25 or 30 feet in length, and they lie along a stretch of the branch only 100 feet or so long. For about 50 feet downstream from the northernmost tunnel there are also open-cut workings from which most of the ore was taken. The horizon is in the Cotter dolomite 40 feet below the Powell. The ore is rosin jack, with a little black jack, and occurs, without gangue, as a filling of irregular cracks and pockets in fine-grained dolomite, or in scattered flint nodules in the dolomite. Some of the ore masses are several inches in size. A little of the jack has been oxidized to crusts of gray crystalline carbonate.

Silver Fox.—This opening lies in the NE¼NW¼ sec. 28, T. 20 N., R. 19 W., on the west side of a ridge between hollows tributary to a west prong of West Sugarloaf Creek. The opening is a tunnel running 120 feet into the hill, with numerous lateral prongs. The horizon is a 4-foot ledge of medium- to fine-grained dolomite, lying 20 feet above the base of the Powell dolomite. Masses of greenish flint occur at the top of the ledge, and solution vugs, lined in part with rather fine crystalline dolomite, appear throughout. The ledge is evidently the same one that carries the ore at the Jackson opening, a mile or so away. The ore is chiefly crusty gray and black zinc carbonate in irregular and scattered pockets as much as 2 feet across; there is also some crystalline gray carbonate and a little crystalline silicate. Residual rosin jack is associated in appreciable amounts with the carbonate. The black carbonate contains specks of malachite in rather greater abundance than is common for the northern Arkansas region.

Jackson.—The Jackson opening lies in the NW¼SE¼ sec. 20, T. 20 N., R. 19 W., on the slope of a point between two hollows that form part of the headwaters of a west prong of West Sugarloaf Creek. The horizon is in the Powell dolomite 25 feet above its base. The working is a small open cut 25 feet in diameter, with two tunnels, 20 and 30 feet in length, driven from the back. The ore-bearing ledge is 4 feet thick and is a massive medium to rather fine-grained dolomite, containing small vugs lined with fine drusy quartz. Greenish chert lenses appear in the upper part. The ore is beautifully crystalline gray zinc carbonate, containing in places a coating or a layer of turkey fat, and occurs in irregularly scattered solution pockets in the dolomite. Some of the carbonate is of the coarse honeycomb type, and a little is black. The black variety may contain small specks of malachite. Some salmon-colored massive opaque carbonate is reported to have been taken from the property. The marketed output during the World War was about 4 tons.

Red Fox.—This property is in the SW¼SE¼ sec. 7, T. 20 N., R. 19 W., on the point between two headwater branches of Malden Creek. Ore appears at two levels in the Powell dolomite—in the †Black Ledge, 60 feet above its base, and in another ledge, 25 feet above the base.

At the upper level an open cut has been made for 100 feet along the outcrop, barely around on the south side of the point. From the cut two tunnels have been driven, the west one 50 feet and the east one with two equal prongs, each 40 feet. Besides these main workings there are smaller open cuts at the same level around the point of the hill to the west. The †Black Ledge in these workings is medium to rather fine grained and contains a few segregated masses of greenish chert and also druses lined with rather small dolomite crystals and fine drusy quartz crystals. The ore is largely well-crystallized gray zinc carbonate, with a little interlayered turkey fat, and fills irregular solution pockets in the rock. These pockets, in the rock remaining on the dump, are commonly as much as a foot in length, but it is reported that most of the production of the property (about 8 tons shipped) came out of a few large pockets that were considerably larger. Most of this ore came from the west prong of the east tunnel. The ore in the rest of the workings was of rather low grade. Shells of white eggshell carbonate coat or are layered in much of the gray carbonate, and it is reported that some white "ash ore", probably this mineral, was taken from the mine and sold at $70 a ton at one time during the World War. A very little residual jack is black.

Workings at the lower level consist of open cuts around the point of the hill, 500 to 600 feet west of the upper workings. The rock is medium to fine grained dolomite and is massive. The ore occurs in scattered pockets in the rock. Although a little residual black jack can be found, most of the ore is zinc carbonate. In addition to the normal gray crystalline type of carbonate, which is well developed, much of the ore is massive, salmon-colored, and opaque. This variety appears to be simply a more massive form of the type, fairly common elsewhere, that is made up of an aggregation of fine opaque flesh-colored or salmon-colored rods; a little of that type is developed here along with the massive phase. An uncommon type of carbonate appearing at this lower level is pisolitic, resembling fish roe.

Low Gap.—This old-time prospect is in the NE¼NW¼ sec. 8, T. 20 N., R. 19 W., on the west side of a long ridge running north from Bergman and just south of a prominent gap near the end of the ridge. The ore is found in the †Black Ledge of the Powell, lying 50 feet above the base of the formation. It is fine to medium grained dolomite and contains druses lined with finely crystalline quartz and also lenses of greenish chert, apparently unrelated to the mineralization. The ore is of low grade and consists of zinc carbonate, some galena, and a little residual red-brown jack, all in solution pockets in the ledge. The carbonate is of the well-crystallized gray type, or it may be coarse honeycomb, or opaque flesh-colored and crusty, or an aggregate of fine flesh-colored rods. The opening is a tunnel that goes in 40 feet, with a short raise to the surface at the end.

Morelock.—This opening, made in 1927, is in the SW¼SW¼ sec. 5, T. 20 N., R. 19 W., on the east slope of a small hollow tributary to the headwaters of Malden Creek. It is a large open cut, 50 feet in length along the contour of the hill, 20 feet wide, and 8 feet deep at the back. The ore bed is 3 feet thick and lies just above the floor of the pit. It is a fine-grained massive dolomite, slightly vuggy in places, the vugs lined with rather small dolomite crystals. The horizon is in the Powell dolomite 35 feet above the base and 15 feet below the †Black Ledge. The ore consists of black jack and galena associated with a litte calcite and occurs in haphazard cracks; the galena also as irregular chunks in the rock. Much of the black jack is bordered, where it joins the dolomite, by a thin zone of red-brown jack. A little finely crystalline pyrite may occupy the border between the jack and the country rock, and a trace of chalcopyrite, as minute crystals, occurs in some of the dolomite vugs.

SHORT MOUNTAIN DISTRICT

The Short Mountain district lies in northern Marion County, northeast of Monarch, and includes Short Mountain and Little Beach Ridge and the headwaters of East Sugarloaf Creek that drain their south sides. The deposits occur in the Powell dolomite, the more productive ones in the †Black Ledge. The ores include lead sulphide, zinc carbonate, and some jack. Lead was mined on Short Mountain as early as 1870, but the total production from the district has been not more than a few hundred tons, consisting chiefly of galena.

Rising Sun.—This property contains workings at two separate localities, probably in the W½ sec. 16, T. 20 N., R. 17 W.

A shaft, reported to be more than 100 feet deep, was sunk near the bottom of a hollow that drains into East Sugarloaf Creek from the south side of Little Beach Ridge. This shaft is at an altitude of 1,025 feet, near the head of the hollow. A second one, not quite so deep, was sunk in the very bottom of the hollow less than 100 feet away. Both of these shafts must have terminated at a horizon near the base of the Powell dolomite. The only ore is a little rosin jack with a very little black jack intermottled; it occurs disseminated in small grains in fine-grained dolomite. The prospect is of extremely low grade.

A second set of openings has been made in the bed of the first tributary hollow that comes in from the left below the shafts mentioned above. These openings are some distance up from the main hollow. They consist of a small open cut in the bed of the hollow and a shallow shaft sunk from a point about 10 feet above the hollow on the right side. The ore is chiefly a good grade of gray and brownish-gray crystalline and honeycomb carbonate, but a considerable proportion of black jack occurs in rather large chunks. Some of the jack masses are 1 foot across in two dimensions but thinner in the third one. The ore-bearing rock is a medium-grained dolomite, probably the †Black Ledge of the Powell, although outcrops are too poor to determine this point definitely. A few tons of fairly good grade ore lies on the dump.

The Rising Sun property is reported to have produced lead from a 200-foot tunnel prior to 1905. The site of this early working was presumably not located by the writer.

Arthur.—This property lies in sec. 5, T. 20 N., R. 17 W., at the north end of Short Mountain, near the point where the highway descends to Peel. There are several workings, all in the †Black Ledge of the Powell.

1. The southernmost opening is a straight tunnel that penetrates for 70 feet into hard rock. It lies at an altitude of 1,030 feet, on the steep eastward-facing scarp of the mountain, about 200 feet below the point where the highway leaves the ridge to descend to Peel. The tunnel is on the upthrown side of a 40-foot fault that crops out less than 100 feet south of the opening. The fault has been located at only this one point, so that the direction of its course could not be determined, but it appears to run about N. 60° W., nearly parallel to the direction of the tunnel.

The ore occurs in disconnected solution cavities, as much as 2 or 3 feet across, in the medium-grained porous dolomite, chiefly in the upper 3 feet of the 6-foot interval shown in the walls of the tunnel. The roof rock is a very fine grained bedded dolomite. At 15 feet from the back of the tunnel a small fault, with a downthrow on the back side of 1 foot, breaks diagonally across the line of the tunnel. A zone 5 feet wide, bordering this fault on the front (upthrown) side, is somewhat more mineralized than the rest of the mine, although even this is of comparatively low grade. The ore is chiefly galena with some black jack and gray zinc carbonate, associated with calcite and pinhead-size drusy quartz. Both the galena and the jack are generally without external crystal form, but the calcite may appear as dogtooth (scalenohedral) crystals. The lead and jack masses attain 3 or 4 inches in size. The quartz lines all the pockets, whether they carry mineral or not. A little malachite shows in some of the jack in which alteration had just begun.

This tunnel is the latest one worked on the Arthur property, having been driven during the period of high prices in the early years of the World War. The production was about 4 tons.

2. Beginning 200 feet north of the tunnel above described, a series of old-time shafts are strung along the hill for about 150 feet. These shafts are in clay, and many of them were originally connected below, at the ore horizon in the †Black Ledge, by cross drifts that pursued a very irregular course from one shaft to the next. Most of the shafts are about 30 feet deep. These shafts were among the first worked in northern Arkansas, having been opened up about 1870. The ore is galena and occurs chiefly in clay. A few residual boulders of fine-grained dolomite, containing seams of calcite, were encountered in the underground drifts. The lead from these shafts was reduced at a smelter at Blackwell Spring, near Monarch, between 1871 and 1874. Branner reports that this and another smelter near Lead Hill produced 52 tons of pig lead. It is not known how much of the ore came from the Arthur shafts, but probably the greater part of it did.

3. About a quarter of a mile northwest of the old shafts, on both sides of the road descending to Peel, several shallow open cuts and short drifts were made in the clay at the horizon of the †Black Ledge in the early years of the World War. These openings probably produced more lead than any other prospect on Short Mountain, but the exact amount is not known. It was probably not more than 100 or 200 tons. The galena occurs in clay that contains, besides the galena, numerous crusts of fine drusy quartz, indicating that the original ore occurred in quartz-lined vugs. This clay also contains numerous siliceous fossils, chiefly gastropods.

Thomas Barclay.—This prospect is in the SW¼NW¼ sec. 8, T. 20 N., R. 17 W., on the left hill slope of the hollow that drains the south side of Short Mountain. The altitude is about 1,005 feet. The main drift is apparently in the †Black Ledge of the Powell dolomite. The ore minerals are black jack, galena, zinc carbonate of several types (turkey fat, honeycomb, gray crystal line), and, according to reports, some silicate. The gangue minerals are fine-grained crystalline quartz and, as reported, calcite. A little chert appears in pockets in the country rock. The ore is said to have occurred in clay along a fracture zone followed by the workings. The main drift goes in about 100 feet. About halfway back a shaft was sunk in the floor of the drift to a depth of 60 feet. It is reported that both galena and black jack were taken from the shaft. A mass of boulders on the dump, consisting of an intimate mix ture of chert and pyrite, is reported to have come from the bottom of this shaft. Some of the boulders show cylinders of pyrite, the size of a pencil and smaller, with chert cores, embedded in a chert matrix. These have undoubtedly replaced crinoid stems in boulders of Boone chert that have been carried to a horizon well down in the underlying Powell through underground solution channels.

Cromwell & Cady.—This prospect lies in the NE¼SW¼ sec. 7, T. 20 N., R. 17 W., at an altitude of 1,000 feet, on one of the headwater branches of the hollow that drains the south side of Short Mountain. The ore horizon is the †Black Ledge of the Powell dolomite. The ore is mixed galena and black jack, with considerable honeycomb carbonate. Gangue minerals are calcite and fine drusy quartz. The mineralization is reported to have been localized along a vertical seam, the width of the ore run being about 6 inches. The galena and carbonate tend to occur in clay. The workings consist of a shallow trench, which followed the ore for about 200 feet and then passed into a tunnel, now caved. It is reported that several hundred dollars' worth of lead has been taken from this mine.

Roy.—This prospect lies on the northwest slope of Short Mountain, in the SE¼SW¼ sec. 6, T. 20 N., R. 17 W., at an altitude of 1,070 feet. The ore horizon is in fine-grained gray dolomite in the Powell dolomite, 40 feet below the St. Joe limestone. The ore occurs in the form of a discontinuous vein, from 3 inches to 1 foot wide, along a small vertical east-west fault that shows a displacement of 4 feet, down on the north. The ore mineral is galena, associated with calcite and fine drusy quartz. Masses of galena as much as 6 or 8 inches across are common but are generally made up of several different crystals. The developments consist of a trench, cutting diagonally into the hill for 100 feet, passing at the rear into a small-bore tunnel 70 feet long. The ore vein is well exposed in the front of the tunnel but becomes barren at the rear end. Considerable work, chiefly of a developmental nature, was done on this prospect during the summer of 1929.

GEORGES CREEK-JIMMIE CREEK DISTRICT

The district that includes the drainage basins of Georges and Jimmie Creeks and their tributaries contains a heterogeneous group of deposits. Those on the headwaters of both creeks and their tributaries are in the Everton formation except one in the St. Joe limestone. Most of those deposits in the Everton are in silicified limestone. At the Bear Hill mine the deposit occurs in a fracture zone that cuts both the Everton and the underlying Powell, and it is reported that the fracture is mineralized throughout its developed extent, to a depth of 160 feet. The †Black Ledge of the Powell carries ore on one prong of Georges Creek, on Jimmie Creek, on the west side of Bull Shoals Mountain, and especially toward the head of Wildcat Creek, a tributary to Jimmie Creek from the northwest. From the general vicinity of Kingdon Springs on down the valley of Jimmie Creek numerous deposits are developed in the Cotter dolomite. The production of the district has consisted of jack, silicate, carbonate, and a little lead. Incomplete statistics indicate that the district has not yielded much if any more than 2,000 tons of concentrates.

Bear Hill.—This mine is in the NE¼SW¼ sec. 11, T. 19 N., R. 17 W., on the headwaters of a small southward-flowing tributary to Georges Creek. The collar of the main shaft is a few feet west of and about 5 feet above the bed of a draw, at an altitude of about 1,000 feet. The horizon of the shaft collar is in the Everton formation about 60 feet below the St. Joe. The main shaft reached a depth of 160 feet, with drifts run at the 45-, 90-, and 143-foot levels. The first level, if a thickness of about 120 feet is allowed for the Everton at this locality, was doubtless in the Everton; the second level probably in the Powell; and the third one almost assuredly in the Powell, as is borne out by the character of the dominant ore rock on the dump, a fine-grained gray dolomite of the Powell type. Much of the mineralized rock on the dump is slightly brecciated. The mine is reported to have been developed on a vertical fissure deposit, about 35 feet in width, and mineralized from the grass roots down. The strike of the fissure is about S. 75° E. No displacement could be determined on this fissure at the surface.

The most abundant type of ore fills the openings in the brecciated and shattered dolomite. The chief mineral is a clear crystalline rosin jack, with some black jack admixed. In the more open druses the jack is ruby jack in fairly well formed crystals. Associated gangue minerals are calcite, fine drusy quartz, crystalline dolomite, a little fine crystalline pyrite, and a very little chalcopyrite. In places the matrix of a dolomite breccia is formed in part by chert. A little crystalline silicate and less crystalline carbonate have been formed as alteration products. Another but subordinate type of ore shows the jack in grains averaging a quarter to half an inch but in places reaching 2 inches, disseminated in chert that has replaced the original rock. Locally jack is disseminated in quartzite. In a few blocks on the dump fine amorphous pyrite forms the matrix for light-colored grains of jack, apparently by replacement of quartzite. Jack also occurs, associated with pink spar, filling small pockets and cracks in the quartzite. These quartzite occurrences undoubtedly represent a horizon in the Everton.

This mine was originally equipped with an especially large mill (capacity, 250 tons in 10 hours), which is now in ruins. It produced about 100 tons of jack concentrates from March 1916 until the big shutdown in the middle of 1917. There was, however, some production in 1907 and perhaps earlier.

Old Lead (Butler & Wassel).—These workings lie in sec. 18, T. 19 N., R. 16 W., on the left slope of a fork of Georges Creek. The ore is found in a massive medium-grained dolomite in the Powell, about 50 feet above its base, probably the †Black Ledge. Solution druses in it are lined with finely crystalline quartz. The ore is chiefly galena but includes also black jack and zinc carbonate and occurs in large replacement pockets in the dolomite. Some galena appears also in small veinlets with or without associated calcite. The ore that has been taken out, however, is embedded in the clay and decomposed dolomite along the deeply weathered outcrop of the ore bed. The largest mass of galena noted was a hemispherical mass about a foot in diameter, made up of several large crystals and weighing 50 or 60 pounds. Lead carbonate (cerusite) has formed to a small extent as an alteration product of the sulphide.

The deposit was worked in a small way during 1928 and 1929 through open cuts and short tunnels over an outcrop length of about 400 feet. Each opening was abandoned as soon as fresh hard rock was reached. Several tons of free ore was produced, but the exact amount is not known.

A short stoped-out tunnel in hard rock on the opposite (west) side of the creek, apparently in the same bed, has yielded black jack, gray crystalline carbonate, and silicate. From this opening 450 tons of ore is reported to have been marketed.

A third and much older opening lies on the same side of the branch as the lead workings but a little way south of them and just across a small tributary hollow. It is a 70-foot tunnel with a 30-foot raise to the surface at the rear. The ore is galena associated with calcite as replacement deposits in medium-grained dolomite.

Beaty.—This mine is in the SE¼SW¼ sec. 1, T. 19 N., R. 17 W. The earlier workings were open cuts in the bed of Jimmie Creek. Developments were always hindered by the water problem, as the creek had to be diverted around the workings. Later this mode of exploitation was abandoned in favor of a shaft, which was sunk a short distance upstream on the north bank of the creek, about 10 feet or so above the creek level, at an altitude of 915 feet. This shaft was about 30 feet deep. From its bottom, drifts were run north and south on the ore bed. The north one goes about 100 feet. The south one was terminated at a somewhat less distance from the shaft, owing to the fact that it was run too close to the surface under the creek bed, with the result that a hole was broken through, letting the creek into the workings. One or two prospect shafts have been put down on the north bank of the creek about 300 feet downstream from the main shaft.

The main ore bed is a "blanket vein" deposit in a medium-grained dolomite at the base of the Everton formation. About 400 feet downstream from the shaft, where this bed crops out, it is 8 feet thick but carries no ore. It contains a few thin zones of fine-grained dolomite and is overlain by 9 or 10 feet of rock of the same type, above which comes a 3- to 4-foot ledge of medium-grained dolomite that is ore-bearing between this point and the shaft. This upper dolomite lies just under the level of the creek opposite the shaft and is the bed that has been exploited in the earlier open-cut workings in the creek bed. The ore face in the drifts leading off from the main shaft is reported to be 15 feet high. This would include the fine-grained bed between the two coarser-grained ones, but, considering the great variation to which the Everton is subject, it is possible that the basal bed is much thicker in the shaft than it is at its outcrop. Although some ore on the dump of the main shaft is in fine-grained rock, most of it is in the medium-grained dolomite.

The beds in the neighborhood of the Beaty are somewhat warped and tilted at low angles in various directions. About 300 feet below the shaft the axis of a shallow syncline crosses the creek. The writer does not attach any special significance to this syncline, more than that it is simply one of the elements of the local structure that has produced the fracturing favorable for the emplacement of the ore.

The ore mineral is mixed rosin, black, and ruby jack, occurring in cracks and solution pockets in the country rock, more definitely along cracks in the fine-grained rock. In some places the jack fills the available cavity to the exclusion of other minerals; elsewhere it is accompanied by gangue minerals, chiefly fine drusy quartz and pink spar, but here and there calcite, chalcopyrite, or pyrite, the latter two in very fine crystals. In a few places the pyrite forms a film between the fine-grained dolomite and jack. It also occurs isolated as small splotches in cracks. The ruby jack forms fairly good crystals in solution pockets, and commonly rosin and black jack give way to ruby jack in the neighborhood of vugs.

The Beaty has had two mills in its history. The earlier one, on the south bank of the creek, milled the rock from the open-cut workings. The later one was built alongside of the upper shaft a short while before the break in the price of ore in 1917. The production of the mine has amounted to about 300 tons of concentrates.

Twinkling Star.—This prospect is a small open cut with a 10-foot drift at the back, on the north bank of Jimmie Creek, about 1,000 feet below the Beaty shaft. The ore is found in a fine-grained gray dolomite that has been squeezed, with incomplete brecciation. The dolomite has been extensively altered to pale bluish-white clay which contains rather coarse crystals of dolomite. Commonly the dolomite forms the fragments and the clay the matrix of the breccia. The top part of the ore is in quartzite. The ore zone is 6 feet thick and grades upward into an unmineralized sandstone 4 feet thick. The bedding structure has been destroyed in the clay rock, even where it is not definitely brecciated; this rock grades downward into dolomitic sandstone that forms the basal foot or two of the Everton. The ore is chiefly crusty carbonate in pockets in the clay rock. It contains a little copper carbonate. Some of the clay rock shows the casts of disseminated jack. A little mixed rosin and black jack occurs in sandstone on the dump, having apparently come from the top of the ore bed at the back of the short drift. This sandstone contains streaks of the bluish clay substance.

Stillwell.—This opening is in the NE¼ sec. 1, T. 19 N., R. 17 W., about half a mile below the Beaty, on the north side of Jimmie Creek, 40 feet above the stream bed. The development consists in superficial scratching that has done little more than expose the bedrock. The ore occurs in cracks in a medium-grained gray dolomite at the base of the Everton formation and in the fine-grained dolomite at the top of the underlying Powell. It is mostly gray crystalline carbonate, but a little rosin and black jack with locally a little galena and without gangue appears in the cracks in the Powell.

Big Buffalo.—This property is in the S½SW¼ sec. 5, T. 19 N., R. 16 W., in the first hollow tributary to Brushy Fork of Jimmie Creek from the east. One group of openings, consisting of six or seven open cuts, lies around the mouth of a small ravine from the west over an area 300 or 400 feet wide and a vertical interval of about 30 feet. The base of this interval is about 970 feet above sea level. Another set of openings, consisting of open cuts and a few short drifts, is strung along the east side of the hollow, perhaps 30 feet above the creek bed, for 200 or 300 feet below the mouth of the ravine. Both sets of openings are in the Everton formation about 40 to 70 feet above its base, although these figures can be only approximately correct, as the structure is somewhat disturbed and the base of the Everton has not been reached by erosion in the immediate vicinity. The ore-bearing rock is a chert, about 30 feet thick, resulting from the silicification of limestone. Here and there the chert has replaced quartzite, although incompletely. Much of the chert interval, especially the upper part, is barren of ore. Float blocks of the chert, with or without jack casts, occur along the creek bed for 500 to 600 feet above the openings.

Except in the bed of the hollow there are very few natural exposures in the vicinity of the openings, so that the structure is not very satisfactorily determined. There is a low regional dip to the north, as shown along the hollow between the mines and its mouth. In the vicinity of the mines the structure is gently undulating. In the bed of the hollow, 150 feet upstream from the ravine that contains the west group of openings, the quartzite is brecciated over a width of several feet, but the extent of the movement that produced the brecciation is not evident. In all probability it was slight. The laminae in the chert of the ore-bearing zone show small-scale tiltings, faults, unconformities, etc., but these features were evidently produced by the silicification and are not truly structural phenomena. These disturbances are not so great as to affect the average horizontality.

The original ore was mottled rosin and black jack, which was either disseminated in the chert in crystals as much as three-quarters of an inch in diameter, but averaging half an inch or less, or else concentrated in irregular pockets 2 or 3 inches across, chiefly along bedding planes. The jack has been largely altered to carbonate and subordinate silicate, which fill the leached-out casts in the chert. The carbonate is in part a black crusty type derived from the larger jack masses in place and generally containing residual grains of jack; in part a gray, flesh-colored, and, rarely, yellow (turkey fat) crystalline (botryoidal) type; and in part a matted granular flesh-colored type, in which the granules are minute opaque, capsule-shaped rods. The gangue minerals are fine drusy quartz along the bedding planes and, less commonly, pink spar, which is in part or largely replaced by opaque, flesh-colored zinc carbonate. Both the chert and the cherty quartzite contain partings of a pale-greenish clay alteration product.

The production of the Big Buffalo has been free carbonate ore.

Tolliver.—This is a low-grade prospect on the left side of Jimmie Creek opposite the mouth of Brushy Fork, probably near the southeast corner of sec. 31, T. 20 N., R. 16 W. The opening is an open cut about 50 feet across in solid rock on the steep hill slope about 40 feet above the bed of Jimmie Creek. It is in the †Black Ledge, a massive 10-foot ledge of fine to medium-grained dolomite in the Powell formation, about 50 feet above the base. The ledge is here very porous, owing to the presence of numerous small solution pockets. These are generally lined with fine quartz. The ore minerals are rosin jack, with some darker mottlings, and a larger amount of gray crystalline zinc carbonate. A little malachite is associated with the carbonate.

Onwata No. 1.—This mine is in the NE¼SE¼ sec. 30, T. 20 N., R. 16 W., on the steep west side of Onwata Hollow, at an altitude of 950 feet, about 80 feet above the bed of the hollow. The horizon is in the Everton formation about 35 feet below the St. Joe. Owing to the fact that the tunnel is caved near the portal, the mine itself could not be examined, but the tunnel is reported to be about 350 feet long and to wind irregularly. Above the portal the beds are unbroken limestone and sandstone. In the open cut in front of the tunnel, however, there is considerable breccia apparently in a zone parallel to the face of the hill (N. 30° E.) and transverse to the direction of the tunnel. This breccia shows limestone fragments in a limy sandstone matrix, but it has in places been silicified, with the development of disseminated jack and larger irregular masses of black jack. Much of the jack has been leached or converted to flesh-colored amorphous or fine rod-shaped carbonate. The portal of the tunnel is in a silicified limestone that carries casts of disseminated jack, and evidently this is the bed on which the mine is developed. The chief ore mineral showing in the chert of the portal is white and black crystalline silicate, the black containing a few green specks of malachite. A small amount of gray crystalline carbonate is also present. A few ¼-inch cubic casts in the chert indicate that a little galena was originally present. A large amount of tallow clay is reported to have been found in the mine, along with the oxidized ores. The production of the mine was essentially silicate, but it contained some carbonate. The total is not known, but the production for 1915 was 145 tons and for 1917 about 90 tons. The mill on the property has been burned down.

Onwata No. 2.—Several small drifts have been run into the hill about 500 feet north of Onwata tunnel 1. Most of them are barren. The largest one goes in about 50 feet through barren limestone but reaches the base of an ore-bearing silicified body at the back end. This body is about 15 feet thick and is much wider in its upper than in its lower part. Most of the workings are in its upper part over a diameter of 35 or 40 feet, and these connect with the surface by means of a second drift about 10 feet higher than the first one. This upper level is in the Everton formation about 25 feet below the St. Joe limestone. The chert beds carrying the ore are somewhat contorted. They thicken and thin irregularly and contain numerous large solution cavities. All the deformation of the beds can be explained by solution during silicification. Considerable alteration to clay has taken place under present weathering conditions, and much of the clay is clean enough to be classed as a tallow clay. The primary ore mineral was jack, which originally occurred as large crystals in the solution cavities. All of it has been oxidized to black silicate and less abundant black carbonate. A little aurichalcite occurs as a final incrustation on black silicate. Coarse calcite crystals (scalenohedrons, 6 inches across) appear in some of the large pockets, generally surrounded by clay. They may be incrusted by crystalline silicate. The ore on this level is very spotty in distribution, and much of the workings shows barren chert walls, without even disseminated jack.

Big Elephant.—This property is on a high southward-facing point between two prongs of Onwata Hollow, in the SW¼NE¼ sec. 30, T. 20 N., R. 16 W. The mineralization has occurred along a vertical north-south fracture that cuts both the St. Joe limestone and the very top of the underlying Everton formation, but most of the ore appears in the St. Joe. The fracture is marked by a certain amount of crumpling, but there is no evident displacement at the base of the St. Joe. The fact that large blocks of the St. Joe are interkneaded with Everton sandstone, 10 feet below the base of the St. Joe, indicates that there was some slumping along the fracture, possibly from solution either during or before the mineralization. The limestone of both formations in a zone about 15 feet wide along the fracture has been silicified to chert. The openings consist of a 60-foot shaft in the St. Joe (altitude of collar, 1,030 feet) and two rather small open cuts at different levels (1,010 and 990 feet) in the rock below, the lower cut along the St. Joe-Everton contact.

The primary ore minerals are jack and galena disseminated in the chert. The galena appears as cubic crystals a quarter of an inch to 1 inch in size. The jack is mixed rosin and black, the latter predominating, and the crystals are mostly between a sixteenth and a quarter of an inch in size, but a few reach 1 inch. Considerable leaching and oxidation have occurred. Zinc silicate is a very common alteration product; zinc and lead carbonate less so. Traces of malachite and aurichalcite appear in the oxidized ores. The only ore noted in Everton chert was minutely crystalline zinc silicate and a small amount of carbonate in the form of fine flesh-colored rods. Jack casts appear in some of the chert, however.

In addition to the mineralization along the fracture there has been local silicification, with the development of small segregated masses of black jack, along the bedding of a limestone about 25 feet below the top of the Everton formation, 200 feet west of the fracture deposit. A little fine chalcopyrite is embedded in the jack, which has been largely oxidized to black and gray carbonate and to black, flesh-colored, and colorless crystalline silicate. A little malachite stain occurs with the black silicate. The gangue mineral is calcite.

A drift only a few feet long has been driven on this deposit, which is of very slight extent.

Another deposit occurs in the base of the St. Joe limestone on the left side of a small draw 400 feet northwest of the fracture deposit. The beds are somewhat jumbled, but some of this condition may be due to surface weathering. Both jack and galena were originally disseminated in the chert that replaced the limestone, but both have been leached out. Most of the jack has been converted to crystalline silicate. Some of the chert shows well-defined casts of dogtooth spar (calcite). A small open cut and a drift a few feet long at its back are the only developments.

Big Buck.—This opening is up an east tributary of Onwata Hollow that enters the main hollow at the Onwata mine. The Big Buck workings are on the east slope of this hollow, about 50 feet above its bed, at an altitude of 985 feet. The main working is a drift, now caved, that has been driven in Everton limestone. The roof of the drift is about 20 feet below the St. Joe. The beds are tilted a few degrees to the south but are apparently unbroken.

The ore-bearing rock on the dump is chert, formed by replacement of the limestone. The chief ore minerals are galena, black jack, and zinc silicate. The galena is disseminated in the chert as crystals 1 inch or less in size, or it may occur on free surfaces along parting planes in the chert. The jack or its casts are commonly a quarter to half an inch in size, but some masses measure 3 or 4 inches. The dominant black jack may carry a little rosin jack. Some of the coarser jack contains a little chalcopyrite, which has altered in place to malachite while the enclosing jack was altering to black silicate. A little zinc carbonate occurs with the silicate.

North Star.—This prospect is in the eastern part of sec. 9, T. 19 N., R. 16 W., on the steep north slope of a hollow tributary to Moccasin Creek from the west. The horizon is in the Everton formation 80 feet above the base. The workings consist of an open cut with a tunnel at the back, now caved. The ore-bearing rock was originally a mixed limestone and medium-grained dolomite, the latter massed chiefly at the base of the mineralized bed, though grading up into the limestone. Both phases were partly silicified along bedding planes by the mineralizing solutions, but the dolomite, apparently as a result of its greater porosity, was invaded to a greater extent. The ore consists of mixed rosin and black jack and carbonate and is disseminated in the chert. In the formation of the carbonate the jack was leached out, leaving the chert honeycombed with casts. The ore zone is only a few feet thick and is capped by 3 feet of sandstone.

Some ore was shipped between 1914 and 1917. J. H. Hand, of Yellville, reports 60 tons in 1917.

Blue Flag.—This property is in the NE¼NW¼ sec. 4, T. 19 N., R. 16 W. The developments consist of three small tunnels, none of them more than 100 feet in length, and an open cut about 50 feet in diameter and 25 feet deep at the back. They are strung along the hillside over a length of about 500 feet, high on the west side of a hollow tributary to Jimmie Creek from the south. The altitude is around 950 feet. The country rock was originally limestone and sandstone of the Everton formation, but both have been more or less silicified to chert. In the front of the open cut there has been some brecciation, but the character of the movement that produced it could not be determined. In this breccia part of the limestone is unaltered, but more of it has been silicified along with the associated sandstone fragments, with the development of some disseminated jack. The jack has been altered to crystalline silicate. The black silicate, derived from jack in place, carries a few specks of malachite. The dumps of the tunnels to the northeast show that the ore was here both crystalline silicate and fine granular or earthy flesh-colored carbonate. The original source of the zinc was disseminated jack in the chert, but the jack has been leached out, leaving only the casts. Considerable red clay has developed as a weathering product in the tunnels, and it is reported that the ore produced from these openings occurred largely as disseminated silicate and carbonate in this clay, but partly also in larger chunks (free ore).

Homestake.—This is an old-time shaft, reported to be 109 feet deep, situated 400 or 500 feet east of Moccasin Creek, a few feet above the bottom of a small draw, in the SW¼SE¼ sec. 3, T. 19 N., R. 16 W. The altitude is 720 feet. The shaft is now filled with water within about 30 feet of the collar. It is in the Cotter dolomite, the collar being about 40 feet below the top of that formation. What little ore shows on the dump is crystalline ruby jack occurring without gangue in cracks in medium-grained dolomite. The ore-bearing bed carries the nodular chert characteristic of the Cotter, and some of the ore is found in cracks in this chert.

Olympia.—The opening on this property is a shaft on the south side of Jimmie Creek, 15 or 20 feet above water level, in the NE¼SE¼ sec. 33, T. 20 N., R. 16 W., about a mile above Kingdon Springs. The shaft was sunk on the basis of the record of several drill holes in the vicinity and is reported to be 96 feet deep. Ore was encountered at 82 feet, and at that level a drift was run east for 100 feet and then north for 50 feet. The ore was of too low grade for the mine to pay and no work has been done since 1909. Operation was seriously hampered by an excessive flow of ground water.

The ore horizon in the shaft is in the Cotter dolomite 150 feet below its top. The ore-bearing rock is a fine-grained dolomite ("cotton rock") that is in part oolitic. Ruby jack, in ¼-inch to ¾-inch crystals, occurs in thin cracks in the dolomite in association with fine drusy quartz and a little marcasite. A small amount of interstitial chert in the dolomite contains a little microscopic feldspar (adularia). No ore was ever marketed and the material on the dump shows less than 1 percent of jack.

Monkey Hill.—This mine is on the south bank of the east fork of Mitchell Creek, 200 to 300 feet above the forks, in the NE¼SE¼ sec. 2, T. 19 N., R. 16 W. The chief working is a shaft (altitude of collar, 720 feet) sunk from a point a few feet above the level of the creek to a depth of about 120 feet. Two ore runs were penetrated. A low-grade run at the bottom of the shaft, after being prospected by a short drift, was abandoned in favor of an upper one at the 50-foot level. At this level a large oval room was cut out southwest of the shaft, its longer axis extending about 150 feet southwest from the shaft, and a smaller irregularly elongated room was cut southeast of the shaft to a distance of 130 feet. The average ore face is about 6 feet, except in the southeast room, where an additional 4 feet has been taken from the floor.

This ore run is in the Cotter dolomite about 100 feet below its top. The ore is ruby jack and occurs as rather small crystals (maximum half an inch) in ¼-inch to ½-inch cracks and crevices of the shattered fine-grained dolomite. Some also occurs in the crevices of the nodular banded chert contained in the dolomite. As a general rule, the crystals of jack are loosely attached to the walls of the fracture, so that they are easily broken out of the rock during the milling. Locally, the jack is massive and may completely fill a crack for 2 or 3 inches without developing any definite external crystal form, although the cleavage shows that the whole mass is part of a single crystal. A few blocks on the dump show definite though rather obscure brecciation, involving dolomite of both medium and fine grain. The breccia fragments have been so completely recemented along points of contact that if it were not for the variations in texture and the presence of angular interstitial cavities no evidence of the brecciation would be preserved. As a general rule the shattering of the beds has been accomplished without any definite brecciation. A very small amount of brownish-gray carbonate shows in some of the breccia, but it is of no commercial importance.

The only gangue mineral noted on the dump of the main mine is fine drusy quartz which lines some of the cracks in the dolomite and chert, but it is uncommon. A little calcite occurs with the jack on the dump of a small prospect shaft a short distance south of the mine shaft but was not noted on the dump of the main shaft.

The mine was once equipped with a rather small mill, which is now in ruins. Its production has been about 200 tons of jack concentrates, according to Charles LeVasseur, of Yellville.

Erie Ozark.—This mine is on the south side of an east tributary of Mitchell Creek in the NE¼NE¼ sec. 2, T. 19 N., R. 16 W., at an altitude of 745 feet. The opening is a shaft on the gently sloping hillside, 20 or 30 feet above the bed of the creek. The ore is developed on the 120-foot level in the shaft. It occurs in fine-grained Cotter dolomite about 175 feet below the top of the formation. Much of the ore-bearing rock is rather porous, apparently owing to rather extensive leaching by water prior to ore deposition. Some nodular chert is present in the ore zone. The ore is ruby jack, which occurs as small crystals and larger irregular masses (maximum 2 or 3 inches) in cracks and crevices in the shattered dolomite. Some of the more massive jack is rosin-colored, and a little inclines toward black. White calcite is in places associated with the jack. Numerous small solution pockets in the dolomite are lined with finely crystalline quartz, and these pockets may contain small crystals of jack or, rarely, of chalcopyrite. Fine rosettes of pyrite appear in cracks in the dolomite, with or without jack, but they are not abundant enough to affect the grade of ore.

The mill formerly present on the property has been torn down.

Cincinnati Bell.—This property lies about halfway up the slope on the north side of Jimmie Creek opposite Kingdon Springs, in the NW¼NW¼ sec. **35**, T. 20 N., R. 16 W., at an altitude of 810 feet. The workings consist of an open cut 100 feet long following the contour of the hill and 10 or 12 feet high at the back. From the back of this cut two tunnels have been driven into the hill, the left one going in straight for about 125 feet and the east one curving gradually to the left through a distance of 150 feet. The geologic horizon is the † Black Ledge, 60 feet above the base of the Powell. The medium-grained dolomite making up the ledge contains numerous solution vugs, which may be lined with fine drusy quartz, or exceptionally with fine-grained dolomite spar. These vugs generally measure 1 inch or less, but a few reach 3 or 4 feet. The ores are chiefly galena and zinc carbonate, but a little jack is also present. The galena may be embedded as irregular-shaped crystals or as imperfect cubes in the dolomite, or it may line solution cavities. The carbonate forms crusts in druses and along cracks. The jack appears as a filling of quartz-lined druses and also embedded in a gray chert that has replaced the dolomite rather sparingly. It is mixed rosin-colored and black. Some of the black carbonate shows traces of malachite. There is less ore showing in the tunnels than in the open cut on the outside.

Willow Springs (Mitchell?).—This opening is a 40-foot tunnel that penetrates the hill on the south side of Wildcat Creek, 300 to 400 feet up from Jimmie

Creek, in the SW¼SW¼ sec. 25, T. 20 N., R. 16 W. The altitude is 620 feet, 5 feet above the bed of Wildcat Creek. The horizon is about 180 feet below the top of the Cotter dolomite. The mine is in a rather fine-grained dolomite. The ore is mixed rosin and black jack that appears mainly along a cross fracture, 15 feet from the portal. A lateral drift, 20 feet long, has been opened to the right on this run, and what little ore shows in the mine is chiefly on the front wall of this lateral drift and on the wall of the main drift opposite its mouth. The jack occurs in vertically elongated lenses that in cross section may reach 10 inches in height and 4 inches in width. The jack has completely filled the available openings, without gangue minerals. A little of it has been altered to gray crystalline carbonate. A second lateral drift has been driven on the left side of the main tunnel, 25 feet from the portal, to a distance of 30 feet, and at the end it bends forward and breaks through to the surface. This drift was apparently in low-grade ground, though a little ore occurs on the front wall at the junction with the main tunnel. A small vertical fault with an unknown displacement, probably less than a foot, crosses the main tunnel near the portal and has produced a brecciated zone 1 or 2 feet wide without affecting the attitude of the adjacent beds. This breccia is iron-stained but not mineralized. The fault is about parallel to the mineralized fracture. A second fault crosses the main drift near the back end. It shows a displacement of 6 inches, down on the front, but has produced neither brecciation nor mineralization.

Bardeen.—Two shafts have been sunk on the hill on the south side of Wildcat Creek about a quarter of a mile above Jimmie Creek in the SE¼ sec. 26, T. 20 N., R. 16 W. Both are in the Cotter dolomite. The lower one is about 40 feet deep and the altitude of its collar is 650 feet, 30 feet above the creek bed and about 150 feet below the top of the Cotter. The only ore found on the dump was a very small amount of ruby jack in a crack in Cotter chert. The upper shaft is about 50 or 60 feet deep, and its collar is at 720 feet, about 80 feet below the top of the Cotter dolomite. There is no ore showing on the dump of this shaft, but much of the dump was obscured at the time of visit by the mud that had recently been cleared out of the shaft.

S. P. King.—This prospect lies in a pasture on the south side of and across the hollow from the road between Flippin and Kingdon Springs, probably in the NW¼ sec. 6, T. 19 N., R. 15 W., at the same altitude and apparently at the same horizon as the Nishwitz, described below. The workings consist of an old-time shaft with shallow open-cut trenches above it. The ore is black, ruby, and predominating rosin jack, and occurs in cracks in the fine-grained Cotter dolomite. Some alteration to gray carbonate has taken place. The gangue minerals are fine drusy quartz and pyrite, the latter lying between jack and the country rock. A trace of malachite is associated with black carbonate. The shaft appears to have been barren a short distance below its collar.

Nishwitz.—This prospect is the most promising one that occurs in the Cotter dolomite. It is situated on the head of a small hollow draining west to Jimmie Creek, probably in the SW¼ sec. 30, T. 20 N., R. 15 W. The altitude is around 710 feet. The prospect is in a massive fine-grained dolomite, containing a little gray and whitish chert, that lies about 100 feet below the top of the Cotter dolomite. It is developed by an open cut 80 feet long, 30 feet wide, and 15 feet deep at the back. The shattering that has controlled the mineralization is limited to a 6-foot interval near the bottom of the pit, although both the overlying and underlying rocks seem to be lithologically very similar and would normally be expected to have reacted to stresses in the same way as the ore-bearing bed.

The ore, which is essentially jack, fills the cavities between the dolomite fragments. Faces of jack 6 to 8 inches across are common. The mineral ranges in color from rosin to red-brown and ruby, but the rosin-colored variety is dominant. A little black jack is also present. Some alteration to crystalline or honeycomb carbonate has taken place, especially near the surface. Most of the carbonate is whitish to gray, but a little of it is yellow turkey fat. Gangue minerals associated in places with the ore, but everywhere in small amounts, are fine drusy quartz, lining the cracks, and pyrite, which may form a thin band between the jack and the country rock. The pyrite also occurs in cracks or disseminated in the country-rock dolomite, not in very close relation to the jack. The quartz is sometimes accompanied by chert.

In contrast to the spotty distribution of the ore in so many of the other prospects of the district, the grade of ore runs uniformly high throughout this working. It is reported that ore from this mine was shipped to Joplin and there milled, though the amount could not have been great. Owing to the lack of outcrops, the geologic conditions that have determined the brecciation are not evident, so that it is not possible to predict the extent of the mineralization.

Robinson.—This prospect is on the west side of Bull Shoals Mountain in the SE¼ sec. 19, T. 20 N., R. 15 W., at an altitude of around 880 feet. The horizon is the †Black Ledge in the Powell. The developments comprise a channel cut, about 100 feet long, passing into a 25-foot tunnel at the rear end. The ore consists of red-brown jack (grading into black), and gray crystalline carbonate, which occur in some of the irregular quartz-lined pockets that are so abundant at this locality. The quartz crystals may be as large as a quarter of an inch, but are generally much smaller. Calcite is a minor constituent of the druses, and malachite occurs in traces, generally as a stain in partly altered jack. Much of the drusy quartz is underlain by a rim of chert. This is a very low-grade prospect of little value.

Lost Bell.—Developments here consist of a shaft sunk on a low island in Wildcat Creek, in the NW¼SE¼ sec. 27, T. 20 N., R. 16 W. The altitude of the collar is 695 feet, which is about 70 feet below the top of the Cotter dolomite. The ore occurs in both fine- and medium-grained dolomite, the latter containing blue-gray chert. The ore m'neral is jack, which appears as small (maximum one-quarter inch, average one-sixteenth inch) but generally well-formed clear crystals in cracks in the dolomite and chert. Most of the jack is rosin-colored, but some in the coarser-grained dolomite is ruby jack. The gangue mineral is calcite, which may or may not be present. Some of the medium-grained dolomite carries crystalline quartz (one-sixteenth to one-eighth inch) in small solution vugs, but this rock is not mineralized and may come from a different level than the ore-bearing rock.

Greenhorn.—The developments on this property consist of a series of small open pits and shafts scattered over a length of several hundred feet around the point of the gently sloping ridge between Sister and Cedar Creeks (the latter a tributary of Jimmie Creek), in the N½NW¼ sec. 26, T. 20 N., R. 16 W. The altitude is around 885 feet. The prospect is in the †Black Ledge in the Powell dolomite. The ore is gray carbonate with some residual rosin jack. The carbonate occurs both as the honeycomb type and also as smooth crystalline crusts. Fine drusy quartz underlies some of the carbonate, and a little malachite occurs here and there as specks in black carbonate. Calcite is also associated with the ore, though a minor constituent.

Round Mountain.—This prospect is a small open cut in the †Black Ledge of the Powell, in the very head of a hollow tributary to Wildcat Creek, in the

S½ sec. 22, T. 20 N., R. 16 W. The altitude is about 835 feet. The ore is mixed rosin and black jack and occurs in pockets in the dolomite without the usual drusy quartz association. Some of the jack is altered to black carbonate, which is considerably green-stained from the presence in small amounts of the copper carbonate, malachite. The prospect is not a very promising one.

Big Star.—This prospect is on a left headwater tributary of Wildcat Creek in the SW¼ sec. 22, T. 20 N., R. 16 W. The ore is found in the †Black Ledge of the Powell dolomite at an altitude of 860 feet. The developments consist of an open cut in the bed of the creek, 200 feet long, 15 feet wide, and 10 feet deep at the back, and a shaft on the east side of the hollow about 15 feet above the bed of the creek. This shaft reaches water at the level of the creek bed, below which it is reported to extend 30 to 35 feet farther. The ore is mixed rosin and black jack, in places with some ruby jack, which tends to appear in well-formed crystals. The jack occurs in pockets in the dolomite, associated with fine drusy quartz. In places it has a border of chert along the lower side. Where the jack is developed in well-formed crystals, these commonly show minute crystals of chalcopyrite on their surfaces. Calcite is a minor constituent of the ore-bearing pockets. Very little alteration of the jack to carbonate has taken place, as the ore-bearing bed lies below water level.

There was formerly a small mill on this property, and some ore was milled out, but no record is available of the amount. The chief handicap of the mine is the spotty distribution of the ore within the ledge.

BIG MUSIC CREEK - SISTER CREEK DISTRICT

The deposits lying within the drainage area of Big Music and Sister Creeks and a few prospects along the White River east of Pine Mountain occur in Everton dolomite, in the †Black Ledge of the Powell dolomite, and in the Cotter dolomite. The ores are chiefly zinc carbonate, with some jack and galena. The district has produced probably not more than 250 tons of concentrates, most of which came from the deposits in the †Black Ledge.

Marble Falls.—This prospect is in the NW¼SE¼ sec. 27, T. 20 N., R. 17 W., in the bed of one fork of Big Music Creek, at an altitude of about 930 feet. The original workings consisted of a shaft and a rather small open cut, but both have been largely filled with stream gravel and mud. The ore-bearing bed is a coarse gray dolomite about 3 or 4 feet thick, whose horizon is in the Everton formation, 35 feet above its base and 35 feet below the St. Joe. The ore showing on the dumps is mixed rosin and black jack, in masses as much as 3 or 4 inches across. It is reported that a large mass of black jack, weighing about a ton, was taken from this prospect and shipped to the World's Fair in St. Louis in 1904. Some of the masses showing on the dump are made up of single crystals, as shown by the cleavage of the mineral. The jack is accompanied in places by a little fine dolomite spar, the size of a pinhead. Some slight alteration to brownish silicate has taken place.

McGregor.—This prospect is in sec. 23, T. 20 N., R. 17 W., on the southeast side of a spur ridge between two prongs of Big Music Creek, at an altitude of 930 feet. The horizon is 30 feet above the base of the Everton formation, which is here 55 feet thick. The working is a drift 180 feet long. The ore is galena, originally developed along an obscure discontinuous fracture in a fine-grained gray dolomite. The dolomite has been silicified along this fracture near the front of the drift. Weathering along the fracture produced a clay filling, the limits of which commonly form the natural walls of the drift. The clay contains rounded decomposed pebbles of Boone chert, which have been let down at least 50 or 60 feet. The only ore observed in the drift was an agglomeration, 3 to 4 inches across, of poorly formed galena crystals, the individual cubes averaging an inch or so in diameter. This mass was embedded in clay, and it is probable that most of the ore taken out was also in clay, although a little ore on the dump is in chert. This chert may represent a silicification of the dolomite, but it may have come from the silicification of some of the limestone which lies just above the ore-bearing bed and which may have been reached in some of the higher stopes in the drift. The prospect appears to be completely worked out.

Big Saddle.—This prospect is near the top of a high hill east of and overlooking Big Music Creek, probably in the SE¼ sec. 13, T. 20 N., R. 17 W., at an altitude of about 940 feet. The working is a straight tunnel, 50 feet long, in the †Black Ledge in the Powell dolomite. This ledge is full of solution pockets lined with fine drusy quartz and carries the ore either in these pockets or in similar pockets that do not have a quartz lining. The original ore was a red-brown jack, inclining to ruby, but most of it has been altered to black and gray carbonate. All the residual jack has a thick coat of carbonate. Chalcopyrite is rather more abundant than usual as small blebs embedded in the jack; on oxidation it is converted to malachite. Some greenish-gray chert fills small cracks in the dolomite. This mine has sold several tons of free ore, mostly carbonate, and 3 or 4 tons of marketable ore still lies on the dump.

Houck.—This property is near the end of a long spur running west from John Benton's house, between Dry Music Creek and a tributary of Big Music Creek, probably in the NW¼ sec. 18, T. 20 N., R. 16 W. The altitude is around 910 feet. The developments consist of one shallow shaft and a series of small open cuts that extend for 700 feet along the north side of the ridge near the top; also two or three smaller open cuts at the same horizon just across the ridge on the south side. Another cut has been opened at the same horizon on the nose of the spur, about 1,000 feet farther west. The ore zone is the †Black Ledge in the Powell dolomite. It contains abundant solution pockets, most of which are lined with fine drusy quartz. The ore occurs in certain of these pockets, but in many of them without the quartz lining. It consists of reddish-brown jack, partly altered to gray crystalline or honeycomb carbonate. Fine grains of chalcopyrite are embedded in the jack. There is a little greenish-gray chert in veinlets in the dolomite, many of them horizontal veinlets with fine drusy quartz at the top. About 60 tons of the carbonate, hand-picked, has been shipped from this property.

Compound.—This mine is on the west side of the long ridge leading north to Pine Mountain, in the SW¼NW¼ or the NW¼SW¼ sec. 9, T. 20 N., R. 16 W., at an altitude of about 950 feet, in the †Black Ledge of the Powell dolomite. The opening is a two-pronged tunnel. The right prong is caved but is reported to be 150 feet long; the left prong goes in about 60 feet. The country rock contains numerous solution pockets lined with fine drusy quartz. The ore is chiefly black jack with a little intermixed rosin jack and occurs in these disconnected pockets in masses as much as a foot across. Some of it has been altered to crystalline carbonate and silicate. Malachite stains show in a few places, and white calcite fills certain quartz druses. A little gypsum is associated with some of the black carbonate. A peculiar translucent to opaque greenish-gray to whitish chert completely fills some of the quartz druses or forms masses directly in contact with the dolomite without a drusy-quartz border. It may in turn have drusy quartz lining cracks in it. Certain irregular masses of this chert are 3 to 4 feet across and contain a little disseminated jack; feldspar (adularia) is a microscopic constituent. Much of this chert is iron-stained in splotches, probably derived from pyrite, and clumps of fine pyrite cubes are embedded in the country-rock dolomite.

This mine is reported to have produced about 70 tons of free jack before 1907. There was also considerable mixed jack and carbonate produced in 1915 and 1916.

Keystone.—This prospect is on the opposite (east) side of the ridge from the Compound, in the E½NW¼ sec. 9, T. 20 N., R. 16 W., at an altitude of about 980 feet. The horizon is somewhere in the Powell dolomite but is not exactly determinable on account of poor exposures. The workings consist of two or three old-time open cuts and a shaft, long since caved, all in a rather fine grained dolomite. What little ore remains exposed is gray crystalline and honeycomb carbonate and black jack, the latter in pockets as large as 8 inches. Some calcite and fine drusy quartz are associated with the ore, and a little chert occurs in places bordering it.

Watson.—This property lies across a ridge south of the Compound, in the E½SW¼ sec. 8, T. 20 N., R. 16 W. The working is a tunnel penetrating for about 50 feet into the †Black Ledge of the Powell dolomite, at an altitude of about 940 feet. The ore rock is fine to medium grained dolomite, containing numerous small solution pockets lined with drusy quartz. The original ore was jack, now largely altered to carbonate, which is accompanied by traces of malachite and azurite. This prospect is of too low grade to hold much promise.

Booth.—This mine is in the SW¼ sec. 16, T. 20 N., R. 16 W., about halfway up the slope of a point between two prongs of Sister Creek, at an altitude of 890 feet, on a massive 10-foot bed, the †Black Ledge, that lies in the Powell dolomite 50 feet above the base. Most of the ore appears to have come from a zone 3 or 4 feet thick in the lower half of this ledge. The ore-bearing rock is somewhat coarser grained than the rest of the Powell but is still to be classed as a rather fine grained dolomite. It is full of small solution cavities. The structure showing within the mine is gently undulating, but there is no break. Fractures running uniformly N. 10° W. occur throughout the mine, but they are tight and show no relation to the ore. The opening is a tunnel which passes immediately into a large but low-ceiled room, about 200 feet in diameter, with numerous pillars at irregular intervals.

The ore minerals are jack and predominant zinc carbonate. The jack is mixed rosin and black jack and appears in irregular pockets in the dolomite. The carbonate is dominantly of a gray honeycomb type formed from jack essentially in place. The gangue minerals are calcite, fine drusy quartz, and, where the jack has weathered out, gypsum. A very little malachite is present, either included in partly altered jack or else embedded in calcite along its border with the country rock. Fine-grained dolomite spar is rather rare.

There is very little ore left in the tunnel. This mine is of rather low grade owing to the haphazard distribution of the ore in isolated pockets, necessitating the working of a large amount of rock to get it. There was formerly a mill on the main fork of Sister Creek below the mine. The mine produced about 100 tons of carbonate concentrates, averaging 44 percent of zinc.

Frost.—This lead prospect is at the top of the right bluff of the White River in the fractional NE¼ of sec. 2, T. 20 N., R. 16 W., at an altitude of 745 feet. Most of the development work has consisted in the blasting away of the face of the steep bluff so that the results are not conspicuous. The horizon is in the Cotter dolomite, perhaps 150 feet below its top. Lead has been found in four different beds. The lowest one, 2 to 7 feet thick, is a fine-grained gray dolomite about 50 feet below the top of the bluff. Although little ore is exposed in this bed, it is reported to be the richest of the four. Bed 2 is 2 feet thick and lies about 30 feet above bed 1; it is also a fine-grained gray dolomite. Bed 3, 4 feet thick, lies at the top of the bluff, 8 feet above bed 2. It is a banded light and dark gray Cotter flint, its lower part being a silicified oolite. Most of the ore showing at present is in this bed. The fourth and top bed is several feet above the third and is known only from the material taken from Mr. Frost's cistern, which lies 200 to 300 feet back from the rim of the bluff. This bed is a coarse blue-gray dolomite.

The ore in each of these beds is galena and occurs in thin veins, more commonly parallel to the bedding than otherwise. A little calcite is associated with the lead on the three lower levels, and drusy quartz in $\frac{1}{16}$-inch crystals occurs on the lowest one, though generally in different pockets from those containing ore. The lowest bed is more shattered and porous than the others, but these features are too much dispersed through the bed to produce any concentration of the ore.

The Frost prospect is, on the whole, of too low grade to be of any commercial importance. According to Will Frost, lead occurs along the bluff both upstream and downstream from it, but the showing is even less promising, nor has there elsewhere been as much development work done as at the Frost.

Hoffman.—This claim is about 1 mile west and a quarter of a mile south from the Frost claim, near the head of a small hollow that drains south to Gunnel Fork of Sister Creek. It is developed by a shallow open cut in the Cotter dolomite at an altitude of 710 feet, about 200 feet below the top of the formation. The ore is galena, associated with a little calcite, in veinlets and small pockets in the dark-colored "cotton rock", which carries a little gray chert.

Durham.—The Durham claim is about 300 feet north of the Hoffman and 10 feet higher. The developments consist of a shaft, 20 feet to the present water level, and an old tunnel that goes in 30 or 40 feet in drab "cotton rock." There is no ore showing.

BAXTER COUNTY

With the exception of the Annie May and Michigan deposits, which are developed in Everton dolomite and which resemble the deposits in adjacent portions of Marion County, the deposits in Baxter County all occur in the Cotter dolomite. The production from the county has been small. The ores have been zinc carbonate, with some jack and lead sulphide.

Shiras.—These openings, also known as the Baker diggings, are tunnels in the steep hillside on the left side of the White River, in the fractional W½ sec. 1, T. 19 N., R. 15 W. The altitude is around 730 feet, about 280 feet above the level of the river. The main tunnel is 5 feet or so high and 10 feet in maximum width and goes 120 feet into the hill. The country rock is fine- and medium-grained Cotter dolomite. The medium-grained type overlies the finer-grained type and apparently carried all the original ore. To judge from the occurrence of ore in clay pockets above the roof of the tunnel within the mine, it appears that this medium-grained dolomite carries ore above the plane of the tunnel. It contains a considerable amount of dark-gray chert, which is lacking in the finer-grained material. Weathering has been very deep at this mine, with the result that, within the tunnel, stretches of hard rock alternate with stretches of red residual clay. The ore, which is galena, occurs as large crystalline masses in the clay and probably also in the hard-rock stretches. Some of the ore in clay has crusts of fine drusy quartz attached to it, indicating that the original ore was developed in quartz-lined pockets in the dolomite. Ore also appears in quartz druses within the flint nodules. A little cerusite and wulfenite have formed as oxidation products on the surfaces of some of the galena masses in the clay. Owing to the slumpage induced by weathering, the rocks in the mine show a degree of disturbance that suggests fault brecciation but a careful tracing of key beds does not bear this out.

Outside of the main tunnel open-cut workings that extend west (upstream) from the portal for 100 feet or so have produced some ore. Beyond this, for 200 feet, two or three more open cuts have been made but have apparently yielded little or no ore.

The production of this property during the war period amounted to several tons, but the exact amount was not ascertained.

Cedar Gap.—This is an old-time prospect near the head of a tributary to Bruce Creek, in the NW¼SW¼ sec. 31, T. 20 N., R. 14 W., at an altitude of about 735 feet. The ore zone is in the Cotter dolomite and covers an interval of 20 feet or more, being developed at different levels in different cuts. A fairly persistent gray and white banded nodular chert in medium-grained dolomite about 3 feet thick forms a convenient reference bed. In the southernmost working (an open cut 40 feet into the hill, 10 feet wide, and 15 feet deep at the back) most of the ore occurs in a zone 4 to 5 feet thick overlying the chert bed. This is in a fine-grained gray dolomite, but in places the texture grades toward medium grain. A little ore occurs in the chert bed in this cut. In the remaining openings, which extend along the hill slope to the north for about 200 feet, the ore comes below the chert bed to a maximum distance of 15 feet and is of considerably lower grade. The largest of these openings is a tunnel about 50 feet from the open cut described above, and is driven 30 or 40 feet into hard rock at a horizon about 15 feet below the chert bed. Most of the remaining workings are small open cuts.

The primary ore is a mixed rosin and black jack, grading in places toward dark ruby jack. Certain patches of jack are as much as a foot across. The redder phases occur in small irregular patches but not in drusy crystals, as is common elsewhere. Some gray and flesh-colored crystalline carbonate is present.

Sorrel.—This prospect is on the head of a branch tributary to Bruce Creek in the NW¼NW¼ sec. 31, T. 20 N., R. 14 W., at an altitude of about 700 feet. An open cut in the Cotter dolomite, 80 feet long, 10 feet wide, and 10 feet deep, passes at the back end into a drift of uncertain length, as it is now caved. The wall rock is medium to rather fine grained gray dolomite containing gray and whitish banded chert nodules. A small amount of crystalline carbonate is present. In and near the bed of the branch a short distance above the Sorrel cut a little galena and ruby jack occur, the latter appearing as small crystals in druses.

Stratton.—This prospect is at McCracken Spring, at the head of another prong of Bruce Creek, in the same 40-acre tract as the Sorrel. Only a round or two of shots have been made in and near the bed of the branch, revealing a small amount of jack. The ore-bearing rock is medium-grained dolomite that contains a considerable amount of banded gray and white chert.

Hawkeye.—This is an open cut, 6 or 7 feet deep and 30 feet in diameter, on the point between two small branches of Bruce Creek, in the SE¼NW¼ sec. 31, T. 20 N., R. 14 W., at an altitude of about 680 feet. The ore is a crystalline gray carbonate and occurs in a fine-grained gray dolomite below a 2-foot ledge of gray and whitish chert, in the Cotter dolomite.

Big John.—This prospect is on the right hill slope of a tributary to Bruce Creek in the NW¼NW¼ sec. 5, T. 19 N., R. 14 W., at an altitude of about 675 feet. The developments consist of a barren tunnel driven for 50 feet into a fine- to medium-grained dolomite and a shallow open cut running about 100 feet west of the portal of the tunnel along the contour of the hill, roughly at right angles to the tunnel. The present exposures indicate that the mineralization followed a fracture along the line of this open cut. The ore minerals are carbonate and jack. The carbonate is chiefly crystalline gray and flesh colored, but some is the yellow variety (turkey fat), and a little of it is coral-pink and finely botryoidal. A trace of malachite occurs in black carbonate. The jack, of which only a little remains, is somewhat redder than usual. The ore fills cracks in the dolomite. Associated with the ore are numerous drusy cavities lined with quartz in $\frac{1}{16}$- to ¼-inch crystals, and some of these cavities may contain crystalline carbonate. Other cavities contain a sparse amount of pink spar, in $\frac{1}{16}$- to ⅛-inch crystals underlying carbonate. A little gray chert, containing embedded jack, is present in a few of the more heavily mineralized cracks of irregular shape.

Morgan.—This prospect lies just east of the highway between Mountain Home and Three Brothers, either in the NW¼NW¼ sec. 14 or the NE¼NE¼ sec. 15, T. 20 N., R. 14 W., at an altitude of about 960 feet. The developments consist of a shaft, now in part caved but probably 20 to 30 feet deep originally, and a long trench 5 feet deep leading back to the shaft. These openings are on a soil-covered flat where there are no natural rock exposures. The rock exposed in the cut and on the dump of the shaft is fine-grained gray Cotter dolomite. The ore is gray crystalline carbonate and occurs as a filling of rather widely spaced cracks in the dolomite. It is reported that a little galena was also found here. A few tons of carbonate has been marketed from this prospect.

Bald Dave.—The knob about 7 miles northwest of Mountain Home, known as Bald Dave, is reported to have showings of both lead and zinc all around it. The greatest concentration of mineral that has been revealed by prospecting is at the west end of the knob, on the head of a small branch that drains northeastward to Pigeon Creek, in the SE¼SW¼ sec. 11, T. 20 N., R. 14 W., at an altitude of about 970 feet. The ore is in a fine-grained gray dolomite in the Cotter formation.

An open cut 40 feet long and 8 feet deep at the back side passes into a small-bore tunnel that penetrates for 50 or 60 feet farther into the gently sloping hill. A second open cut begins at the same place as the first one but bears off at an angle to it. Where these two trenches join, a shaft was sunk. Although the walls of the tunnel and trenches are barren today, it is reported that all the workings produced some ore.

The ore on the dump near the shaft is chiefly gray and flesh-colored carbonate and occurs as crack fillings. Most of this carbonate is in the form of a crystalline film lining the cracks, but some of it is in rather thick honeycomb masses. Some of the ore-bearing dolomite was shattered to a breccia before the ore was deposited, but as the bedding of the resulting fragments cannot be determined it is uncertain whether such masses represent true breccia or simply a more intense shattering in place. A little rather dark colored jack has been preserved, and it is reported that this prospect contains a little galena. Some of the jack is bordered by a thin film of limonite, evidently altered in place from pyrite.

Hawkeye.—This prospect is on the left hill slope above Buck Branch, in the SE¼SE¼ sec. 36, T. 21 N., R. 13 W., at an altitude of around 700 feet. The ore-bearing rock is a fine-grained gray dolomite in the Cotter, probably near the top of the formation. It contains gray nodular chert and is overlain by a more cherty bed, 2 to 3 feet thick, in which the chert is more or less banded in shades of light and dark gray.

The ore is chiefly a crystalline (botryoidal) zinc carbonate in varying shades of gray, flesh-color, and (less commonly) brownish. It occurs in pockets in the dolomite, most of them being lined first with drusy quartz. Here and there a mass of the original black jack 3 or 4 inches in maximum size may be preserved, but this is the exception. Besides being embedded in the dolomite, the jack also occurs directly in the chert. Some of the jack in dolomite is bordered by a fine line of pyrite.

The developments consist of several shallow open cuts over an area about 200 feet in diameter. Most of the ore has been taken from a single trench, 200 feet long, 10 feet wide, and 10 feet deep, that bears N. 60° W., suggesting that the ore has been concentrated along a fracture.

Hulsenbeck.—The Hulsenbeck prospect lies at the head of a small ravine in the NE¼SE¼ sec. 36, T. 21 N., R. 13 W., at an altitude of about 700 feet. The developments consist of an open cut, 25 feet long, 15 feet wide, and 15 feet deep, connected with another one in the creek bed about 20 feet in diameter and not quite so deep. The ore-bearing rock is a fine-grained gray dolomite in the Cotter formation, probably near the top. It contains a little nodular chert. The ore consists of black jack and gray crystalline carbonate, which occur in cracks and pockets in the dolomite. Some of the jack masses are as much as a foot in size. A very subordinate amount of galena is present. The ore minerals are in many places separated from the country rock by a film of drusy quartz. Much of the jack exposed in the sides of the cut is iron-stained from the weathering of associated pyrite. A few tons of ore have been shipped from this prospect, but the exact amount was not ascertained.

Bean.—This property includes five or six small prospects extending for a quarter of a mile along a definite horizon just below the brow of the bluff on the left side of the North Fork of the White River in the NW¼SE¼ sec. 22, T. 21 N., R. 12 W. The bluff is here about 250 feet high. The workings are short tunnels that go fairly straight into the hill, the longest one being about 50 feet in length. The ore bed is a medium- to fine-grained porous dolomite, 6 to 7 feet thick, in the Cotter, probably near the top of the formation. In the lower 4 feet it contains considerable white to gray chert in irregular blebs, and it is overlain, at least in the northeast drifts, by 1 to 2 feet of coarse gray dolomite. The bedding is practically horizontal. The ore zone is broken by a system of essentially vertical fractures that strike about S. 60° W., and the alinement of the tunnels along these fractures suggests that they may have served as sites for mineralization, although ore may appear in pockets 15 feet from the fractures.

The chief ore mineral is gray carbonate, but a little residual black jack is present, especially in the floors of the tunnels. The ore occurs to some extent in bedding seams but more generally in pockets in the dolomite and flint. One chunk of carbonate is reported to have weighed 50 pounds. Apparently the original jack was also in rather large pockets. Certain of the tunnels show a little malachite, reported to reach the size of quail eggs, associated with black carbonate of zinc. A very small amount of pyrite was noted in the northeast tunnel along the border between the jack and dolomite.

A few tons of carbonate ore has been marketed from this mine.

Commercial.—This prospect is on a gentle slope near the head of a flat hollow in the NW¼SE¼ sec. 25, T. 19 N., R. 14 W., at an altitude of about 750 feet. The developments consist of a shaft, originally 40 feet deep but now largely filled, and an open cut, 10 feet deep and 50 feet long, sloping in to the shaft from the south. The rock is fine- to medium-grained Cotter dolomite that carries some chert as small nodules. The ore is black and rosin jack and occurs in cracks in the dolomite. Some of the ore masses are bordered by drusy quartz, but most of the jack is embedded directly in the dolomite. A little malachite shows in the small amount of black carbonate that has been formed by alteration from the jack.

Cincinnati.—The Cincinnati prospect is an old-time shallow shaft in a level pasture about a quarter of a mile south of and across the hollow from the Commercial. It lies at the same altitude. There are no outcrops in the near vicinity, but the rock exposed on the dump of the shaft is fine-grained Cotter dolomite, carrying mixed rosin and black jack in pockets and in shatter cracks. Some sand, mixed with a large proportion of dolomitic material, has filtered into the cracks in addition to the ore. Some of the jack is bordered by a drusy crust of rather fine-grained quartz, but much of it lies directly against the dolomite. Flesh-colored and gray crystalline carbonate are minor alteration products.

Michigan.—With the exception of the Annie May, the Michigan mine is the only one examined in Baxter County that is not in the Cotter formation. It is in the Everton formation and is the most promising prospect in the county. It is in the W½NE¼ and the NE¼NW¼ sec. 1, T. 17 N., R. 14 W., about 1 mile north of Buffalo station on the Missouri Pacific Railroad, across a divide. It lies at an altitude of about 650 feet on the head of a steep draw that drains westward to the White River, less than a mile away. The horizon is about 50 feet above the base of the Everton formation. The beds here dip gently to the south, so that at Buffalo station the base of the Everton is about 100 feet lower than it is at the mine.

The developments consist of several open cuts, the largest of which is 70 or 80 feet long, 20 feet wide, and about 15 feet deep at the back end. From the rear of this cut a tunnel goes into the hill about 60 feet farther; 20 feet from its portal there is a short drift to the left.

The ore bed is about 7 feet of fine-grained dark-gray dolomite, overlain by 10 feet of barren silicified limestone, rather thin bedded. In certain blocks on the dump the texture of the ore-bearing dolomite becomes somewhat coarser, but some of this rock shows a banding of residual limestone or of chert parallel to the bedding, suggesting that it was developed directly from limestone without having passed through the fine-grained dolomite stage. A large amount of limestone occurs in the section both above and below the ore bed, but the immediately underlying rock for several feet is fine- and medium-grained dolomite.

The ore is in places very rich but spotty in distribution. That exposed on the left wall near the portal consists of a high-grade rosin jack with a little darker-colored jack sprinkled through, associated with pink spar in thin veins. A minor amount of brecciation preceded ore deposition. Minute crystals of chalcopyrite or malachite occur on the jack crystals. Certain of the open druses contain globules of black bitumen. Fine drusy quartz is common as a crack lining, and calcite appears in a few places on top of the other druse-forming minerals. The dolomite in places contains veinlets of dark chert carrying disseminated jack. Here and there the casts of disseminated jack appear in the lower 1 to 4 feet of the normally barren chert overlying the main ore zone, but no ore has been preserved at this higher level.

The mine as a whole shows a prominent development of red clay, both at the ore horizon and in the overlying chert. In these clay zones the ore was undoubtedly carbonate, some of which still remains. Some of the carbonate on the dump is in the form of fine coral rods, and some occurs as pseudomorphs after pink spar.

Annie May.—This mine is in Baxter County, probably in sec. 6, T. 17 N., R. 13 W. It lies on the right side of a short hollow that drains the north slope of the Leatherwood Mountains, at an altitude of 630 feet. The opening is a cut, 50 feet long, 25 feet wide, and 5 feet deep, on gently sloping ground at the top of the steeper part of the hollow. The ore-bearing rock is a medium-grained dolomite with a little sandstone. Some silicification accompanied ore deposition, producing chert in the dolomite and quartzite in the sandstone. The original mineralization produced jack and pink spar in irregular crosscutting veins, but much of the jack has been altered to gray crystalline carbonate, which may appear in part as a coating over the pink spar. A trace of chalcopyrite accompanies the primary ore. The remains of a small mill are still on the property, but the production has been small.

SHARP AND LAWRENCE COUNTIES

The ore deposits of Sharp and Lawrence Counties occur in the Smithville formation (according to E. O. Ulrich and Josiah Bridge), chiefly in shattered dolomite that is rather fine grained. A few of the deposits are in medium-grained dolomite or in chert that has been derived from limestone. No faults have been recognized with which the ore deposition can be correlated, although the district has not been studied in as much detail as those farther west, owing chiefly to the lack of topographic maps. The district does not show as much relief in topography as those farther west, and outcrops are much poorer, so that structural details in the vicinity of the different mines are not generally revealed. The workings are commonly shafts that are at present inaccessible, or else open cuts that have been partly filled with soil. Many of the deposits, however, appear to be runs of the same type as those that have been productive in the districts to the west. The ores are zinc carbonate and jack, with a little lead sulphide. Statistics on the production of the district are incomplete; the known production has been about 2,000 tons of concentrates, much of which was made before the World War, but the production for the district as a whole has probably been at least twice this amount. The earliest zinc mining in the State was done in Sharp and Lawrence Counties in 1857 or 1858.

Included in this district is one small deposit in Independence County that is of especial interest in that the ore-bearing rock is the Joachim limestone.

Campbell Zinc Co.'s shaft 1.[50]—Shaft 1 of the Campbell Zinc Co. is in an abandoned quarry on the west side of the Hoxie-Black Rock highway, three-quarters of a mile south of the town of Black Rock, Lawrence County. The

[50] By Hugh D. Miser.

highway here follows the west bank of the Black River, and the top of the shaft is about 25 feet above the normal water surface.

Beginning about 1912, numerous prospect drill holes in search of zinc ore have been sunk at and near the shaft. Some of them attained a depth of more than 300 feet, but most of them did not exceed about 150 feet. The 8- by 8-foot shaft, begun about 1912, was started in such a location that one drill hole, 346 feet deep, was in the center of the shaft, another hole, about 300 feet deep, was in the southeast corner, and a third was a few feet northwest of the shaft. After the shaft had reached a depth of 180 feet work was discontinued until 1925, when sinking was resumed. At the time of the last visit (July 9, 1926) it had reached a depth of 277 feet. It did not find ore deposits of the same richness and thickness as reported in the three drill holes in the quarry.

The rocks as revealed in the walls of the quarry, 25 feet high, are massive layers of fine-grained hard buff dolomite. A hard saccharoidal sandstone crops out on the hill slopes above exposures of dolomite west and northwest of the shaft. The sandstone occurs as a bed at least several feet thick, though the spur in which the quarry has been made does not contain any sandstone. To explain the absence of the sandstone in the quarry spur, J. W. Reid, a mining engineer of Memphis, Tenn., has suggested that a fault runs in a northeasterly direction through a point several hundred feet west of the quarry. From my brief visits in the region, amounting to only 3 days, I was unable to draw any conclusions about faults here or elsewhere, though it appears to me that exposures of sandstone and dolomite are too few to determine whether the sandstone is lenticular or is a continuous bed cut out at places by faulting.

The record of the shaft, as determined from the rocks removed from it and kept separately on the dump by Dave Gilmore, the foreman, is given below.

Record of Campbell Zinc Co.'s shaft 1

	Feet
No rocks available for examination	0–186
Gray dolomite containing a little calcite and pink spar	186–198
Conglomerate or breccia with minute quantities of zinc blende and pink spar	198–206
Gray fine-grained dolomite, containing some greenish flint	206–222
Gray fine-grained dolomite	222–230
Gray fine-grained dolomite, a little green shale, and minute quantities of calcite and pink spar	230–248. 5
Gray fine-grained, very hard dolomite in which there are dark spots	248. 5–253. 8
Gray medium-grained dolomite cut by a few fractures along which there is some pink spar	253. 8–264
Bluish light-gray dolomite. Much pink spar but no zinc blende; a little pyrite and a few pockets of calcite	264–272
Dolomite, shaly clay, and brecciated conglomerate, contains zinc blende halfway round shaft; described fully in text below	272–274
Light-gray fine-grained limestone; contains no zinc blende	274–277

The ore-bearing bed lies in a nearly horizontal position and is a brecciated partly dolomitized conglomerate which rests unconformably upon the light-gray fine-grained limestone. The limestone has also been dolomitized at places, especially near the conglomerate.

The ore bed on the east side of the shaft has a level base and ranges in thickness from 14 to 30 inches, thinning toward the north, but on the south side it ranges from 3 to 4 feet. The bulk of it here, as on the east side, is dolomite and soft greenish earth, both of which contain loose grains of white dolomite spar and horizontal layers of pink spar and calcite as much as 1 inch thick, though some of the veins of pink spar extend downward a few inches into the limestone. The ore bed as thus revealed on the south and east sides of the shaft contains a fair quantity of zinc blende. Mr. Gilmore, who is an experienced Joplin miner, estimates that it contains about 7½ percent of metallic zinc.

The ore-bearing bed attains a thickness of 7 feet on the north and west sides of the shaft but contains too little zinc blende to be minable. The bed is a dark earthy dolomite containing both angular and partly rounded fragments of dolomite and light-gray limestone. Considerable pink spar is present throughout the bed. Breccialike conglomerate is found above the ore on both the south and east sides of the shaft but is not more than a foot thick.

The record of the drill hole in the middle of the shaft showed zinc blende to extend continuously from a depth of 272 to 346 feet. The shaft penetrated the limestone underneath the blende-bearing conglomerate to a depth of 3 feet and found it to be barren of ore. This shows the drill record to be erroneous in part, though this may be explained by the fact that the ore-bearing bed is soft and easy to crumble and cave in a drill hole, causing it to salt the cutting from lower depths. It is not known how far the limestone extends in depth, or whether any ore occurs below the bottom of the shaft.

Considerable water leaks into the shaft through the dolomite, but after the shaft has been pumped out a fairly small pump can keep the water under control. As the bottom of the shaft is about 250 feet below the normal water surface of the Black River, a navigable stream only a few hundred yards away, the quantity of water entering the shaft is not great.

Since the shaft was examined, six drill holes, the deepest 340 feet deep, have been sunk at distances of 40 to 150 feet southeast, south, west, and northwest of the shaft. These holes, which were bored to determine the extent of the ore body explored by the shaft, indicate the existence of bodies of zinc blende at two levels. That at the lower level corresponds to the bedded ore body in the shaft and is reported to have been found in four of the recent drill holes at depths nearly the same as in the shaft. The ore-bearing zinc thus lies in a nearly horizontal position and was found, according to report, to range in thickness from 5 to 17 feet. The effects of underground solution in the deeper zone are shown by softening of the matrix of the conglomerate in places and by the occurrence of open ground with dolomite crystals in the shaft and also in some of the drill holes.

The upper ore-bearing zone, as shown by the recent drill records, lies northwest, west, and southwest of the shaft. It is reported as being present in all drill holes in these directions and to range in thickness from 2 to 58.5 feet. It dips toward the west, as indicated by the depths at which its top was reached in the different drill holes. These depths range from 64 to 155 feet below the altitude of the mouth of the shaft, showing an inclined ore body not parallel to the lower one nor to the bedding of the rocks.

Campbell Zinc Co.'s shaft 2.[51]—Shaft 2 of the Campbell Zinc Co. is a mile west of shaft 1, in a gently rolling wooded area where there are abundant exposures of dolomite.

[51] By Hugh D. Miser.

The shaft, 156 feet deep, was put down many years ago. Zinc ore was mined on the 110-foot and 156-foot levels, and a large concentrating mill was erected at the shaft. The shaft could not be entered at the time of visit (April 1926), and the mill building had tumbled down. Mr. J. W. Reid, a mining engineer of Memphis, who accompanied me to the shaft, entered it some years ago. He told me that the shaft followed down a vertical or nearly vertical fault, in consequence of which the ore bed is 60 feet lower on the west side of the shaft than on the east side. The ore bed is a brecciated dolomite and was followed eastward by a drift on the higher level and westward by a drift on the lower level. Mr. Reid carefully sampled the richer parts of the ore bed, and told me that the two assays made of these samples gave a zinc content of 1.2 and 2.2 percent. The ore body is thus a lean one—in fact, about $150,000 was spent in mining and milling operations, and the production is reported to have been only 20 tons of zinc concentrates.

The ore is chiefly zinc blende, which occurs along the fractures and between the dolomite fragments. A little pink spar is associated with the blende.

The dolomite both on the surface and in the workings has a low easterly dip on the west side of the fault, but the dip is said by Mr. Reid to increase to many degrees along a zone several feet wide adjacent to the fault. This more steeply dipping dolomite contains secondary zinc minerals, carbonate and possibly silicate, to a depth of 100 feet or more below the surface. An outcrop of dolomite 500 feet southwest of the shaft reveals veinlets of secondary zinc minerals, carbonate or silicate or both.

Campbell Zinc Co.'s shaft 3.[52]—Shaft 3 of the Campbell Zinc Co. is 1 mile west of shaft 1, in the shallow valley of a small stream running east. Besides the shaft, which is 40 feet deep, several drill holes are reported to have been sunk in the vicinity.

The rock exposed on the hill slopes south of the shaft is fractured dolomite showing "blows" of zinc carbonate, and that northwest of the shaft is sandstone in a bed several feet thick.

The shaft and drill holes are said to have found brecciated dolomite containing pink spar and sphalerite. The drill holes are reported to have passed through a bed of sandstone, apparently the same bed as the one on the hill slope to the northwest, which dips about 20° SE. The shaft is reported to have found a deposit of lead and zinc ore in the form of a fissure running northeast. The face of ore as revealed in the workings is said to have been 7 to 8 feet high. A long open solution cavity many feet deep following a joint or fault was noted in the dolomite about 100 yards south of the shaft. It has a trend of about N. 70° E. The fragments of mineralized rock on the waste dumps consist of dolomite breccia containing quantities of sphalerite and pink spar.

I did not learn of any production from this shaft, though there may have been a small one.

McCaa prospects.[52]—These prospects are in the SE¼NW¼ sec. 15, T. 17 N., R. 2 W., 5½ miles west of Black Rock. Work has been done here at different times, and some was done in 1926 by T. F. Shell and W. H. Beatty, who held a lease at the time of visit (April 1926). The work was done as a result of the discovery of pieces of galena in gullies in the fields on Mr. McCaa's tract. The sinking of the shafts, the deepest 22 feet in depth, led to the discovery of further galena in clay and in the underlying dolomite from which the clay is residual, though one or two shafts found no galena. The ore-bearing part of the dolomite is a breccia in which the galena is accompanied by a small amount

[52] By Hugh D. Miser.

of dolomite spar and calcite. The amount of galena observed at the time of visit was very small.

Gibson-Finch.—This mine is in a gently rolling wooded tract in the SE¼SW¼ sec. 10, T. 17 N., R. 2 W., 5½ miles west of Black Rock. A deep soil mantle obscures the geologic relations of the deposit. The workings consist of several old pits and shafts, now largely caved, that lie within an area 200 feet or so in diameter. The ore is galena and occurs in thin cracks and irregular replacement pockets in fine-grained dolomite ("cotton rock"). Pink spar and fine drusy quartz are in places associated with the lead, but they are not conspicuous. Fractures of the type that would be favorable for the formation of a rich ore body have not been encountered in the shafts. Some of the replacing ore appears in structurally homogeneous rock, in which replacing galena may be developed simply as a skeletal crystallization over a volume of several inches, containing within its limits a larger volume of the country rock than of ore mineral. The property was prospected as early as 1898 and as late as 1926, but there is no record of any production.

Adams.[53]—The tract owned by Fred Adams comprises the NW¼SE¼ sec. 10, T. 17 N., R. 2 W., 5½ miles west of Black Rock. Several shafts 35 feet or more deep have been made at different times at fairly widely separated localities on the tract. Some of the work was done in the seventies. The country rock is gray dolomite, which is exposed at some places but is generally concealed by residual clay. The shafts passed through the clay into the dolomite and revealed galena, sphalerite, and smithsonite in the dolomite. A small quantity of galena was seen by me in an exposure of soft yellow decomposed dolomite by the roadside, and part of a 100-pound mass of galena was observed in the wall of a recently made shaft. Some lead ore is said to have been shipped from the openings on the tract.

Anderson.[53]—The prospect on R. S. Anderson's land, in the N½SW¼ sec. 10, T. 17 N., R. 2 W., 5½ miles west of Black Rock, consists of a trench 40 feet long and several feet deep, which was made early in 1926 by W. L. Hogg, one of several lessees at the time of my visit (April 1926). The dolomite in which the trench was blasted crops out over much of the surface in the wooded, gently sloping tract. A surface showing of zinc carbonate in ledges of fractured dolomite led to the blasting of the trench here. The trench revealed a brecciated gray fine-grained dolomite containing zinc blende in association with pink spar and with a little calcite. The blende does not occur in large masses but is disseminated through the pink spar and calcite. It occurs in the dolomite for the entire length of the trench, however, but is present in larger amounts at some places than others. The trench looks promising, and I believe that if a sufficient quantity of mineralized rock similar to that in the cut is found the deposit can be worked when market conditions justify. The ore revealed in the trench would probably be classed as of rather low grade, provided the trench is considered as a whole or even in large part.

Old Mill.[53]—The Old Mill property (the Gibson mine of Branner and others), in the southeastern part of sec. 9, T. 17 N., R. 2 W., 6 miles west of Black Rock, was worked for zinc ore many years ago. Open cuts were made over an area of a few acres. Both zinc blende and carbonate were mined; they were concentrated in a mill, and three carloads of concentrates are reported to have been sold.

The open cuts were made near a small eastward-flowing stream. They passed through a few feet of surficial clay at some places but started in

[53] By Hugh D. Miser.

outcropping rock ledges at others. The rocks revealed by them are nearly flat-lying beds of gray dolomite, some of which is brecciated and some of which is cut by closely to widely spaced fractures.

Zinc carbonate occurs in small quantities in the surficial clay and also as a coating adhering tightly to some of the dolomite and in places as material penetrating the dolomite to a depth of a few inches. The fresh unaltered dolomite that is fractured and brecciated contains a small quantity of pink spar along the fracture planes and between the breccia fragments. Intermixed with the spar is zinc blende (sphalerite). Both the blende and the zinc carbonate apparently occur in small quantities. Although the openings were partly filled with water, earth, and rock at the time of visit (April 1926), much could be learned from the walls that were accessible.

Hoppe.—This mine, in the NE¼ sec. 19, T. 16 N., R. 2 W., was one of the sources of ore for the Calamine smelter. It was shut down in 1872 and has not been extensively worked since. The opening is a large cut 200 feet long, 50 feet wide, and 15 feet deep at present, though its original depth was somewhat greater. From the sides and ends of the cut tunnels were originally driven for variable distances into the wall. The lower end of the cut is almost at the level of a hollow that drains into Cypress Creek.

The primary ore, some of which remains, was mixed black and rosin jack associated with pink spar, but the commercial product of the mine was zinc carbonate. Part of the carbonate has replaced pink spar. The ore occurs in irregular cracks and replacement masses chiefly in a fine-grained dolomite. A little of the ore-bearing rock is chert that has replaced either dolomite or limestone, more probably the latter. Another type of ore rock is a medium to rather coarse-grained light-gray dolomite that, laterally, becomes intermottled with limestone in such a way as to indicate that it has replaced the limestone. Perhaps a large part of the carbonate ore taken from the mine in the early days came from surficial clay overlying the ore in the dolomite.

Kimberly.—The Kimberly mine (Casper mine of Branner report) is in the SW¼NE¼ sec. 18, T. 16 N., R. 2 W. The general dip of the rocks near the mine is at a gentle angle to the north, but right at the mine there is a monoclinal steepening of the dip to 13° N. 20°–30° E.

There are two openings. The southern one is an open cut 80 feet long, 15 feet wide, and 10 to 15 feet deep. Its direction of elongation is N. 60° W. and thus is parallel to the axis of the monoclinal flexure. The best ore occurs in irregular cracks and replacement pockets in a bed that was originally limestone but has been altered to a medium-grained dolomite. Only the top part of a thick limestone bed has been affected, and without regard to bedding, so that the dolomite varies in thickness over short distances. Most of the ore, which is essentially coextensive with the dolomite, is contained within a thickness of 3 or 4 feet. The dolomite shows a greenish tinge due to the interstitial development of a greenish clay mineral. The ore is mixed black and rosin jack, with pink spar and chert as gangue. The chert has replaced the dolomite, mainly adjacent to the ore pockets. At the southeast end of the pit dolomitization has been negligible, and the ore is confined to a cherty mass that has replaced the top foot of the limestone. The cap rock to the ore bed is a barren fine-grained dolomite. The lower part of the pit is everywhere in barren limestone.

The second opening is a tunnel lying roughly parallel to the open pit and about 30 feet northeast of it. The tunnel goes southeast into the hill for 140 feet to a natural cave. This cave, according to J. B. Butler, of Lynn, contained about 2 feet of mud and jack. The cave was followed for a distance of 50 feet, in which it curved gradually to the south. Owing to the gentle slope of the surface above, the depth of the tunnel below the surface is nowhere very great, but as the bedrock here is mantled by only a thin cover of soil, the tunnel has held up fairly well. A shaft was sunk to it from the surface about 100 feet from its portal. The tunnel has in its walls a discontinuous blanket vein of jack ore, generally 2 to 6 inches thick, occurring along the bedding contact of a dolomite above with a limestone below. The horizon is evidently the same as that of the mineralized rock in the open pit. A trace of chalcopyrite is associated with the pink-spar gangue in this tunnel. The rock containing the ore is a very coarse-grained dolomite, approaching a gray spar.

The production of the Kimberly mine has been between 30 and 40 tons of jack concentrates.

J. B. Butler.—This mine is an open cut in the right bank of Big Cypress Creek, in the NW¼NE¼ sec. 18, T. 16 N., R. 2 W. It was originally 100 feet long parallel to the creek and 20 feet wide. The ore face increased in thickness from 1 foot on the side next to the creek to 5 feet on the opposite side. Water from the creek gave considerable trouble during the operation of the mine, and as soon as work was suspended the pit was filled with creek sand and gravel. The ore was mixed black and rosin jack, associated with pink spar in cracks and irregular replacement pockets in fine-grained dolomite. The original rock ran about 5 percent of zinc; the concentrates, as shipped, ran 63 percent of zinc. The production of the mine has been between 30 and 40 tons of concentrates.

A small mill owned by J. B. Butler is located near the site of the cut. Between 1922 and 1929 about 350 tons of carbonate concentrates were turned out here, but the ore came from other diggings in the adjacent region. Four carloads (about 140 tons) was milled in 1927.

Penn.—This prospect lies in a fairly flat wooded tract in the NW¼SW¼ sec. 7, T. 16 N., R. 2 W. There is a 14-foot shaft that begins in a fine-grained dolomite ("cotton rock") and reaches or passes through a medium-grained light-gray dolomite, with greenish interstitial clay, at some level near the foot of the shaft. Both types of rock contain ore, in irregular cracks and replacement pockets. The cracks appear to be confined to a run about 10 feet wide, whose direction is N. 40° E. About 100 feet northeast of the main shaft ore is exposed on the run in a shallow open pit, though it is not so rich as at the shaft.

The ore is mixed black and rosin jack associated with pink spar. A little of the jack has oxidized to crusty and honeycomb types of carbonate. A trace of chalcopyrite accompanies the ore, and a little pyrite is disseminated in the "cotton rock" or, perhaps, segregated along the borders of the pink spar or jack. Very little development work has been done here, but fairly rich ore is exposed in the top of the shaft, and the prospect is promising enough to warrant some further prospecting along the lines of the supposed ore run.

Raney.—This mine is on top of a low flat ridge in the NW¼ sec. 15, T. 16 N., R. 3 W. The workings consist of many shallow surface cuts over a diameter of 250 feet, with one or two old shafts, 20 feet or so in depth. The ore-bearing rocks are medium to rather coarse grained dolomite and chert. The dolomite contains abundant pink spar in irregular replacing pockets, and in places rather large blocks of the dolomite are completely altered to pink spar. Most of the production has been zinc carbonate, but the original mineral, which is conspicuous on the dump, is mixed black and rosin jack. It occurs in part disseminated in the dolomite in blebs as large as half an inch, but also in part peppered through the dolomite on a very fine scale—a state in which it is not recoverable by the ordinary methods of concentration. More commonly the jack is associated with pink spar in irregular replacement blebs or in irregular cracks in both the dolomite and the chert. Finely crystalline pyrite is dusted through certain bands in the dolomite and chert but is not present in great enough bulk to be commercially objectionable.

The Raney mine produced ore for the Calamine smelter in 1857 and in 1871 and 1872. Within the last few years between 30 and 40 tons of carbonate concentrates have been turned out at the Butler mill from ore taken from the Raney mine. The production during the earlier periods of activity is not known.

Barber.—This mine lies 1¾ miles northeast of Smithville, in the SE¼SE¼ sec. 22, T. 17 N., R. 3 W. The working is an open cut, 70 by 100 feet in size and 10 feet deep, lying in a field. The ore-bearing rock is a fine-grained gray dolomite (cotton rock) that weathers buffy and whitish. It is overlain by a barren partly dolomitic limestone. The ore is a high-grade gray to flesh-colored crystalline zinc carbonate, with a little of the residual jack preserved in spots. Pink spar is in places developed as an original gangue, but much of it has been replaced by the carbonate. Some of the richer masses of crystalline carbonate contain eggshell-like layers of white opaque shell carbonate. The residual jack is chiefly rosin colored, but some black jack is intermixed. The jack occurred originally as a filling of cracks in the dolomite and also in the form of large replacing masses in the dolomite and in a cherty replacement product of the dolomite. A little of it was also disseminated in the dolomite. The production of the mine during the World War is reported to have been around 300 tons of free carbonate ore.

Richardson.—This mine is reported to have produced ore for the Calamine smelter in 1857. It lies directly on the northwest side of the Smithville-Imboden road, 1¼ miles from Smithville, in the NW¼NE¼ sec. 27, T. 17 N., R. 3 W. The opening is an old-time irregular-shaped pit, 50 feet across and 5 feet or more deep. The country rock is fine- to medium-grained dolomite, containing segregated bodies of fine drusy quartz that stand out on the weathered surface. There is also some limestone in the bottom of the pit, but it does not carry ore. Oxidation has been complete, so that the ore is entirely zinc carbonate. It is associated with pink spar, much of which it coats over, and occurs in cracks and pockets in the dolomite.

Hendrick.—This opening lies about 250 feet toward Smithville from the Richardson mine, in the same 40-acre tract but on the opposite side of the Smithville-Imboden road. The shaft, now caved, is reported to be 80 feet deep. The ore is mixed black and rosin jack and occurs in a fine-grained dolomite ("cotton rock") as a crack filling and also in replacement pockets as large as 3 inches or more. Pink spar may or may not be associated with it. The dolomite contains a little finely disseminated pyrite and also irregular replacing masses of gray chert as much as 3 or 4 inches in size. Some of the jack has been altered to gray carbonate. The shaft is apparently on a zone of slight structural movement, whose direction and extent are unknown, owing to the lack of surface outcrops.

Lincoln.—This mine is in a field in the SE¼NW¼ sec. 27, T. 17 N., R. 3 W. The shaft, reported to be 93 feet deep, was sunk on the record of four or five drill holes put down on the property. In addition to the shaft there are also an open cut, 30 by 40 feet in size and 10 feet deep, about 600 feet northeast of the shaft, and a curving inclined trench, 200 feet long and 20 feet deep at the back, 300 feet northwest of the shaft. The ore-bearing rock is a massive fine-grained dolomite. The stratigraphic section penetrated in the shaft includes some blue-gray limestone, but this is not ore bearing. The ore at the shaft is mixed black and rosin jack, associated with pink spar in small irregular cracks and replacement vugs in the dolomite. The original mineralization at the level of the two surface cuts was the same, but here oxidation has converted most of the jack to carbonate of various forms, especially to gray crystalline and crusty types. Some of the pink spar has been replaced by carbonate. It is reported that development work in the shaft was hampered by an excessive flow of ground water. At present the water level stands 12 feet below the surface of the ground. The property was formerly equipped with a mill, and some ore was concentrated, but the amount was not ascertained.

In the NE¼NW¼ sec. 27, on the Henderson tract, three or four small open-cut prospects reveal fairly good carbonate ore with a little jack.

Moore.—This mine is in a region of no outcrops, about 1 mile east of Smithville, in sec. 34, T. 17 N., R. 3 W. The opening is a pit 100 feet long, 30 feet wide, and 10 feet deep. The ore-bearing rock is buff fine-grained dolomite ("cotton rock"), but some gray limestone is closely associated in the section. The ore is zinc carbonate, which occurs in rather large crystalline chunks and also, less abundantly, replacing pink spar. Whether the original jack from which it was derived occurred in fracture veins or in replacement chunks in the "cotton rock" was not ascertained. It is reported that some of the original jack is preserved in the bottom of the pit. Considerable buff clay formed in the country rock during the alteration. The production from the mine is reported to have been a little over 100 tons of free ore.

King Jack.—The working here is a big open cut, 125 by 70 feet in ground plan and 15 feet deep. It lies on a wooded gently sloping tract in the SW¼NW¼ sec. 29, T. 17 N., R. 3 W. The ore is mixed rosin and black jack and occurs, associated with pink spar, in cracks and replacement pockets in a fine-grained bluish-gray dolomite. Some of the replacement pockets are 8 inches or more across. A little finely crystalline chalcopyrite accompanies the ore, and pyrite, in small cubes, occurs in cracks in the dolomite and also along the boundary between the dolomite and pink spar of the ore pockets. A small amount of carbonate has developed as an oxidation product of the jack, occurring in the gray crystalline form or replacing pink spar, but it is of no commercial importance. The production of the mine is reported to have been about 300 tons of concentrates, milled on the property.

Red Fox.—Workings on this property consist of several open cuts on the left bank of Cooper Creek in the SW¼NW¼ sec. 29, T. 17 N., R. 3 W. The right bank of the creek here is a bluff, but the left bank is gently sloping. The cuts are below the level of high water, and most of them have been filled up. The largest one noted lies parallel to the creek; it is 100 feet long and 10 feet wide and probably was originally 5 to 10 feet deep.

The ore occurs in a fine-grained gray to greenish-gray dolomite, but also to some extent in a medium-grained dolomite. The original jack is mixed black and rosin colored and occurs partly as a crack filling, partly in the form of irregular replacement pockets, and partly disseminated in the dolomite in blebs as large as half an inch. This disseminated ore is found in the medium-grained dolomite rather than in the fine-grained; it also occurs in a chert formed during the mineralization by silicification of a dolomite. Pink spar and calcite are associated with the jack in the cracks and replacement pockets. Drusy quartz forms the wall lining of certain vugs developed in the chert. A small amount of zinc carbonate occurs as a coating over pink spar in certain druses.

The production from the Red Fox property has been about 70 tons of concentrates. The ore was milled at a small plant on the opposite side of the creek from most of the workings.

Miller.—Several open cuts were worked during the World War in secs. 29, 30, 31, and 32, T. 17 N., R. 3 W. Only one, situated beside the road between Smithville and Reed, was examined by the writer. It is 40 feet long and 30 feet wide and was originally 30 feet deep. The ore is gray crystalline and crusty zinc carbonate, with some mixed black and rosin jack. It is associated with pink spar in irregular cracks and replacement masses in a fine-grained dolomite. Some of the pink spar has been replaced by carbonate. A trace of chalcopyrite occurs in the unoxidized ore. A mill was in operation on the property during the period of production and is reported to have worked about 140 tons of carbonate concentrates. Of this amount, not more than 30 tons came from the cut mentioned above. From one of the other openings on the property a mass of jack weighing 575 pounds is reported to have been taken out in one block, within 4 or 5 feet of the surface.

Widow Franklin.—This prospect is on top of the bluff on the east side of the Strawberry River in sec. 36, T. 17 N., R. 4 W. A shaft, reported to have been 20 feet deep, is 200 feet back from the rim of the bluff, and an open cut, 40 feet long, 15 feet wide, and 5 feet deep, lies within 50 feet of the shaft. The ore is mixed rosin and black jack, with some carbonate both in the gray crystalline form and replacing pink spar. The original jack is associated with pink spar and a little calcite in cracks and replacement pockets in a fine-grained gray to buff dolomite. Some of the jack pockets are a foot or so across, though made up of several interlocking crystals. A little finely crystalline pyrite follows the borders between the dolomite and the ore and gangue minerals.

Rock Springs.—The opening on this property is an open cut, 40 feet long, 15 feet wide, and 5 feet deep, lying at the top of the bluff on the east side of the Strawberry River, 30 or 35 feet above water level, in sec. 36, T. 17 N., R. 4 W. The ore-bearing rock is a fine-grained dolomite (cotton rock). The ore is crystalline gray carbonate with some residual black and rosin jack. It occurs, associated with pink spar, in cracks and irregular replacement masses in the dolomite. Some of the carbonate has replaced pink spar. A little of the jack is disseminated in the dolomite in blebs from one-fourth to three-fourths inch in size.

Graceland.—The working on this property is a shaft situated directly in the bed of a headwater prong of Pine Creek, in sec. 26, T. 17 N., R. 4 W. The shaft has been filled up by creek gravel. The ore is chiefly mixed black and rosin jack and occurs, associated with a subordinate amount of pink spar, in cracks and replacement pockets in a fine-grained dolomite (cotton rock) Some of the replacing jack masses grade down in size until they approach the disseminated type of ore. A little calcite and a trace of chalcopyrite accompany the ore in the larger masses. A small mill was at one time located at the forks of the hollow, 800 feet below the shaft, but it has been completely torn down. The production was not ascertained, but it was not more than a few tons.

A shallower shaft is 600 or 700 feet up the other (left-hand) fork from the mill, on the right side of the hollow. There are no rock outcrops near, and one wonders what has determined the location of such an opening. The ore-bearing rock is both fine- and medium-grained dolomite, but much of it has been silicified to a dense chert. The ore is mixed black and rosin jack and occurs in small replacement pockets in the chert and dolomite associated with a scant amount of pink spar.

George Smith tract.—This tract of 335 acres is in secs. 1, 2, and 12, T. 16 N., R. 4 W. It was not visited by the writer, but numerous samples of the ore were examined. The ore is mixed rosin and black jack associated with pink spar in irregular cracks and replacement pockets in a fine-grained dolomite (cotton rock). There is some carbonate developed from the jack, and the tract is reported to have supplied carbonate ore for the Calamine smelter in and prior to 1872. There are on the property numerous small prospect openings a few feet in diameter, none greater than 4 feet deep.

Fugate Hollow.—Although very little development work has been done on this property, considerable ore shows along a stretch of 300 to 400 feet in the bed and on the left bank of the hollow where a few prospect pits have been made. The occurrence is the SW¼SE¼ sec. 9, T. 16 N., R. 4 W. The country rock, which is well exposed in the bed of the hollow, is fine-grained dolomite whose average attitude approaches horizontality, but in the neighborhood of the richer showings of ore the structure is somewhat wavy, showing local dips of as much as 15° SE. The ore is chiefly rosin jack with a little intermixed black jack and with insignificant amounts of pink spar and calcite as gangue. It occurs in shatter cracks in the dolomite in which only a minor amount of replacement is involved. The occurrence of ore is spotty, so that certain masses may run fairly high in grade with the intervening masses being lean. There is no persistent structural feature that controls the location of the richer masses, so that the deposit may be expensive to work.

Arbuckle.—Workings on this property lie on the right side of Big Creek in the NE¼SW¼ sec. 16, T. 16 N., R. 4 W. The land was originally prospected by several drill holes, and some of the development work has been controlled by the showings of the drill records. One of the holes, 196 feet deep, beginning at a point 40 feet above the level of the creek, showed an 8-foot ore run at 35 feet and a second run at 70 feet. A shaft was sunk on this hole as far as the lower ore run, but the run was not worked. On the 35-foot level a drift was run east for about 30 feet. The ore is rosin jack associated with a very minor amount of pink spar, in irregular cracks and replacement pockets in fine-grained dolomite. Whether the run is linear or essentially a blanket vein is not known, but to judge from the distribution of ore showings elsewhere in the immediate neighborhood it is more probably a blanket vein. A mill was built near the portal of the shaft and was on the point of beginning operation when the financial panic of 1907 arrested further progress.

A second hole, 222 feet deep, was drilled at a point 240 feet N. 30° E. from the shaft, its collar lying 5 feet lower than the collar of the shaft. Ore is reported as " good " in this drill hole, but no details are available on its depth.

A third hole, 225 feet deep, was drilled on the bank of the creek, 10 feet above water level, at a point lying perhaps 300 feet N. 5° W. from the shaft. Ore is reported to have been struck 25 feet below the collar and to have continued for the 200 feet to the bottom, but it should be remembered that in drilling of this type cuttings are often unintentionally salted by an ore bed from above.

A second shaft, lying between the main one and drill hole 3, is 30 feet deep and is reported to have struck ore at the bottom when the shut-down came. As the collar of this shaft is 5 feet lower than that of the main one, the ore encountered is evidently the upper ore bed of the main shaft.

The greatest showing of ore on the property has been uncovered in an open cut just downstream from drill hole 3. The cut is 125 feet long, 10 feet wide, and 5 to 15 feet deep. The long axis of the cut bears a little north of east. The lowest part of the floor is about 10 feet above the creek level. A spur cut for a distance of 50 feet to the south from a point near the east end of the pit shows the ore to extend for at least 25 feet from the main cut. The ore is mixed rosin and black jack and occurs in association with pink spar in cracks and rather large replacement pockets (as much as a foot or more in diameter) in the fine-grained dolomite of the country rock. Some of the ore rock includes replacement masses of light-gray chert, but such masses do not appear to be related to the mineralization. Some hand-picked ore from this cut was teamed to the railroad at Imboden, 17 miles to the northeast, prior to 1907, but the amount was small. This prospect looks somewhat more promising than those at most other places in Sharp and Lawrence Counties, though there is no evident structural feature that would tend to localize the ore.

Land belonging to the Arbuckle Mining Co. in the N½NW¼ sec. 21 has been prospected by means of 10 drill holes, the deepest being 360 feet deep. R. M. Willett reports the discovery of jack in all of these drill holes.

Daylight.—The workings on this property consist of three shafts in the N½NW¼ sec. 21, T. 16 N., R. 4 W. Shaft 1 is 33 feet deep, with a 10-foot drift to the west at the bottom. The best ore, consisting of rosin jack with a very small amount of intermixed blackjack, lies 2 or 3 feet above the bottom of the shaft. It occurs in cracks and replacement pockets in a fine-grained dolomite and is not accompanied by gangue minerals, although at the top of the shaft conditions are reversed and pink spar occurs without accompanying ore.

Shaft 2, which is 10 feet deep, lies 400 to 500 feet west of shaft 1 and shows somewhat more ore on the dump. The ore is mixed rosin jack and carbonate, associated with pink spar, and shows the same type of occurrence as at no. 1 in a fine-grained dolomite.

Shaft 3, 14 feet deep, lies 150 feet north of shaft 2. According to R. M. Willett, of Hoxie, this shaft had just reached ore when sinking was stopped. A drill hole in one corner of the shaft, according to him, shows the ore to occur in a zone 14 feet thick, though, of course, the ore minerals make up only a small part of this zone.

There has been no production from the Daylight property. Galena is reported to have been found in some drill holes on the property.

Willett property.—Land owned by R. M. Willett in the N½SW¼ and the SE¼NW¼ sec. 20, T. 16 N., R. 4 W., has numerous showings of ore, although no development work has been done other than the blasting out of a few small surface pits. Most of the mineral shows on a small wooded hill that lies back of a 30- to 40-foot bluff on the south side of Big Creek. Rosin jack associated with pink spar is the commonest ore mineral. In places black jack is mixed with the rosin jack. Oxidation of the jack to zinc carbonate is common, so that much of the mineral that has been uncovered is mixed. A trace of chalcopyrite was observed in one pit at the top of the bluff, and a little galena is reported by Mr. Willett to have been found on the top of the hill. The mineral occurs in irregular cracks in a fine-grained dolomite (cotton rock).

Calamine.—This mine is on a gently sloping soil-covered hillside half a mile west of the village of Calamine, in the SE¼SE¼ sec. 22, T. 16 N., R. 4 W. It is one of the oldest zinc mines in Arkansas, having been worked, according to residents of the district, as early as 1857 or 1858. At that time a zinc smelter was built at the village, where carbonate ore from this mine, as well as from a few other diggings in the vicinity, was reduced. The mine has been worked very little in more recent years, though during the World War a little ore from the property was milled at the Pearce mill. The production, coming over a period of 70 years or more, with most of the work having been done in the early years, is not known.

The workings consist of several old-time shafts, some of which are reported to have been 100 feet or more deep, and several shallow surface cuts. The upper parts of the surface cuts have been in deep clay, which, after the cuts have been abandoned for a few years, slumps down and conceals the underlying rock. The largest cut was a trench about 300 feet long, 5 feet wide at the bottom, and 15 feet deep at the back end. It is reported by Branner [54] to have passed into a tunnel at the rear end. All traces of this tunnel are now gone, owing to the filling in of the cut by surface wash.

The ore occurs in irregular cracks and replacement pockets in a fine-grained dolomite and to a less extent in a cherty sandstone that contains segregated masses of bluish clay. A little of the ore-bearing rock appears to have been an intraformational conglomerate, showing fragments of dolomite in the cherty sandstone matrix. Probably, also, much of the ore was taken from surficial clay. Branner reports that the ore-bearing bed is 8 feet thick.

Practically all of the commercial ore has been gray to flesh-colored crystalline carbonate, but the original ore, in the dolomite, some of which remains, was mixed black and rosin jack, associated with pink spar. Pyrite is more abundant at this mine than is usual for northern Arkansas, though it is not abundant enough to affect the commercial quality of the ore. It occurs as amorphous segregated bodies an inch or so across, in the dolomite. A little galena is reported by R. M. Willett to have occurred with the zinc ores, though none of it shows at present.

The smelter at Calamine, according to Branner's report,[55] was built in 1857 by the Independence Mining Co. It was promoted by St. Louis capital and was accordingly demolished by the Confederate forces during the Civil War. It was rebuilt in 1871–2 by the American Zinc Co. and was operated for about six months (Branner). Edward B. Cornell,[56] who worked some of the mines in the district in 1900, reports that from the best information he has been able to obtain, the amount of spelter turned out at the Calamine smelter was about 200 tons. Most of this was made during the second period of operation. Only carbonate ore was reduced, and this came from other mines in the district as well as from the Calamine mine.

Golconda.—The working on this property is a 100-foot shaft, in a gently sloping field in the NE¼SE¼ sec. 31, T. 16 N., R. 4 W., about 1 mile west of Grange post office. It is reported to have been driven in 1898. No drifting has been done from the shaft. According to R. M. Willett, the upper 30 feet in the shaft showed lead ore, then came 30 feet of barren rock, then 4 feet of "rich" zinc ore with some lead, and finally 36 feet (to the bottom) of lean zinc ore. The ore minerals in the 4-foot ore zone are a peculiar red-brown form of jack and galena. Associated with these are pink spar and, to a minor extent, calcite and chalcopyrite. Near the top, where galena is the only ore, pink spar is the associated gangue mineral. The ore occurs in cracks and replacement pockets in a fine-grained dolomite. The cracks are rather small but more closely set than usual, and some of the rock has been brecciated. Owing to lack of exposures it is not known to what extent there has been struc-

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[54] Branner, J. C., The zinc and lead region of north Arkansas: Arkansas Geol. Survey Ann. Rept. for 1892, vol. 5, p. 235, 1900.

[55] Idem, pp. 67, 231.

[56] Personal communication to the late C. E. Siebenthal.

tural movement of the rocks at the shaft. It is reported that masses of lead weighing 100 pounds were taken from the surface at the shaft.

Fitzhugh.—This is a shallow open cut, 3 or 4 feet deep and 30 feet in diameter, lying in a wooded tract in the NW¼SW¼ sec. 32, T. 16 N., R. 4 W., a quarter of a mile east of the Golconda shaft. The ore-bearing rock is a fine-grained dolomite that has been shattered and mineralized rather thoroughly. The ore was originally jack and subordinate galena, associated with pink spar in the shatter cracks. Much of the jack has been leached out or altered to carbonate. The individual jack masses average half to three-quarters of an inch in diameter. The jack is dominantly red-brown, with some mixed black and rosin jack. The prospect was opened up a year or two before the time of the writer's visit, in the fall of 1929.

Pearce.—Development on this property consists of a 113-foot shaft, on a low flat ridge in the SE¼NW¼ sec. 10, T. 15 N., R. 4 W. From the bottom of the shaft a drift 30 feet long, 20 feet wide, and 10 feet high was made into ore. Most of the development work, however, was done on a level 50 feet below the collar, where a room was stoped out to a distance of 30 or 40 feet from the shaft.

The country rock is fine-grained dolomite ("cotton rock"), which crops out at numerous places in the neighborhood of the shaft through a thin soil mantle. Most of the ore occurs in this rock, in cracks and irregular replacement pockets, but a little of it occurs in dolomitic sandstone. Some of the material on the dump shows breccia, composed of fragments of this sandstone and of the more normal type of "cotton rock." The ore is mixed jack and carbonate, associated with pink spar. Most of the jack is rosin-colored, but it contains a little black jack mixed in.

The Pearce mine has been one of the largest producers in Sharp and Lawrence Counties, having yielded about 700 tons of concentrates, according to R. M. Willett. The shaft was sunk in 1900, and according to a private report made in 1904 by Daniel Dwyer, a mining engineer of Joplin, the first concentrates, amounting to 60 tons, were shipped in 1903. The greatest production, however, came during the World War. It is reported that ore is present throughout the depth of the shaft, but that the 50-foot level was worked chiefly on account of the absence of carbonate at this particular level. The jack concentrates from this level ran 61 percent of zinc and only 0.40 percent of iron. During the World War ore from a few other mines in the vicinity was concentrated at the Pearce mill. The mill is now demolished.

Runyan.—This is an open cut 3 feet deep and 20 feet in diameter, probably in the NW¼NE¼ sec. 30, T. 15 N., R. 3 W. The ore is mixed black and rosin jack and occurs associated with pink spar in cracks in a fine-grained dolomite. A little pyrite occurs in blebs in the dolomite.

Crow.—This opening is in the SE¼ sec. 21, T. 15 N., R. 5 W., in Independence County, about 1 mile southeast of Cave City. It is a shaft 10 or 12 feet deep on the side of a gently sloping hill. The ore consists of galena and rosin jack associated with pink spar and calcite in a few thin cracks in a fine-grained dolomite. The prospect has no value as a commercial possibility, but is of interest in showing the distribution of mineral. The rock has been mapped [57] as belonging to the Joachim limestone.

[57] Miser, H. D., Deposits of manganese ore in the Batesville district, Ark.: U.S. Geol. Survey Bull. 734, pl. 1, 1922.

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