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DEPOSITS OF MANGANESE ORE IN THE BATESVILLE DISTRICT, ARKANSAS

BY

HUGH D. MISER

WITH A CHAPTER ON THE MINING AND PREPARATION OF THE ORES

BY

W. R. CRANE
OF THE BUREAU OF MINES

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DEPOSITS OF MANGANESE ORE IN THE BATESVILLE DISTRICT, ARKANSAS.

By Hugh D. Miser.

LOCATION.

The Batesville manganese district is in the southern part of the Ozark region, a short distance west of the Mississippi embayment of the Gulf Coastal Plain, mostly in Independence county but partly in Sharp, Izard and Stone counties, in north-central Arkansas. (See fig. 1.) It forms an east-west belt, 4 to 8 miles wide, extending from the Ball mine, 2 miles east of Hickory Valley, westward to Guion, a distance of 24 miles. The town of Batesville, from which it is named, is 2 miles south of its southern border. The manganese-bearing area and some of the surrounding region are shown on the accompanying map (Pl. I, in pocket).

INVESTIGATION AND ACKNOWLEDGMENTS.

The field work on which this report is based was done by the writer in March, April, May, and June, 1918, in accordance with the plan of the United States Geological Survey to obtain information regarding the quantity, location, character, and extent of the manganese-ore deposits in the United States and to encourage the production, so that as much shipping as possible could be freed from use in the importation of foreign ores in order to carry troops and supplies to Europe during the war. The writing of the present report was completed in November, 1919.

A brief preliminary report entitled, "Manganese in the Batesville region, Arkansas," was published in September, 1918, as a press bulletin of the United States Geological Survey. A longer preliminary report was published November 15, 1920, as Bulletin 715–G of the United States Geological Survey. An abstract of a paper on the manganese deposits of the Batesville district that was presented April 23, 1919, before the Geological Society of Washington was published July 19, 1919.[1] A paper on hausmannite in the Batesville

[1] Washington Acad. Sci. Jour., vol. 9, No. 13, 1919.

district, by J. G. Fairchild and the writer, was published January 4, 1920.[2]

The writer desires to acknowledge his indebtedness to the following members of the United States Geological Survey: E. F. Burchard, under whose direction the present investigation was conducted, for advice during both the field and office work; D. F. Hewett, who spent several days in the Batesville district in the fall of 1917, for

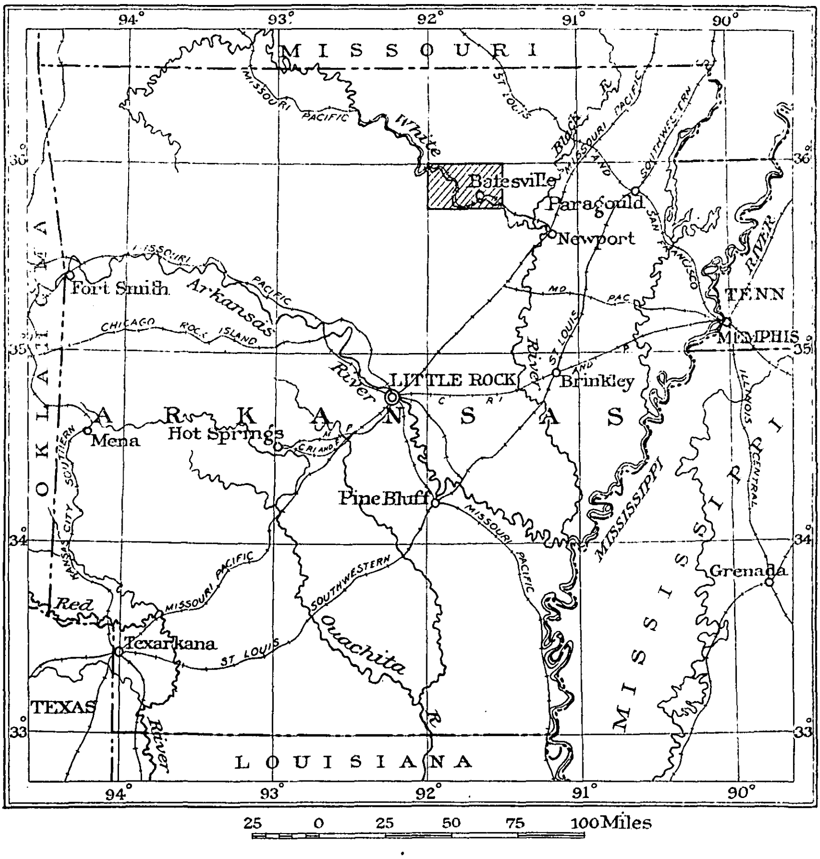


FIGURE 1.—Index map of Arkansas showing the location of the Batesville manganese-ore district.

advice in planning the field work and for many suggestions during the progress of the office work; E. O. Ulrich, for the examination of fossil collections and for much information regarding the age and relations of the rock formations of the Ordovician, Silurian, and Devonian systems; G. H. Girty, for the study of fossil collections from the Boone chert of Carboniferous age and a statement concerning them; W. T. Schaller and E. S. Larsen, for mineralogic

[2] Washington Acad. Sci. Jour., vol. 10, No. 1, 1920.

determinations; and R. C. Wells and Chase Palmer, for chemical analyses of rock and mineral specimens.

W. R. Crane, of the Bureau of Mines, has contributed a chapter on the mining and preparation of the ores, which appears on pages 86–103, and he has supplied several of the photographs from which illustrations have been made.

Acknowledgment is also due to the residents in the Batesville district for their uniformly courteous treatment and to the following persons for information: W. H. Denison and J. S. Baker, of Cushman, Ark.; J. F. Kennard, R. S. Handford, E. C. McComb, J. C. Shepherd, and N. A. Adler, of Batesville, Ark.; J. F. Barksdale, of Anderson, Ark.; W. H. Beatty and C. S. Blair, of Birmingham, Ala.; W. C. Gordon, of Iron Mountain, Mich.; William Trebilcock, of North Freedom, Wis.; A. O. Ihlseng, of New York City; Rex Robor; G. A. Adkins; and Captain Vance.

Reports by D. D. Owen, William Elderhorst, E. T. Cox, R. A. F. Penrose, jr., J. C. Branner, J. F. Newsom, T. C. Hopkins, H. S. Williams, Gilbert Van Ingen, A. H. Purdue, E. O. Ulrich, E. C. Harder, D. F. Hewett, G. H. Girty, D. E. Woodbridge, Tom Shiras, and others have been freely consulted and drawn upon. Most of the reports on the Batesville district are listed in the bibliography, which follows, and others are referred to at different places in the report. Special mention should be made of the monographic report by Penrose on the uses, ores, and deposits of manganese, published in 1891. Both the text of this report and the accompanying geologic map were constantly used by the writer in his field and office work. It is referred to at many places in the present report, and parts of it are quoted.

BIBLIOGRAPHY.

The following list includes papers treating of the manganese deposits of the Batesville district and some of the more important papers on the geology of the district.

1858.

OWEN, D. D., First report of a geological reconnaissance of the northern counties of Arkansas, pp. 37–41, 136, 138.

The geology of a part of the Batesville district is briefly treated, and the manganese deposits on Lafferty Creek are described.

ELDERHORST, WILLIAM, Chemical report of the ores, rocks, and mineral waters of Arkansas: First report of a geological reconnaissance of the northern counties of Arkansas, pp. 161–169.

Gives analyses and descriptions of manganese ores.

COX, E. T., Report of a geological reconnaissance of a part of the State of Arkansas: First report of a geological reconnaissance of the northern counties of Arkansas, pp. 216–222.

Describes the geology of Independence County and the manganese deposit on the property of Martin Cason, on which the Cason mine was later opened.

1886.

HARVEY, F. L., The minerals and rocks of Arkansas, 32 pp., Philadelphia.
Mentions the existence of pyrolusite, braunite, psilomelane, and wad in Independence County but gives only a brief general description of them.

1891.

PENROSE, R. A. F., Jr., Manganese—its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1.
Describes every manganese region in North America known at that time. The manganese deposits and geology of the Batesville district are described in great detail. The report is accompanied by a map showing the distribution of the rock formations and the location of the manganese mines and prospects.

—— The origin of the manganese ores of northern Arkansas and its effect on the associated strata (abstract): Am. Assoc. Adv. Sci. Proc., vol. 39, pp. 250–252.
Discusses the manganese ores of the Batesville district.

1893.

HOPKINS, T. C., Marbles and other limestones: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 4.
The limestones of northern Arkansas, including those of the Batesville district, are described in great detail. The report is accompanied by a geologic map, which is similar to the one that accompanies the report by Penrose.

1894.

WILLIAMS, H. S., On the age of the manganese beds of the Batesville region of Arkansas: Am. Jour. Sci., 3d ser., vol. 48, pp. 325–331.
Discusses the age of the manganese-bearing rocks.

PENROSE, R. A. F., Jr., The superficial alteration of ore deposits: Jour. Geology, vol. 2, p. 306.
One paragraph is devoted to a discussion of the origin of the manganese deposits of the Batesville district.

1895.

WILLIAMS, H. S., On the recurrence of Devonian fossils in strata of Carboniferous age: Am. Jour. Sci., 3d ser., vol. 49, pp. 94–101.
Discusses the Carboniferous rocks of the Batesville district.

1897.

BRANNER, J. C., The phosphate deposits of Arkansas: Am. Inst. Min. Eng. Trans., vol. 26, pp. 580–598.
The phosphate deposits that are described include those of the Batesville district.

1898.

WELLER, STUART, The Batesville sandstone of Arkansas: New York Acad. Sci. Trans., vol. 16, pp. 251–282.
Reviews the literature on the formation, describes fossils recently collected from it, and discusses its correlation from the paleontologic and stratigraphic data.

1900.

WILLIAMS, H. S., The Paleozoic faunas of northern Arkansas: Arkansas Geol. Survey Ann. Rept. for 1892, vol. 5, pp. 268–362.

This paper gives much information on the correlation and the faunas of the rock formations.

1901.

VAN INGEN, GILBERT, The Siluric fauna near Batesville, Arkansas, I: School of Mines Quart., vol. 22, pp. 318–329. Columbia Univ. Geol. Dept. Contr., vol. 9, No. 76, pp. 318–329.

Describes the Cason shale and St. Clair limestone and discusses their geologic relations. Briefly describes the manganese deposits. Includes a bibliography.

—— The Siluric fauna near Batesville, Arkansas, II: School of Mines Quart., vol. 23, pp. 33–74. Columbia Univ. Geol. Dept. Contr., vol. 9, No. 76, pt. 2.

Describes the characters of the various fossil species from the St. Clair limestone.

1902.

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

The phosphate deposits of the Batesville district, most of which are in the Cason shale, are described fully. The following statement is made: "Throughout much of the region * * * manganese has been mined or prospected for, and as the phosphate rocks generally overlie the manganese the latter mineral may frequently serve as a guide to the prospector for phosphate rock."

1904.

ULRICH, E. O., Determination and correlation of formations [of northern Arkansas]: U. S. Geol. Survey Prof. Paper 24, pp. 90–113.

Discusses the correlation of the rocks of northern Arkansas, including those of the Batesville district.

1907.

PURDUE, A. H., Developed phosphate deposits of northern Arkansas: U. S. Geol. Survey Bull. 315, pp. 463–473.

The developed phosphate deposits which occur in the Cason shale on Lafferty Creek, on the western edge of Independence County, are described. The geology of the phosphate region is also described briefly.

1909.

HARDER, E. C., Manganese deposits of the United States: U. S. Geol. Survey Bull. 380, pp. 267–270.

A preliminary report.

1910.

HARDER, E. C., Manganese deposits of the United States, with sections on foreign deposits, chemistry, and uses: U. S. Geol. Survey Bull. 427, pp. 102–118, 127, 269–270.

Describes briefly the geology and manganese ores of the Batesville district. The general relations, forms, origin, and commercial importance and production of the ores are discussed. Analyses of the ores and descriptions of several mines are given.

1911.

GIRTY, G. H., The fauna of the Moorefield shale of Arkansas: U. S. Geol. Survey Bull. 439, 148 pp., 15 pls.

Gives systematic descriptions of the fossils and discusses their stratigraphic position and the nomenclature and correlation of the formation in which they occur.

1915.

GIRTY, G. H., Fauna of the so-called Boone chert near Batesville, Arkansas: U. S. Geol. Survey Bull. 595, 45 pp., 2 pls.

Describes collections of fossils from the upper part of the Boone chert and discusses the correlation of the chert.

—— Fauna of the Batesville sandstone of northern Arkansas: U. S. Geol. Survey Bull. 593, 170 pp., 11 pls.

Describes the fauna of the Batesville sandstone and gives its relations to other faunas.

1917.

SHIRAS, TOM, Manganese mining in Arkansas: Eng. and Min. Jour., vol. 104, No. 25, pp. 1079–1080, Dec. 22.

The history of the Batesville district, the manganese ores, and the methods of mining are briefly treated.

HEWETT, D. F., Manganese output in Arkansas district affected by labor shortage: Eng. and Min. Jour., vol. 104, No. 21, p. 931, Nov. 24.

Discusses briefly the occurrence and character of the manganese ores, the production of ore in 1918, and mining conditions in the Batesville district.

1918.

SHIRAS, TOM, Manganese washing plant of the Eureka Company, Arkansas: Eng. and Min. Jour., vol. 105, No. 17, p. 778, April 27.

The washing plant of the Eureka Manganese & Mining Co. at the Montgomery mine is described and the quantity of ore treated is given.

WOODBRIDGE, D. E., The Arkansas manganese field: Eng. and Min. Jour., vol. 106, No. 15, pp. 669–670, Oct. 12.

Describes briefly the geology and ore deposits of the Batesville district and gives a full discussion of the economic possibilities and mining conditions in the district.

HARDER, E. C., Manganiferous iron ores: U. S. Geol. Survey Bull. 666–EE.

Describes briefly the low-grade manganese ore of the Batesville district and gives analyses and production by years of this kind of ore.

BATESVILLE-CUSHMAN MANGANESE FIELD, Batesville, Ark.: Batesville Board of Trade, 30 pp.

Describes the topography, manganese deposits, and methods of mining in the Batesville-Cushman field. Parts of the reports by Harder (1910) and Penrose (1891) and of the press report by the present writer (1918) are quoted.

1920.

HARDER, E. C., and HEWETT, D. F., Recent studies of domestic manganese deposits: Am. Inst. Min. Eng. Trans., vol. 63, pp. 3–50.

The ore-forming minerals, stratigraphic relations, genesis, production, composition, and reserves of the manganese ores of the Batesville district are discussed.

HISTORY AND PRODUCTION.

The manganese ore deposits of the Batesville district have been worked at times since 1849 and have yielded both high-grade and low-grade manganese ores. Most of the work on the deposits of high-grade ore has been done during two periods of activity, one beginning in 1885 and ending in 1898, and the other beginning in 1915 and ending at least temporarily in November, 1918, when the demand for domestic manganese ores greatly decreased. Most of the work on the deposits of low-grade ore has been done since 1904. By far the greater part of the high-grade manganese ore produced during the first period of activity was mined at the Southern mine, and the greater part of the low-grade ore was produced by the Cason mine.

The early history and production of the Batesville district is summarized as follows by Penrose:[3]

The existence of manganese in the Batesville region has been known for over forty years, but it has only been since 1881 that the ore has been mined to any considerable extent. Col. Matt. Martin, of Batesville, was the first to discover the value of this ore, and between 1848 and 1850 he and Mr. M. D. Fields acquired large tracts of land in the manganese region. This was done on the advice of Prof. Gerard Troost, who was then State Geologist of Tennessee. Col. Martin worked some of these lands to a limited extent and as early as 1850–1852 shipped small quantities of ore to Boston, New York, and Philadelphia. One shipment is also said to have been made to Liverpool, where it was used at the chlorine works of Charles Tennant, in Glasgow. At this early date, however, there were no railways in the State, and the ore could be brought to market only by hauling in wagons to the White River or Black River and shipping by barge to the desired destination. The ore mined by Col. Martin was taken to New Orleans in barges and shipped thence by sea.

For over 25 years after Col. Martin's first shipments occasional small quantities of manganese were mined in the Batesville region. The ore shipped during this period was mostly if not altogether used for chemical purposes and not in the manufacture of steel, which to-day consumes the whole production of Arkansas. A few hundred tons would probably include the total quantity produced up to 1868. In that year Mr. William Einstein, of St. Louis, made the first shipment of manganese from Arkansas for steel purposes. It was sent to Messrs. Schoenberger & Co., Juniata Iron Works, Pittsburgh, Pa. The ore was shipped by barge down the White River, thence to the Mississippi, and up the Ohio to its destination. The total quantity amounted to 10 tons, which was sold at Pittsburgh for $30 per ton. At that time, however, the production of steel in the United States was very small compared with its present manufacture, and the demand for manganese was correspondingly less than at present.

For 12 years after Mr. Einstein's shipment little or no mining was done in the Batesville region. The test of Mr. Einstein's ore is said to have proved a success, but the comparatively small demand for manganese at that time was mostly supplied from Virginia, Georgia, and foreign sources. Moreover, there was still no means of railway transportation in the State, and it was not until 1871–1872, when the St. Louis, Iron Mountain & Southern Railway was extended

[3] Penrose, R. A. F., jr., Manganese—its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, pp. 104–107, 1891.

south from the Missouri line to Little Rock, that shipping facilities were obtained. Even then Newport was the nearest railway point, and it was 35 to 40 miles distant from the manganese region. The ore had to be shipped by barge to that place and there transferred to cars. It was not until 1886, when the Batesville branch line was extended to the manganese region, that the ore could be shipped all the way by rail.

In 1881 Mr. E. H. Woodward, representing the Ferro-Manganese Co., started operations in Arkansas. Mr. Woodward had already become identified with the Georgia manganese region and was well known in all the other manganese localities of the Appalachian Mountains. He bought and leased tracts of land in the Batesville region and from then until 1887 mined intermittently, shipping altogether probably about 5,000 tons or more of ore. A large part of this came from the Southern, the Turner, the Trent, and the Montgomery mines.

At the time Mr. Woodward began his operations the demand for manganese for use in steel was rapidly increasing, and the output of his mines, representing as it did the first systematic production of manganese in the Batesville region, found a ready sale.

In October, 1885, the Keystone Iron & Manganese Co., of Pennsylvania, acquired large tracts of land in the Batesville region. They commenced operations on the Southern Hill and have worked continuously ever since. They are the largest operators in the region and have probably mined over a half of the ore that has been shipped from Arkansas. Their total production since they commenced work until December 31, 1890, has been 18,111 tons.

In the same year (1885) the St. Louis Manganese Co., of St. Louis, Mo., was organized and commenced work in the region of Cushman and elsewhere. They mined up to September, 1890, 1,700 tons of ore. About the same time the Missouri Furnace Co., of St. Louis, acquired manganese lands in the Lafferty Creek district, but their work has been limited. The total output up to September 1, 1890, was a little over 500 tons. Besides these companies others commenced operations at or near the same time, but their production has been small. Among them were the American Manganese Co., the White River Manganese Co., the Arkansas Manganese Co., and the Blair Mining Co., as well as others.

The extension, in 1886, of the Batesville branch of the St. Louis, Iron Mountain & Southern Railway from Newport through Batesville to Cushman has greatly facilitated the transportation of the manganese ores and has opened up mining localities which would otherwise have been inaccessible. In 1888 Messrs. Abbot & Ring, of Chicago, opened up properties on Polk Bayou. Later the firm was changed to Skinner & Abbot, and in 1889 it was again changed to John B. Skinner & Co. Mr. Skinner has erected a large washer on Sullivan Creek, and energetic arrangements are now being made for the extensive mining and treatment of the manganese ores of that part of the Batesville region. The production of these firms from April 20, 1889, to June 26, 1890, was over 700 tons.

Besides the companies already mentioned occasional shipments of manganese ore have been made by private individuals, among whom are H. M. Hodge, R. R. Case, I. N. Reed, J. P. Montgomery, John W. McDowell, A. A. Steele, Wm. Reves, J. B. Gray, Messrs. Pritchett, Russell, Drake, and others. These shipments, however, were small and a few thousand tons would cover the aggregate amount.

Correct figures of the total amount of manganese mined in the Batesville region are difficult to get, except since the time the ore has been shipped by rail. The records of the ore shipped by barge down the White River before the railway was extended to Batesville were either not kept at all or have been lost.

It is probable, however, that the total amount of manganese shipped from the Batesville region from the time mining was first begun until December 31, 1890, does not exceed 35,000 tons and is between that and 30,000 tons.

The Keystone Manganese & Iron Co., as stated by Penrose, began work at the Southern mine in 1885. The company operated this mine almost continuously until 1898 and produced from it between 30,000 and 35,000 tons of high-grade manganese ore, which is almost one-half of the total output of this class of ore for the entire district. During parts of the period from 1885 to 1898 this company operated other mines also, among which were the Polk Southard, Turner, Cason, George, Henley, G. A. Wilson (Lone Star), and J. A. Reves mines. It mined and shipped 3,500 to 4,000 tons from the Polk Southard mine, 3,000 tons or more from the Turner mine, and several hundred tons or less from each of the other mines.

The Cason mine was operated by the Keystone Manganese & Iron Co. about 30 years ago, but it produced very little ore until 1904. Beginning in that year the mine was operated almost continuously until November, 1918, by various firms and persons, among whom were the Frisco Ore Mining Co., Batesville Manganese Co., and W. H. Denison. The total output from 1904 to 1918, inclusive, has been approximately 61,321 tons. A statement of the production by years is given on page 12.

The Martin Manganese & Mining Co., of Roanoke, Va., operated the Polk Southard, Club House, Rowe Field, Blue Ridge, Cummins Hollow, and Shaft Hill mines in 1909 and 1910, after which these mines laid idle until 1915. From 1915 until November, 1918, these mines were operated more or less continuously by the Independence Mining Co., of which E. C. McComb, of Batesville, Ark., is owner and manager.

W. H. Denison, of Cushman, Ark., has not only operated manganese mines in recent years but has acted as sales agent for the Independence Mining Co., the Eureka Manganese & Mining Co., R. S. Handford, N. A. Adler, and most of the other producers in the Batesville district. In 1905 he operated the Meeker mine on a small scale, and in 1916, 1917, and 1918, he operated various other mines, among which were the Kimbrough, Martin No. 2, Brooks Hill, Kimmer, Roseborough, Southern, Shaw, McConnell, Roach, Cason, and Turner. During parts of these years he and J. F. Barksdale, of Anderson, Ark., operated the George, Johnson Hill, Sand Field, Manganese Field, Ruminer Rough, and Barksdale mines and the mine of the United Phosphate & Chemical Co.

The Cushman Manganese Co., which is a firm consisting of three members, W. H. Denison, R. S. Handford, and J. F. Kennard, operated the Rogers mine in 1917 and 1918, and the Page and Wren mines in 1918.

The Eureka Manganese & Mining Co., of Cushman, Ark., of which W. H. Denison is president and W. H. Beatty is manager, began the operation of the Montgomery mine in May, 1917, and it mined, milled, and shipped about 3,600 tons of manganese-ore concentrates during 1917 and 1918. The ore was concentrated in a washing plant that was erected by this company at the mine.

N. A. Adler, of Batesville, Ark., operated the Adler and Searcy mines in 1916 and 1917, and he, together with W. H. Denison, did some work in 1916 at the Club House mine and the W. A. Chinn cut. The production made at the Searcy mine by Mr. Adler during these years was 1,175 tons.

Mines operated by R. S. Handford, of Batesville, Ark., during parts of 1916, 1917, and 1918 included the Pittman, Harvey, Ellen Clark, Klondike, and Rogers mines, and during parts of these years he, together with J. J. Skelton, operated the Skelton Hill, Verna, and Hankins Hollow mines. Besides being a member of the Cushman Manganese Co., he was a partner with J. C. Shepherd in the erection and operation of a small washing plant at the Button prospect, in 1918.

The Marqua Mining Co., of Granite City, Ill., operated the Mount Etna, Grubb Cut, Lassiter, and Izard mines in 1917 and 1918 and did some work at the Tosh Hill, Section Eight, and Section Thirty-four prospects. The production of this company during these years was 1,182 tons of high-grade manganese ore and 460 tons of low-grade ore. All the above-mentioned properties belong to William Einstein, of St. Louis, Mo., who leased them to the company.

J. C. Shepherd, a zinc operator in the Rush district of northern Arkansas, together with other persons leased and purchased several properties in the Batesville district in 1918. The Waco Manganese Co., a firm of which he is a member, erected a washing plant on the T. S. M. Patterson tract, 4 miles south of east from Cushman, and operated it for a short time in the fall of 1918. Mr. Shepherd and R. S. Handford built a small washing plant at the Button prospect and operated it for a short time in 1918. Mr. Shepherd and R. A. Baker mined and shipped several carloads of manganese ore from the Sis Clark mine in the last half of 1918. Mr. Shepherd and J. R. Wilson operated for a short time a small washing plant at the Ball mine and had partly erected a larger plant in November, 1918, on which work was stopped because no market for the ore could be found after that time. Mr. Shepherd leased or purchased the W. W. Allen mine in the spring of 1918 and erected a washing plant near it. He was succeeded by the Leader Mining Co., of which he became president. The operation of the washing plant was begun by this company in September, 1918, but it continued for only a short time.

The Oklahoma-Arkansas Oil & Mining Co., of Holdenville, Okla., leased the Searcy mine from N. A. Adler in the spring of 1918, but it was soon succeeded by the Bill-Jim Mineral Co., of Holdenville, Okla., which erected a washing plant at the mine. The mine and washing plant were, however, not operated by the last-named company, but later in 1918 Logan Rives leased the mine and operated it and the washing plant for a short time. Mr. Rives also operated the George and Ellen Clark mines for a few months in 1918.

J. A. Welch leased the Roach mine from the Manganese Development Co. in 1918 and had partly erected a washing plant when manganese mining in the district was stopped, owing to the termination of the World War.

The Oklahoma-Kansas Mining Co., of Miami, Okla., purchased, in 1918, the Schlieper and Denison mines and erected a washing plant at the Denison mine. The plant was completed about the time when the armistice with Germany was signed and has not been operated.

The United States-Canadian Manganese Co. purchased the Weaver tract, 4½ miles north-northwest of Pfeiffer, and after some prospecting had been done it erected a washing plant which was practically completed in November, 1918.

The Standard Manganese Co., of Chicago, Ill., operated the Cutter mine in 1918 and erected a washing plant near East Lafferty Creek in which to separate the manganese ore from the inclosing clays. The production by this company was very small.

S. B. McConnico, of Chicago, Ill., did considerable prospecting on Bell Hill, 4½ miles east of Cushman, in the spring of 1918, and the tract that he had prospected was leased by him and other persons, who organized the Liberty Manganese Co., of Chicago. The construction of a washing plant by this company was well advanced in November, 1918, when work on it was stopped.

The United States Steel Corporation through its subsidiary companies, the Tennessee Coal, Iron & Railroad Co. and the Oliver Iron Mining Co., made several borings with diamond drills in the Batesville district in 1918 to find bodies of manganese ore like that in the Cason shale which is worked at the Cason mine. No such bodies were discovered. The records of most of the borings are given on pages 42–45.

Other companies and individuals who have been operators or prospective operators in the Batesville district from 1915 to 1918 include the following: Ozark Manganese Co., of Superior, Wis.; Magnolia Mining Co., of St. Louis, Mo.; Stone County Mining Co., of Red

Stripe, Ark.; Loyalty Mining Association, of Holdenville, Okla.; Polk Bayou Mining Co., of Batesville, Ark.; Manganese Development Co., of Chicago, Ill.; National Manganese Co.; Vance Mining Co., of Batesville, Ark.; Ozark Mining Co., of Batesville, Ark.; Everton Mining & Development Co.; Anderson Manganese Co.; W. A. Hamer, of Sandtown, Ark.; Henry Clark, of Cave City, Ark.; D. E. Woodbridge, of Duluth, Minn.; E. W. Buskett, of Joplin, Mo.; Walter Denison, jr., of Cushman, Ark.; W. A. King, of Mount Pleasant, Ark.; T. M. Tate, of Anderson, Ark.; T. F. Shell, S. W. Deener, I. J. Matheny, and Ernest Neill, of Batesville, Ark.; W. E. Barnes, J. R. Martin, W. C. Collie, Jim Wolford, W. T. Gray, George Brewer, and H. H. Anderson.

The production of manganese ore and ferruginous manganese ore in the Batesville district by years, from 1849 to 1921, inclusive, is given in the accompanying table, which is compiled mainly from Mineral Resources, published by the United States Geological Survey, but partly from other sources.

Manganese and ferruginous manganese ores produced in the Batesville district, Ark., 1849–1921, in long tons.

Year.	Manganese ore (35 per cent or more of manganese).[a]	Ferruginous manganese ore (10 to 35 per cent of manganese).	Year.	Manganese ore (35 per cent or more of manganese).[a]	Ferruginous manganese ore (10 to 35 per cent of manganese).
1849-1867	600	....	1901	91	....
1868	10	....	1902	82	....
1881	100	....	1904	....	600
1882	175	....	1905	....	3,321
1883	400	....	1906	62	8,900
1884	800	....	1907	....	4,133
1885	1,483	....	1908	....	4,066
1886	3,316	....	1909	....	3,325
1887	5,651	....	1910	500	5,030
1888	4,312	....	1911	....	2,177
1889	2,528	....	1912	....	1,332
1890	5,339	....	1913	....	9,650
1891	1,650	....	1914	....	1,970
1892	6,708	....	1915	1,288	2,655
1893	2,020	160	1916	6,250	3,645
1894	1,934	....	1917	10,140	9,100
1895	2,991	....	1918	7,731	9,173
1896	3,421	....	1919	2,558	564
1897	3,240	....	1920	3,445	4,403
1898	2,662	....	1921	728	278
1899	356	....			
1900	145	....		82,716	74,482

[a] The figures for production of manganese ore for 1910 and previous years perhaps include a small amount of ore carrying less than 35 per cent of manganese.

GEOGRAPHY.

RELIEF.

The Batesville district is on the southern edge of the Ozark Plateau, south of which lie the Boston Mountains. Both the plateau and the mountains are subdivisions of the Ozark region.

The district here described is rough, but the relief is not great. Many narrow valleys trench all parts of its plateau surface, so that very little level land remains. The lowest elevation, which is less than 250 feet above sea level, is on White River near Batesville, and the highest, 950 feet, is on Pine Mountain. The streams flow in channels that are generally 100 to 400 feet below the crests of the hills and ridges. The hill slopes are steep, and there are many bluffs adjacent to the streams, especially on the outer sides of the stream bends. (See Pl. II, *A*.) Of the bluffs along White River (see Pl. III, *A* and *B*) the largest and most picturesque is Penters Bluff, which is about 1 mile long and about 400 feet high. The small number of level tracts and the more gentle slopes are mantled with residual soil or with wash from higher ground. Rock outcrops are common in most parts of the district but are especially abundant on the steeper slopes.

The Batesville district is not a single plateau but comprises parts of three plateaus which are separated by low and very sinuous escarpments. These plateaus from south to north are the Batesville, Springfield, and Salem plateaus. The middle one of these, the Springfield Plateau, stretches from east to west through the center of the district. It is 8 to 10 miles wide, and on or near its north border Gid, Mount Pleasant, Sandtown, and Hickory Valley, are situated, and on or near its south border Sulphur Rock, Moorefield, and Batesville are situated. Although this plateau is extensively dissected, many of the interstream areas, which are hills and narrow finger-like ridges, are flat topped and in any view that shows the sky line of the country are seen to be remarkably uniform in height. The surface of the plateau, however, is not level, but slopes to the south from about 25 feet to about 50 feet per mile. The highest points on its north border are from 700 to 900 feet above sea level, whereas most of those on its south border range from 500 to 600 feet above sea level. The plateau is formed by the resistant Boone chert, though a part of it, lying north of Sulphur Rock and Moorefield, is underlain by the Moorefield shale and Batesville sandstone. The general southward slope is due to the dip of the Boone chert in this direction. Most of the manganese deposits occur in the valleys and on and near the crests of the hills within this plateau area; none have been found south of it and very few north of it.

North of the part of the Springfield Plateau described above lies another plateau that is known farther north and west as the Salem Plateau. The Salem Plateau is separated from the Springfield Plateau by a low, sinuous escarpment, known farther west as the Eureka Springs escarpment. The surface of the part of the Salem Plateau within the Batesville district has about the same elevation along the north border of the district as the north border of the Springfield Plateau—that is, about 750 feet above sea level—but it slopes southward so that near Hickory Valley, Sandtown, Mount Pleasant, and Gid it is 100 to 200 feet lower than the adjacent border of the Springfield Plateau. This surface has been formed on the St. Peter sandstone, a resistant formation, and its southward slope is due to the southward dip of this sandstone. Many valleys trench this plateau, and many hills, composed of rocks that are younger than the St. Peter sandstone, rise above its general surface near Cave City and Mount Pleasant. Manganese deposits have been found at a few places on this plateau.

A small plateau, to which the name Batesville is here applied, lies south of and higher than the Springfield Plateau. Its largest area lies between Oneal and White River Junction, and smaller parts of it lie south of the Missouri Pacific Railroad between Batesville and Sulphur Rock. The eastern part of the town of Batesville is on one of these smaller parts of it. This plateau has been formed on the Batesville sandstone. It stands from 100 to 200 feet above the south border of the Springfield Plateau and from 500 to 650 feet above sea level. In the largest area the surface of the plateau slopes to the south, which is the direction of the general dip of the Batesville sandstone.

The three plateaus in the Batesville district do not represent three peneplains but three structural plains, whose formation and preservation are due to the resistant rock formations that underlie them. The occurrence of gravels of Upper Cretaceous or Tertiary age on many of the highest hills on both the Salem and the Springfield plateaus east of the longitude of Cushman suggests that these gravel-covered hills may mark the elevation of a former peneplain now thoroughly dissected, but perhaps most if not all of the hills in the vicinity of and west of Cushman are lower than the level at which this peneplain stood. This supposed peneplain truncated the edges of the resistant rock formations on which the plateaus were later formed by erosion. The relation of the peneplain to the plateaus and to the Boston Mountains, which are just south of the Batesville district, is shown in figure 2. The peneplain is probably of Upper Cretaceous or early Tertiary age, but further field studies over a much larger part of the southern Ozark region than the Batesville district and over the adjoining parts of the Gulf Coastal Plain will be necessary before its age can be determined accurately.

DRAINAGE.

The drainage of all parts of the Batesville district empties into White River, the largest stream in the district. Cura and Dota creeks enter Black River, which enters White River outside the district, and the streams north and northeast of Cave City enter Strawberry River, which joins Black River. White River is navigable above Guion at the west end of the Batesville district, and a series of three dams and locks have been built by the United States Government to aid navigation. One of these is just below Batesville, the second is at Earnharts, and the third is at Walls Ferry station. Next to White River the largest streams of the area are West Lafferty, East Lafferty, Spring, and Sullivan creeks and Polk Bayou, the last of which is really a creek and not a bayou. Many of the creeks are perennial and are supplied with water from springs in all parts of the area. They can be easily forded throughout most of the year but are subject to sudden rises after heavy rains.

CULTURE.

The Batesville district is not densely populated, though all parts of it are inhabited. The largest town is Batesville the county seat of Independence County. Among the smaller towns and the more important villages are Cushman, Cave City, Mount Pleasant, and Guion.

A branch of the Missouri Pacific Railroad passes through Sulphur Rock, Moorefield, and Batesville and thence follows the left bank of White River to and beyond the western limit of the district. Short branches of this railroad extend to Pfeiffer and Cushman. A spur formerly ran from the mouth of Lafferty Creek to the village of Phosphate, but both the spur and the village have long been abandoned.

Public and secondary roads reach all parts of the district, but only a few of them are maintained in good condition,

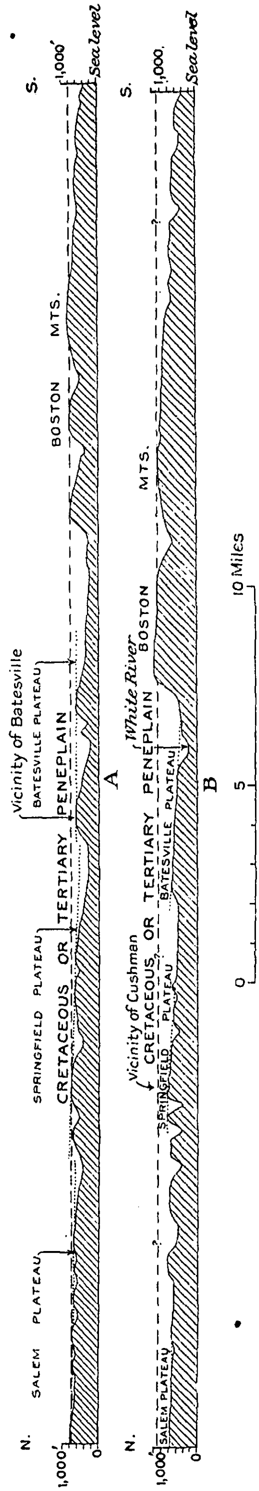


FIGURE 2.—Generalized north-south profile sections through the Batesville district, showing the plateaus described in this report, the Boston Mountains, and the Cretaceous or Tertiary peneplain. A, Cross section about 2 miles east of Batesville. B, Cross section about 1⅓ miles west of Cushman. The position of the Cretaceous or Tertiary peneplain is not known, but it was probably about 300 feet above Cushman.

although limestone, broken chert, and gravel suitable for road building are at hand in many places. Owing to the roughness of the country the roads follow very few of the lines of sections or townships.

The district is adapted to general farming, fruit-growing, and grazing, and agriculture is the chief occupation. Lumbering is also important. The mining of manganese ore has, however, at times been one of the most important industries. A limestone quarry at Pfeiffer that furnishes a high-grade building stone has been in operation for many years, and limestone has been quarried at other places for building stone and for making lime. Sandstone has been quarried for local use as a building stone, and a quarry at Guion has yielded glass sand.

GEOLOGY.

ROCK FORMATIONS.

GENERAL FEATURES.

All the rocks of the Batesville district that have been exposed or penetrated by wells are of sedimentary origin. They comprise sandstone, shale, limestone, chert, and some beds of gravel and sand. They are of Ordovician, Silurian, Devonian, Carboniferous, Cretaceous (?), and Quaternary age. They are graphically represented in the generalized sections in Plate IV, and their names and sequence together with their stratigraphic positions as determined by different geologists are shown in the correlation table opposite this page.

ORDOVICIAN SYSTEM.

ST. PETER SANDSTONE AND OLDER ROCKS.

The St. Peter sandstone is the surface rock over most of the area that is represented on the map (Pl. I) by the pattern designated as St. Peter sandstone and older rocks. Most of the rocks below this sandstone are drab-colored magnesian limestones, but some are sandstones, and they crop out on West Lafferty, East Lafferty, and Sullivan creeks and Polk Bayou. They were penetrated to a depth of 1,615 feet in the well at the Southern mine, the log of which is given on pages 45, but their greatest observed thickness, 210 feet, is on the west slope of Pine Mountain. Future studies will be required to group the beds below the St. Peter sandstone into formations, and many or all of the groups thus determined will doubtless be found to be equivalents of rock formations to which names have been assigned in other parts of the Ozark region. Some of the lowest beds reached in the above-mentioned well may prove to be of Cambrian age.

Names and equivalents of formations in the Batesville district and other parts of northern Arkansas.

Penrose, R. A. F., jr., Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, 1891. Batesville district.		Branner, J. C., Am. Inst. Min. Eng. Trans., vol. 26, pp. 580–598, 1897. Northern Arkansas.		Williams, H. S., Arkansas Geol. Survey Ann. Rept. for 1892, vol. 5, pp. 277, 284, 1900. Northern Arkansas.		Branner, J. C., and Newsom, J. F., Arkansas Agr. Exper. Sta. Bull. 74, p. 67, 1902. Northern Arkansas.		Ulrich, E. O., U. S. Geol. Survey Prof. Paper 24, 1904. Northern Arkansas.		Harder, E. C., U. S. Geol. Survey Bull. 427, pp. 103–107, 1910. Batesville district.		Ulrich, E. O., Geol. Soc. America Bull., vol. 22, pls. 27, 28, 29, 1911. Northern Arkansas.		Present report. Batesville district.	
Lower Carboniferous or Mississippian.	Batesville sandstone.	Lower Carboniferous or Mississippian.	Batesville sandstone.	Carboniferous.	Batesville sandstone.	Lower Carboniferous or Mississippian.	Batesville sandstone.	Carboniferous (Mississippian).	Batesville sandstone.	Carboniferous (Mississippian).	Batesville sandstone.	Tennesseean.	Batesville sandstone.	Carboniferous (Mississippian).	Batesville sandstone.
	Fayetteville shale.		Fayetteville shale.		Spring Creek black shales and limestones = Fayetteville shale of Dr. Penrose's report.		Fayetteville shale.		Moorefield shale.		Moorefield shale.		Moorefield shale.		Moorefield shale.
	Boone chert.		Boone chert and limestone.		Boone chert.		Boone chert and limestone.		Boone limestone.		Boone chert.	Waverlyan.	Boone chert. Fern Glen limestone.[a]		Boone chert.
Age not given.	Sylamore sandstone.[b] [c]	Devonian (?).	Sylamore sandstone.[b] [c] Eureka shale.	Devonian.	Eureka shale (typical). Sylamore sandstone.[b] Eureka shale (in part).	Devonian.	Sylamore sandstone.[b] [c] Eureka shale.	Devonian.	Noel shale. Sylamore formation.	Devonian(?).	Chattanooga shale (?)[d] Sylamore sandstone member (?).		Chattanooga format on. Sylamore sandstone member.	Devonian.	Chattanooga shale.[e] [f]
															Penters chert.[e]
														Silurian.	Lafferty limestone.[g]
Silurian.	St. Clair limestone.	Lower Silurian.	St. Clair marble.	Silurian.	St. Clair limestone.[h]	Silurian.	St. Clair marble.	Silurian.	St. Clair limestone.	Silurian.	St. Clair limestone.	Silurian.	"Upper St. Clair limestone." [i] St. Clair limestone.		St. Clair limestone.
													Brassfield limestone.[j]		Brassfield limestone.[j]
					Cason shale.			Ordovician.	Cason shale.	Ordovician.	Cason shale.		Cason shale.	Ordovician.	Cason shale.
				Ordovician.	Polk Bayou limestone.[h]				Polk Bayou limestone.		Polk Bayou limestone.		Fernvale or Upper Polk Bayou limestone.		Fernvale limestone.
	Izard limestone.		Izard limestone.		Izard limestone.	Ordovician.	Izard limestone.		Izard limestone.		Izard limestone.	Ordovician.	Kimmswick limestone.		Kimmswick limestone.
													Lowville limestone. Izard limestone.		Plattin limestone.
													Joachim limestone.		Joachim limestone.
	Calciferous group.		Saccharoidal sandstone.		Saccharoidal sandstones.		Saccharoidal sandstone.		Key sandstone.		St. Peter sandstone.		St. Peter sandstone.		St. Peter sandstone.
			Magnesian limestones. Sandstones, cherts, etc.		Calciferous or magnesian limestones.		Magnesian limestone. Sandstone, cherts, etc.		Yellville limestone.		Yellville limestone.		Everton limestone. Yellville formation.		Magnesian limestone and sandstone.

[a] Ulrich in the geologic section for the southwest flank of the Ozark uplift (Geol. Soc. America Bull., vol. 22, pl. 29) lists several formations between the Fern Glen and the Chattanooga; they are represented in southwestern Missouri but so far as known are not represented in northern Arkansas. He regards his Fern Glen limestone of northern Arkansas as lying below the Boone chert, but the accepted usage of the United States Geological Survey places all beds of Kinderhook age (including the Fern Glen) in the Boone chert.

[b] Probably absent in the Batesville district.

[c] Confused with sandstone at the base of the Boone chert and at some places confused with sandstone in the Cason shale.

[d] The beds doubtfully assigned to the Chattanooga are a part of the Cason shale.

[e] Penrose is the only geologist who has described the Chattanooga shale and Penters chert of the Batesville district, but he included them in the Boone chert.

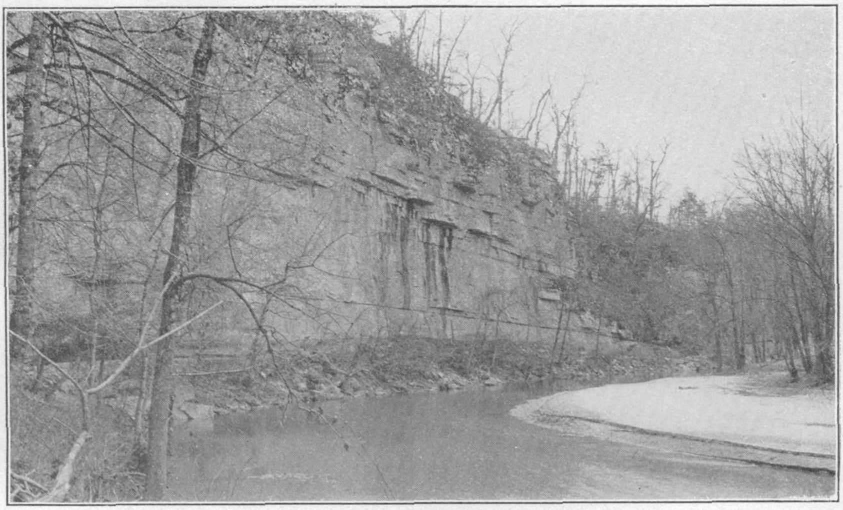
[f] The shale of the Batesville district here called Chattanooga is said by Ulrich to be older than the typical Chattanooga and also older than the Chattanooga of northern Arkansas outside the Batesville district. The Chattanooga of the Batesville district is regarded by him as of the same age as the Genesee shale of the northern Appalachian region, which belongs in the lower part of the Upper Devonian. The typical Chattanooga and the Chattanooga of northern Arkansas outside the Batesville district are placed by him in the Carboniferous system.

[g] The Lafferty limestone has not been described by other geologists it appears not to have been observed before the present investigation.

[h] In a previous paper (Am. Jour. Sci., 3d ser., vol. 48, pp. 325–331, 1894) Williams restricted the name St. Clair to the "Polk Bayou" limestone and applied the name "Cason limestone" to the typical St. Clair limestone. The name St. Clair should have been applied to the "Cason" limestone. This mistake was corrected by him in 1900, in the above-mentioned report of the Arkansas Geological Survey.

[i] A term provisionally applied by Ulrich (Geol. Soc. America Bull., vol. 22, pp. 559, 560, and pl. 28) to the upper part of a considerable thickness (100+feet) of Silurian crystalline limestone supposed to include beds corresponding to the typical St. Clair. The "upper St. Clair" of Ulrich is exposed at Marble, Okla. and so far as known is not exposed in Arkansas.

[j] Occurrences of the Brassfield limestone were discovered by Ulrich several years ago at places between Duff and Tomahawk Ark.; none were known in the Batesville district before 1918.

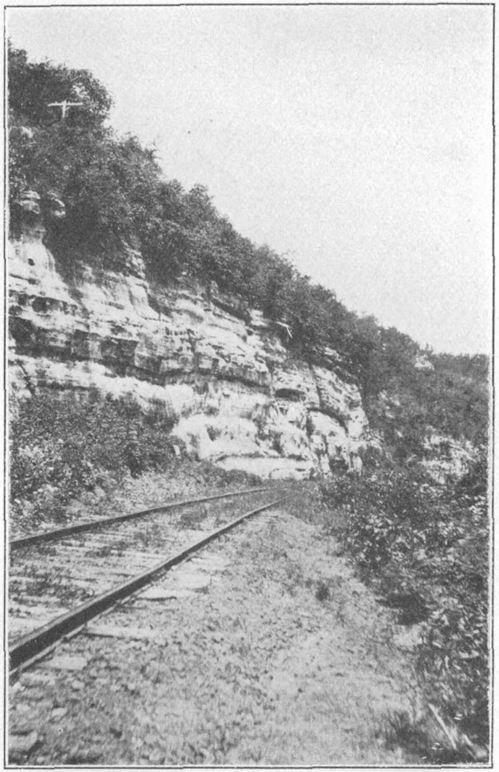


A. VIEW LOOKING DOWN POLK BAYOU, 4½ MILES NORTH OF BATESVILLE, SHOWING A BLUFF ON THE OUTSIDE OF A BEND IN POLK BAYOU.

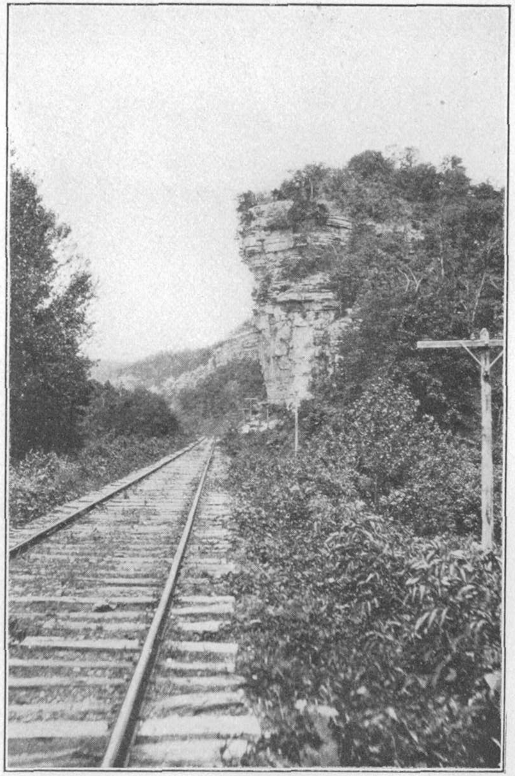
The bluff is composed of the Plattin limestone. Photograph by W. R. Crane.

B. VIEW LOOKING NORTH AT PENTERS BLUFF STATION, SHOWING CHARACTERISTIC OUTCROPS OF PLATTIN LIMESTONE ON THE HILL SLOPE.

Manganese ore ready for shipment is shown on platform near railroad.

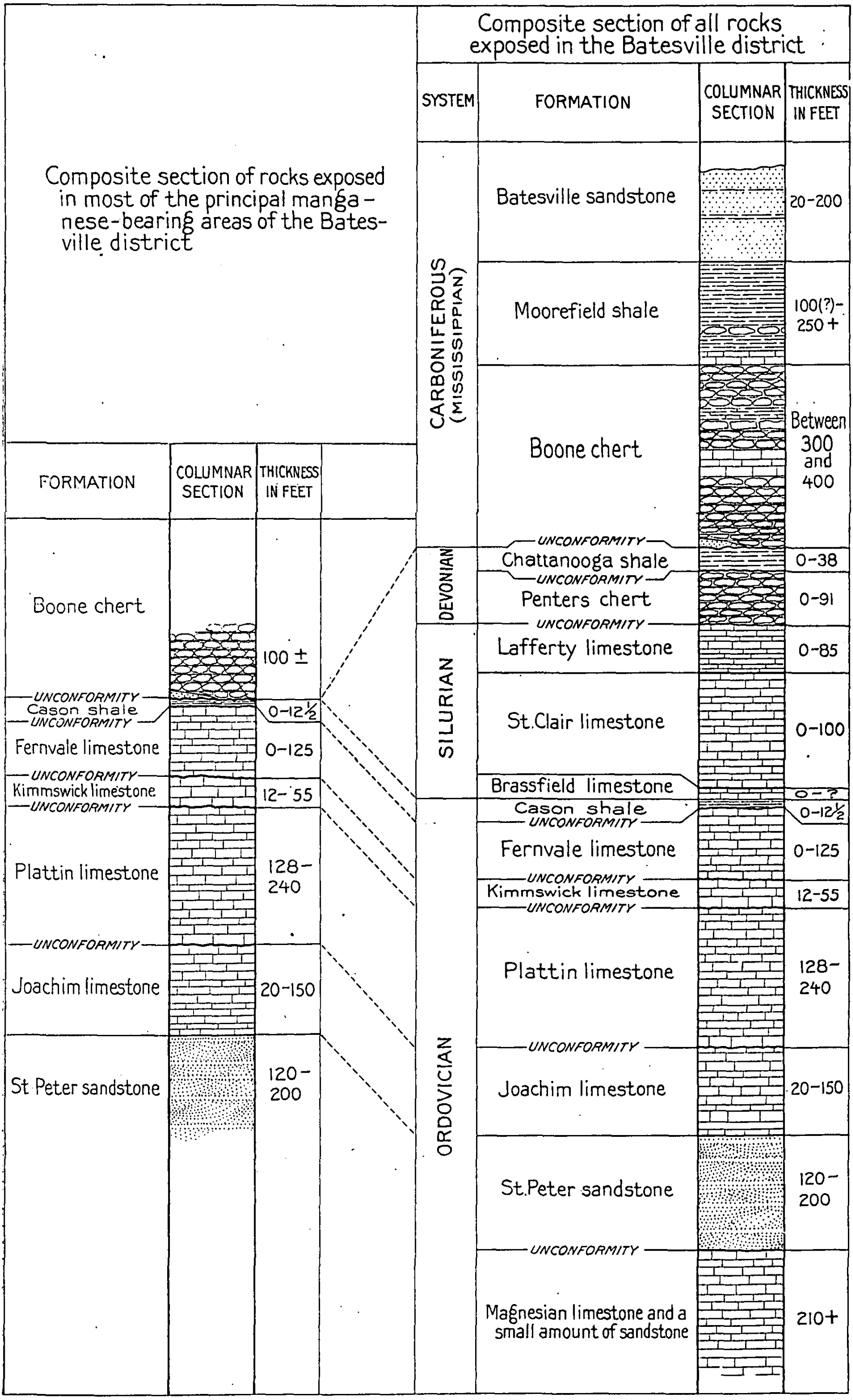


A. BLUFF OF ST. PETER SANDSTONE NEAR BROTHERS SPUR, ON THE MISSOURI PACIFIC RAILROAD, 3 MILES WEST-NORTHWEST OF GUION.

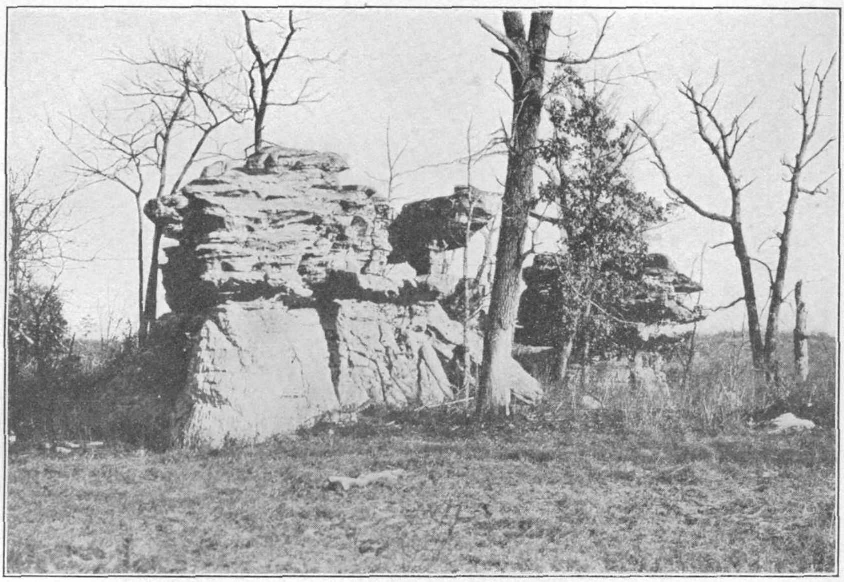


B. VIEW OF A BLUFF ON WHITE RIVER LOOKING WEST-NORTHWEST FROM A POINT 1 MILE NORTHWEST OF GUION.

The bluff is composed of the Joachim and Plattin limestones.

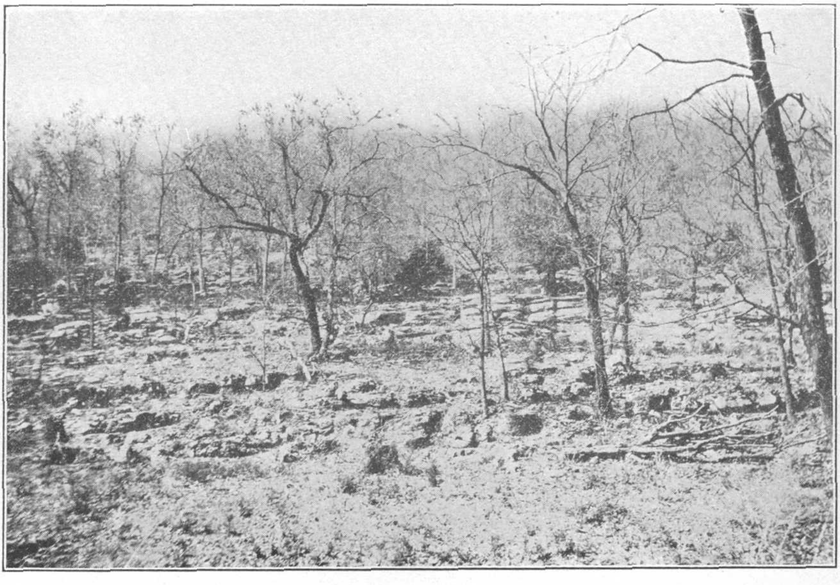


GENERALIZED SECTIONS OF THE PALEOZOIC ROCKS EXPOSED IN THE BATESVILLE DISTRICT.



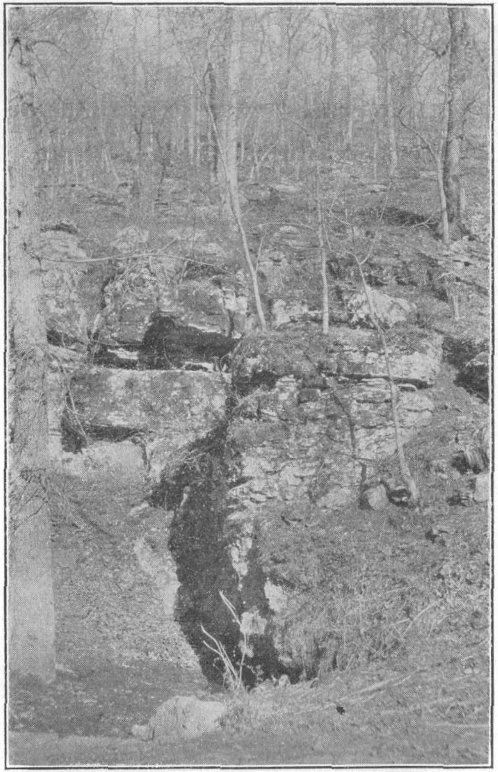
A. PINNACLES OF ST. PETER SANDSTONE, KNOWN AS HOODOO ROCKS, ON SULLIVAN CREEK, 5 MILES EAST OF CUSHMAN.

Photograph by W. R. Crane.



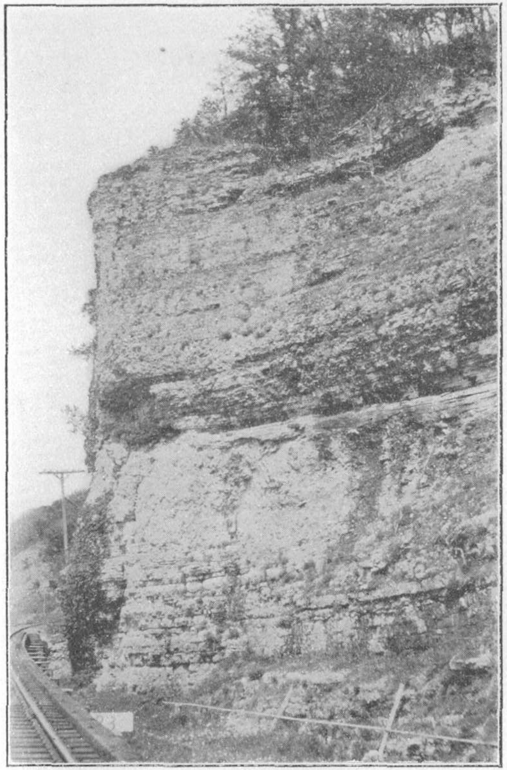
B. HILL SLOPE ON EAST SIDE OF SULLIVAN CREEK, 5½ MILES NORTH OF BATESVILLE.

Shows outcrops of the Joachim and Plattin limestones.



A. BLOWING CAVE ON EAST SIDE OF POLK BAYOU, 3½ MILES NORTH OF BATESVILLE.

The bluff at whose base is the entrance to the cave is composed of the Kimmswick limestone. The ledges above the bluff are composed of the Fernvale limestone.



B. BLUFF ON WHITE RIVER JUST NORTH OF WALLS FERRY STATION, SHOWING BOONE CHERT RESTING UNCONFORMABLY UPON PENTERS CHERT.

The basal bed (limestone) of the Boone thins out to the left. View looking north.

The St. Peter sandstone is exposed over large and small areas in the northern part of the Batesville district, the largest ones being near Mount Pleasant, Sandtown, and Cave City. It is the oldest formation with which the manganese ores are associated, though they do not occur in the sandstone but in residual clays and in recent stream wash lying upon it. The thickness of the sandstone varies from place to place, and as erosion has cut through it to the underlying limestones at only a few places in the area examined by the writer few opportunities were afforded for measuring its entire thickness. The thickness is 200 feet on the west slope of Pine Mountain, at least 75 feet 1½ miles west-northwest of Williamson, 125 feet in the vicinity of Cushman, as shown by the log of the well at the Southern mine, and 120 feet in the vicinity of Sandtown. The sandstone of which the St. Peter formation is composed is massive and is either white or cream-colored on fresh surfaces but brown on much of its exposed surface, owing to the oxidation of included pyrite. It consists of well-rounded, medium-sized, transparent quartz grains, cemented by a small amount of calcium carbonate. It becomes friable on weathering, in places shows lamination, cross-bedding, and ripple marks, and in the many bluffs formed by its outcrops it presents fluted surfaces. (See Pls. III, *A*, and V, *A*.)

JOACHIM LIMESTONE.

The Joachim limestone is exposed as narrow bands on the slopes of the hills over much of the area here described. It represents the lower part of the "Izard limestone," so called in previous geologic reports on this part of northern Arkansas. Its thickness ranges from 20 to 150 feet, the minimum being found at a locality 1½ miles west-northwest of Williamson and the maximum at the mouth of Blowing Cave Creek, but at most places the thickness is between 40 and 100 feet.

The formation consists almost entirely of drab-colored fine-grained magnesian limestone, whose rather massive beds crop out on the hill slopes as rough ledges. (See Pl. V, *B*.) The lowermost beds are very sandy and at a few places are interbedded with thin layers of cream-colored sandstone. The sand grains in both the limestone and the sandstone are well-rounded translucent quartz grains, like those that make up the St. Peter sandstone. Fossils are very meager; the writer observed only a few Cryptozoa and a single *Orthoceras* in the lower part of the limestone, at a locality near the mouth of Blowing Cave Creek.

Residual clays and other surficial materials not only partly conceal the limestone, but at many places extend down into subsurface channels, some of which were formed by the widening of fissures along joints. Among these materials at some localities there are masses of manganese ore. A small quantity of sphalerite (zinc sulphide) has been found in the limestone by the roadside about half a mile north of Cave City.

PLATTIN LIMESTONE.

The Plattin limestone is the surface rock over a large part of the Batesville district. Its area of outcrop is in an irregular eastward-trending belt, in parts of which the limestone is still concealed by younger rocks, and in other parts it has been completely eroded, so that older rocks are exposed. In this belt it is not only exposed in many bluffs, but ledges and loose boulders of it abound on the hill slopes. (See Pls. II, *A* and *B*; III, *B*; V, *B*; and XV, *B*.) Many areas where the Plattin limestone and the Joachim limestone are exposed have an exceedingly rugged surface and are locally known as "roughs." The thickness ranges from 128 feet to 240 feet, the minimum being at a locality three-fourths of a mile northwest of Guion and the maximum on Polk Bayou between the mouths of Sullivan and Cave creeks. The thickness at most places is about 200 feet. The Plattin limestone is even bedded and occurs in both thin and thick layers. Most of it is dove-colored or grayish blue, though a few thin beds are buff. It is compact and has a conchoidal fracture, and its texture is homogeneous, except that it contains many minute cavities filled with colorless calcite crystals. At places it has yielded a few fossils.

Lithographic stone has been found in the Plattin limestone at a few localities. The following paragraph concerning it is abstracted from Hopkins's report:[4]

Certain layers of the Plattin limestone are so fine grained as to appear like lithographic stone of good quality, but thus far the search for such stone has not been successful. The most promising locality is on West Lafferty Creek, where lithographic stone was obtained from layers 2 to 4 inches thick which aggregate about 2 feet in total thickness. The greater part of this stone was worthless on account of the fine crystalline particles scattered through it.

The limestone has been burned for lime one-half mile west-northwest of Williamson, but the kiln had been abandoned before the time of visit. Several caves have been made in the Plattin limestone by solution along fissures. Some of these are on Cave Creek, but the most noteworthy of them is Blowing or Farrell Cave, 1 mile west of Cushman, which has been formed largely in the Plattin limestone but partly in the overlying Kimmswick limestone.

The limestone itself does not contain any manganese ore, but residual clays and stream wash that overlie the weathered edges of the limestone or that fill subsurface cavities, channels, and hollows,

[4] Hopkins, T. C., Marbles and other limestones: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 4, pp. 111–112, 1893.

many of which were formed by the widening of fissures along joints, contain much of the richest manganese ore of the Batesville district. (See Pls. XII and XV, *B*.)

In the earlier geologic reports on this part of Arkansas the Plattin has been described as the "Izard limestone," but the "Izard" as it was defined included not only the Plattin but also the Joachim limestone. The contact between the Joachim and Plattin limestones wherever it was observed by the writer, is even, but according to Ulrich these two formations are separated by a stratigraphic break, which he says is partly represented farther west in Arkansas by the Jasper limestone. He says also[5]: "So far as known the Plattin limestone corresponds to the Platteville limestone of the upper Mississippi Valley and to the Lowville limestone of New York. Hence the break between the Plattin and Joachim limestones is represented in the last-named regions by the Stones River and Chazy limestones, which are approximately 2,000 feet thick."

KIMMSWICK LIMESTONE.

The Kimmswick limestone is exposed in very narrow belts on the hill slopes in much of the manganese-bearing area. Like the underlying Joachim and Plattin limestones it contains no manganese ore, but residual clays that overlie its surface or that extend downward into solution channels in it contain manganese ore at many places. Its thickness ranges from 12 to 55 feet, the minimum thickness having been measured at a locality three-fourths of a mile northwest of Guion and the maximum at the O'Flinn prospect, 2 miles northwest of Pfeiffer. The following measurements show its thickness at other places in the Batesville district: On the hill north of the mouth of Cave Creek, 48 feet; on Polk Bayou, at the mouth of Prairie Creek, 30 feet; on the south slope of Blue Ridge, 1½ miles northeast of Cushman, 25 feet; on East Lafferty Creek, at the abandoned village of Phosphate, 20 feet; in the saddle one-half mile east of Penters Bluff station, 22 feet; and at the northwest end of Penters Bluff, 40 feet.

The Kimmswick limestone is an even-bedded massive light-gray fine-grained limestone, but at some places it is coarse grained, and at others its uppermost beds are compact and grayish blue, thus resembling the greater part of the Plattin limestone. (See Pl. VI, *A*.) Although it is generally fossiliferous identifiable fossils have been obtained at only a few places. Most of the fossils are white and chalky and are thus lighter in color than the other parts of the limestone. Thin lenses and nodules of light and dark colored chert are present at many places and are more numerous in the upper part of the limestone than in the lower part. The lowest bed on West Lafferty Creek contains much quartz sand and on weathering, by which

[5] Personal communication.

the calcium carbonate is dissolved out, forms a porous brown sandstone. Exposed boulders and ledges of the limestone abound throughout a large part of its belts of outcrop, and in places their weathered surfaces are rough and knotty.

The Kimmswick limestone overlies the Plattin limestone and is in turn overlain by the Fernvale limestone, and although the exposures examined by the writer indicate that the contacts between them are even, each of these limestones, according to Ulrich, who has studied their fossil and stratigraphic relations over a much wider area than the writer, is separated from the next by an unconformity.

The correlation table opposite page 16 shows that the limestone to which the name Kimmswick is now applied was included in the lower part of the St. Clair limestone of Penrose[6] and in the lower part of the St. Clair marble of Branner and Newsom,[7] and that it constituted the lower part of the Polk Bayou limestone of Williams and some later writers.[8] Ulrich[9] was the first geologist to recognize the limestone here described as being the same as the Kimmswick limestone of Missouri.

FERNVALE LIMESTONE.

The Fernvale limestone is the surface rock on the hill slopes in much of the manganese-bearing area. It is, in fact, the source of most of the manganese ore that has been produced in the Batesville district. Although some minable ore occurs in the limestone, especially in its uppermost beds, the greater part of the minable ore that is derived from the rock occurs in residual clays, which lie on not only this limestone but also the Kimmswick, Plattin, and Joachim limestones. The ore in the clay and in the limestone consists of masses of manganese oxides. The masses in the clays range in weight from less than 1 pound to 22 tons, and they have been set free from the limestone by the solution and removal of the calcium carbonate. The oxides have been derived from manganese-bearing carbonates by superficial weathering and do not extend below the permanent ground-water level. The ores in or derived from the Fernvale limestone are fully described under the heading "Ore deposits" (pp. 59–69).

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[6] Penrose, R. A. F., jr., Manganese—its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, 1891.

[7] Branner, J. C., The phosphate deposits of Arkansas: Am. Inst. Min. Eng. Trans., vol. 26, pp. 580–598, 1897. Branner, J. C., and Newsom, J. F., The phosphate rocks of Arkansas: Arkansas Agr. Exper. Sta. Bull. 74, pp. 61–123, 1902.

[8] Williams, H. S., The Paleozoic faunas of northern Arkansas: Arkansas Geol. Survey Ann. Rept. for 1892, vol. 5, pp. 268–362, 1900. Ulrich, E. O., Determination and correlation of formations [of northern Arkansas]: U. S. Geol. Survey Prof. Paper 24, pp. 90–113, 1904. Harder, E. C., Manganese deposits of the United States, with sections on foreign deposits, chemistry, and uses: U. S. Geol. Survey Bull. 427, pp. 102–118, 1910.

[9] Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, p. 421, pls. 27 and 28, 1911.

The Fernvale limestone ranges in thickness from a feather edge to 125 feet, the maximum thickness occurring at Penters Bluff. It is about 100 feet thick at most places in the area here described, but it thins westward so that it is only 28 feet thick at a locality three-fourths of a mile northwest of Guion, and it thins out to the east less than 1 mile southwest of Hickory Valley. Farther east it is apparently absent. The following thicknesses were measured at other localities: On the south point of the hill one-fourth of a mile west of the Cason mine, 25 to 30 feet; on Polk Bayou, 2½ miles north of Batesville, 100 feet; on the south point of the hill north of the mouth of Cave Creek, 85 feet; on the south slope of Blue Ridge, 1½ miles northeast of Cushman, 65 feet; at the Club House mine, half a mile north of Cushman, 95 feet; on East Lafferty Creek, near the site of the abandoned village of Phosphate, 100 feet; and in Hankins Hollow, 1¾ miles northeast of Penters Bluff station, 115 feet.

The Fernvale limestone consists almost wholly of limestone. The other constituents are the manganese ore and a small quantity of chert. The limestone is coarse grained, massive, and cross-bedded. Its exposed ledges are friable and have rough surfaces, and on some steep slopes thin slabs break off parallel with exposed surfaces that are at high angles to the bedding. The color is dark gray, but the unweathered parts of the limestone as well as some of the weathered parts have a pinkish cast. Parts of the limestone, especially the uppermost beds, are very dark gray or brown, owing to iron and manganese oxides that are more or less uniformly disseminated through the rock. A few fossils occur in all parts of the limestone, but they are most numerous in beds near the top and near the base. The following analyses show the composition of the limestone:

Analyses of the Fernvale limestone.

	1	2	3
Manganese (Mn)	[a]3.09	[b]0.11	....
Ferric oxide (Fe_2O_3)	2.33	.11	0.27
Alumina (Al_2O_3)	4.16	.24	.10
Silica (SiO_2)	4.10	.73	.69
Lime (CaO)	44.51	54.82	55.21
Magnesia (MgO)	.30	.24	.27
Potash (K_2O)	.35	.01	....
Soda (Na_2O)	.16	.48	....
Phosphoric acid (P_2O_5)	3.02	....	.35
Water (H_2O)	2.25	....	....
Carbonic acid (CO_2)	33.88	....	....
Loss on ignition (CO_2, etc.)	....	43.08	43.39
	98.15	99.82	100.28

[a] Computed from Mn_3O_4. [b] Computed from MnO_2.

1. From Hankins Hill, near the head of Hankins Hollow, 1¾ miles northeast of Penters Bluff station. R. N. Brackett, analyst. Penrose, op. cit., p. 180.
2. From the Brooks Hill mine, 1¾ miles east-southeast of Cushman. R. N. Brackett, analyst. Hopkins, T. C., Marbles and other limestones: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 4, p. 217, 1893.
3. From lower Polk Bayou. R. N. Brackett, analyst. Hopkins, T. C., idem.

At some places the limestone contains nodules and thin lenses of gray and brown chert and many irregular masses of brown chert, some as much as several feet in their longest dimensions. Many such nodules and masses have been freed from the limestone by weathering, so that they are now more numerous in the residual clays than in the limestone. They are found in the manganese-bearing clays at many of the mines and prospects, one of the most noteworthy occurrences being at the Southern mine. There, as well as at other places, the chert contains much drusy quartz and many doubly terminated quartz crystals, half an inch or less in their longest dimension, which are now found on the waste dumps. Many of the crystals are transparent, but most of them are brown from the presence of minute inclusions of manganese oxide. The chert is porous, and much of it contains casts of fossils. The presence of most of this chert in residual clays several miles from any known occurrence of the unaltered limestone indicates that the limestone once existed at these localities, though all its constituents except the insoluble chert and clay have been removed.

Although exposures of the Fernvale limestone are numerous, especially in bluffs and on steep slopes, it is concealed over much of the Batesville district by its own residual clay and by clays and fragments of chert derived from younger rocks. Most of the clay that is residual from the limestone is sticky, and the prevailing colors are red and chocolate-brown, but in places some of it is yellow. These clays and the other surficial materials overlie the irregular surface of the unweathered limestone, in which underground hollows and channels 50 feet or more deep have been formed by solution. (See figs. 4, 5, and 17.) Such channels and hollows, as well as the limestone pinnacles and horses that separate them, are well displayed in open cuts at the Cummins Hollow and Club House mines. Some of the channels are straight and represent widened fissures along joints. A few caves and sink holes also have been formed in the limestone. One of these caves is on the W. K. Tate place, 2½ miles north of Penters Bluff station; another is at the Harvey mine, just east of Penters Bluff station; a third is a blowing cave in Hankins Hollow, 1¼ miles northeast of Penters Bluff station; a fourth is at the Club House mine, half a mile north of Cushman; and a fifth, known as the Searcy cave, is just east of the Searcy mine, 3¼ miles north-northwest of Pfeiffer. Manganese ore has been mined in the caves at the Harvey and Club House mines.

The Fernvale limestone, as stated in the description of the Kimmswick limestone, rests unconformably upon that limestone and it is unconformably overlain by the Cason shale and where the Cason is absent by younger formations. The upper surface of the Fernvale is irregular, containing channels and fissures, some as much as 2 feet deep, that are filled with the materials of the succeeding deposit, which is usually conglomeratic or earthy, but at a few places the fissures contain a gray oolitic limestone.

The Fernvale in the Batesville district is the oldest formation of Richmond age. The Richmond deposits are placed in the Ordovician system by the United States Geological Survey, but they are placed in the Silurian system by Ulrich. The Fernvale was included in the St. Clair limestone of Penrose,[10] in the St. Clair marble of Hopkins, Branner, and Newsom,[11] and in the upper part of the Polk Bayou limestone of Williams and other geologists.[12] It was first identified by Ulrich[13] as being the same as the Fernvale limestone of middle Tennessee.

CASON SHALE.

The Cason shale received its name from its occurrence at the Cason mine, 3 miles north-northeast of Batesville. This shale and the Fernvale limestone just described are the manganese-bearing formations of the Batesville district. The manganese ores in it consist of manganese oxides, which occur as irregular masses, as thin seams and ledges, and as " buttons " both in the residual clays and in the undecomposed shale. Iron oxides occur in the same forms. The original form of the manganese in the shale was a carbonate, and the forms of the iron were a carbonate and a sulphide. The ores are fully described under the heading "Deposits in the Cason shale and its residual clay," beginning on page 57.

The Cason shale is generally present in the vicinity of Cushman, Penters Bluff station and Williamson, and along East and West Lafferty creeks and their tributaries, but it is absent along most of the course of Polk Bayou and at most places farther east. It appears to be absent in the vicinity of Guion, although the rocks in that part of the district were not studied in as great detail as they were farther east.

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10 Penrose, R. A. F., jr., op. cit.

11 Hopkins, T. C., Marbles and other limestones: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 4, 1893. Branner, J. C., op. cit., pp. 580–598. Branner, J. C., and Newsom, J. F., op. cit., pp. 61–123.

12 Williams, H. S., op. cit., pp. 268–362. Ulrich, E. O., Determination and correlation of formations [of northern Arkansas]: U. S. Geol. Survey Prof. Paper 24, pp. 90–113, 1904. Purdue, A. H., Developed phosphate deposits of northern Arkansas: U. S. Geol. Survey Bull. 315, pp. 463–473, 1907. Harder, E. C., op. cit., pp. 102–118, 1910.

13 Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, p. 421, pls. 27 and 28, 1911.

The shale is thin, at no place exceeding 12½ feet in thickness, but its residual clay at the Montgomery mine is 20 feet or more thick, suggesting that the shale at that locality was probably more than 12½ feet thick. A bed of shale 22 feet thick and an underlying bed of phosphate rock 1 foot thick which were found in a drill hole in the NE. ¼ SE. ¼ sec. 25, T. 14 N., R. 6 W., are doubtfully called Cason shale. Thicknesses that were measured at other localities are as follows: O'Flinn prospect, 2¼ miles northwest of Pfeiffer, 3 feet or more; Cason mine, 0 to 10 feet; Blue Ridge mine, 1½ miles northeast of Cushman, 8 feet or less; Club House mine, half a mile north of Cushman, 4½ feet; Meeker mine, half a mile west of Cushman, 6 feet more or less; Frazier prospect, 2 miles west by south of Cushman, about 10 feet; F. M. Barnes prospect, 3 miles west-southwest of Cushman, 11–12 feet; S. W. Weaver mine, 3½ miles west-southwest of Cushman, 2½ feet; Martin No. 2 mine, 4 miles west-southwest of Cushman, 3 feet or more; Kimbrough mine, 4 miles west-southwest of Cushman, 3 feet or more; Button prospect, 1½ miles east-southeast of Penters Bluff station, 0 to 4 feet; Hinkle mine (one of Pittman mines), 1½ miles northeast of Penters Bluff station, 2 feet; abandoned phosphate mine on west side of Lafferty Creek, 1¼ miles southeast of Penters Bluff station, 10 feet 11 inches to 12 feet 5 inches;[14] northwest end of Penters Bluff, 1 foot; bluff just south of Penters Bluff station, a few inches; and C. L. Sanders prospect, half a mile west of Anderson, 3 feet.

The Cason shale is composed mainly of shale but partly of sandstone and phosphate rock. Not only does the proportion of these constituents and of the manganese and iron minerals vary from place to place but their character also varies considerably, so that not many sections of the formation made at distant or even near-by places would be the same.

The shale is greenish gray, platy, and calcareous and contains more or less quartz sand and phosphatic material. Several pieces of the shale were tested for phosphate, and it was found in them all, indicating that at least a small quantity of it is probably present in all the shale. At a few places the phosphatic material occurs as small pebbles, some of which are almost 1 inch in their longest diameter. The shale in most of its exposures has been affected considerably by weathering, so that at such places it is yellow or brown, but at the Cason mine most of it, as it was revealed in the workings at the time of examination, was red. Only a small part of the shale there retains its greenish-gray color.

A bed of sandstone, attaining at places a thickness of several feet, is generally present west of Polk Bayou wherever the formation

[14] Purdue, A. H., op. cit., p. 469, 1907.

occurs. This sandstone is greenish gray, brown, or yellow; it contains quartz grains and more or less phosphatic material, which occurs in the form of fragments of shells or of grains and pebbles 1 inch or less in their longest dimension, some well-rounded and some angular, and it is known as "phosphate rock" on account of its content of phosphorus. It is exposed as ledges on the hill slopes, and blocks of it lie on the slopes below the exposed ledges. The ledges are a great aid to prospectors for manganese ore because the ore is always found below them. A specimen of the sandstone that was collected in Lafferty Hollow contains numerous grains of glauconite.

Microscopic study of thin sections of the sandstone and shale by E. S. Larsen and the writer revealed the presence of small grains of zircon, but it failed to reveal any volcanic ash or feldspar, which Wolff, who studied a few thin sections, concluded might be present.[15] The supposed volcanic ash, as suggested by Hayes,[16] who studied similar material in central Tennessee, was found to be phosphate; the supposed feldspar appears to be fragments of phosphatic shells that show curved light and dark colored bands under crossed nicols in the microscope.

Although phosphate is widely distributed in the Cason shale, it has been mined in commercial quantity at only a few places in the vicinity of the abandoned village of Phosphate. The mines have not been worked for several years. The developed deposits were described by Purdue,[17] and deposits in all parts of the Batesville district were described by Branner and Newsom.[18]

The section at the principal phosphate mine, which is on Lafferty Creek 1¼ miles southeast of Penters Bluff station, is given below.[19]

Section at phosphate mine 1¼ miles southeast of Penters Bluff station.

	Ft.	in.
St. Clair limestone.		
[Cason shale:]		
Brown to black shale	2	
Low-grade manganiferous iron ore	1	3
Green to dark clay shale	1	2
High-grade phosphate	4½–6	
Manganiferous iron ore		2
Low-grade phosphate	4	
Polk Bayou [Fernvale] limestone.		

[15] Penrose, R. A. F., jr., op. cit., pp. 127–128, 170, 594.

[16] Hayes, C. W., The Tennessee phosphates: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 2, p. 522, 1896.

[17] Purdue, A. H., op. cit., pp. 463–483, 1907.

[18] Branner, J. C., and Newsom, J. F., op. cit.

[19] Purdue, A. H., op. cit., pp. 469–470.

The two phosphate beds mentioned in the above section are described as follows by Purdue:[19]

It is only the upper of the two phosphate beds that is now quarried for commercial purposes. This is a compact, homogeneous, light-gray rock with a specific gravity of about 3. At a distance it has the appearance of volcanic tuff. The color is due to small white particles that are thoroughly mixed with dark-gray material. The white particles appear to the unaided eye and under the magnifier as if they might be small fragments of bones. The dark-gray material is made up of particles of varying size, some so small that they can be seen only with the magnifier, others a quarter of an inch in diameter. These particles are more or less angular, some of them strikingly so, making the stone distinctly conglomeratic in appearance. The stone emits an earthy odor. In order to determine whether the gray particles are really fragmentary material or concretions and also to ascertain the nature of the white fragments, a specimen was submitted to Dr. Albert Johannsen, of the United States Geological Survey, for microscopic examination, who reports as follows:

"The thin section is made up chiefly of organic remains, perhaps fragments of bone, in a cement of calcite, with very little of an isotropic, deep-purplish mineral, having an index very much less than Canada balsam—probably fluorite. The sections show no concretions; the calcite seems to be a filling between the fragments of bone."

A small portion of rock at the outer edge has been leached of lime by surface waters and when freshly quarried is dark colored. This is called by the quarrymen "black phosphate." It contains a considerable amount of water, to which the color is attributable, and is richer in phosphate than the remainder of the bed.

The lower bed is similar to the upper one, though darker in color, more compact, and not conglomeratic so far as observed. The darker color is due to the smaller amount of the white material and possibly to a larger amount of iron or manganese or both. It has a greenish tinge, which is suggestive of glauconite. This bed becomes very ferruginous in its upper part and is * * * separated from the bed above by a thin layer of manganiferous iron ore.

The following analyses of specimens of the rock were made in the laboratory of the United States Geological Survey. No. 1 was a specimen taken from the lower bed; Nos. 14–18 were specimens from the bed now being worked.

Analyses of phosphate rock from Arkansas.

No.	Where taken.	Phosphoric acid (P_2O_5).	Equivalent in calcium phosphate ($Ca_3(PO_4)_2$).
		Per cent.	*Per cent.*
14	4 inches from top of bed	25.86	56.45
15	Middle of bed	27.24	59.46
16	8 inches from bottom of bed	27.40	59.81
17	"Black phosphate"	32.60	71.06
18	Composite sample	29.18	63.70
1	From lower bed	13.46	29.38

The Cason shale rests upon the Fernvale limestone everywhere in the Batesville district except at the Ball mine, where it apparently

[19] Purdue, A. H., op. cit., pp. 469–470.

rests on the Kimmswick limestone, though both the Kimmswick and the Cason at that locality have completely disintegrated to clay. The contact between the Fernvale and the Cason is irregular. This fact together with the thinning out of the Fernvale in the vicinity of Hickory Valley indicate that an unconformity separates the Cason shale from the underlying rocks. This means that a period of emergence and erosion preceded the deposition of the materials that now constitute the Cason shale. The fossils, according to Ulrich, indicate that this shale was deposited in shallow marine water. The conclusion that it was deposited in shallow water is supported by the conglomeratic character of parts of the formation.

The Cason is overlain at some places by the St. Clair limestone, but the occurrence of fossils of the Brassfield limestone in residual clays above the altered Cason shale at the Montgomery mine shows that the Brassfield once overlay the Cason shale at that locality. The Brassfield, according to the fossils, is older than the St. Clair. This fact and the apparent absence of the Brassfield at other localities in the region seem to indicate that an unconformity separates the Cason from the St. Clair, but the contact between the Cason and St. Clair wherever it is revealed is even and does not suggest an unconformity, because there is no abrupt change in the character of rocks. The unconformable relations of the Brassfield limestone to underlying rocks of the Richmond group in southwest-central Tennessee suggest that the Brassfield and the Cason in the Batesville district may also be separated by an unconformity, but further work will be required to decide this matter. In much of the Batesville district all the Silurian and Devonian rocks, including the St. Clair limestone, are absent, and the Boone chert, of Carboniferous age, rests unconformably upon the Cason shale.

Except for "buttons," which are numerous at a few localities, fossils are comparatively rare in the Cason shale. The "buttons" are flattened concretion-like masses half an inch to 1 inch in their longer diameter and from a quarter to half an inch thick and are stated by E. O. Ulrich [20] to be fossils belonging to the genus *Girvanella*, which is a form of algal growth. They were once spherical or nearly so and were composed mainly of calcium carbonate and partly of manganese carbonate, but they have been flattened by pressure. As they are revealed in the rock outcrops and in the residual clays most of them have been replaced by manganese and iron oxides. The unaltered "buttons" are greenish gray, the partly oxidized "buttons" are red, those of manganese oxides black, and those of iron oxide red. Many of them show concentric banding, and many contain centers of chert and earthy material. They lie parallel with the bedding of the shale and are more or less uni-

[20] Personal communication.

formly disseminated through the shale and its residual clay. Their most noteworthy occurrence is at the Cason mine, which has been the largest producer of low-grade manganese ore in the district. (See Pl. X, *A*.) There "buttons" composed of manganese oxides are so numerous that the residual clay itself has been mined and shipped without treatment, and much of the shale has been quarried and shipped as ore. The average manganese content of these ores has been about 20 per cent. Only a part of the shale at this mine, however, contains "buttons" of manganese oxides; the rest of it contains "buttons" of which the principal constituents are manganese and calcium carbonates. This is in fact the only locality in the district where the carbonate buttons have been discovered. Analyses of the carbonate and the oxide "buttons," also an analysis of shale that incloses the buttons at this mine are given on pages 139 and 140.

The other known occurrences of "buttons" of manganese oxides are at the Montgomery, Adler, Johnson Hill, and Ball mines and at the Button and O'Flinn prospects. Buttons of iron oxide were observed by the writer at two of the Pittman mines, at the mine of the United Phosphate & Chemical Co., at the Breeden prospect, and at the W. T. Gray mine.

The *Girvanella*, according to Ulrich, are similar to *Girvanella richmondensis*, a species which is found in beds of the Richmond group in Indiana. They and the other fossils, together with the relations of the Cason shale to the underlying and overlying rocks, indicate that the Cason is the next to the oldest formation of Richmond age, the Fernvale limestone being the oldest. The Richmond group, as previously stated, is placed in the Ordovician system by the United States Geological Survey and in the Silurian system by Ulrich.

The Cason shale, as shown in the correlation table opposite page 16, was included in the St. Clair limestone by Penrose.[21] Williams,[22] the first geologist to define the Cason as a separate formation, placed it in the Silurian system. The shale is exposed at many mines and prospects and descriptions and several sections of it in these exposures are given in the descriptions of the mines and prospects, beginning on page 103.

SILURIAN SYSTEM.

BRASSFIELD LIMESTONE.

Fossils of the Brassfield limestone occur in the residual clays of this limestone at the Montgomery mine, 6 miles east by north of Cushman. These clays overlie the weathered ore-bearing Cason

[21] Penrose, R. A. F., jr., Manganese—its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, 1891.

[22] Williams, H. S., On the age of the manganese beds of the Batesville region of Arkansas: Am. Jour. Sci., 3d ser., vol. 48, pp. 325–331, 1894.

shale. The fossils, some of which are illustrated in Plate VII, *A*, have been found in the clays and on the picking belt by which the manganese-ore concentrates were conveyed to the ore bin. They have been preserved as casts of the interior walls and have been entirely replaced by manganese oxide. According to Ulrich they consist of gastropods (*Cyclonema daytonense*), brachiopods (*Tripleciaortoni*), algal forms (*Girvanella*), and cephalopods of the genera *Cycloceras* and *Orthoceras*. The Brassfield limestone at this locality has been entirely decomposed, leaving only its residual clay and the above-mentioned fossils.

There may be a few exposures of the undecomposed limestone in the Batesville district, but none were discovered by the writer. In fact, the only known exposures of the Brassfield limestone in the southern Ozark region were discovered by Ulrich [23] at three localities in the Yellville quadrangle, which is west of the Batesville district. There the limestone, specimens of which were examined by the present writer, is granular, light gray, and fossiliferous and contains a small amount of glauconite. Its lithologic character as shown by the specimens is very similar to that of the Brassfield limestone in southwest-central Tennessee, where it has been studied by the writer.

ST. CLAIR LIMESTONE.

The St. Clair limestone is exposed in several small areas in the Batesville district but is absent over most of it, and as would be expected from the irregular distribution of the limestone its thickness varies considerably from place to place. The greatest thickness, 100 feet, was measured on the south point of the hill just west of the Cason mine.

The easternmost occurrence of the St. Clair is in the wagon road almost 1 mile north of Hickory Valley. The limestone is exposed at several places along Miller Creek, from 1 to 2 miles north-northeast of Pfeiffer, one of the places being St. Clair Spring, from which the limestone receives its name. The measured thickness of the exposed beds at that spring is 35 feet, but not all the beds appear to be exposed, so that the actual thickness is perhaps 40 feet or more. The limestone is well exposed in a small area near the Searcy Cave, 3 miles north-northwest of Pfeiffer; it is 50 feet thick on the hill slope just north of the cave. It is exposed in a small area at and near the Cason mine, where it attains a thickness of 100 feet; also near the Champlain prospect, 2½ miles north of Batesville, where it is a few feet thick; and at another locality, about half a mile farther east, where it is 12 feet thick. Fifty feet of the limestone crops out near Big Spring without the base being revealed. The

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

limestone is generally present in the vicinity of Walls Ferry station, Penters Bluff station, Phosphate, Anderson, and Williamson, and it was observed at a few places in the vicinity of Guion. The thickness in this part of the Batesville district is at most places 10 to 15 feet and nowhere was a thickness of more than 18 feet measured.

The St. Clair limestone has a pinkish light-gray color and is coarse grained, but at its upper part is bluish gray and fine grained at a few places and the lowermost beds are shaly. The bulk of it closely resembles the Fernvale limestone, but its lighter color is one of the features that distinguishes it from the Fernvale. It consists of massive beds which generally protrude through the surficial material on the hill slopes. In the western part of the Batesville district large blocks of it have broken loose from the parent ledges and are now found on the slopes for some distance below them.

An analysis of a sample of the St. Clair limestone from St. Clair Spring is given by Hopkins.[24] Although a few feet of the Fernvale limestone, which was included in the St. Clair by him, is exposed near the spring the boulders and ledges of the St. Clair are far more numerous than those of the Fernvale. The sample therefore was probably collected from the St. Clair limestone. The analysis follows:

Analysis of St. Clair limestone from St. Clair Spring.

[R. N. Brackett, analyst.]

Lime (CaO)	54.70
Manganese oxide (MnO_2)	.26
Iron oxide (Fe_2O_3)	.19
Silica (SiO_2)	.54
Alumina (Al_2O_3)	.18
Magnesia (MgO), Potash (K_2O), Soda (Na_2O)	.78
Loss on ignition (CO_2, etc.)	43.35
	100.00

Fossils, which include brachiopods and trilobites, are very numerous at most localities. Pebble-like *Girvanella* 1 inch or less in diameter, which are found in the lowermost beds, are perhaps the most interesting fossils because they contain more or less manganese. They are more numerous and are better exposed at the Cason mine than elsewhere. (See Pl. VIII, *B*, *C*.) The unweathered *Girvanella* are gray and show concentric structure; they contain a mixed carbonate, of which calcium, iron, and manganese are the bases; and according to the analysis on page 137 they contain

[24] Hopkins, T. C., Marbles and other limestones: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 4, p. 217, 1893.

5.94 per cent of manganese, whereas the unaltered limestone that incloses them contains only 1.52 per cent of manganese, which is also probably in the form of a carbonate. The *Girvanella* that are in the weathered parts of the limestone have been oxidized and replaced by manganese and iron oxides (see Pl. VIII, *A*), and those that are in the shaly beds at the base of the limestone have been flattened by pressure like those in the Cason shale.

The St. Clair limestone is of Niagaran age and is stated by Ulrich,[25] who has recently studied its fossils, to be of approximately the same age as the Rochester shale of New York or the Laurel limestone of Tennessee, Kentucky, and Indiana.

The St. Clair is younger than the Brassfield limestone and hence overlies it, but as the Brassfield is not known to be exposed anywhere in the Batesville district the stratigraphic relation of these two limestones was not determined. At many places the St. Clair rests upon the Cason shale; at others it rests upon the Fernvale; and at a locality 1 mile north of Hickory Valley it rests upon the Kimmswick limestone.

The next youngest formation is the Lafferty limestone, of Silurian age, of which only one small area of outcrop is known. In some other parts of the Batesville district the St. Clair is overlain unconformably by the Penters chert, of Devonian age, and in some by the Boone chert, of Carboniferous age.

The St. Clair, as it was defined by Penrose[26] and by Hopkins,[27] included the Kimmswick limestone, the Fernvale limestone, the Cason shale, and the St. Clair limestone as it is now defined. The name St. Clair was restricted by Williams[28] to the uppermost of these four formations.

LAFFERTY LIMESTONE.

The Lafferty limestone is exposed near the crest of the north point of a hill at the Tate Spring, 1¼ miles north of Penters Bluff station and about half a mile west of West Lafferty Creek, from which it receives its name. The deep hollows on either side of the above-mentioned point unite to the north, and the wet-weather stream which receives their run-off joins West Lafferty Creek a short distance southwest of a small store.

The limestone, as measured by an aneroid barometer, is 85 feet thick. It is even bedded, compact, and earthy and on weathering becomes platy. The upper 20 feet is gray; most of the rest is red, but part of it is gray. A few fossils are present. Ledges of this

[25] Oral communication.
[26] Penrose, R. A. F., jr., op. cit., pp. 124–128.
[27] Hopkins, T. C., op. cit., pp. 212–252.
[28] Williams, H. S., The Paleozoic faunas of northern Arkansas: Arkansas Geol. Survey Ann. Rept. for 1892, pp. 281 et seq., 1900.

limestone abound on the hill slopes, and very little surficial material overlies it.

The Lafferty limestone conformably overlies the St. Clair limestone and is in turn overlain by the Boone chert, of Carboniferous age. The absence of the Lafferty limestone in other parts of the Batesville district, combined with the fact that the Penters chert and Chattanooga shale of Devonian age are absent at this locality, shows that the Boone chert rests unconformably upon the Lafferty limestone. The St. Clair limestone is stated by Ulrich [29] to be approximately of the same age as the Laurel limestone of Indiana, Kentucky, and Tennessee. The Laurel in southwest-central Tennessee is succeeded by the Waldron clay, the Lego limestone, the Dixon limestone, and other rocks of Silurian age, the oldest being named first and the youngest last. Of these the Dixon is a red earthy limestone. The suggestion is made by Ulrich that the Lafferty limestone may be equivalent, in part at least, to the Dixon limestone. The few fragmentary fossils that were collected from the Lafferty have been examined by him, and he says that their evidence does not militate against the correlation that he has proposed.

The Lafferty limestone was probably not observed by the other geologists who have worked in the Batesville district, or if observed it was not recognized as being a distinct formation from the typical St. Clair limestone.

DEVONIAN SYSTEM.

PENTERS CHERT.

The Penters chert is exposed within two small areas in the southern border of the Batesville district. One of these is from 1 to 2 miles north of Pfeiffer and the other extends from Penters Bluff station southward to a point 2 miles south of Walls Ferry station. Future study in the region will doubtless reveal other areas or extensions of the present known areas, as an exhaustive study of the formation was not attempted during the investigation for this report.

The formation receives its name from Penters Bluff station, near which the best known exposures of the entire formation occur. Between that place and Biltmore switch it forms vertical or nearly vertical bluffs. The upper part of the formation is excellently exposed in bluffs at and near Walls Ferry station. (See Pl. VI, *B*.) Exposures of chert ledges were observed near Pfeiffer, but the greater part of the formation is there concealed by surficial material, which consists mainly of chert fragments.

The formation ranges in thickness from a feather edge to 91 feet, the maximum having been found in a drill hole in the NE. ¼ SE. ¼

[29] Oral communication.

sec. 25, T. 14 N., R. 6 W. It was found to be 88½ feet thick in a drill hole in the SW. ¼ NW. ¼ sec. 24, T. 14 N., R. 6 W., and 62 feet thick in a drill hole in the northeast corner of the NW. ¼ SE. ¼ sec. 26, T. 14 N., R. 6 W. It is 20 to 25 feet thick in the vicinity of Penters Bluff station.

The Penters chert is composed mainly of massive dense chert that breaks with a conchoidal fracture, but it contains a small quantity of gray fine-grained limestone at and near the base. The color of most of the chert is light to bluish gray, but that of the upper part is black wherever it is overlain by the Chattanooga shale. These colors are not everywhere restricted to different parts of the chert, for in some places parts of it are banded and mottled. On hill slopes the chert breaks up into gray angular fragments that are very hard.

A bed of breccia as much as 6 or 7 feet thick occurs at the top of the chert in some places. It consists of angular blocks of chert of large and small sizes that have been firmly cemented together by an earthy material in which there are grains of quartz sand and fine particles of chert. It is not sharply separated from the bedded chert below, for traces of bedding that it shows become more and more distinct toward the base. Not only are the massive blocks in the breccia tilted at high angles but the unbroken beds of the formation themselves are flexed to some extent and are inclined as much as 40° from the horizontal at a few localities. The breccia, in fact, represents the surficial part of the formation that had become fractured and more or less weathered on an old land surface which existed before the submergence preceding the deposition of the Chattanooga shale. The flexing is probably due to the settling of the beds to fill solution cavities in the underlying St. Clair limestone. That the beds were flexed during a land stage following the deposition of the siliceous material of which the Penters chert is composed is shown by the fact that the overlying formations—the Chattanooga shale of Upper Devonian age and the Boone chert of Mississippian age—do not partake of the flexing but rest upon the upturned edges of the Penters chert.

No fossils have been discovered in the Penters chert, so that its correlation and the determination of its age are based upon its lithologic character and its relations to the underlying and overlying formations. This chert rests upon the St. Clair limestone, which represents a part of the Niagara group, of middle Silurian age. The contact between these two formations was nowhere observed, being concealed by surficial material; but the absence of the Lafferty limestone, which also represents a part of the Niagara group, indicates that the Penters chert and St. Clair limestone are separated by an unconformity. The Penters chert is unconformably overlain by the

Boone chert, of Mississippian age, near Penters Bluff and Walls Ferry stations and possibly at places near Pfeiffer, but at some places near Pfeiffer it is overlain unconformably by the Chattanooga shale, of Upper Devonian age. The existence of an unconformity at the top is shown by the fact that the shale rests in a nearly horizontal position upon beds that are not only greatly fractured but that are more or less contorted. (See Pl. VI, *B*.)

The Penters chert, being underlain by rocks of middle Silurian age and overlain by rocks of Upper Devonian age, could be of upper Silurian, Lower Devonian, or Middle Devonian age. Ulrich suggests that it is possibly of the same age as the Clear Creek, a cherty limestone of southeastern Missouri and southern Illinois, and of the same age as the Camden chert, of west-central Tennessee. Both the Clear Creek limestone and the Camden chert have been shown by their fossils to be equivalent to at least a part of the Oriskany group of Lower Devonian age, of the northern Appalachian region.[29a] The lower part of the Arkansas novaculite (a variety of chert) of west-central Arkansas and southeastern Oklahoma has not yielded any fossils in Arkansas, but it is correlated with the two formations just named. It therefore appears that the Penters chert and the lower part of the Arkansas novaculite are of the same age.

Space can not be spared here for a discussion of the stratigraphic relations and lithologic character of the Clear Creek limestone and Camden chert and the lower part of the Arkansas novaculite; but so far as known none of their features militate against the correlation of the Penters chert with these formations.

The chert to which the name Penters is herein applied was observed by Penrose[30] and was described by him as a part of the Boone chert.

CHATTANOOGA SHALE.

A few exposures of the Chattanooga shale have been observed near the village of Pfeiffer; in other parts of the Batesville district it is absent or is not exposed. It is exposed on the Simpson White place in the SW. ¼ NW. ¼ sec. 24, T. 14 N., R. 6 W., 1¼ miles north of

[29a] Since the above statements were written two reports—one by C. O. Dunbar and another by T. E. Savage—discussing the age of the Clear Creek and Camden formations have been published. Dunbar (Stratigraphy and correlation of the Devonian of western Tennessee: Tennessee Geol. Survey Bull. 21, 1919) concludes that the Camden chert at the type locality, Camden, Tenn., is of Onondaga age and not of Oriskany age. Furthermore, he has identified and named certain formations that had previously been included in the Camden chert. The oldest of these formations (named by him the Decaturville chert) he regards as of Helderberg age; the next (his Quall limestone) as of Oriskany age; and the youngest (his Harriman chert) as of Oriskany age. Savage (The Devonian formations of Illinois: Am. Jour. Sci., 4th ser., vol. 49, pp. 169–182, 1920) agrees with Dunbar's determination of the age of the typical Camden chert and therefore says (p. 175), "The Clear Creek chert is now referred to the basal portion of the Ulsterian (Onondaga) series."

[30] Penrose, R. A. F., jr., op. cit., pp. 131–133.

Pfeiffer, on the E. A. Silberstein tract 2 miles north-northwest of Pfeiffer and at one other near-by locality. The best exposures are on the Simpson White place. At these localities only parts of the shale are exposed, so that the entire thickness could not be measured. The shale was, however, found in a drill hole in the northeast corner of the NW. ¼ SE. ¼ sec. 26, T. 14 N., R. 6 W., half a mile west of Pfeiffer, where it is 38 feet thick, and it was found in a drill hole in the NE. ¼ SE. ¼ sec. 25, T. 14 N., R. 6 W., half a mile east of Pfeiffer, where it is 22 feet thick. Records of these drill holes are given on page 44. The shale, as shown by the records of the drill holes and as revealed at the surface at the above localities, is underlain by the Penters chert and overlain by the Boone chert.

An occurrence of the shale was observed in the N. ½ sec. 28, T. 14 N., R. 6 W. There 3 feet of the top of the shale is exposed and although the lower part is not exposed, it apparently rests upon the Fernvale limestone. Penrose[31] reports an occurrence of the shale in an old prospect pit in the north part of sec. 33, T. 14 N., R. 6 W. Slabs of the weathered laminated shale were found in a recent drill hole in the NW. ¼ SW. ¼ sec. 34, T. 14 N., R. 6 W. A record of this drill hole is given on page 43. Penrose[32] also says the shale "was opened for a depth of 20 feet without reaching the bottom" in the NW. ¼ sec. 15, T. 14 N., R. 5 W.

The shale is black; it contains a small quantity of pyrite; it is platy, splitting into large thin slabs of uniform thickness; and the freshly broken parts give off the odor of petroleum. The black color has caused some people to think that the shale contains coal, but prospecting has failed to discover any. Lenses and irregular masses of sandstone, which are described on pages 38–39, occur at the base of the Boone chert at several localities. They may represent the Sylamore sandstone, which is the basal member of the Chattanooga shale farther west in Arkansas; but as they are small and widely scattered and are not overlain at any place by black shale, they are regarded by the writer as representing an initial deposit of the Carboniferous period.

A few fossils that have been procured by the writer from the shale have been determined by Ulrich as belonging to the species *Schizobolus truncatus*. This shell was originally found in the Genesee shale of New York. It is now known from many places between that State and Arkansas, and according to Ulrich all its known occurrences are of the same age. The Genesee shale, hence presumably also the shale to which the name Chattanooga is here applied, belongs in the lower part of the Upper Devonian. Ulrich maintains that the shale under discussion is older than the typical Chattanooga

[31] Penorse, R. A. F., jr., op. cit., p. 133.
[32] Idem, pp. 132–133.

shale, which he places in the Carboniferous system, and is older than the Chattanooga at other places in Arkansas, which he also places in the Carboniferous system.

The Chattanooga shale rests upon the Penters chert at most localities and is separated from it by an unconformity, the evidence for which was discussed in the description of the Penters chert. The shale is overlain by the Boone chert and is separated from it by a stratigraphic break or unconformity, which is indicated by the absence of the Chattanooga shale over most of the Batesville district.

As has been mentioned above, Penrose observed the shale, but he described it as a part of the Boone chert.

CARBONIFEROUS SYSTEM.

BOONE CHERT.

The Boone chert, as the name implies, consists predominantly of chert, but it contains also limestone, sandstone, and shale. It is the surface rock over a larger area in the Batesville district than any other formation, and owing to its wide distribution and its resistance to weathering this rock and the débris derived from it are found at most localities.

The largest area of outcrop is an irregular westward-trending belt 7 miles or less in width, on or near whose north border Hickory Valley, Cushman, Anderson, and Guion are situated, and on or near whose south border Pfeiffer, Batesville, and Oneal are situated. All parts of this belt are trenched by numerous deep narrow valleys, and many of the intervening hills or ridges reach a common elevation, which decreases toward the south—the direction in which the Boone chert gently dips. This belt is therefore a dissected southward-sloping plateau. The culminating points on its north border are 700 to 900 feet above sea level, whereas those on the south border are generally 500 to 600 feet above sea level. Although the Boone chert is the surface formation over most of this belt, many valleys have been cut deep enough to reveal some of the underlying rocks, and at Childress Mountain younger rocks overlie the Boone. North of this belt the Boone chert has been almost completely eroded, but a few hills are capped by it. Many hills in the vicinity of Cave City, Sandtown, and Mount Pleasant are capped by its loose fragments and by its fractured layers that settled as the underlying limestones were removed by solution.

The thickness of the Boone is not known, but it is at least 300 feet and may be as much as 400 feet.

The relative proportions of chert and limestone vary both vertically and horizontally, but most of the limestone that is free from chert is found near the middle of the formation. The limestone is gray, compact, and very pure and ranges from fine to coarse grained. Most of the beds are massive and range in thickness from 1 to several feet. An even-bedded, fine-grained, light-gray limestone in beds 2 feet 10 inches to 6 feet thick is being quarried and dressed at Pfeiffer for use as a high-grade building stone. (See Pl. IX, *A*.) The thickness of the limestone suitable for this purpose there is 40 feet. A similar though cross-bedded limestone has been quarried for building stone 2 miles north-northeast of Batesville, but the presence of chert nodules in parts of it caused the quarry to be abandoned. A gray crinoidal limestone has been quarried at Denieville and burned into lime, but the presence of many layers and lenses of chert in the limestone proved to be harmful and perhaps caused the quarry to be abandoned. A drill is said to have passed through 135 feet of limestone in the middle of the north part of sec. 9, T. 13 N., R. 7 W., without reaching the bottom of the bed.[33] This is the greatest reported thickness of limestone in the Batesville district.

A few feet of brown crinoidal limestone is exposed in a manganese-ore prospect on the C. L. Sanders farm, in sec. 27, T. 15 N., R. 8 W., half a mile west of Anderson. This limestone is at the base of the Boone and overlies what appears to be the Cason shale, of Ordovician age. The writer believes it is the St. Joe limestone, which is a widespread, prominent member of the Boone chert farther west in Arkansas, in northeastern Oklahoma, and in southwestern Missouri. Several feet of a similar limestone was observed on the Alex Fults place, in the NW. ¼ sec. 33, T. 15 N., R. 9 W., about 1¾ miles south of Guion, and this is also believed to be an occurrence of the St. Joe limestone member of the Boone. At other places in the Batesville district the basal beds of the Boone include sandstone, shale, and earthy gray crinoidal limestone, but at most localities the basal beds are chert or cherty gray limestone. None of these beds are similar lithologically to the St. Joe limestone, although they may be of the same age.

Chert occurs in all parts of the formation and is the principal rock in the upper and lower parts. The vertical transition from beds of limestone to beds composed wholly or mainly of chert is everywhere gradual—by increase of the one and decrease of the other. In some layers of limestone the chert occurs in widely separated nodules; in others some of the nodules are united; in still others the chert is a sheet or lens in the middle of the layers. At many places it forms successive layers without limestone. The chert where unaffected by weathering is dense, hard, compact, and brittle, has a more or less perfect conchoidal fracture, and is white or light gray, but at

[33] Hopkins, T. C., Marbles and other limestones: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 4, p. 105, 1893.

some places it is blue, green, or black and has the waxy luster of chalcedony.

When the formation weathers the limestone is carried away in solution, leaving only its residual clay, whereas the chert becomes more or less porous and much fractured and forms a stony surficial material over most of the Batesville district, even in areas where limestones older than the Boone are exposed. A few caves and many subsurface channels have been formed not only in the limestone of the Boone but also in the underlying limestones, and the chert has settled into them. In places one and in others as many as three limestone formations have been entirely removed except for their clays, and these clays are still overlain by the Boone chert that has settled far below its original position. This settling of the chert, which is well displayed at some of the manganese mines and at the limestone quarry 2 miles north-northeast of Batesville, has been gradual, so that the layers have been bent and fractured and dip at high or low angles in all directions. The maximum extent of settling is at least 250 feet and at places may exceed 300 feet.

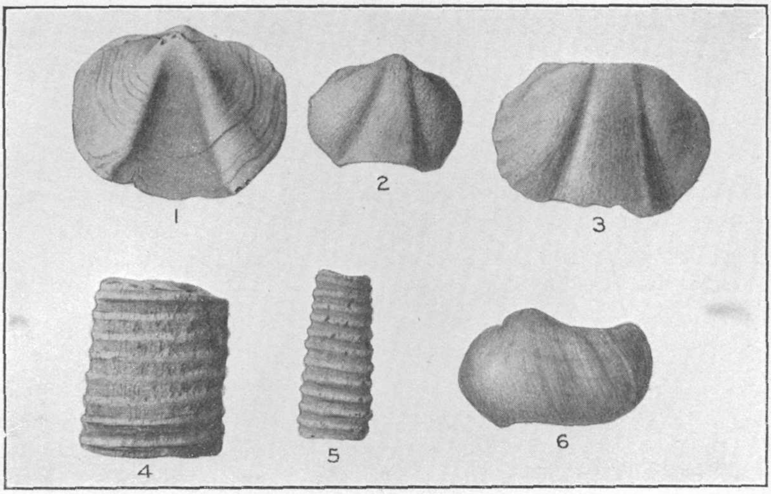
Girty[34] states that black calcareous shale and shaly limestone, aggregating a thickness of 30 feet, occur in the upper part of the formation, near Ruddells Mill on Spring Creek, 2½ miles west of Batesville.

Lenses and irregular masses of white, gray, yellow, and brown sandstone, composed of well-rounded translucent quartz grains, occur at the base of the Boone chert at several localities. There is a possibility that this sandstone is the Sylamore sandstone member of the Chattanooga shale, of Devonian age, but its small and widely separated areas of distribution lead the writer to believe that it was an initial deposit of the Carboniferous period, during which the materials that later formed the Boone chert were laid down. Ulrich[35] accords in this interpretation of the origin and age of the sandstone.

The observed occurrences of this sandstone are as follows: There are two masses of white to brown sandstone on the west side of Polk Bayou, 1¼ miles south of Blowing Cave. As they are isolated they were probably formed by the sand washing into solution pockets in the underlying Fernvale limestone. A few feet of thin-bedded brown sandstone that contains small chert pebbles underlies the Boone chert on the hill slope one-fourth of a mile south of Big Spring. A mass of gray sandstone 40 feet long east and west and 25 to 30 feet thick is exposed on the north slope of a hill, about one-eighth of a mile east of Penters Bluff station. The sand that

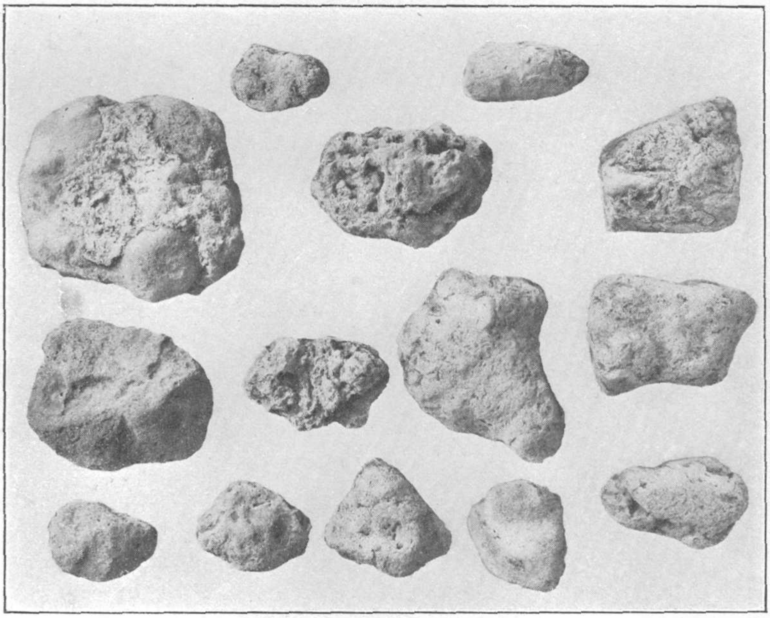
[34] Girty, G. H., Fauna of the so-called Boone chert near Batesville, Arkansas: U. S. Geol. Survey Bull. 595, p. 9, 1915.

[35] Oral communication.



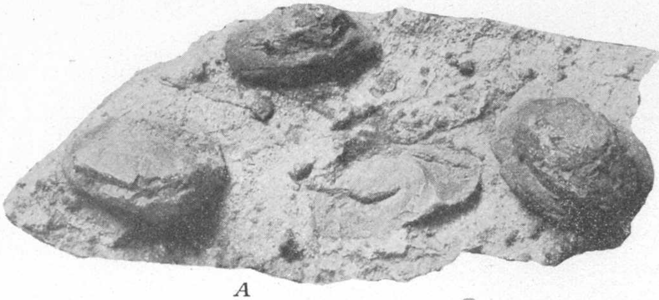
A. FOSSILS REPLACED BY MANGANESE OXIDE; FROM THE MONTGOMERY MINE.

1–3, Triplecia ortoni; 4, 5, Cycloceras sp.; 6, Cyclonema daytonense. Four-fifths natural size. Species determined by E. O. Ulrich. Photograph by R. S. Bassler.

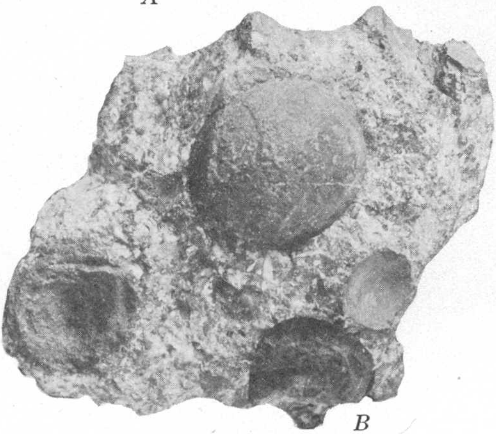


B. PEBBLES OF MANGANESE ORE FROM A GRAVEL BED IN A SMALL STREAM 1¾ MILES EAST OF CUSHMAN.

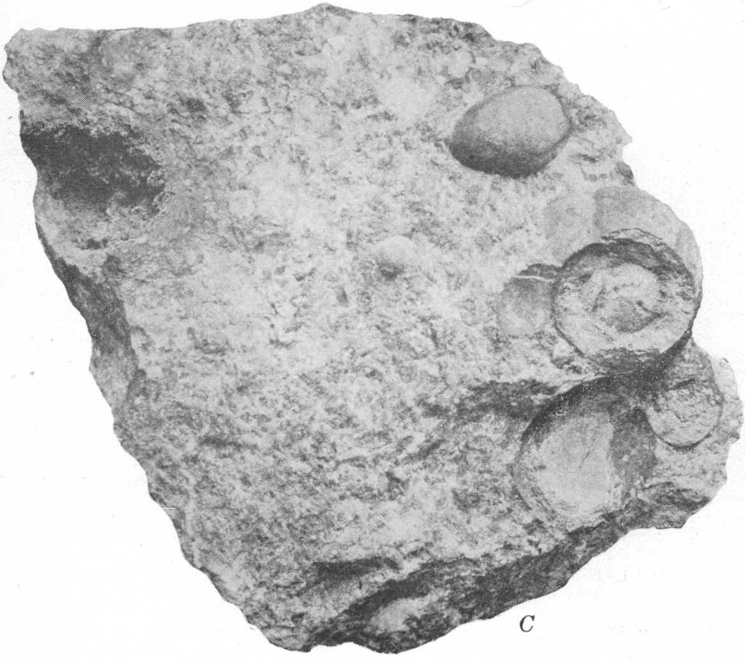
One-half natural size



A



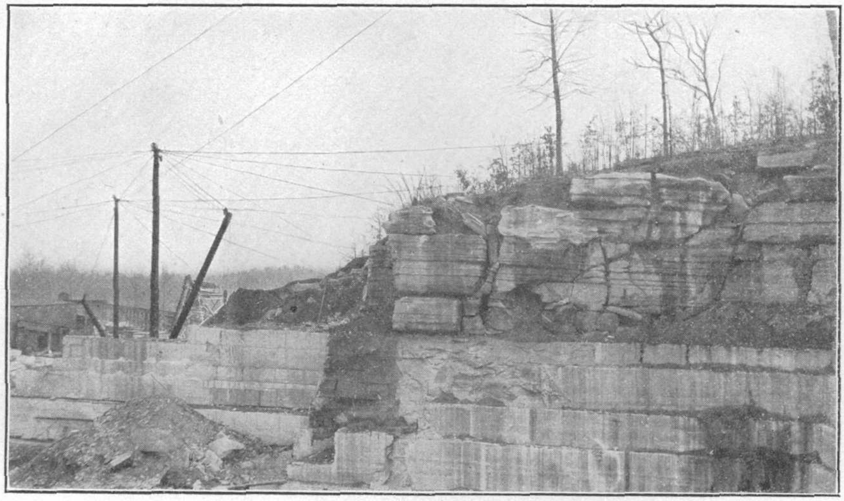
B



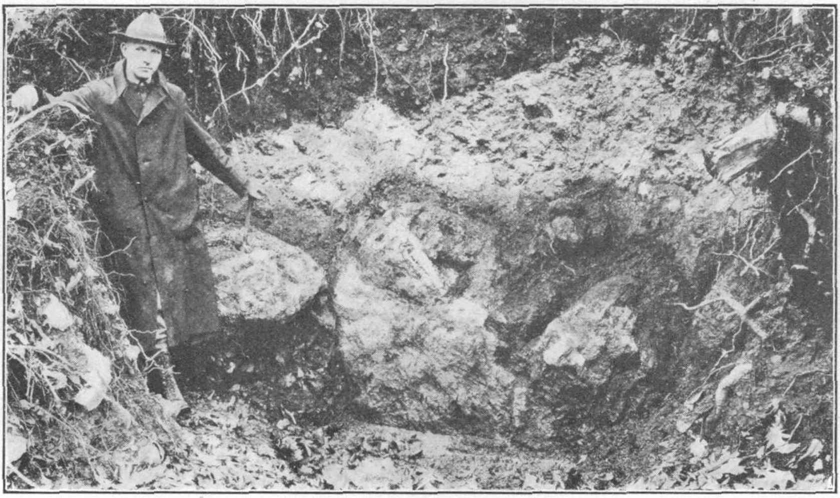
C

FOSSILS FROM THE CASON MINE.

A. Girvanellas (replaced by iron and manganese oxides) on the weathered surface of St. Clair limestone. Natural size.
B and *C*. Girvanellas in fragments of limestone from the lowermost beds of St. Clair limestone. Natural size.

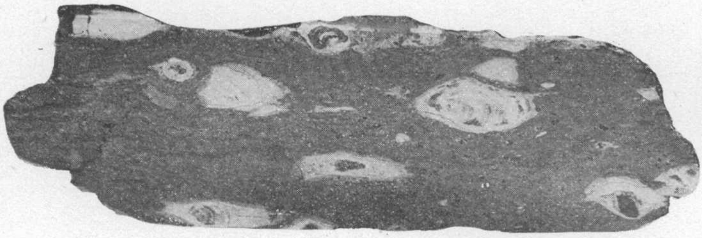


A. LIMESTONE IN BOONE CHERT AT THE QUARRY OF THE PFEIFFER STONE CO. AT PFEIFFER.

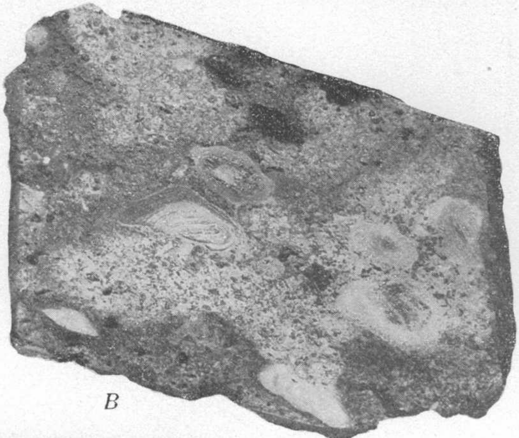


B. LARGE IRREGULAR MASSES OF MANGANESE ORE IN RESIDUAL CLAY NEAR THE SURFACE AT THE OZARK MINE.

The hammer held by the man is resting on one of the masses. Photograph by W. R. Crane.



A



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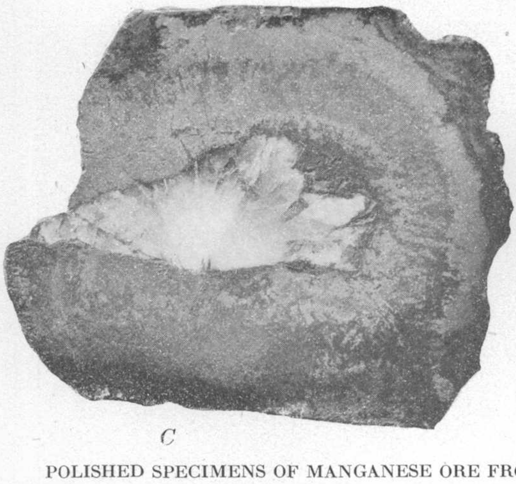
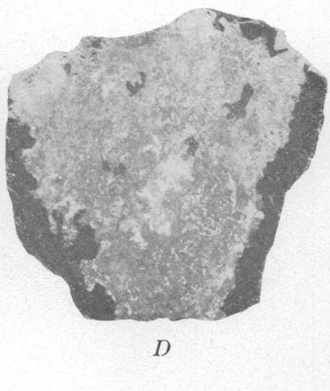


C

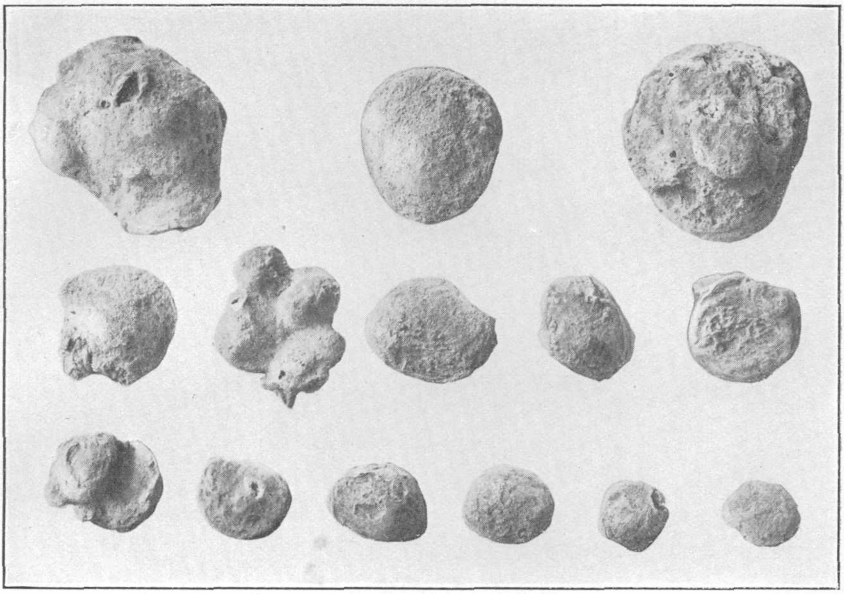


D

POLISHED SPECIMENS OF MANGANESE ORE FROM THE BATESVILLE DISTRICT.

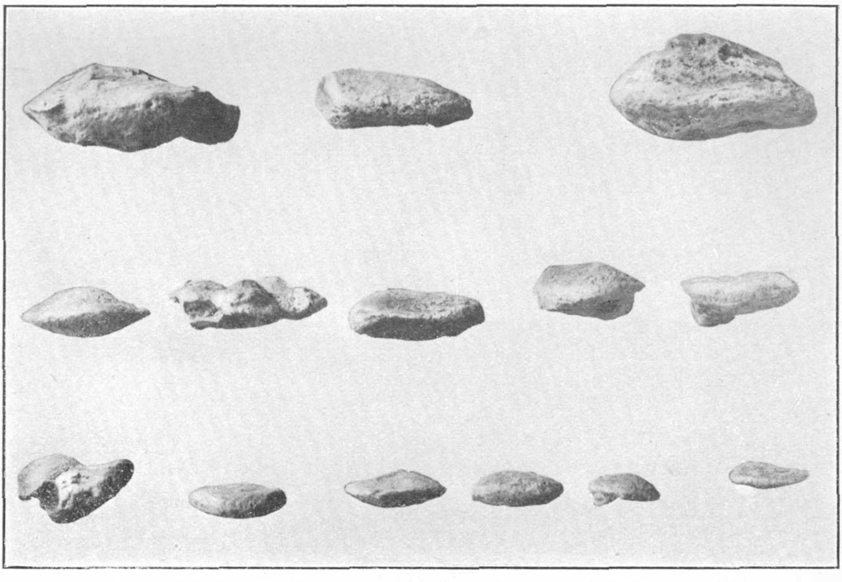
A. Fragment of red shale from the Cason shale at the Cason mine, showing buttons of girvanellas that have been replaced by manganese oxide (light gray).
B. Porous manganese ore with buttons of girvanellas from the Montgomery mine.
C. Slab of manganese ore from the Wildcat prospect showing an intimate mixture of hausmannite and psilomelane in a roughly zonal arrangement and a radiating mass of white barite at the center. The light steel-gray mineral and the black mineral immediately adjacent to the barite are psilomelane; the rest of the black mineral is hausmannite.
D. Manganese-bearing carbonate from Fernvale limestone at the Harvey mine, showing its partial replacement by black manganese oxide.

All specimens are natural size.



A. TOP VIEW.

Two-thirds natural size.



B. EDGEWISE VIEW.

Two-thirds natural size.

BUTTONS (GIRVANELLAS) OF MANGANESE OXIDE FROM THE MONTGOMERY MINE.

makes up the mass was apparently deposited in a solution cavity in the St. Clair limestone. Not only was sand deposited in the cavity, but small fragments and large blocks of the Penters chert were washed or fell into it and were more or less mixed with the sand. The top of the sandstone mass occurs at the same height on the hill slope as the contact between the Penters and Boone cherts. A lens of sandstone a few feet thick and 100 feet or more long lies between the Boone and Penters cherts in the bluff one-fourth of a mile south of Penters Bluff station. The sand grains at this locality are not confined to the lens but extend downward into the Penters chert, in which they are distributed along joints and bedding planes.

Two feet or less of red and greenish-gray calcareous shale occurs at the base of the Boone in places along Cave Creek. This shale, as it is revealed in most exposures, has weathered to a yellow shaly clay. A specimen of *Conularia* was found in this shale at the W. A. Chinn cut near Cave Creek.

Fossils are scarce in the Boone chert in the Batesville district, in marked contrast to their abundance farther west in Arkansas, but the few that have been found show that it belongs to the Mississippian series of the Carboniferous system. One small collection was obtained from a limestone bed in the lower part of the formation, about 1 mile southeast of Big Spring. These specimens have been studied by Girty, who says that the fauna represented by them may be related to the typical faunas of the Boone chert but that it appears to fall in better with the fauna of the Ridgetop shale and that of the lower part of the Fort Payne chert in the southeast corner of the Waynesboro quadrangle of southwest-central Tennessee. The following species in the collection have been tentatively identified by Girty: *Productus setiger?*, *Spirifer subequalis*, *Spirifer arkansanus*, *Pseudosyrinx* aff. *P. keokuk*, and *Reticularia pseudolineata.*

Girty,[36] who describes the lithologic character and fauna of a chert member 200 to 250 feet thick at the top of the Boone, thinks that the chert member is younger than the typical Boone chert of Boone County, Ark., and that it deserves to be regarded as a distinct formation in the Batesville region. The above-mentioned collection of fossils is the only evidence at hand concerning the age and correlation of the part of the Boone below the chert member. The relations of the chert member to the underlying beds were not determined by Girty, and no opportunity to study it was afforded the present writer during the investigation of the manganese deposits. The writer therefore believes that this chert member should be included in the Boone chert until further field evidence is obtained to support Girty's suggestion that it be regarded as a distinct formation.

[36] Op. cit., pp. 5–23.

The Boone chert rests upon the following formations at different places and is separated from them by an angular unconformity: Kimmswick limestone, Fernvale limestone, Cason shale, St. Clair limestone, Lafferty limestone, Penters chert, and Chattanooga shale. The unconformity between the Boone and Penters cherts is very conspicuous in the bluffs along the left bank of White River from Penters Bluff station to a locality about 2 miles south of Walls Ferry station. (See Pl. VI, *B*.) The Boone chert is overlain by the Moorefield shale which, like the Boone, is of Mississippian age.

MOOREFIELD SHALE.

The Moorefield shale is exposed over large areas lying east and west of Batesville. As these areas are south of the manganese region the Moorefield is only briefly described here. The thickness of the formation is not definitely known, but it apparently ranges from 100 feet or less to more than 250 feet. The formation consists of black and greenish shale, a few limestone concretions, and a limestone phase several feet thick at the base, which has been called "Spring Creek limestone." The fauna of this limestone and of the overlying shale has been described by Girty in Bulletin 439 of the United States Geological Survey.

BATESVILLE SANDSTONE AND YOUNGER ROCKS OF CARBONIFEROUS AGE.

The Batesville sandstone is exposed over rather large areas at Batesville and in areas east and west of that place, but as all these areas are south of the manganese-bearing district, only a brief description of the sandstone is here given. The present writer observed the sandstone at only a few places, and for this reason he quotes the following description of it from Penrose:[37]

"Overlying the Fayetteville [Moorefield] shale, is a sandstone formation with lenticular beds of gray, black, or brown shale. This formation lies on both sides of the White River, reaching to the area of the Fayetteville [Moorefield] shale and the chert hills on the north, and, on the south, disappearing under the overlying rocks at the foot of the Boston Mountains. It is well developed at the town of Batesville and has been named, by the State geologist, the Batesville sandstone. It consists of a brown or buff colored, fine-grained sandstone, generally soft though sometimes hard. It splits easily along the lines of bedding, in slabs varying from a few inches to 3 or 4 feet in thickness, and is extensively worked for structural purposes * * * in Batesville. The shales in the sandstone occur as lenticular deposits, often ending very abruptly, though sometimes traceable for several miles. They and the sandstones appear, in many places, to be mutually replaceable. The thickness of the Batesville sandstone is very changeable, varying from 20 or 30 feet to almost 200 feet. One mile east of the town of Batesville, on the bluffs of Blue Creek, it shows a thickness of 170 feet, and, as it is still at the foot of the bluffs, it is probably thicker."

[37] Penrose, R. A. F., jr., Manganese—its ores, uses, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, p. 139, 1891.

The fauna of the Batesville sandstone has been described in detail by Girty in Bulletin 593 of the United States Geological Survey.

The Fayetteville shale and Pitkin limestone, of Mississippian age, and rocks of Pennsylvanian age are widely exposed in and near the Boston Mountains, south of White River, but none of them are present in the manganese-bearing district.

UPPER CRETACEOUS OR TERTIARY GRAVELS.

Worn pebbles of chert occur on or near the crests of the highest as well as some of the lower hills near Cushman and Mount Pleasant and east of these villages. At some places they form a surficial gravel bed a few feet thick, at others they occur in pockets several feet thick in the residual clays of limestones, and at others they are disseminated through pockets of yellow and red sand in residual clays. The pebbles are 5 inches or less in their longest dimension and are fairly or well rounded. They rest upon all the rock formations from the St. Peter sandstone to the Boone chert, inclusive, although most of them have obviously been derived from the Boone chert. The occurrence of the pebbles on and near the tops of the hills over the east two-thirds of the Batesville district indicates that the present patches of gravel are only the remnants of a widespread gravel bed that formerly covered much of the Batesville district and that has since been almost entirely eroded. Furthermore, the occurrence of some pockets of gravel and sand in the residual clays of limestones indicates that they were deposited in solution channels in the unaltered limestones. The gravels were deposited upon a nearly level surface, whose altitude is probably attained by some of the highest hills on which the gravels are found, but many if not most of the remnants of the gravel bed have settled by gravity or have been carried by streams below the original position of the bed. The settling took place as the underlying limestones were decomposed by the removal of the calcium carbonate in solution while the present valleys of the region were being carved. The evidence at hand indicates that some of the lowest remnants, although they are now on the crests of hills, are 200 to 300 feet below the supposed elevation of the original gravel bed.

The age of the gravels is by no means definitely known, and a study of them over a much larger area than the Batesville district will be necessary before any satisfactory conclusion can be reached.

Extensive deposits of gravels are described by Stephenson and Crider[38] as occurring at and near Grandglaise and Newark, Ark. Some of those gravels are of Upper Cretaceous age, but most of them are believed by Stephenson and Crider[39] to be of late Pliocene age.

[38] Stephenson, L. W., and Crider, A. F., Geology and ground waters of northeastern Arkansas: U. S. Geol. Survey Water-Supply Paper 399, pp. 37–39, 96–97, 1916.
[39] Idem, pp. 97–100.

The younger gravels have not had sufficient study to determine their age with certainty, but they are probably not younger than Tertiary. The gravels in the Batesville district are without doubt remnants of one of the gravel beds farther east, and their age, so far as it can now be determined, may be either Upper Cretaceous or Tertiary.

QUATERNARY SYSTEM.

TERRACE DEPOSITS AND ALLUVIUM.

A few small patches of terrace deposits, which consist partly of rounded chert pebbles and partly of surficial loam, occur along the large and small streams in the area here described and lie from 50 to 100 feet or more above the streams.

The larger and most of the smaller streams flow in flat-bottomed valleys and are bordered by flood plains, the widest of which are those of White River. Although gravels and cobbles make up a large part of the valley filling, the surface is usually covered with rich loam and sand, and most of it makes good farm land. Most of the gravels and cobbles were derived from chert fragments, but some of them from sandstone. Alluvial cones, composed largely of angular chert fragments, are present at the mouths of many small hollows in the areas where the Boone chert is the surface rock. The flood plains of Polk Bayou and West and East Lafferty creeks are generally underlain by sand that has been derived from the St. Peter sandstone, and for this reason travel on the roads along these streams is generally difficult.

WELL RECORDS.

The well records given below describe in detail the rocks passed through by the drills. The first seven are records of holes that were drilled in 1918 by the United States Steel Corporation through its subsidiary companies, the Tennessee Coal, Iron & Railroad Co. and the Oliver Iron Mining Co. The records were compiled by the writer during his examination of the drill cores.

Record of drill hole No. 1 in the NW. ¼ SW. ¼ sec. 34, T. 14 N., R. 6 W.[a]

[Elevation of top of drill hole 600 feet above sea level.]

Age and formation.			Thickness.	Depth.
			Feet.	*Feet.*
		Chert fragments derived from the Boone chert	28	28
Carboniferous.	Boone chert.	Gray chert	13	41
		Gray chert and cherty fine-grained gray limestone	7	48
		Cherty fine-grained gray limestone; contains some pyrite.	2	50
		Fine-grained gray limestone; contains angular chert fragments and thin layers of greenish glauconite-like material.	1	51

[a] For exact location, see fig. 10.

Record of drill hole No. 1 in the NW. ¼ SW. ¼ sec. 34, T. 14 N., R. 6 W—Contd.

Age and formation.			Thickness.	Depth.
			Feet.	*Feet.*
Silurian.	St. Clair limestone.	Fine-grained gray limestone; some pink crystals are scattered through it.	8	59
		Coarse-grained pinkish-gray limestone	47	106
Ordovician.	Fernvale limestone.	Pinkish-gray coarse-grained limestone; pinkish color is darker than that of the overlying beds of the St. Clair.	55	161
		Gray fine-grained limestone with a slightly pinkish cast.	5	166
		Coarse-grained pink limestone	9	175
		Coarse-grained pink limestone; contains thin layers of compact bluish-gray limestone.	9	184
	Kimmswick limestone.	Fine-grained light-gray limestone	23	207
		Coarse-grained limestone that is darker gray than the overlying beds.	3	210
		Fine-grained and coarse-grained gray limestone	5	215
		Fine-grained and coarse-grained gray limestone with a pinkish cast.	11	226

Record of drill hole No. 2 in the NW. ¼ SW. ¼ sec. 34, T. 14 N., R. 6 W.[a]

[Elevation of top of drill hole about 500 feet above sea level.]

	Thickness.	Depth.
	Feet.	*Feet.*
Chert fragments and gray clay	62	62
Laminated gray clay and chert fragments; one grain of sphalerite one-eighth of an inch in diameter was observed in the clay. Laminations in the clay show that it dips at high angles	20	82
Chert fragments in gray siliceous clay	23	105
Gray and brown laminated clays; contains some pyrite	10	115
Sandy clay	11	126
Chert fragments in gray clay	7	133
Chert fragments in gray laminated clay; contains small crystals of pyrite	9	142
Laminated, fine-grained gray siliceous earthy rock that appears to be weathered shale. The inclination of the laminae in the drill cores shows that some of them dip as much as 45°	18	160
The same rock as the above except that it is lighter gray and contains pyrite	12	172
Yellowish dark gray coarse-grained limestone (Fernvale); contains pyrite	10	182
Greenish-gray granular limestone (Fernvale); contains pyrite; inclined laminae or bedding planes suggest that these and the overlying beds of limestone are not in place	17	199
Limestone like that above and sandy gray clay	12	211
Laminated sandy gray clay	10	221
Coarse-grained dark-gray limestone (Fernvale)	10	231
Laminated sandy gray clay; the inclination of the laminae shows that some of them dip as much as 60°. Fossils in the clay indicate that it is a weathered phase of the Chattanooga shale of Devonian age	15	246
Laminated sandy gray clay; some of the laminae dip as much as 40°; pyrite, green chloritic material, and drusy quartz are present	15	261
Dark-gray coarse-grained limestone (Fernvale); contains pyrite and layers of gray clay	11	272

[a] For exact location see fig. 10.

The materials penetrated by this drill hole consisted mainly of clay, which was washed out of the hole by water during the drilling. The firmer materials described above were obtained as a core and represent only a small part of those that were penetrated. Their character and relations suggest that probably none of them are in place. They have apparently settled into an old solution channel in the Fernvale limestone. (See fig. 11.) The chert fragments were derived from the Boone chert, and some of the laminated clay was derived from the Chattanooga shale.

Record of drill hole in the SE. ¼ SW. ¼ sec. 28, T. 14 N., R. 6 W.

Age and formation.			Thickness.	Depth.
		Surficial chert fragments derived from the Boone chert.	*Feet.* 120	*Feet.* 120
Carboniferous.	Boone chert.	Gray chert	33	153
		Phosphatic limestone	1	154
Ordovician.	Fernvale limestone.	Gray coarse-grained limestone	4	158
		Rusty gray coarse-grained limestone	22	180
		Light to dark gray coarse-grained limestone	21	201

Record of drill hole in the NE. ¼ SE. ¼ sec. 25, T. 14 N., R. 6 W.

Age and formation.			Thickness.	Depth.
		Chert débris	*Feet.* 10	*Feet.* 10
Carboniferous.	Boone chert.	Gray hard chert	10	20
		Gray hard chert, calcareous in parts	49	69
		Fine-grained gray limestone	2	71
		Gray calcareous fossiliferous shale	1	72
Devonian.	Chattanooga shale.	Platy black fossiliferous shale	22	94
	Penters chert.	Gray and bluish flint, but it is dark at top and parts of it show banding and mottling.	91	185
Ordovician (?).	Cason shale (?)	Platy grayish-black shale	22	207
		Dark-colored fossiliferous phosphate rock; contains some pyrite.	1	208
Ordovician.	Kimmswick limestone.	Light-gray fine-grained limestone; contains a small quantity of chert near its top.	20	228

Record of drill hole at the northeast corner of the NW. ¼ SE. ¼ sec. 26, T. 14 N., R. 6 W.

Age and formation.			Thickness.	Depth.
		Chert débris, derived from weathering of underlying Boone chert.	*Feet.* 38	*Feet.* 38
Carboniferous.	Boone chert.	Chalky chert; calcareous in parts	52	90
		Blue flint	13	103
		Gray fine-grained limestone; cherty in parts	22	125
Devonian.	Chattanooga shale.	Black shale	38	163
	Penters chert.	Gray chert and flint becoming dark-colored in upper part.	62	225
Ordovician.	Fernvale limestone.	Dark-gray coarse-grained limestone; parts of it are rusty. A sample of the rusty limestone was found by Chase Palmer, of the U. S. Geological Survey, to contain 5.82 percent of manganese.	21	246

Record of drill hole in the SW. ¼ NW. ¼ sec. 24, T. 14 N., R. 6 W.

Age and formation.			Thickness.	Depth.
			Feet.	*Feet.*
		Surficial material	3½	3½
Devonian.	Chattanooga shale.	Fossiliferous black shale	5	8½
	Penters chert.	Gray and bluish-black dense, very hard flint. There are a few thin layers of gray limestone.	48½	57
		Gray chert and flint	33	90
		Gray fine-grained impure limestone with some pyrite and black phosphate rock.	7	97
Ordovician.	Cason shale (?)	Gray and red shale	5	102
	Fernvale limestone.	Gray fossiliferous granular limestone; rusty in most parts. A sample of rusty limestone which was analyzed by Chase Palmer, of the U. S. Geological Survey, was found to contain 1.48 per cent of manganese.	33	135

Record of drill hole in the NW. ¼ NE. ¼ sec. 4, T. 13 N., R. 6 W.

Age and formation.			Thickness.	Depth.
			Feet.	*Feet.*
		Surficial chert fragments derived from Boone chert	98	98
Ordovician.	Kimmswick limestone.	Medium-grained light-gray limestone	15	113
	Plattin limestone.	Compact dove-colored limestone	35	148

Record of the well at the Southern mine.[a]

[Elevation of top of well, 645 feet above sea level.]

	Thickness.	Depth.
	Feet.	*Feet.*
Detritus [fragments of chert and limestone buried in residual clay]	50	50
Izard limestone [Joachim and Plattin limestones]	240	290
Sandy limestone [Joachim limestone]	10	300
Saccharoidal sandstone [St. Peter sandstone]	125	425
Interbedded gray limestones and sandstones, with calcareous sandstones	45	470
Massive gray and brown limestone with disseminated grains of sand	38	508
Massive gray limestone with disseminated grains of sand (82 feet) running into a chocolate-brown limestone with similarly disseminated grains of sand (15 feet)	97	605
Slightly calcareous gray sandstone	9	614
Highly calcareous gray sandstone	82	696
Massive chocolate-brown and gray limestone	19	715
Massive gray limestone	70	785
Massive gray limestone, harder than the last	115	900
Slightly sandy gray limestone (4 feet) passing at its base into a white sandstone (51 feet)	55	955
Sandy dark-gray limestone	45	1,000
Fine-grained calcareous gray sandstone, becoming coarser at the base	130	1,130
Massive gray limestone with disseminated grains of sand	25	1,155
Fine-grained white sandstone	25	1,180
Sandy gray limestone running into fine-grained white sandstone	20	1,200
Massive chocolate-brown limestone	75	1,275
Massive gray limestone with disseminated fine grains of sand	75	1,350
Massive gray limestone with disseminated coarse grains of sand	30	1,380
Massive gray limestone	30	1,410
Fine-grained white sandstone	20	1,430
Massive gray limestone with disseminated grains of sand	45	1,475
Fine-grained calcareous gray sandstone	55	1,530
Fine-grained calcareous white sandstone	140	1,670
Shaly gray limestone with thin strata of green shale, passing at its base into a shaly calcareous sandstone (2 feet)	52	1,722
Very fine grained calcareous gray sandstone with thin strata of black shale	203	1,925
Creamy-gray limestone to the base of boring	115	2,040

a Penrose, R. A. F., jr., op. cit., p. 118.

STRUCTURE.

GENERAL FEATURES.

The strata in the Batesville district, which must have been deposited in a nearly horizontal position, have undergone little deformation. The general doming of the beds in the Ozark region has given those of this area a slight dip to the south, which is disguised at several places by minor folds and a few normal faults. Most of the minor anticlinal flexures form small irregular domes, and the synclinal flexures form irregular basins, but they are referred to simply as anticlines and synclines in this report.

The folding and faulting in this district affect all the strata, including those of Mississippian age, and therefore took place late in the Mississippian epoch or at a later date. Not only was the faulting probably contemporaneous with the folding, but the faulting and folding were probably contemporaneous with like movements that took place near the close of the Carboniferous period in other parts of the Ozark region. There is some evidence, however, that one if not more of the present folds of the Batesville district were begun about the close of the Ordovician period.

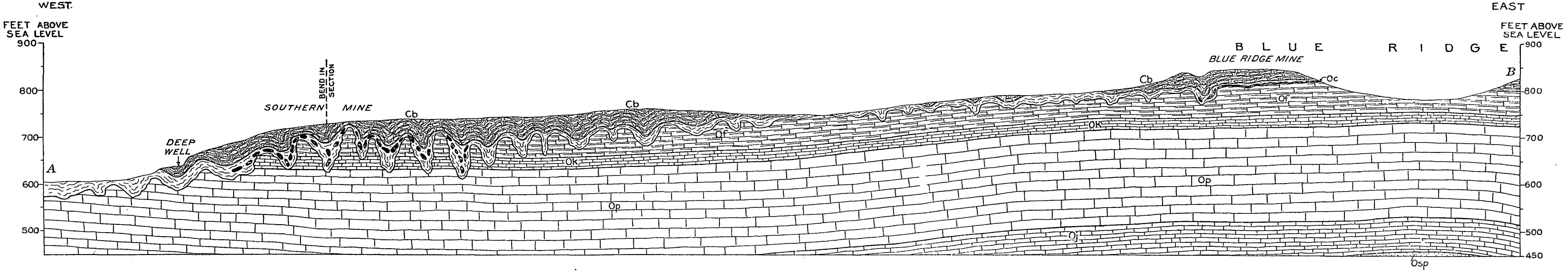
FOLDS.

Many small folds were observed during the present investigation, and many others can doubtless be discovered if a better topographic map than the one at present available can be had. A few folds that are sufficiently pronounced and those that are intimately associated with important manganese deposits receive special mention below.

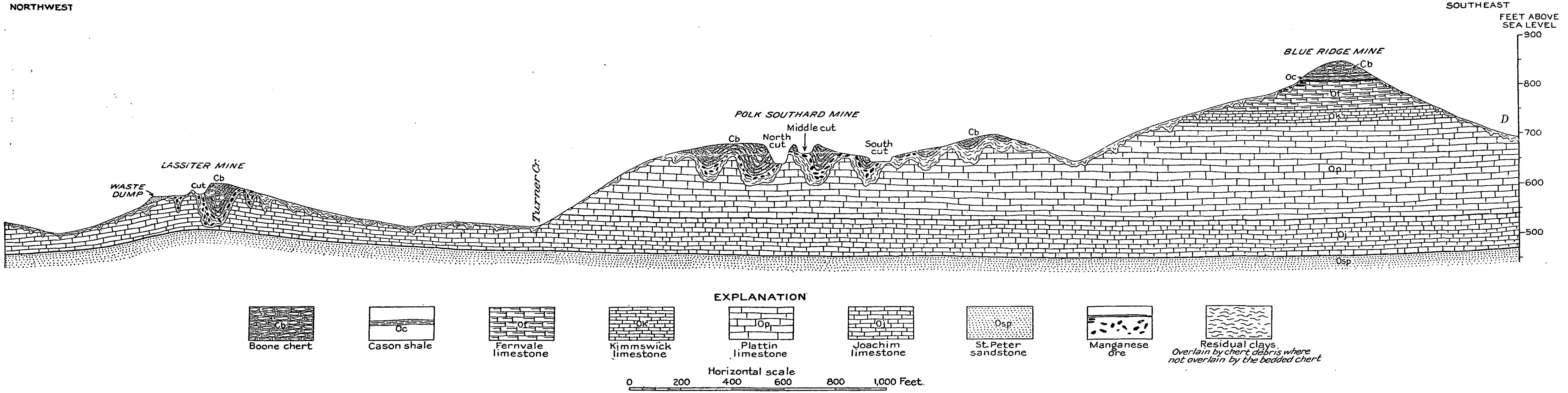
An anticline whose axis lies along the crest of the ridge north of the Cason mine (fig. 10) extends northeastward for at least 1¼ miles from this mine. A small area of outcrop of the Plattin limestone half a mile northeast of this mine is on the crest of the anticline.

The rocks at the Cason mine (fig. 10) lie in a shallow syncline which is a minor cross fold on the southeast side of the anticline just mentioned. The axis of the syncline trends northwest. The St. Clair limestone and Cason shale in the West cut, which is on the west side of the syncline, dip 15° to 20° NNE., and in the North cut, which is on the east side of the syncline, they dip at about the same angle to the southwest.

A broad eastward-trending syncline lies about 1¼ miles north-northeast of Cushman, and in it are the Blue Ridge, Southern, Grubb Cut, Rogers, Wren, Polk Southard, and Turner mines. (See Pl. XII.) The Blue Ridge, an east-west ridge which is capped by the Boone



A. SECTION ALONG LINE A—B ON PLATE XVII ILLUSTRATING THE OCCURRENCE OF THE MANGANESE-ORE DEPOSITS AT THE SOUTHERN AND BLUE RIDGE MINES.



B. SECTION ALONG LINE C—D ON PLATE XVII ILLUSTRATING THE OCCURRENCE OF THE MANGANESE-ORE DEPOSITS AT THE LASSITER POLK SOUTHARD, AND BLUE RIDGE MINES.

chert, is on or near the axis of the syncline. On the south side of the syncline the St. Peter sandstone and Joachim limestone are revealed in an anticline in the southern part of sec. 3, T. 14 N., R. 7 W., and on the north side they are revealed in two anticlines just north of Turner Creek, in secs. 33 and 34, T. 15 N., R. 7 W.

The axis of a shallow east-west syncline half a mile wide passes through Anderson. The oldest exposed formation in this syncline is the St. Peter sandstone, and the youngest exposed east of Anderson is the Fernvale limestone. The Earl Collie, Sand Field, Manganese Field, Ruminer Rough, and Barksdale mines and the Caraway prospect are in this syncline.

The St. Clair limestone is exposed on the crest of a low anticline just south of Big Spring, and the Fernvale limestone on the crest of one just east of Walls Ferry station and another 1½ miles south of that place.

A small syncline lies in the NW. ¼ sec. 35, T. 15 N., R. 6 W., near the E. W. Roach prospect, 1½ miles east-northeast of Sandtown. The surface in this vicinity is gently rolling, and although most of the surface is underlain by the St. Peter sandstone the Plattin and Joachim limestones underlie a nearly circular area about 500 feet in diameter and dip at high angles toward its center. The limestones, therefore, lie in a funnel or saucer shaped syncline. The Plattin limestone, in the center of the syncline, is brecciated in places and its outcrop occupies a circle 250 feet in diameter. Outside this circle the Joachim limestone is exposed in a narrow belt, and outside this belt the St. Peter sandstone is exposed. A syncline similar to the one just described lies about half a mile north of the E. W. Roach prospect, but the Joachim limestone is the only limestone that is present in it. A third saucer-shaped syncline lies 1 mile north of Hickory Valley. The St. Clair limestone is exposed at and near its center, and the Kimmswick and Plattin limestones are exposed outside the area of the St. Clair. Another syncline of this type lies 2 miles east-northeast of Hickory Valley, and there is another 2½ miles northeast of this village. The Plattin limestone outcrops in nearly circular areas at the centers of both synclines. The synclines just described are apparently similar in shape to some that are near Rolla, Mo., and that are mapped and described by Lee[40] as "structural sinks" and "filled cave structures." He ascribes their synclinal structure to the sagging and falling in of the strata that formed the roofs of caves. Further study of the saucer-shaped synclines in the Batesville district may show that they had the same origin as those in Missouri.

There are several monoclinal folds, among which is one at the abandoned village of Phosphate and farther southwest, where the

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[40] Lee, Wallace, The geology of the Rolla quadrangle: Missouri Bur. Geology and Mines, vol. 12, 2d ser., pp. 64–68 and geologic map, 1913.

strata dip to the south or south-southwest; for a distance of several miles southeast of Cushman the strata dip to the southwest, toward Big Spring; the strata between Cura Creek, near Hickory Valley, and Sullivan Creek, to the west, have a general south-southeast dip.

FAULTS.

Faults are rare in the Batesville district, only seven being known, and all are normal faults. Although no exposures were found showing the angle of dip of the fault planes, their dip is probably high at all places.

The longest fault extends in an east-northeast direction for a distance of 7 or 8 miles from a locality about 2 miles north of Batesville; it passes just south of the Cason mine (figs. 10 and 11), also passes just south of Pfeiffer, and probably terminates about 1 mile north of Sharps Cross Roads. The downthrow is on the south side and is perhaps 400 feet throughout much of the length of the fault. The strata just north of the fault at the Cason mine dip 15°–20° S., and similar dips in this direction were observed on the north side of the fault for a distance of 1 mile farther northeast.

The next longest fault extends east-northeast for 4 miles from Ruddell's Mill, which is 2½ miles west of Batesville. The fault was not traced by the writer as far west as Ruddell's mill, but the occurrence of the fault at that place is indicated on one of the geologic maps (Batesville sheet) that accompanies volume 4 of the Annual Report of the Arkansas Geological Survey for 1890. The downthrow is on the south side of the fault and is probably 100 feet or more. The same geologic map indicates another fault that extends west-northwest from a point about half a mile southwest of Ruddell's Mill. The downthrow is on the south side. This fault was not studied by the writer, and its location as shown on Plate I is taken from the map mentioned above.

A northeastward-trending fault 1 mile long lies 2¾ miles north-northwest of Cushman. The downthrow, which is on the southeast side, is about 200 feet near the northeast end of the fault and 50 feet near the southwest end.

A fault trending east by north passes through Penters Bluff station and extends eastward as far as West Lafferty Creek; it probably crosses White River west of the station. How far the fault extends into Stone County has not been determined. The downthrow is on the south side and is about 250 feet at the station, but it gradually decreases to the east. The oldest exposed formation on the north side of the fault at the station is the Plattin limestone, whereas the oldest on the south side at that place is the Fernvale limestone.

Two short parallel faults 250 feet apart, having an eastward trend, occur on Polk Bayou 4½ miles east-northeast of Cushman. The Joachim and Plattin limestones are exposed in the belt between the faults, whereas the St. Peter sandstone is exposed both north and south of the belt. The rocks in this belt have settled about 100 feet. (See fig. 18.)

ORE DEPOSITS.

MINERALS OF THE ORES.

General features.—The manganese ores of the Batesville district consist of oxides, six of which, psilomelane, hausmannite, braunite, manganite, pyrolusite, and wad, have been identified. Although these minerals may be found separately, two or more are generally mixed in the same deposit, and at a few places they are associated with ferruginous manganese ores and with small quantities of brown and red oxides of iron. At some places the ferruginous manganese ores predominate. Psilomelane is the most abundant manganese mineral, but hausmannite, braunite, and wad constitute a considerable part of the ores.

The identification and naming of the manganese minerals is based largely on the table in a report by Fermor [41] on the manganese deposits of India. In general if the mineral is uncrystallized or amorphous and has a hardness greater than 4 it is classed as psilomelane. If it is soft and shows no signs of crystalline structure nor of the compact firm amorphous structure of psilomelane it is classed as wad. If it is crystalline and can not be scratched with a brass pin but can be easily scratched with a knife it is classed as manganite, whereas if it can be easily scratched with a brass pin and if it blackens the fingers it is classed as pyrolusite. If it is crystalline and can be scratched with difficulty with a knife it is considered to be braunite or hausmannite. Braunite has a brownish-black streak and yields gelatinous silica when a solution of it in hydrochloric acid is evaporated, whereas hausmannite has a chestnut-brown or reddish-brown streak and yields no gelatinous silica when a hydrochloric acid solution of it is evaporated. Many oxides of manganese that have been found in the United States and in other countries have not been adequately studied, and some of these are doubtless included among the oxides in the district under discussion. There is, therefore, a possibility of errors in identifying some of the manganese oxides.

[41] Fermor, L. L., The manganese-ore deposits of India: Geol. Survey India Mem., vol. 37, pt. 1, pp. 228–229, 1909.

The chief minerals in the Batesville district, including the manganese oxides that have been identified with a fair degree of certainty, are described below.

Psilomelane.—Psilomelane is black or steel-blue, is amorphous, breaks with a conchoidal fracture, and at a few places shows botryoidal surfaces. It has a specific gravity of 3.7 to 4.7 and commonly has a hardness of 5 to 6.5, so that a steel knife blade scratches it with difficulty if at all. Although its chemical composition may be represented by the formulas $MnO_2.(Mn, K, Ba)O.nH_2O$ and H_4MnO_5, the composition is not definite, as the percentage of manganese ranges from 50 to 57, and as the amounts of minor accessory constituents, such as iron, barium, potassium, and water, show a wide range. This is the most abundant manganese mineral in the Batesville district. Three analyses of it are given below:

Analyses of psilomelane from the Batesville district.

	1	2	3
Manganese protoxide (MnO)	77.85	84.995	82.448
Oxygen (O)	14.56	10.483	10.002
Ferric oxide (Fe_2O_3)	.90		
Alumina (Al_2O_3)	.80		
Lime (CaO)	1.81	Trace.	1.178
Baryta (BaO)	.21	.512	.282
Magnesia (MgO)	(a)		Trace.
Potash (K_2O)	1.99		
Soda (Na_2O)	.97		
Phosphoric acid (P_2O_5)	.67		
Silica (SiO_2)	.83	2.845	5.329
Water (H_2O)		1.820	.611
	100.59	100.655	99.850

a Very slight trace.

1. Penrose, R. A. F., jr., Manganese—its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, p. 145, 1891. R. N. Brackett, analyst. Specimen for analysis "from Cave Creek, 9 miles north of Batesville, Independence County."

2, 3. Owen, D. D., First report of a geological reconnaissance of the northern counties of Arkansas, pp. 161-163, 1858. William Elderhorst, analyst. Specimens for analysis from "the main manganese mine 2 miles above West Fork of Lafferty Creek, Independence County."

Hausmannite.[42]—Hausmannite is a brittle steel-gray mineral, having a chestnut-brown or reddish-brown streak and a submetallic luster. It is finely to coarsely granular but locally crystalline, is translucent on thin edges, and has an uneven fracture, a perfect basal cleavage, and a hardness of about 5.5. It is weakly magnetic, as some of the finely powdered mineral may be picked up by a magnet. The crystals, which appear to be small octahedra, cover cavities in the massive mineral. The chemical composition is expressed by the formulas Mn_3O_4 and $MnO.Mn_2O_3$. Chemically pure haus-

[42] The occurrence, physical and optical properties, and chemical composition of the hausmannite in the Batesville district have been fully described by the writer and J. G. Fairchild in a paper that was published in the Journal of the Washington Academy of Sciences, in vol. 10, No. 1, 1920.

mannite would contain 72 per cent of manganese. Next to psilomelane it is the most abundant manganese mineral in the Batesville district. It has heretofore been classed as braunite. The accompanying analyses represent the composition of two samples of hausmannite, one being from the W. T. Gray mine and the other from the Club House mine. The samples were carefully prepared in order to free them as far as possible from a little psilomelane which they contained. Polished surfaces showed the presence of psilomelane as fine disseminated particles and as veinlets too minute to be observed by a pocket lens on a rough, fractured surface; more psilomelane was seen in sample No. 1 than in sample No. 2.

Analyses of hausmannite from the Batesville district.

[J. G. Fairchild, analyst.]

	1	2
Manganese protoxide (MnO)	91.38	90.40
Oxygen (O)	7.78	8.87
Iron oxide (Fe_2O_3)	None.	a .48
Alumina (Al_2O_3)	None.	
Silica (SiO_2)	None.	.10
Lime (CaO)	Trace.	Trace.
Magnesia (MgO)	Trace.	Trace.
Baryta (BaO)	.26	None.
Total water (H_2O)	.62	1.03
	100.04	100.88
Manganese (Mn)	70.76	70.00
Specific gravity at 15.5° C	4.836	4.778

a A trace of iron.
1. Sample from W. T. Gray mine.
2. Sample from Club House mine.

Penrose[43] gives an analysis of a mineral from the Batesville district whose description accords rather closely with that of hausmannite, but the analysis corresponds to the formula Mn_2O_3. He therefore considered the mineral to be a silica-free braunite. Although a mineral corresponding to the formula Mn_2O_3 is possible, the present writer believes that the sample analyzed consisted largely of hausmannite but contained a little psilomelane. This belief is based upon the following facts: 1. Of the many specimens of hausmannite studied in the present investigation not one was found that was entirely free from psilomelane, and this is apparently the only mineral with which it is intimately mixed. 2. It is practically impossible to separate the hausmannite from the smallest particles of psilomelane, except perhaps with the aid of a microscope. The analysis given by Penrose follows:

[43] Penrose, R. A. F., jr., op. cit., pp. 148–149.

Analysis of braunite [?] from the Batesville district.

[R. N. Brackett and W. A. Noyes, analysts.]

Manganese protoxide (MnO)	87.47
Oxygen (O)	9.62
Ferric oxide (Fe_2O_3)	.44
Alumina (Al_2O_3)	.11
Lime (CaO)	.34
Baryta (BaO)	.48
Magnesia (MgO)	Trace.
Potash (K_2O)	.10
Soda (Na_2O)	.05
Phosphoric acid (P_2O_5)	.25
Silica (SiO_2)	.18
	99.04

Braunite.—Braunite is a brittle steel-gray mineral having a brownish-black streak, a submetallic luster, and a hardness of 5.5 to 6. It is weakly magnetic. Some of it has a granular texture, but the greater part is crystalline. Its crystals are small and numerous and are octahedral. The composition is usually expressed by the formula $3Mn_2O_3.MnSiO_3$. The percentage of manganese in chemically pure braunite ranges from about 63 to 66. Some silica—from 7 to 10 per cent—is always present, which indicates that it is chemically combined. It appears as a gelatinous residue when hydrochloric acid containing braunite in solution is evaporated. An analysis of braunite follows:

Analysis of braunite from the Batesville district.[44]

[William Elderhorst, analyst.]

Manganese protoxide (MnO)	75.386
Oxygen (O)	7.979
Ferric oxide (Fe_2O_3)	3.523
Cobalt oxide (CoO)	Trace.
Lime (CaO)	1.833
Magnesia (MgO)	.192
Silica (SiO_2)	9.968
Water (H_2O)	1.295
	100.176

Manganite.—Manganite ($Mn_2O_3.H_2O$) is a brittle steel-gray granular or crystalline mineral with a dark-brown or nearly black streak. It has a hardness of 4 and therefore can be scratched with a knife but not with a brass pin. Manganite crystallizes in the orthorhombic system and the crystals are generally bladed, wedge-shaped, or needle-like. It contains 62.4 per cent of manganese and 10.3 per cent of water. The specific gravity ranges from 4.2 to 4.4.

[44] Owen, D. D., First report of a geological reconnaissance of the northern counties of Arkansas, pp. 164–165, 1858.

Although it is present at a number of localities in the Batesville district it forms a very small part of the manganese ores. Nodules from some of the deposits are made up of alternate layers of psilomelane and radiating crystals of manganite.

Pyrolusite.—Pyrolusite (MnO_2 generally with a little H_2O) is a grayish-black to jet-black mineral, having a crystalline or granular structure and a black or bluish-black streak. It has a hardness of 2 to 2.5, and can therefore be scratched with a brass pin. Much of it crumbles between the fingers and blackens them. The specific gravity is about 4.8. It contains 63.2 per cent of manganese. It has been generally regarded as derived from manganite by the loss of water. Pyrolusite occurs at few localities and in small quantity.

Wad.—Wad is a dark-brown to black very soft earthy mineral, which is commonly considered to be an impure hydrous oxide of manganese. It is associated with more or less iron, silica, alumina, and water. It is present at many localities in the Batesville district and at some of these places it exceeds in quantity the higher-grade manganese minerals. During the last few years, when there was a demand for low-grade ores, considerable wad was shipped from the district. Most of the wad that has been shipped contained from 20 to 30 per cent of manganese. Dendrites, branching mosslike growths of wad, are common along joints in the Boone chert where it is associated with manganese deposits and along cracks and on fossils in the St. Clair limestone.

Other manganese minerals.—A pink crystalline manganiferous calcite (manganocalcite) occurs in a lenticular horizontal vein 1 inch thick and 2 feet long near the top of the Cason shale at the Cason mine. The same mineral was observed in the ore deposit in the top of the Fernvale limestone at the W. A. Chinn cut. A brown manganese-bearing carbonate occurs at the Harvey mine near Penters Bluff station, at one of the Pittman mines on West Lafferty Creek, and at the Cason mine. An analysis of a partly oxidized sample of this mineral, from the Harvey mine, is given on page 60. An analysis (p. 137) of the fossil girvanellas in the lower part of the St. Clair limestone at the Cason mine indicates the presence of manganese carbonate in them. A brown translucent manganese silicate, which thus far has not been identified, was found in a tunnel 30 feet long in a hollow on or near the south line of sec. 16, T. 14 N., R. 6 W. This tunnel is mentioned on page 129 as one of the openings of the Adler mine.

Iron oxides.—Iron oxides, which probably comprise several hydrous sesquioxides of iron, are associated with the manganese ores at many localities. Of these limonite ($2Fe_2O_3.3H_2O$) and hematite (Fe_2O_3) are the most abundant. But as the mineralogic species of the iron oxides found in each deposit have not been determined these oxides are called in this report simply brown or red oxides of iron, according to their color. The hematite at a few localities has a foliated or micaceous structure and part of it is soft and unctuous.

Ferruginous manganese ore.—The ferruginous manganese ores are generally more or less intimate mixtures of poorly defined oxides of manganese with oxides of iron in various proportions. The iron oxides are usually limonite and hematite. The manganese is generally in the form of psilomelane, though braunite, manganite, and wad are common at some places. The content of manganese ranges from 10 to 35 per cent or more. The higher grades are used in making spiegeleisen and ferromanganese and the lower grades in making high-manganese pig iron.

Barite.—The manganese ores at a number of places contain barite but not in sufficient quantity to injure their value. Most of the barite consists of tabular crystals 3 inches or less in their longest dimension or of coarsely granular aggregates embedded in the masses of manganese oxides. (See Pl. X, *C*.) These crystals and aggregates are generally colorless or white, but specimens of ore from the Cummins Hollow and Johnson Hill mines were observed that contained amethyst-colored barite. Some of the barite contains manganese oxides that have partly replaced it. Tabular-shaped cavities were observed in specimens of ore at the Grubb Cut and Hunt Hollow mines. They were once probably occupied by barite that has since been removed by solution. At the McConnell and Page mines and the Fortune and Eliza Patterson prospects the barite occurs as white hairlike crystals, one-tenth of an inch or less in length, that line cavities in the ore. Barite was also observed associated with manganocalcite in a small pocket in the top of the Fernvale limestone at the W. A. Chinn cut and with the same mineral in a small vein near the top of the Cason shale at the Cason mine.

Chert and quartz.—Although chert fragments and pebbles occur in parts of the ore-bearing clays at most localities in the Batesville district, they are found in the masses of manganese ore at only the Roach, Chapel Hill, McGee, Hawkins, and Story mines and at a few other localities. Some masses of porous chert in the ore-bearing clay contain drusy quartz, and doubly terminated quartz crystals were found on a few of the old mine dumps where such chert had been placed. These crystals are most abundant at the Southern mine. There they are half an inch or less in their longest dimension, and although many are transparent most of them are brown from the presence of minute inclusions of a manganese oxide. Grains of quartz sand occur in some of the ore-bearing clays and at some places lenses of such sand overlie or occur in the ore-bearing clays, but at only a few places are sand grains embedded in the ore. The principal mine, part of whose ore is sandy, is the Ball mine.

Phosphate rock.—Phosphatic sandstone and shale, beds of high-grade phosphate rock, and phosphatic pebbles are associated with much of the manganese ore in the Cason shale and have been described under the heading "Cason shale" (pp. 24–26), but some details will be given in the descriptions of the manganese mines and prospects.

Calcite.—Calcite in fine particles is disseminated through some of the ore. As a rule it represents simply the part of the Fernvale limestone that has not been replaced by the manganese ore. Veins of calcite a fraction of an inch thick are in the ore-bearing part of the Cason shale at the Cason mine. A piece of manganese ore 3½ inches in its longest dimension that was found on the dump at the L. J. Weaver mine is coated with a layer of calcite one-sixteenth of an inch or less thick. A mass of onyx marble was encountered in a cave partly filled with manganese-bearing clay at the Club House mine; it is described on page 214.

Other minerals.—Specimens of the Cason shale that were found at the Cason mine by D. F. Hewett, of the United States Geological Survey, show films and crystals of arsenopyrite.

Minute quantities of galena (PbS), the largest piece the size of a man's fist, were found in the lower part of the St. Clair limestone at the Cason mine while this limestone was being quarried from above the Cason shale. The galena observed by the writer occurred in cavities formed by the solution of fossil girvanellas and in fine veins in the parts of the limestone that contain the girvanellas. Galena has been found in the Montgomery mine also, and a specimen of it weighing a few ounces was given to the writer. Part of the galena in the specimen had been changed to greenish-yellow pyromorphite $(PbCl)Pb_4(PO_4)_3$ and was embedded in manganese oxide.

Pyrite occurs in small quantity at the Cason mine in the green and partly reddened parts of the Cason shale and in the beds of the St. Clair limestone that immediately overlie the Cason shale.

Relations of the manganese minerals.—The masses of manganese oxides are generally irregular in shape and have rough surfaces; at only a few places are they nodular or botryoidal and smooth. Although most of the masses that are mined are in clay some are in limestone, shale, chert, and sandstone, and there is much evidence to show that the manganese oxides have replaced all these inclosing materials. Only a small part of the oxides have replaced clays; the greater part of them are a residue from the decomposition of limestone and shale. The oxides have also partly replaced some of the coarsely granular barite.

Manganiferous calcite (manganocalcite), which has been found in limestone and shale at a few places, has replaced parts of these rocks. The occurrence of manganese oxides as a coating on masses of manganese-bearing carbonates and of thin veins of oxides in such masses is proof that the oxides represent oxidized portions of the carbonates. (See Pl. X, *D*.) These relations suggest that all the manganese oxides of the Batesville district have been derived from the oxidation of manganese-bearing carbonates.

The oxides generally occur mixed. Almost every specimen that has been examined contains two oxides, the following combinations being the most common: psilomelane and braunite, psilomelane and hausmannite, and psilomelane and manganite. Braunite lines cavities in psilomelane and occurs as more or less porous granular aggregates. Hausmannite is generally disseminated as large and small grains through compact psilomelane. Specimens are common that show a gradation from psilomelane with a few fine grains of hausmannite scattered through it to a coarsely granular hausmannite containing only a small quantity of psilomelane. Braunite is generally if not entirely confined to manganese deposits that were formed by the replacement of limestone and shale. One specimen was studied that showed thin seams of psilomelane cutting hausmannite and earlier psilomelane.

Some hausmannite occurs in the Fernvale limestone as a replacement material, but most of it is found in clay as residual masses that have been set free by the decomposition of the limestone. It appears to be absent from deposits formed by the replacement of the Cason shale and residual clays. This seems to show that a smaller supply of oxygen was available in the limestone than in the shale and clays, for hausmannite contains a smaller percentage of oxygen than the other manganese oxides that are present in the district.

Some of the nodules of oxides in which psilomelane and manganite are present are made up of concentric layers, in which the manganite has the form of radiating needles.

TYPES OF DEPOSITS.

GENERAL FEATURES.

The workable manganese and ferruginous manganese deposits of the Batesville district may be grouped into the following five types, partly according to the rock formations and clays in which they occur and partly according to their origin:

Deposits in the Cason shale and its residual clay.
Replacement deposits in the Fernvale limestone.
Residual deposits derived from the Fernvale limestone.
Replacement deposits in clay.
Transported deposits in stream gravels.

Most of the ore-bearing clays are residual from the Fernvale limestone and the Cason shale, but some are residual from the Joachim, Plattin, and Kimmswick limestones. The deposits in the Cason shale and in the clays have yielded the greater part of the production of the district. The ores in the clays and those in the stream gravels are in masses ranging in weight from less than 1 pound to 22 tons. Most of these masses have simply been freed by weathering from the rock formations named above and have settled by gravity or have been washed by streams to their present positions. At most mines and prospects only one type is represented, but at some two types and at a few three types are present and have yielded ore in commercial quantities.

DEPOSITS IN THE CASON SHALE AND ITS RESIDUAL CLAY.

Manganese and ferruginous manganese ores are widely distributed in the Cason shale. The deposits have been worked at a number of places and have yielded most of the ferruginous manganese ores and a considerable part of the manganese ores that have been produced in the Batesville district. The Cason shale is generally present in the vicinity of Cushman and farther west. East of Cushman it is absent at most places, but the ore deposits in that area are larger and contain a higher manganese content and a lower iron content than the deposits farther west. The shale is thin, at no place exceeding 12½ feet in thickness, but its residual clay is 20 feet or more thick at the Montgomery mine, suggesting that the shale at that locality was probably more than 12½ feet thick.

The ores consist of iron and manganese oxides, which are in places more or less intimately mixed. The manganese oxides are mainly psilomelane and braunite, and the iron oxides include both red and brown oxides. These minerals occur as irregular masses, as thin horizontal seams and beds, and as "buttons," which are flattened concretion-like masses about an inch in their longest diameter.

The "buttons" are stated by E. O. Ulrich[45] to be fossil girvanellas which are an algal growth. They were once spherical or nearly so and were composed principally of calcium carbonate but partly of manganese carbonate, and they have since been flattened by pressure and have been replaced by manganese and iron oxides. (See Pl. X, *A*.) They lie parallel with the bedding of the shale and are more or less uniformly disseminated through the shale and its residual clay at some localities. The most noteworthy occurrence of the manganese "buttons" is at the Cason mine, which has produced more low-grade manganese ore than any other mine in the district. They are so numerous that the "button"-bearing residual

[45] Oral communication.

clay of the Cason shale has been shipped without any treatment, and in recent years much of the "button"-bearing shale has been quarried and shipped as ore. This ore has averaged about 20 per cent of manganese. Only a part of the shale at that mine contains "buttons" of manganese oxide; the rest contains red and gray "buttons" composed largely of manganese-bearing calcite. Various stages in the transition of gray carbonate to red carbonate "buttons" and the replacement of the red "buttons" by manganese oxide are well displayed in the cuts. (See fig. 12, p. 141.)

Other noteworthy occurrences of "buttons" of manganese oxide are at the Montgomery mine and the Button prospect, and a comparatively small number of them were observed at the Adler mine, O'Flinn prospect, Johnson Hill mine, and Ball mine. At all these workings the "buttons" are in clays, except at the O'Flinn prospect, Button prospect, and Johnson Hill mine, where some of them are in shale. (See Pl. XI.)

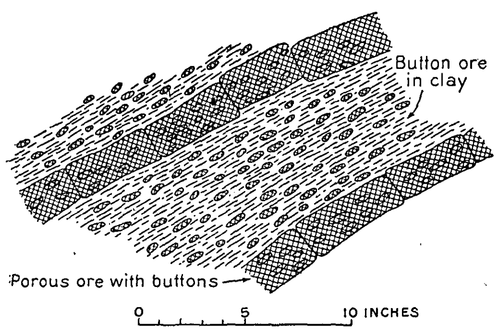

FIGURE 3.—Sketch showing occurrence of manganese ores at Montgomery mine. (After Harder.)

Considerable prospecting has been done recently by means of diamond drills to discover other areas of "button"-bearing Cason shale, but none have been found. The records of the drill holes are given on pages 42–45. There appears to be very little chance of finding new deposits of such shale by any method of prospecting.

"Buttons" of red iron oxide were observed in the residual clay of the Cason shale at two of the Pittman mines, at the mine of the United Phosphate & Chemical Co., at the Breeden prospect, and at the W. T. Gray mine.

The irregular masses of ore are generally porous and have rough surfaces, but those that have a botryoidal shape are usually smooth. Such masses constitute most of the ore at the Ball mine and much of it at the Montgomery mine. The lenses and beds are shaly and porous at most places and are parallel with the bedding of the shale. Three localities at which they occur are the Meeker and Blue Ridge mines and the F. M. Barnes prospect. Although they occur in different parts of the shale, they are most common in the base. At some places it is nearly or quite impossible to distinguish the ledge in the base of the Cason shale from a nearly horizontal replacement deposit of ore that occurs at places in the top of the Fernvale limestone.

Some of the masses, lenses, and beds just described occur in sandstone but most of them in shale and clay, and the manganese oxides constituting them have replaced parts of the country rock, as is shown by the occurrence of sand grains, pebbles of phosphate rock, and irregular areas of shale, clay, and sandstone in the ore. Not only do these materials occur in such ore, but "buttons" of manganese oxide were observed in lenses and masses of ore at the Ball, Cason, and Montgomery mines, showing that manganese oxides have replaced some of the clay and shale through which the manganese "buttons" were scattered. (See fig. 3 and Pl. X, *B*.)

The occurrence of manganese-bearing calcite disseminated through those parts of the Cason shale at the Cason mine that have been least affected by weathering suggests that all the manganese oxides in the deposits described above have been formed by the oxidation of the carbonate. This suggestion is supported by the occurrence in the Fernvale limestone of manganese-bearing calcite that has yielded at least some of the manganese oxides in that limestone and its residual clays. If this interpretation is correct, the oxidation of the manganese-bearing carbonates is perhaps superficial, and the oxides may not extend below the ground-water level of the district.

REPLACEMENT DEPOSITS IN THE FERNVALE LIMESTONE.

The occurrence of manganese minerals in the Fernvale limestone is discussed as follows by Penrose:[46]

> The manganese, as seen in the St. Clair [Fernvale] limestone, exists in the same or almost the same chemical and physical condition as in the clay that now incloses it in the various manganese localities—that is, it occurs as oxides in bodies of different sizes. It is very probable that the manganese originally existed in the limestone in the form of a carbonate and was subsequently oxidized into its present condition. Possibly this oxidation may be only superficial, and below the water level of the country the ore may still retain its carbonate form. Small quantities of the carbonate sometimes exist in a finely disseminated state in the limestone, even on the surface, but practically all the manganese in the limestone, as now seen in surface exposures, is in the oxide state, and the disseminated carbonate is insignificant in comparison with the larger masses of oxides.
>
> It is very possible that, in some cases, the manganese oxide in the limestone may be in a different stage of oxidation from that in the clay and may therefore represent a different mineralogical form of oxide; but in many cases at least the ores in both positions seem to represent the same oxide or oxides. Very often the ore in the limestone contains small inclusions of more or less pure crystalline calcite; while where the ore occurs in the clay the inclusions have sometimes been leached, leaving hollow cavities which give the ore a honeycombed appearance. The cavities are often partly filled with red, yellow, or dark-brown clay, representing the residual product of the calcite. Sometimes, however, especially in the more compact ore, the calcite remains in its original form, even when the ore has been freed from the limestone for a long time.

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[46] Penrose, R. A. F., jr., Manganese—its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, pp. 167–168, 1891.

The shape of the ore bodies in the limestone varies considerably in different places but always conforms in a general way to the bedding of the rock. The ore occurs as irregular lumps and masses, often connected by thin layers of the same material; as lenticular bodies, a few feet to several yards in length; as flat masses or small concretions lying in the planes of bedding of the rock; as small disseminated particles and nodules the size of small shot; and, in some places, in so fine a state of division as to form a dark chocolate-brown coloring matter. This last form sometimes occurs in thin layers in the rock and sometimes as a finely disseminated material, giving the dark-brown color often seen in the limestone. When considerable quantities of it are present the rock often loses part of its highly developed crystalline structure and presents a dark, earthy appearance. The larger masses of ore occur both in this dark-colored and in the light-colored rock. In the latter case they are usually associated with more or less red clay, either in the form of a thin coating around the masses of ore or as films between layers of ore.

Since the above paragraphs were written by Penrose several openings have been made in the Batesville district that reveal the presence of manganese-bearing calcite. The discovery of this calcite, together with evidence that much if not all of the manganese oxide in the Fernvale limestone and its residual clay is derived from it, supports the statement by Penrose given above, namely, that the oxidation of the manganese-bearing calcite is possibly only superficial and that the manganese may still retain its carbonate form below the water level of the country. The most noteworthy occurrence of manganese-bearing calcite is in the uppermost beds of this limestone at the Harvey mine. This calcite is a fine to coarse-grained mineral which has entirely replaced parts of the limestone, and which has been partly oxidized and replaced by manganese and ferruginous manganese oxides. (See Pl. X, *D*.) A small quantity of the oxide-bearing carbonate has been quarried and shipped as a low-grade ore. A few boulders of ore that were mined near the surface appeared to consist entirely of manganese and ferruginous manganese oxides, but when they were broken open they were found to contain cores of the unoxidized carbonate. An analysis of a sample of this carbonate that was partly oxidized follows:

Analysis of manganese-bearing carbonate at the Harvey mine.

[R. C. Wells, analyst.]

Manganese (Mn)	35.50
Iron (Fe)	6.54
Silica (SiO_2)	1.51
Alumina (Al_2O_3)	2.06
Lime (CaO)	10.60
Magnesia (MgO)	.96

Although the sample for the analysis was partly oxidized, the chief constituents as indicated by the analysis and by the presence of only a small quantity of iron and manganese oxides in the sample are manganese, iron, and calcium carbonates, which are chemically combined. The mineral is here regarded as manganiferous calcite. This or a similar mineral occurs in the Fernvale limestone at one of the Pittman mines and at the W. A. Chinn cut.

The manganese oxides and the manganese-bearing carbonate generally occur in the upper part of the Fernvale limestone and they are by no means uniformly distributed through this part of the limestone. At only the following places have the oxides been found in sufficient quantity in the limestone for such parts of the limestone to have been shipped as ore: One of the Pittman mines, the Club House mine, the Henley mine, the Adler mine, the W. A. Chinn cut, and one of the Walter Chinn prospects. None of the deposits at these localities have yielded more than a few hundred tons of manganese-bearing limestone that was found profitable to work. Other localities where masses of manganese oxides were observed in the Fernvale limestone are the A. R. Chinn, Simmons, Champlain, and Williamson-Gulley prospects and the Searcy, Rutherford, Roberts, Cutter, Verna, Hankins Hollow, and Cummins Hollow mines.

RESIDUAL DEPOSITS DERIVED FROM THE FERNVALE LIMESTONE.

General features.—The manganese deposits derived from the Fernvale limestone are more numerous than those of any other type and have yielded by far the greater part of the output of high-grade manganese ore from the Batesville district and have also yielded a considerable part of the output of low-grade ore. Furthermore, they contain the largest reserves of available ore in the district. The largest known deposit of this type is that at the Southern mine, which has produced 36,500 tons of ore. Other deposits of this type that have yielded a production of about 400 tons or more are at the W. T. Gray, Searcy, G. A. Wilson, Roberts, Denison, Sis Clark, Brooks Hill, Grubb Cut, Rogers, Polk Southard, Turner, Lassiter, Club House, Shaft Hill, Hankins Hollow, Cummins Hollow, Ruminer Rough, and Manganese Field mines.

The manganese ores consist entirely of masses of oxides and they occur in residual clays that overlie not only the Fernvale limestone but also the Joachim, Plattin, and Kimmswick limestones. These masses in their shape and in the character of their component minerals are like the masses of manganese oxides in the Fernvale limestone that have been described above. In fact, they were once embedded in this limestone, and after they were set free from it by the removal of the calcium carbonate they settled by gravity or were washed by streams to their present position. On account of their scientific interest the ores transported by streams will be described separately. They are of minor commercial importance.

Manganese-bearing clays.—The manganese-bearing clays are a residue from the decomposition of not only the Fernvale limestone but also the Joachim, Plattin, and Kimmswick limestones. Most of the clays were derived from the Fernvale limestone, which at many places has been entirely decomposed, so that the clays there rest upon the lower limestones or upon their residual clays. The decomposition of the Fernvale limestone is in part described as follows by Penrose:[47]

> Throughout the manganese region all stages of decomposition of the limestone and all stages of erosion of the residual products can be seen. Sometimes the limestone is exposed in its full thickness and shows no sign of decomposition. This is especially true along its extreme southerly outcrop, where it rises from under a heavy, protecting cap of chert. But to the north it has succumbed more and more to decomposing influences and has finally disappeared altogether, leaving nothing but the residual clay and ore, the skeleton, as it were, of the original limestone formation. As long as the limestone has remained intact, the massive chert, which overlies it, has protected it to a greater or less extent from decomposition. But as soon as the dissolving action has set in the residual clay sinks down and allows the overlying chert to settle down on it. In this way the chert bed is shattered and broken, allowing the free percolation of surface waters and greatly accelerating the decomposition of the limestone. The more carbonate of lime that is dissolved from the limestone the more the chert is undermined and broken and the faster the remaining limestone is decayed.
>
> The decay of the limestone begins at the top of the bed, and generally in places where it crops out on the sloping sides of ravines. These, being the most exposed points, are attacked first, and thence the dissolving action spreads back into the hill and under the chert.

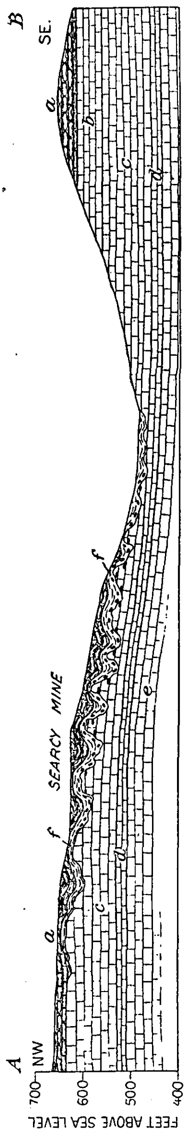

FIGURE 4.—Section along line *A–B* on figure 8, illustrating the occurrence of the ore deposit at the Searcy mine. *a*, Boone chert; *b*, St. Clair limestone; *c*, Fernvale limestone; *d*, Kimmswick limestone; *e*, Plattin limestone; *f*, manganese-bearing clay.

The decay of the Fernvale limestone has formed subsurface hollows and channels in it, and these have at places been widened so much that only narrow pinnacles or "horses" of the unaltered limestone separate them. (See figs. 4 and 5.) Such channels and hollows as well as the pinnacles or "horses" are well displayed in open cuts at the Cummins Hollow and Club House mines. Some of the channels are straight and represent widened fissures along joints. A few caves and sinkholes also have been formed in the limestone. A cave is in it on the

[47] Op. cit., pp. 175–176.

W. K. Tate place, 2½ miles north of Penters Bluff station; another is at the Harvey mine; a third is a blowing cave in Hankins Hollow; a fourth is at the Club House mine; and a fifth, known as the Searcy Cave, is just east of the Searcy mine. Manganese ore has been discovered and mined in the caves at the Harvey and Club House mines.

At many places the whole of the Fernvale limestone has as previously stated been decomposed and its residual clay in such places rests upon the irregular surfaces of the Joachim, Plattin, and Kimmswick limestones in which subsurface hollows and channels as much as 75 feet deep occur. (See Pl. XII.) Analyses of dark chocolate-brown Fernvale limestone and of its chocolate-brown residual clay, samples for which were obtained from a pit on the William Martin tract (see description of Hankins Hollow mine on pp. 231–233), were given by Penrose to show the chemical changes in the decay

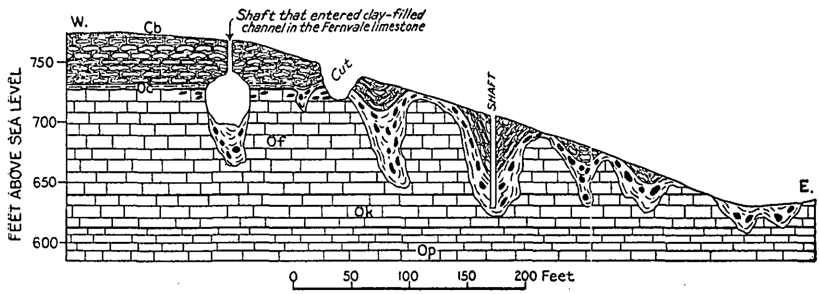

FIGURE 5.—Sketch section at Club House mine, showing the occurrence of manganese ore in the Cason shale, in the Fernvale limestone, and in residual clays that lie in channels in the limestones. Cb, Boone chert; Oc, Cason shale; Of, Fernvale limestone; Ok, Kimmswick limestone; Op, Plattin limestone. Black spots and heavy lines at base of Cason shale represent manganese ore.

of the Fernvale limestone.[48] These analyses and the chemical changes computed by him are as follows:

Analyses of the Fernvale limestone and its residual clay and loss of constituents in the decay of the limestone.

[R. N. Brackett, analyst.]

	Limestone.	Clay.	Percentage of constituents of the limestone saved in the clay.	Percentage of constituents of the limestone lost from the clay.
Manganese oxide (Mn_3O_4)	4.30	14.92	42.41	57.59
Ferric oxide (Fe_2O_3)	2.33	1.98	10.44	89.56
Alumina (Al_2O_3)	4.16	30.18	88.65	11.35
Lime (CaO)	44.51	3.89	1.07	98.93
Magnesia (MgO)	.30	.26	10.62	89.38
Potash (K_2O)	.35	.96	33.63	66.37
Soda (Na_2O)	.16	.61	46.74	53.26
Water (H_2O)	2.25	10.72	58.37	41.63
Carbonic acid (CO_2)	33.88	None.	None.	100.00
Phosphoric acid (P_2O_5)	3.02	2.53	10.24	89.76
Silica (SiO_2)	4.10	33.55	100.00	None.
	99.36	99.60		

[48] Op. cit., pp. 179–184.

The manganese-bearing clays vary in thickness, owing partly to the irregular surface of the limestones upon which they rest and partly to the extent of the decomposition of the limestones. They may therefore vary greatly in thickness at one mine. They are usually thin where the chert capping has been entirely removed. At most places they are only a few feet thick but exceptionally they attain a thickness of 80 feet. Abundant outcrops of limestone in an ore-bearing area indicate that the ore-bearing clays are in relatively small quantities. At such places the clays are confined almost entirely to subsurface channels and pockets in the limestone.

The clays are generally red or chocolate-colored but in places are yellow. They are usually sticky when wet, and they become friable when dry, so that most of the clay that adheres to the masses of manganese ore crumbles and falls off the ore before it is shipped. Slickensides in the clays are numerous and are described as follows by Penrose:[49]

The gradual and irregular sinking of the clay has caused numerous faults and joints in the deposit, running in all directions both in straight and in curved lines. The faces of these disturbances are deeply scored, showing distinct marks of striation (slickensides) and a bright, highly glossy surface. When the clay is red, the slickensides are often of a brilliant crimson color; and when it is brown they are of a very highly polished black or dark-brown color. Sometimes manganese in solution has been carried into these joints and has been deposited as a thick black film or sheet.

Besides manganese ore the clays contain loose undecomposed masses of limestone and fragments of chert, which is residual from the Kimmswick and Fernvale limestones, and its surficial portions contain chert fragments that have been derived from the Boone chert and chert pebbles that have been derived from the gravel bed of Upper Cretaceous or later age which once covered much of the district but which has been almost completely eroded. At the Southern mine and a few other localities the chert is drusy and small doubly terminated quartz crystals are associated with it.

Manganese ores.—The manganese ores of this type are, as previously stated, a residue from the weathering of the Fernvale limestone, having been set free from it by the removal of the inclosing calcium carbonate through solution. This source is shown by (1) the similarity of the shape of the masses of ore in the clay to those of the manganese oxides in the limestone, (2) the occurrence of the same manganese oxides in the same relations in both the clay and the limestone, and (3) the presence of casts of fossils in some of the ore that is in the clay. Some of the masses of fossiliferous chert that have been derived from the weathering of the Fernvale limestone

[49] Penrose, R. A. F., jr., op. cit., p. 187.

have been partly replaced by manganese oxides and the casts of their fossils are preserved in the ore, but the purity of much of the ore that shows casts of fossils together with the absence of fossiliferous chert at most places indicates that much of the fossil-bearing ore has not replaced fossiliferous chert but fossiliferous limestone. The chert may have been replaced before it was set free from the limestone or afterward. No evidence bearing on this point was observed. Penrose says:[50]

The distribution of manganese ore in the clay, as would be expected from its unequal distribution in the limestone, is irregular and is the principal cause of the uncertainty in mining it. In some places, though rarely, it is evenly distributed throughout a large body of clay; but in most places it is in numerous pockets surrounded by clay containing no ore. These pockets vary greatly in character: Sometimes they are comparatively solid bodies, separated only by thin films or seams of clay and containing from 50 to 500 tons or more of ore; sometimes they consist of large and small masses of ore embedded together in greater or less quantities in certain places in the clay; at other times they are composed of small nodules or grains (called "wash dirt" or "shot ore" by the miners) disseminated throughout the clay. The mass of these pockets of "wash dirt" contain from 5 to 25 per cent of manganese ore. Sometimes large areas of clay contain little or no ore, just as large areas of the original limestone often hold enough insoluble material to form a clay bed yet contain no manganese.

As the bodies of ore in the original limestone tended in a general way to follow the almost horizontal bedding of the rock and often had an oblong, flat shape, it would be expected that they would retain something of that shape in the residual clay. In most cases, however, the horizontal position has been considerably disturbed by the unequal decay of the limestone, and the flat bodies of ore have been broken into angular fragments, or crushed together in a shapeless, shattered mass. Sometimes the fragments of ore have been separated in the unequal sinking of the clay and have been carried to different depths. Where the ore originally existed in the limestone as separate nodules the same agencies have tended to scatter them, thus still further dividing the deposits as they originally existed in the limestone. This action has undoubtedly, in many places, caused a more general distribution of manganese in the clay than was the case in the St. Clair [Fernvale] limestone. Of course the aggregate amount of ore has not been increased, but the original pockets have been broken up and separated.

In some places, however, where the decaying limestone has retained a comparatively even surface, the pockets of ore preserve their general horizontal position. Such is the case at the Southern mine, near Cushman, where, though the ore bodies sometimes pitch at high angles, a characteristic mode of occurrence is as almost horizontal pockets, gently undulating and of variable thickness.

It is also a noteworthy fact that, where the surface of the St. Clair [Fernvale] limestone has been worn into the domes and peaks, * * * the clay and its accompanying ore have a distinct dip, pitching away from such protuberances on all sides. This feature is a natural consequence of the sinking of a soft, plastic clay on an uneven surface, and the knowledge of it will prove of value in the practical mining of the ore. When a body of ore is found in the clay

[50] Penrose, R. A. F., Jr., op. cit., pp. 184–186.

at or near the surface of one of these limestone peaks its dip will be found to conform more or less closely to the angle of slope of the surface of the limestone.

The manganese ores consist mainly of the hard oxides, psilomelane, hausmannite, and braunite, with braunite in the least quantity, and of the soft oxide, wad. The hard oxides occur mostly as irregular masses but partly as slabs and nodules, and their masses range in size from fine particles to boulders that weigh as much as 22 tons or more, though boulders so large are rare. (See Pl. IX, *B*.) The wad occurs as irregular bodies of large and small size and as lenses and beds, and masses of hard oxides are distributed through many of them. Some deposits contain two or even three different grades of ore. The larger masses generally contain a higher percentage of manganese and a lower percentage of iron than the finer particles. This means that the lump ore is, as a rule, higher in grade than the wash ore. The first-grade ore at some of the mines is hard and compact and contains 50 per cent or more of manganese; the second grade is porous, light, and soft, though firm, and contains 30 to 35 per cent of manganese; and the lowest or third grade is light, earthy, and soft and contains 20 to 25 per cent of manganese. At some places there is as much of the second grade as of the first grade and twice as much of the third grade as of the other two grades combined. The character and relative proportions of the several grades of ore, however, differ in different deposits.

Much ore of the highest grade produced in the district—that with 55 per cent or more of manganese—has been obtained from areas (called "roughs") over which outcropping boulders and ledges of the Joachim and Plattin limestones abound, but in such areas the manganese-bearing clays are in comparatively small quantity. Such ore is farther from its source than most of the ore in the region, and the chert covering has been entirely removed from above the ore-bearing clays. In consequence of this the ore has been more easily attacked by weathering than most of the ores and has lost its more porous soft parts either by erosion or solution or both processes, so that only the hardest and most compact parts remain. Some of the occurrences of these high-grade ores are at the Denison, Hankins Hollow, Cummins Hollow, Johnson Hill, Ruminer Rough, Manganese Field, Barksdale, Sand Field, and Earl Collie mines. Analyses of this grade of ore are given on page 83.

The capping of the deposits.—The clays containing this type of deposits are capped at many places by the Cason shale, by the Boone chert, and by gravels and sand.

Where the Cason shale is present its shaly parts and the phosphatic sandstone that it contains in much of the western part of the district have been broken up during the decomposition of the Fernvale limestone, and as stated by Penrose,[51] they have in places "been disintegrated into a more or less sandy clay and mixed with the other residue from the limestone; in other places they have not as yet been entirely decomposed and are associated with the clay as soft, earthy, honeycombed, and partly disintegrated masses commonly known as ocher." Although this weathered shale overlies the manganese-bearing clays at places it is in turn generally overlain by the Boone chert, but this chert in most of the eastern part of the Batesville district rests directly upon the manganese-bearing clays, the Cason shale being absent there except in small areas.

The Boone chert and the weathered Cason shale overlie the manganese-bearing clays at many places not only where the Fernvale limestone has been partly or entirely decomposed but at many places where the Kimmswick limestone has been completely decayed, and even at places where a part or all of the Plattin limestone has been decayed. They have therefore at many places settled far below their original position. (See figs. 4 and 5 and Pl. XII.)

This persistence of the chert as a capping material is due to its resistant nature as compared with that of the limestones, which are more easily attacked by ground waters than is the chert. Concerning the thickness of the chert capping Penrose says:[52]

The thickness of the chert formation in the manganese region, where it is seen unaffected by weathering, varies from 125 to over 200 feet; but where the St. Clair [Fernvale] limestone has completely decayed and the chert has been let down upon the residual clay, it never has even the lesser thickness and usually does not exceed 30 to 60 feet. Sometimes the chert has been locally turned on end in the subsistence that it has undergone, and in sinking shafts in such places it has occasionally been found necessary to go down over 60 feet before reaching ore-bearing clay. This depth, however, does not represent the actual thickness of the chert bed, as the shaft is not sunk at right angles to the stratification, but obliquely to it, and therefore the thickness is exaggerated. Possibly not 50 feet from such a place the chert may be more nearly horizontal, and another shaft may pierce less than half this thickness of the rock before reaching the clay. Such occurrences are common at the Southern mine, where the thickness of the chert capping, as estimated by shafts, varies from less than 10 to over 60 feet.

The amount of the settling of the chert is equal to the thickness of the limestones that have been removed minus the thickness of the residual clays that separate the chert from the undecomposed limestones. The lowest limestone upon which chert-covered clays rest is the Joachim limestone. The thicknesses of the Plattin, Kimmswick, and Fernvale limestones, parts or all of which have been removed, are not uniform, so that it is necessary to determine the thickness of these limestones at or near each locality to be considered.

[51] Penrose, R. A. F., jr., op. cit., p. 175.
[52] Idem, pp. 191–192.

Even then the amount of settling can only be roughly approximated at most localities. Beds of the Boone chert have settled 75 feet or more at places at the Club House mine, at least 150 feet at the Polk Southard and Turner mines, and at least 250 feet at the Lassiter mine, but at no place have they probably settled more than 300 feet.

During the settling of the beds they have been shattered, faulted, and bent, so as to conform with the irregular surface of the underlying limestones, and they now dip at angles which range from a

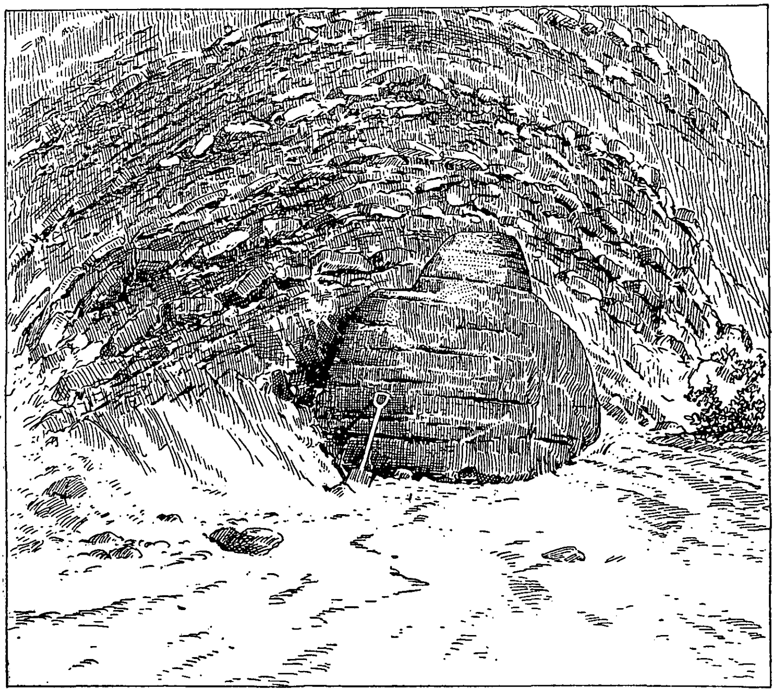

FIGURE 6.—The Grubb cut. The rock in the center is a pinnacle of Fernvale limestone. The manganese-bearing clay surrounds the pinnacle and occupies the foreground. The clay is overlain by the bent, shattered layers of the Boone chert that dip away from the pinnacle. (After Penrose.)

few degrees to 60°. (See figs. 6 and 20.) These displaced masses of chert are known by the miners as "flint bars."

Surficial beds, composed of well-rounded chert pebbles and quartz sand, not only overlie the ore-bearing clays at some places but they actually occur as lenses and irregular masses in the clays at a few places, as at the W. T. Gray mine. These lenses and masses are known as sand bars and gravel bars and were probably formed in underground channels in limestones that have since decomposed, leaving their residual clays in which the gravels and sand are now found. The sand and gravels have been derived from beds of Upper Cretaceous or later age, which once covered much, if not all, of the

Batesville district, and which have since been almost completely eroded. Much of the sand and gravel has settled or has been carried by streams below its original level.

REPLACEMENT DEPOSITS IN CLAYS.

Manganese deposits formed in clays by replacement of the clays by manganese minerals introduced by ground waters are not numerous and their aggregate tonnage is not great, though in some deposits there are probably 10,000 tons or more of ore. The original source of the manganese in such deposits was probably the Cason shale or the Fernvale limestone, but at all localities where this type of deposits occurs these formations have been completely decomposed, and if any residue remains it is clay.

The clays in which these deposits occur contain more or less sand and chert pebbles and fragments, and as some of the clay inclosing them has been replaced by manganese ore, these materials are present in much of the ore. Furthermore, the replacement of much of the clay has not been complete, and irregular areas of clay are included in parts of the ore. The ores are low-grade ferruginous manganese ores, the manganese content usually being 35 per cent or less and the iron, silica, and alumina contents high. They occur in large irregular masses and as veins several feet in their longest dimension and in small masses many of which are nodular or botryoidal and have smooth surfaces. The larger masses at most places are composed mainly of a soft, earthy, compact black wad but partly of psilomelane, manganite, and iron oxide, and are cut by many joints, whose faces are black and show deeply striated slickensides. The smaller masses contain a larger proportion of psilomelane and manganite. The deposits of this type examined by the writer include those at the McGee, Hawkins, Chapel Hill, Montgomery Hill, and Roach mines and at the Cochran, Eliza Patterson, E. W. Roach, Jeff Weaver, and Pool prospects.

TRANSPORTED DEPOSITS IN STREAM GRAVELS.

Some of the hard, compact masses of manganese oxides that have been set free by the decomposition of the Fernvale limestone and Cason shale have been transported by streams and have been laid down in gravel beds. Deposits that have been formed in this way occur in the beds of wet-weather streams that drain hollows on whose hill slopes the manganese-bearing clays and loams are exposed at the surface or they occur in alluvial cones at the mouths of such hollows. One deposit—that at the Sand Field prospect—is on a terrace standing about 100 feet above East Lafferty Creek, but the terrace is perhaps a remnant of an old alluvial cone. Such deposits that have been worked have been formed by small streams, and the ore in them has not been transported far from its sources, but much ore from the same sources has doubtless found its way into the larger streams and has been carried out of the district. The reason why no workable deposits occur in alluvial material along the larger streams is that most of the areas drained by them contain little or no manganese ores, whereas the small streams drain areas that contain ores in comparatively large quantities. At some localities where most of the ore-bearing clays have been removed more ore has been found in stream wash than elsewhere.

The best example of a manganese-bearing alluvial cone is at the Pittman mine at the mouth of Cummins Hollow; another fairly good example is at the mouth of Hankins Hollow. Manganese ores have been mined from the beds of small streams in hollows at the Hankins Hollow, Cummins Hollow, Johnson Hill, Pugh, Adler Hollow, Earl Collie, and McConnell mines, and at the O'Gilsby and Rudolph prospects.

The manganese ore consists of hard, compact masses, which have been partly rounded by abrasion and which range in size from fine pebbles to cobbles weighing 30 pounds, though at the Sand Field prospect the occurrence of boulders weighing 1,000 pounds is reported. (See Pl. VII, *B*.) The Pittman mine, at the mouth of Cummins Hollow, has produced 200 tons of ore, which exceeds the output of any other deposit of this type. The marketed ore there as well as that at the other places here named consisted of high-grade lump ore. The wash ore, which includes the finer pebbles, is usually a ferruginous manganese ore. The high percentage of iron is due to the occurrence of small pebbles of iron oxides mixed with those of manganese oxides.

OTHER OCCURRENCES OF MANGANESE MINERALS.

Manganese minerals occur in small quantity in the Boone chert, in the St. Joe limestone member of the Boone chert, and in the St. Clair limestone.

The most important occurrence of manganese in the St. Clair limestone is at the Cason mine. There the unweathered, pebble-like masses (*Girvanella*) that are in the lowermost beds contain a mixed carbonate composed of calcium, iron, and manganese carbonates. According to the analysis on page 137, these masses contain 5.94 per cent of manganese, whereas the unaltered limestone inclosing them contains only 1.52 per cent of manganese, which also is probably in the form of a carbonate. In the weathered parts of the limestone the *Girvanella* have been oxidized and replaced by manganese and iron oxides (see Pl. VIII, *A*), and there are also thin films and dendrites of manganese oxide. Yellow and brown clays that fill some crevices in the lowermost beds contain concretions the size of buckshot of manganiferous iron oxide, and in the west part of the mine a red clay that is residual from the St. Clair limestone contained a mass of manganese oxides a few inches in diameter. The occurrence of this mass beside a boulder of limestone in place suggests that the limestone is the source of the manganese.

The St. Joe limestone member of the Boone chert at the Alex Fults prospect contains psilomelane, which is disseminated through parts of it as minute irregular-shaped particles and as larger masses some of which are a few inches in their longest dimension. This limestone, at the C. L. Sanders prospect, contains a lenticular mass of manganese oxide a few inches thick, which extends upward into it from the weathered Cason shale. This limestone is present on the western edge of the Batesville district in places only but is not differentiated from the Boone chert on the geologic map (Pl. I).

The occurrence of manganese in the Boone chert, which overlies the ore-bearing clays at most localities, is described as follows by Penrose:[53]

Wherever the chert overlies or is mixed with the manganese-bearing clay it is almost always more or less stained with manganese, which usually occurs as a thin layer, coating the loose fragments or permeating the cracks of the rock. Such layers are often so numerous that the chert presents a network of intersecting black lines. An examination of the chert formation where it is solid and overlies the undecomposed limestone shows that it is free from this stain, but wherever it is broken and overlies the ore-bearing clay it invariably contains more or less black discoloration. It seems more than likely, therefore, that this manganese did not originally belong in the chert formation but that it was brought there. It was probably derived in solution from the underlying ore deposit by capillary action and deposited in crevices of the broken chert. The existence of such crevices would greatly facilitate capillary action, and it is a noticeable fact that the amount of manganese in the chert increases as the contact with the clay is approached.

In many fragments of chert the manganese solutions have permeated the entire mass and have changed parts of it into an opaque, black material. These permeations seem to follow the most pervious portions and run into them in the form of "stringers" or irregular masses. Subsequent disintegration has often removed the part that was not impregnated, leaving masses of a highly siliceous manganese ore of a stalactitic, botryoidal, or mammillary form.

FORMS OF THE ORES.

The manganese ores occur in several physical forms, two or more of which may be represented at a single mine. Brief descriptions of these forms follow:

Shapeless porous to compact masses which have rough surfaces. These range in size from minute particles to boulders that weigh many tons. This is the most common form. (See Pl. IX, *B*.)

[53] Penrose, R. A. F., jr., Manganese—its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, pp. 196–197, 1891.

Tabular masses or slabs. They range in weight from a fraction of a pound to several tons, and in size from small thin plates to slabs 2 to 5 feet thick, 4 to 10 feet wide, and 20 feet long.

Nodular or kidney ore and smooth botryoidal masses. This form is most abundant in deposits that have been formed in clays by the replacement of the clays by manganese oxides.

Breccia ore, composed mainly of chert fragments but partly of chert pebbles cemented together by manganese oxide. This form is usually confined to the deposits that have been formed in clays by the replacement of the clays by manganese oxides.

Flattened pebble-like masses called "buttons," about 1 inch in their longest diameter. These are confined to the Cason shale and its residual clays as at the Cason and Montgomery mines. (See Pls. X, *A* and *B*, and XI.)

Lenses and ledges parallel with the bedding of the inclosed rocks. Where they occur in residual clays they or their fragments lie more or less parallel with the bedding of the rocks, which is preserved in the clays at some places. (See fig. 3, p. 58.)

Fossil ore. Although *Girvanella* ("buttons") are common in the manganese ores and the casts of other fossils are found at a few places, well-preserved specimens of other fossils that have been replaced by manganese ore are rare. Fossil gastropods, brachiopods, and cephalopods thus replaced have been found at the Montgomery mine. A photograph of some of them is given in Plate VII, *A*.

The names used by the miners to designate the several physical forms of the ores are as follows:

"Lump ore," "nugget ore," "boulder ore." These terms are applied to masses of ore that are large enough to be separated from the clay by hand picking. "Lump ore" is the most common of these terms.

"Wash dirt." This means ore-bearing clay whose particles of ore are too small to be hand picked.

"Wash ore." This term is applied to the smaller masses or particles of ore that require washing to separate them from the ore-bearing clay.

"Shot ore." This means small fragments or nodules of ore the size of mustard seed or a little larger.

"Button ore." Such ore consists of flattened pebble-like masses about 1 inch in their longest diameter, like those at the Cason and Montgomery mines and at the Button prospect.

"Branch ore." This means both large and small masses of ore that are mixed with sand and pebbles in the beds of small streams.

OUTCROPS OF THE DEPOSITS.

The manganese ore itself, regardless of the type of deposit to which it may belong, is exposed at most places where it is present. The exposures generally consist of fine particles and large masses of ore lying loose on the hill slopes and in the beds of small streams, and the quality of such ore is usually the same as that below the surface. At places where the ore is not exposed its presence may be indicated by exposures of reddish-brown or chocolate-colored clays and by the occurrence of manganese and iron stains in and on chert that overlies the ore-bearing clay. At a few places only the iron oxides with which the manganese ores are associated are revealed on the surface.

The brown loamy soil that overlies the manganese-bearing clays is usually very fertile where it does not contain too many chert fragments, and it supports a good growth of white oak, hickory, walnut, and other hardwoods.

RELATIONS OF THE DEPOSITS TO ROCK STRUCTURE.

Although most of the manganese deposits bear no definite relation to the structure of the rock formations, several of them, including a few of the largest deposits in the district, occur in synclines. Perhaps future studies, aided by better topographic maps than the present Batesville map used in the field by the writer, will show that many more of the deposits bear certain relations to the rock structure.

The Southern, Grubb Cut, Rogers, Wren, Polk Southard, Turner, and Blue Ridge mines are in a single syncline; the Barksdale, Ruminer Rough, Manganese Field, Sand Field, and Earl Collie mines are in a single syncline; the W. T. Gray mine is in a syncline; and the Cason mine is in a syncline. All these synclines are shallow, and except the one at the Cason mine they all trend easterly; the syncline at that mine trends northwesterly. These are only a few of the mines of the district; but the fact that the aggregate production of both high-grade and low-grade ores from the mines that are in synclines is more than twice the combined production from all the other mines and prospects has led the writer to believe that the occurrence of large deposits in synclines is not accidental but that the synclines have been favorable places for the accumulation of the ores.

How and when the ores were accumulated in these synclines are undetermined questions, though some facts are known that may aid in their solution. The ore deposits at the mines mentioned above are in the Cason shale or they are residual from the weathering of this shale and the Fernvale limestone, especially the topmost beds of the limestone. Part of the accumulation of these deposits has doubtless taken place in comparatively recent times by the diversion of manganese-bearing solutions toward the bottoms of the synclines before the present valleys of the district were carved by erosion. But most of the accumulation was probably effected before the materials that formed the Boone chert of Carboniferous age were laid down.

The deposit at the Cason mine is in the Cason shale, and the areal extent of both the deposit and the shale are practically the same, so that the presence of the Cason shale at this locality certainly has determined the occurrence and size of the ore body. The materials that form this shale were either laid down in a small embayment of the sea or eroded from the adjoining areas before the St. Clair limestone above the Cason shale was laid down.

The other deposits here mentioned were derived from the weathering of the Fernvale limestone. The Cason shale, apparently the original source of the manganese, overlies this limestone at some of these localities and at others it has been almost completely eroded during the carving of the present valleys of the district. During the transfer of the manganese from the Cason shale to the Fernvale limestone the manganese-bearing solutions were perhaps diverted toward the synclines. That this transfer of much of the manganese of the district from the shale to the limestone took place before the deposition of the materials forming the Boone chert seems to be proved by the occurrence of manganese ores in the Fernvale limestone and its residual clays in parts of the district from which the Cason shale was eroded before the Boone chert was deposited. It is not certainly known that the synclines containing the deposits here mentioned existed at that time, but as the one at the Cason mine was then in existence it seems plausible that others had already been formed. Further flexing of the rocks in these folds has, however, taken place later. The accumulation of the ores is more fully treated under the heading "Origin of the ores" (pp. 75–81.)

RELATIONS OF THE DEPOSITS TO SURFACE FEATURES.

The manganese ores occur at all elevations from the base of the hills to their crests or from about 300 to about 800 feet above sea level, and although much of the ore, which consists of oxides, has settled by gravity or has been carried by streams to its present position most of it remains at or near the level where the oxides were formed. With a few exceptions, of which the most notable is at the Cason mine, the ores occur in the residual clays of the Cason shale and of the Fernvale and lower limestones. If the Cason shale and the Fernvale limestone, which are the sources of the ore, contained originally more or less manganese at most localities in the district, it follows that the greater the quantity of the clays they yielded through weathering the more numerous and the larger would be the manganese deposits. This is true at many places, although most of their clays as well as most of the ore they originally contained have been eroded from the region. The greatest quantities of ore-bearing clays that are still preserved in the district are on and near the summits of even-crested hills, many of which mark the approximate elevation of a former though now dissected peneplain of Upper Cretaceous or Tertiary age.

ORIGIN OF THE ORES.

PREVIOUS VIEWS.

The views of the origin of the manganese ores of the Batesville district are not numerous. They are briefly outlined in the following paragraphs:

Owen,[54] the first geologist to describe the ores, described them as occurring in veins in the "cavernous sub-Carboniferous limestones," but he said nothing concerning the source of the manganese.

Penrose,[55] who made a detailed examination of the deposits about 30 years ago, concluded that the manganese was derived from the pre-Cambrian rocks of the St. Francis Mountains region of Missouri and that it was carried southward from this region by surface waters and laid down either in shallow sea water near shore or in coastal lagoons and swamps contemporaneously with the calcareous and detrital material that formed the Fernvale limestone and Cason shale. He, however, did not distinguish the Fernvale limestone and Cason shale as separate formations but included them in his St. Clair limestone, which has since been divided by H. S. Williams and E. O. Ulrich into the Kimmswick limestone, Fernvale limestone, Cason shale, and St. Clair limestone, the oldest being named first and the youngest last. The name St. Clair as now used is thus restricted to the beds above the Cason shale. Penrose held the opinion that the manganese was probably deposited as a carbonate or possibly an oxide. The present ore deposits in the clays are stated by him to have been derived from his so-called St. Clair limestone by its recent decay and by the removal of its more soluble parts, thus setting free the masses of ore. He concluded that the original form of the manganese in the rocks was, as previously stated, probably that of a carbonate and that the manganese was subsequently oxidized into its present condition, although at the time of his investigation no definite proof of this was available either in the rock exposures or in the mines and prospects. He furthermore expressed the opinion that "this oxidation may be only superficial, and below the water level of the country the ore may still retain its carbonate form."[56]

Van Ingen[57] visited the region in 1896 and in his description of the Cason mine says:

> The manganese seems to be here in the original form in which it was accumulated, inclosed in a mud or clay that was probably the residual soil resulting

[54] Owen, D. D., First report of a geological reconnaissance of the northern counties of Arkansas, pp. 39, 136, 1858.

[55] Penrose, R. A. F., jr., op. cit., pp. 156 et seq.

[56] Idem, p. 167.

[57] Van Ingen, Gilbert, The Siluric fauna near Batesville, Ark., I: School of Mines Quart., vol. 22, pp. 324–325, 1901; Columbia Univ. Geol. Dept. Contr., vol. 9, No. 76, pp. 324–325, 1901.

from the subaerial erosion of the Ordovicic limestone. Such erosion took place during a portion of late Ordovicic and early Siluric time, when the Ordovicic limestones already deposited had been elevated above sea level. * * * The manganese ore found in place in the Cason shale at the Cason mine proved to be nonmarketable because of its high percentage of contained phosphorus, which fact caused the abandonment of the workings there.[58] The marketable ore, on the other hand, seems to be in all cases restricted to the recrystallized ore, which after erosion has been accumulated in the lower portions of the residual clay that fills depressions in the eroded Ordovicic limestone. Residual clays filling depressions in the Siluric [St. Clair] limestone alone were, on the other hand, found to be lacking in manganese ore. It is only when the erosion has been so long continued as to have formed hollows below the level of the Cason shale and the drainage has been of such nature as to permit of little transportation of the eroded material that the marketable nonphosphorus-bearing ore is found recrystallized and forming large irregular masses in the residual clay. * * * It is the author's opinion that the [Cason] shale was formed during a period of terrestrial conditions, but whether the place of deposition was upon land, in fresh water, or in seacoast swamps or deltas, can not at present be determined.

Harder visited several of the mines in 1908 in connection with his investigation of the important manganese districts of the United States. He agreed with Penrose as far as the original source of the manganese and the accompanying sediments is concerned.[59] He did not, however, accept Penrose's idea that most of the ores as they now occur were derived from the decomposition of limestone beds, but he thought they were derived directly from the Cason shale. He concluded that the manganese was deposited in the oxide form in the Cason shale and that it was reconcentrated "during two subsequent land stages—first, during the late Silurian and Devonian partial emergence, and second, during the post-Paleozoic erosion of the Boone chert."[60] He held the view that the reconcentration during the first period took place on shallow areas or even land masses that separated deep embayments of the sea in which the St. Clair limestone was laid down. Concerning the second period of reconcentration, he says:[60] "Erosion has resulted in a concentration, partly mechanical and partly chemical, of the ores in the ore-bearing layer [Cason shale] and in the residual clays on the hill slopes below it."

Woodbridge,[61] who spent several weeks in the Batesville district in 1918, says: "Throughout the greater portion of that part of the district of economic value the Cason shale and the Fernvale lime have

[58] This mine, as stated elsewhere in this report, has been worked in recent years, although the ore is of low grade.—H. D. M.

[59] Harder, E. C., Manganese deposits of the United States with sections on foreign deposits, chemistry, and uses: U. S. Geol. Survey Bull. 427, pp. 117–118, 1910.

[60] Idem, p. 118.

[61] Woodbridge, D. E., The Arkansas manganese field: Eng. and Min. Jour., vol. 106, No. 15, pp. 669–670, October 12, 1918.

decayed into a series of siliceous clays, and in these clays is the manganese that has been freed from those rocks and left as a minable residuum."

RESULTS OF PRESENT INVESTIGATION.

The present investigation has yielded considerable material that bears on the origin of the manganese deposits of the Batesville district. The conclusions of the present writer are based not only upon the information obtained by him but also upon the results obtained by other geologists who have worked in this and other manganese-ore districts in the United States. They differ in some features from the earlier views and are presented in the following paragraphs:

The Cason shale was probably the local source of all the manganese, although most of the present ores have been derived directly from the weathering of the upper part of the Fernvale limestone. The reasons for this assumption are (1) the widespread occurrence of manganese ores in the Cason shale, (2) the almost complete absence of manganese minerals in rocks that overlie this shale, and (3) the presence of an unconformity at the base of the shale. This shale was an initial deposit on an old land surface, and the conclusion that considerable manganese was concentrated in such a deposit accords with the conclusion of G. W. Stose regarding the origin of much of the manganese ores of Tennessee and Virginia.

The manganese that was deposited with the sediments forming the Cason shale was, as stated by Penrose and Harder, perhaps brought from a land mass of pre-Cambrian igneous rocks in the St. Francis Mountains region, whose southern border is 85 to 90 miles north-northeast of Cushman, Ark. That these rocks contain manganese is shown by a number of analyses[62] of them, by the occurrence of piedmontite (a manganese-bearing epidote) in the granite porphyries,[63] and by the occurrence of manganese ores in them.[64] The manganese ore at a deposit on Cuthbertson Mountain, near Arcadia, Mo., which was examined in 1918 by the present writer, appears to have been formed in a quartz porphyry, although it now occurs in residual clays associated with masses of the unaltered rock. Cambrian and Ordovician limestones were also doubtless exposed on the land area from which the manganese is supposed to have been derived, but the few analyses[65] that have been made of them indicate that

[62] Winslow, Arthur, Lead and zinc deposits: Missouri Geol. Survey, vol. 7, p. 479, 1894. Haworth, Erasmus, The crystalline rocks of Missouri: Missouri Geol. Survey, vol. 8, pp. 140, 181, 213, 1895. Washington, H. S., Chemical analyses of igneous rocks: U. S. Geol. Survey Prof. Paper 99, pp. 533, 871, 1917.

[63] Haworth, Erasmus, op. cit., pp. 190–192.

[64] Pumpelly, Raphael, Preliminary report on the iron ores and coal fields: Missouri Geol. Survey, pp. 20–26, 1873. Nason, F. L., A report on the iron ores of Missouri: Missouri Geol. Survey, vol. 2, pp. 20, 94, 95, 1892.

[65] Winslow, Arthur, op. cit., p. 480.

as a rule they contain a much smaller percentage of manganese than the igneous rocks.

Geologists generally believe that the former land area in the St. Francis Mountains region on which the manganese became concentrated in residual material existed while the calcareous materials that later formed the Joachim, Plattin, Kimmswick, and Fernvale limestones were being deposited. These limestones were formed over extensive areas in southeastern Missouri and southern Illinois, which are in the eastern part of the Ozark region, and in northern Arkansas, which is in the southern part of the Ozark region. This land area supplied very little detrital material to the sea while these limestones were being laid down, and for this reason rocks on it must have undergone considerable decomposition, so that it became covered by a heavy mantle of residual material, in which manganese minerals were present. A period of erosion followed the deposition of the Fernvale limestone, so that a mantle of residual material was formed on the surface of this limestone, as well. The eastern and southern parts of the Ozark region were later submerged, and the residual material that had gathered on the St. Francis Mountains land mass and on the Fernvale limestone was swept into the sea and laid down on the uneven surface of the Fernvale limestone and on lower limestones where the Fernvale had been removed. This material formed the Cason shale.

It is necessary to assume that conditions in the Batesville district were more favorable for the deposition of manganese than elsewhere in the Ozark region. The Cason shale is widespread, occurring at places in Arkansas as far west as Jasper, Newton County, and the Maquoketa shale, at least in part the equivalent of the Cason shale, occurs in southeastern Missouri and southern Illinois. Yet the only manganese deposits of commercial importance in this entire region are those of the Batesville district, which occur in the Cason shale or have been derived from it, and those in the St. Francis Mountains, which are in igneous rocks or in clays that overlie Cambrian limestones near the igneous masses. The conglomeratic character of the Cason shale and the occurrence of a shallow-water fauna in it indicates that it was deposited in shallow water. This conclusion agrees with that drawn by Purdue [66] from his study of phosphate deposits that also occur in the Cason shale. The manganese in the Cason shale was perhaps deposited in coastal lagoons where the manganese-bearing waters that flowed from the St. Francis Mountains land mass would have stood exposed to the evaporating action of the atmosphere. This view was first proposed by Penrose [67]

[66] Purdue, A. H., Developed phosphate deposits of northern Arkansas: U. S. Geol. Survey Bull. 315, pp. 471–472, 1907.

[67] Penrose, R. A. F., jr., op. cit., pp. 590–591.

and the same view was proposed by Dale[68] to explain the origin of manganese deposits in Newfoundland, which resemble closely the deposit at the Cason mine.

The manganese was probably deposited in the Cason shale as a carbonate. The best evidence for this belief is found at the Cason mine, where a manganese-bearing calcite occurs in the parts of the shale that have been least affected by weathering. This calcite, as indicated by analyses on page 140, is present not only in the fossil girvanellas but also in the shaly matrix that incloses them. This occurrence is fully described under the heading "Cason mine," on pages 139–142.

After the deposition of the Cason shale the materials that formed the Brassfield, St. Clair, and Lafferty limestones of Silurian age, the Penters chert and the Chattanooga shale of Devonian age, and the Boone chert and other formations of Carboniferous age were laid down. Most of these formations are separated by unconformities, showing that deposition was interrupted by periods of emergence and erosion, and that during those periods some of the formations named above were partly or entirely eroded from large or small areas in the Batesville district.

During one or more of the periods of erosion prior to the deposition of the Boone chert of Carboniferous age much of the manganese was transferred from the Cason shale to the upper part of the Fernvale limestone, where it was apparently deposited as a carbonate replacing the limestone. This is shown by the occurrence of manganese ores in the limestone and its residual clays at many places from which the Cason shale had been removed by erosion before the Carboniferous period and is also shown by the occurrence in this part of the limestone of manganese-bearing calcite from which it is believed that the present manganese oxides in the limestone and its residual clays were derived. During this transfer the manganese was perhaps concentrated into bodies of large and small size, for the irregular distribution of the present ore bodies shows that it could not have been uniformly distributed through the limestone.

Erosion reduced the region to a peneplain during the Cretaceous or the Tertiary period, and although this peneplain has been for the most part destroyed its approximate elevation is marked by many even-crested hills of the manganese-bearing region. The decay of the Fernvale limestone and of the Cason shale and the formation of much of the manganese-bearing clays, as well as the oxidation and a large part of the reconcentration of the manganese minerals in the Fernvale and in the Cason, the writer believes took place during or

[68] Dale, N. C., The Cambrian manganese deposits of Conception and Trinity bays, Newfoundland: Am. Philos. Soc. Proc., vol. 54, p. 442, 1915.

soon after the period in which the above-mentioned peneplain was produced, although these processes have operated to some extent down to the present time.

The hypothesis that conditions are especially favorable for the decay of rocks and the concentration of manganese minerals in a region of low relief, such as that occurring on a peneplain, was first proposed by Hewett[69] in his description of several manganese mines in Virginia and Maryland, and it has been accepted and applied by other geologists.[70]

The manganese carbonate was probably not changed to the oxide until the last period of reconcentration, for the relations of the oxides to the manganese-bearing carbonate in the Cason shale at the Cason mine and in the Fernvale limestone at the Harvey mine, at one of the Pittman mines, and at the W. A. Chinn cut indicate that the oxidation of the carbonate is only superficial. Synclines, as pointed out on pages 73–74, have been favorable places for the accumulation of manganese minerals. The bedding planes and the upper surface of the Fernvale limestone have perhaps guided the manganese solutions laterally from the sides of the synclines into their lower parts. This limestone, as previously stated, was exposed on an old land area before the mud and other materials that later formed the Cason shale were deposited, and the porosity of its upper exposed part was perhaps increased by weathering at that time. Such an increase in porosity, if it took place, may also have facilitated the circulation of the manganese solutions toward the synclines and may have favored the more general occurrence of the manganese ores in the upper part of the limestone than in its lower part.

Very little, if any, of the manganese-bearing carbonate or the oxides was deposited in fissures in the Fernvale limestone and Cason shale; they replaced parts of these formations, including beds of limestone, shale, and sandstone. The fossil girvanellas, which are very numerous in the Cason shale at a few places, were especially subject to replacement by manganese oxides and at places by iron oxides. All stages of their replacement by manganese oxides are displayed at the Cason mine.

Most of the masses of ore that are now in clay have been set free by decay from the Fernvale limestone and Cason shale. Such masses

[69] Hewett, D. F., Some manganese mines in Virginia and Maryland: U. S. Geol. Survey Bull. 640, pp. 43–47, 1917.

[70] Hewett, D. F., Stose, G. W., Katz, F. J., and Miser, H. D., Possibilities for manganese ore on certain undeveloped tracts in the Shenandoah Valley, Va.; U. S. Geol. Survey Bull. 660, pp. 281–282, 1918.

Stose, G. W., Miser, H. D., Katz, F. J., and Hewett, D. F., Manganese deposits of the west foot of the Blue Ridge, Va.: Virginia Geol. Survey Bull. 17, p. 54, 1919.

have settled more or less below their original position, and some of them have been transported by streams. At only a comparatively few places have the manganese oxides replaced residual clays.

CHEMICAL COMPOSITION.

The manganese ores may be grouped as to composition into two general classes—high-grade ores and low-grade or ferruginous ores.

Most of the high-grade ores contain from 45 to 52 per cent of manganese, though some carloads that have been shipped averaged as much as 60.80 per cent. They generally contain from 3 to 8 per cent of iron, 0.15 to 0.30 per cent of phosphorus, and 2 to 8 per cent of silica. Some of the ore that has been marketed contained more than 0.30 per cent of phosphorus and a very little contained 0.50 per cent or more. As it is usual to specify that the phosphorus content of ores to be smelted shall not exceed 0.25 per cent, some of the ores contain more phosphorus than the maximum specified content just mentioned. Phosphorus is in fact the most harmful ingredient in the ores of the district, but as it is not uniformly disseminated it can generally be avoided in mining. In places more phosphorus occurs in the associated material than in the ore itself, and it can therefore be largely eliminated by properly preparing the ore for the market. At some places the silica content exceeds 8 per cent, which is the maximum amount usually accepted by buyers without deducting a penalty, but at some of these places the silica can be materially lessened by properly treating the ore. During the last few years, when the demand for domestic manganese ores was especially great, much ore was shipped from the Batesville district that contained very high percentages of both silica and phosphorus.

The two analyses given below show the approximate average composition of 231 carloads of high-grade ore shipped in 1917 and of 165 carloads shipped in 1918, and they represent the average composition of the greater part of the high-grade manganese ore that was shipped during these years. They were computed from the available analyses, supplied by W. H. Denison, of carload shipments that contained 35 per cent or more of manganese. The computation consisted in adding together percentages of each constituent in the analyses of the carload shipments and then dividing the sums by the number of carload shipments in which each constituent was determined. The analyses used in the computation do not include any shipments from the Montgomery mine in 1917, but all the shipments from this mine in 1918 were included. This accounts in part for the high percentage of phosphorus in the ore that was shipped in 1918, for the ore from that mine has averaged approximately 0.40 per cent of phosphorus.

Approximate average composition of high-grade manganese ores shipped from the Batesville, Ark., district in 1917 and 1918.

	1	2
Manganese (Mn)	47.60	45.72
Iron (Fe)	[a] 5.77	[b] 5.59
Phosphorus (P)	[c] .24	[d] .36
Silica (SiO_2)	[e] 6.79	[f] 8.68
Alumina (Al_2O_3)	[g] 2.98	....

[a] Iron was determined in 194 cars.
[b] Iron was determined in 125 cars.
[c] Phosphorus was determined in 193 cars.
[d] Phosphorus was determined in 91 cars.
[e] Silica was determined in 135 cars.
[f] Silica was determined in 130 cars.
[g] Alumina was determined in 125 cars.

1. Average of 231 carloads shipped in 1917.
2. Average of 165 carloads shipped in 1918.

Most of the low-grade or ferruginous manganese ores contain 20 to 35 per cent of manganese, 8 to 20 per cent of iron, and 5 to 26 per cent of silica. The phosphorus content is about the same as that of the high-grade ores.

The chemical composition of the marketed ores, which as noted in the preceding paragraph differ widely in quality, is directly dependent upon several factors, of which the following are some of the most important: The character and number of the manganese minerals; the compactness and size of the masses of ore; and the presence of impurities such as iron oxides, phosphorus-bearing material, clay, limestone, quartz sand, and fragments and pebbles of chert. The quality of the marketed ores therefore depends in part upon the care used in their preparation.

The highest grade ores of the district consist of compact or nearly compact very hard masses, from about 1 pound to several hundred pounds in weight, of psilomelane and hausmannite, with a smaller quantity of braunite. Such high-grade ores occur at the Ruminer Rough, Manganese Field, Sand Field, Johnson Hill, Earl Collie, Barksdale, Cummins Hollow, Hankins Hollow, and Denison mines, and at a few other mines and prospects. The first analysis given below represents the approximate average composition of 39 carloads of lump manganese ore from the above-named mines and the second represents the composition of 250 tons shipped from the Cummins Hollow mine in 1918. Most if not all of this ore was hand picked. "Wash ore"—pieces that weigh a fraction of a pound—is also present at these mines. It generally has a higher percentage of iron than the "lump ore," because it contains many small particles of iron oxide which can not be profitably separated from the manganese minerals.

Average composition of the highest grade of manganese ore produced in the Batesville district.

	1	2
Manganese (Mn)	56.32	58.11
Iron (Fe)	a 2.80	1.63
Phosphorus (P)	b .13	....
Silica (SiO_2)	c 6.18	6.90
Alumina (Al_2O_3)	d 2.41	....
Moisture	....	1.10

a Iron was determined in 34 cars.
b Phosphorus was determined in 28 cars.
c Silica was determined in 32 cars.
d Alumina was determined in 11 cars.

1. Average composition of 39 carloads from different mines.
2. Composition of 250 tons from the Cummins Hollow mine.

The most common type of high-grade ore, analyses of which are given below, is like the bulk of the ore at the Southern, Grubb Cut, Rogers, Turner, Polk Southard, Wren, Lassiter, Club House, Searcy, Ozark, Brooks Hill, and other mines. The ore at these mines occurs as loose masses, ranging in size from small fragments ("wash ore") to larger masses ("lump ore"), some of which weigh several tons. The masses are generally compact, irregular in shape, and black on weathered surfaces but have a bright luster on fresh surfaces. They are composed mainly of black and steel-blue psilomelane and fine to coarse grained hausmannite, which may or may not occur in equal proportions, and they contain some braunite. Tests at some places show that the "wash ore" and "lump ore" occur in equal proportions.

Analyses of the most common type of high-grade manganese ore produced in the Batesville district.

	1	2	3	4
Manganese (Mn)	47.927	48.183	53.685	49.41
Iron (Fe)	6.875	6.550	2.850	a 5.43
Phosphorus (P)	.197	.255	.186	b .21
Silica (SiO_2)	3.220	2.985	2.400	c 5.52
Alumina (Al_2O_3)	....	....	....	d 2.91
Moisture	6.490	7.179	4.229	....

a Iron was determined in 55 cars.
b Phosphorus was determined in 53 cars.
c Silica was determined in 28 cars.
d Alumina was determined in 23 cars.

1. Analysis by A. S. McCreath of 5 cars of washed ore from the Southern mine.
2. Analysis by A. S. McCreath of 3 cars of washed ore from the Southern mine.
3. Analysis by A. S. McCreath of 15 cars of lump ore from the Southern mine.
4. Approximate average composition of 56 cars of lump ore from the Rogers, Polk Southard, Southern, Ozark, Searcy, and Brooks Hill mines.

The "wash ore" at any mine generally contains at least a few per cent less manganese, and at some mines it contains more iron, phosphorus, and silica than the "lump ore."

There are many classes of ore that have a lower content of manganese than those just described. Among them are the deposits at the Montgomery, Ball, and Cason mines. The ores at these mines are dissimilar and are also unlike any ores found at other deposits. Their composition as well as the composition of the ores at many other mines is discussed under the heading "Mines and prospects" (pp. 103–265).

The most complete analyses of manganese ore from the Batesville district that are available were supplied to the writer by E. C. McComb and are given below. They are analyses of carload lots of ore from the Southern, Polk Southard, and Turner mines, the ores of which are similar and were mixed before they were shipped. In addition to the constituents that are usually determined they show appreciable amounts of lime, magnesia, and barium and traces of nickel, copper, and arsenic.

Detailed analyses of manganese ore from the Southern, Polk Southard, and Turner mines, Batesville district.

	1	2	3	4
Manganese (Mn)	45.04	48.22	56.36	53.37
Iron (Fe)	6.87	5.8	1.75	2.35
Phosphorus (P)	.227	.214	.126	.170
Silica (SiO_2)	6.28	3.05	1.71	2.80
Alumina (Al_2O_3)	3.06	2.87	2.16	3.24
Lime (CaO)	1.45	1.2	.90	.75
Magnesia (MgO)	2.45	.58	2.25	.65
Nickelous oxide (NiO)	.16	.00	.28	Trace.
Barium oxide (BaO)	4.17	2.79	3.02	2.94
Copper (Cu)	.028	Trace.	.016	Trace.
Arsenic (As)	Trace.	.012	Trace.	.019
Combined water	6.96	7.25	4.92	....
Moisture	6.00	6.00	2.00	10.00

1, 2. "Wash ore" from the Southern and Polk Southard mines.
3, 4. "Lump ore" from the Southern, Polk Southard, and Turner mines.

Many analyses of carload shipments of both high-grade and low-grade ores are given in the descriptions of the mines and prospects (pp. 103 et seq.), and analyses of a few samples are given, if analyses of carload shipments from particular mines and prospects are not available.

COMMERCIAL USES OF THE ORES.

The ores from the Batesville district have been used for making ferromanganese, spiegeleisen, and high-manganese pig iron. Very little if any ore has been found suitable for chemical uses, because the amount of manganese peroxide is, as a rule, less than 80 per cent—the minimum usually required for such purposes—and it is not likely that commercial quantities of chemical ore will be discovered. Penrose[71] states that the dark-brown manganiferous clay at the Brooks Hill mine has been successfully used in St. Louis in the manufacture of artificial brownstone and colored bricks. Similar clays occur at other localities. They could be used to produce the

[71] Penrose, R. A. F., jr., Manganese—its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, p. 251, 1891.

spots of some varieties of speckled bricks and could be mixed with red-burning clay for brown bricks and with buff-burning clay for gray bricks.

ECONOMIC POSSIBILITIES.

Little manganese ore is now (1922) being mined in the Batesville district, but, as stated under the heading "History and production," the output of manganese ore was 82,716 tons from 1849 to 1921, inclusive, and that of ferruginous manganese ore for the same period was 74,482 tons. Mining in the district was especially active during the World War, when the restriction of imports of foreign ores caused a great demand for domestic ores, for which very high prices were paid.

The manganese deposits of the Batesville district were examined by the writer in the spring and summer of 1918, during the period of increased activity, and as a result of his examination the following statement concerning available ore reserves was issued:[72]

> An estimate of the quantity of available manganese ore of all grades in this region where mining is not preceded by systematic prospecting is difficult to make. Of the 180 deposits examined, about half contained an estimated available reserve of 200 tons or less. Only about one-third contain 1,000 or more tons and only a few contain more than 5,000 tons, though certain of these contain many thousand tons. A small number of prospects and mines, however, were not visited, and these and the unexplored deposits may increase considerably the reserve. The deposits of the region perhaps include at least 250,000 tons of available ore containing 40 per cent or more manganese and 170,000 tons of available ore containing less than 40 per cent manganese.

The above estimates show a greater quantity of available high-grade manganese ore than of low-grade ore, although in reality the total quantity of low-grade ore exceeds that of the high-grade ore. In making these estimates several factors, including the following, were considered: 1. The cost of mining and preparing many of the low-grade ores would not be much less than that for the high-grade ores. 2. As the low-grade ores generally have a very high silica content and a low iron content, the market for them is limited.

It is impossible to make any estimate of the ore that can be mined and marketed at a profit under normal or nearly normal conditions, when the ores command much lower prices than they did during the World War. The comparatively high cost of production of the ores and the high percentages of phosphorus and silica in some of them will retard manganese mining, though the district can doubtless produce some ore under normal conditions in the future as it has at times in the past. The quantity, however, will probably be considerably less than the estimates given above.

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[72] U. S. Geol. Survey Press Bull., Sept., 1918.

Whenever conditions again cause an abnormal demand for domestic manganese ores increased production in the Batesville district will doubtless result.

LIMITS OF THE ORE-BEARING AREA.

The deposits that have been developed and have produced manganese ore in commercial quantity lie in an irregular belt 4 to 8 miles wide extending from Lafferty Hollow, near Williamson, eastward to the Ball mine, 2 miles east of Hickory Valley, a distance of 20 miles. (See Pl. I.) Cave City and Mount Pleasant are in the north border of the belt, and Hickory Valley, Pfeiffer, the Cason mine, Cushman, and Walls Ferry are in its south border. Manganese minerals have, however, been found in small quantity as far west as Guion. In this belt the Fernvale limestone, one of the ore-bearing formations, is apparently thicker, and the Cason shale, the other ore-bearing formation, is present in larger areas than they are elsewhere in the southern part of the Ozark region. Although manganese ore is not present in these formations or in their residual clays everywhere in the above belt, it occurs in commercial quantity only in those areas where one or both formations or their residual clays are present. At many places, as in the vicinity of Cave City, Sandtown, and Mount Pleasant, the ore-bearing residual clays have escaped erosion, although the Fernvale limestone and Cason shale have been entirely decomposed, but these clays occur only in areas where either one or both of the Joachim and Plattin limestones have not been eroded. It is therefore useless to look for large quantities of manganese ore in areas where the St. Peter sandstone and lower formations are exposed.

The Fernvale limestone and Cason shale have a general though low southward dip, and in this direction they pass beneath rock formations of Silurian, Devonian, and Carboniferous age. None of these younger rocks contain manganese ores, and no workable deposits will probably be discovered by deep drilling in the Fernvale and Cason where they are overlain by younger rocks, because the evidence, as pointed out elsewhere in this report, indicates that the manganese has been concentrated into minable deposits only at and near the surface.

MINING AND PREPARATION OF ORES.

By W. R. Crane, *of the Bureau of Mines.*

INTRODUCTION.

The urgent demand for manganese ore in the United States during the prosecution of the war greatly stimulated its production and encouraged a wide and careful search for workable deposits, which resulted in the discovery of new localities as well as the revival of interest in old districts. Extensive prospecting and development work was done in such well-known areas as the Cartersville district in Georgia, the Batesville district in Arkansas, and in many large areas in Virginia, Tennessee, Alabama, North Carolina, South Carolina, and in several of the Western States.

The manganese ores of the Batesville district, as explained by Mr. Miser on pages 56–70, vary greatly in their character and in their mode of occurrence. Considerable care should therefore be taken in the operations of prospecting, developing, and mining them. Deposits that have been located and give promise of having a fair amount of ore must be developed and mined so as to safeguard the operations against irregularity and uncertainty in the extent of the ore. The form of the ore deposits determines the methods employed in mining, and likewise the character of the ores mined determines the methods of preparing them for market, the variation in quality and the uncertainty in quantity being necessarily kept in view throughout the work.

METHODS OF MINING.

The mining of manganese ores may for convenience be divided into three general operations—prospecting or testing, development, and mining.

Testing by shafts, wells, and pits.—The method of prospecting usually employed in the Batesville district is testing by shallow pits and ditches. Deep pits or wells are not as much used for testing as in other districts, owing probably to the relatively thin cover lying on the slopes. Notable exceptions to this practice are found in the testing done by wells and shafts at the Shaft Hill, Grubb Cut, Rogers, and Southern mines, and to a less extent at other places scattered throughout the district. Before actual testing is begun it is desirable to obtain as much information as possible concerning the presence of manganese. It is doubtful whether any serious attempt should be made to test a property that has no signs of manganese above ground. Nodules and fragments of ore almost invariably lie upon the surface if manganese is present in any quantity worth attention. If manganese is found on the surface of the property one or more wells or test pits should be sunk, and if the results are encouraging or satisfactory other pits should be put down.

Owing to the irregular form of manganese deposits, it is particularly desirable to dig a sufficiently large number of pits to demonstrate that ore occurs throughout the area prospected. Pits should not be placed farther apart than 50 feet, and closer spacing is generally preferable but is seldom practiced, owing to the great cost, especially when deep holes are necessary.

It is just as important to know the thickness of a deposit as to know its lateral extent, consequently the test pits or trenches should not terminate when the deposit is reached or simply penetrate it for a foot or more; the test is not complete until the deposit has been entirely passed through, unless the deposit is of exceptional thickness. The number of the pits and their arrangement on the surface give the area covered, and with the information from such tests available it is possible to make a more or less definite calculation regarding the probable amount of ore on the property.

Test-pit work is usually done by contract, the price being 40 cents to 50 cents per linear foot for pits 30 to 36 inches in diameter; testing has been done also under normal conditions by day labor at a cost of 25 cents per foot.

Churn drills have been employed for a few tests of manganese-bearing ground in the Batesville district, but the danger of "salting" the test holes through rubbing the bit on pieces of manganese exposed on the walls renders this method of testing unsatisfactory. However, if proper precautions are taken by casing the holes as drilled good results can be obtained.

In testing by pits or holes it is common practice to throw the material taken out into piles indiscriminately about the holes. No opportunity is afforded at a later date, as is often desired, to examine the material removed in the order of its removal. It is much more satisfactory to place each lot taken from the hole in a separate pile, thus forming a row of small piles, the first lot taken out being next to the hole. Even though the material was scattered somewhat it would afford a more or less legible record for years after the testing was done.

If the cover is slight the deposit may be exposed by shallow holes and trenches, and owing to the comparatively small amount of work required much ground can be tested at a small cost.

Trenches as well as the deeper pits are usually employed as openings for the removal of ore should a workable deposit be discovered, and the work of testing is thus merged into that of mining. Prospecting by whatever method employed is seldom completed before mining is begun, and this overlapping often leads to unnecessary work and expense. It is well to keep the various operations separate, so far as possible, until the time when each has served its full purpose.

Where the thickness of the overburden and the depth of the manganese-bearing deposit together are known to be 50 to 100 feet shafts should be sunk, which will serve both as a means of testing the deposit and for developing and working it should it prove satisfactory. In firm ground shafts of rectangular section are employed and are as a rule lined with hewed or sawed frames and split poles or with plank. Shafts differ, therefore, from test pits in size and shape, the more common sizes being 4 by 4 feet and 4 by 5 feet.

The cost of lining shafts ranges from $1.50 to $2 a foot, and the cost of sinking and lining together is about $3.50 to $4 a foot, all the work being done by day labor. In some localities shaft sinking is contracted for at $1.25 a foot unlined and $2 a foot lined, the lumber being furnished.

Development work.—After the prospecting has been completed the next step toward production of ore is to develop the property by making cuts, driving drifts or tunnels, and sinking shafts or inclines through which to remove the ore.

If there is little or no overburden present the deposit may be attacked by simply digging into the bank or digging a trench directly into the deposit, the trench serving in a way as an exploratory opening; subsequent cutting away of the walls of the trench develops the open cut. Should there be considerable depth of cover on the deposit it may be necessary to employ drifts or tunnels in the development work, and in certain localities where the deposit extends downward and it is neither desirable nor possible to begin the development opening at a lower point, an incline or slope may have to be employed. Several open cuts may be connected by one or more drifts, through which all ore must be handled.

Deposits situated on sloping ground are developed to advantage by drifts and tunnels, but on level or nearly level ground shafts are employed. The shaft is then the connecting opening between the surface and the deposit, which provides a means of ingress and egress to men, a flue for ventilation, and a passage for the handling of the ore.

From the foot of a shaft drifts are run on the deposit, and owing to the usual irregularity of the deposits the drifts are also very irregular as to direction followed. As the shaft is the development opening connecting the deposit with the surface, so the drift used in connection with the shaft is the development passage within the deposit. Owing to the ease and the small expense of sinking shafts, many miners consider it better practice to sink them at short distances apart rather than to employ long drifts, which may have to be supported. A group of shafts, connected by drifts run at different levels, facilitates the movement of air currents and the handling of ore, as each shaft is usually provided with a windlass.

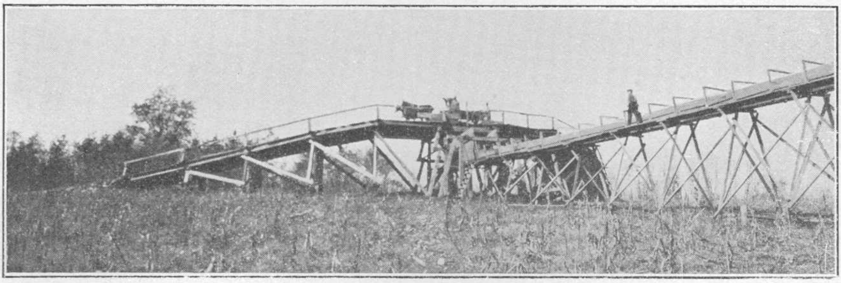
The one essential for all development work, regardless of whether it is open-cut work or underground mining, is that the horizontal passages must be kept level. Otherwise water may accumulate in them, but the most important consideration is that of handling the ore, which can not be readily done if the passages are not practically level.

Open-cut work.—Although some steam shovels have been used in the district, yet by far the greater part of the work of taking out ore is done by hand. Several mines are operating with plows and scrapers, and a number of hydraulicking operations are planned. Mining by pick and shovel, the loosened material being loaded into wheelbarrows, wagons, or cars or fed direct to sluices, is the most common method of working manganese-bearing clays or gravels. (See Pl. XIII, *C*.) Quarrying methods are resorted to when the deposits occur in the hard, unaltered Fernvale limestone and Cason shale. The clay and manganese are loosened by pick and bar, the larger pieces of mineral are sorted out, and the bulk of the clay is either sent to the washing plant or deposited on the spoils bank. The ore removed from solution cavities in limestone is usually hand picked, and all fines are discarded with the associated clay; other deposits situated at some distance from an available water supply are treated in like manner. The mining and hand picking of ores is commonly spoken of as "dry mining" and is largely employed in some parts of the district, particularly at Blue Ridge, Rowe Field, and Brooks Hill mines.

Owing to the extreme irregularity in thickness of the deposits, none of which has any great depth, any attempt at systematic mining is soon abandoned, and the cuts develop into irregular openings extending into hillsides. Boulders in the clay and bosses and pinnacles of the bed rock increase very materially the irregularity of the workings and obstruct the handling of the excavated materials. Trouble from this cause interferes most with the larger steam-shovel operations.

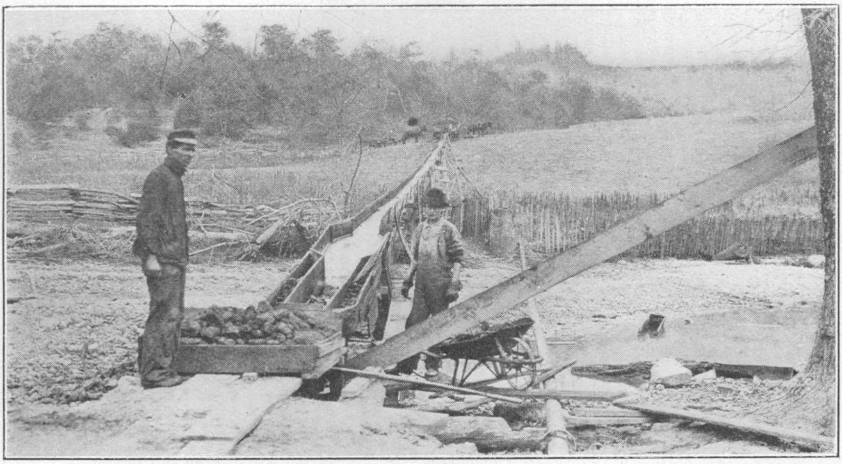
Should the testing show that the deposit does not lie in such a position as to be advantageously mined at the point where development work must begin it may be reached by drifts, but preferably by narrow open cuts, through which all excavated materials must be handled. The open cut proper is then formed by enlarging the development cut when the deposit has been reached.

The method of mining the ore from the Fernvale limestone and Cason shale differs considerably from work in clay deposits because the ore-bearing material consists of ledges of hard rock that require drilling, blasting, and considerable pick and bar work. After the overburden, composed of soil, clay, and fragments of rock has been removed the ore-bearing ledges are loosened by small charges of dynamite, and the manganese ore is then broken up by sledges, is hand picked, and placed in stock piles. In most localities in the western part of the district where such ore is mined it is necessary to remove a bed of phosphate rock that lies immediately above it. The phosphate rock is not discarded but is placed to one side in the expectation that it will have a commercial value at some future time.



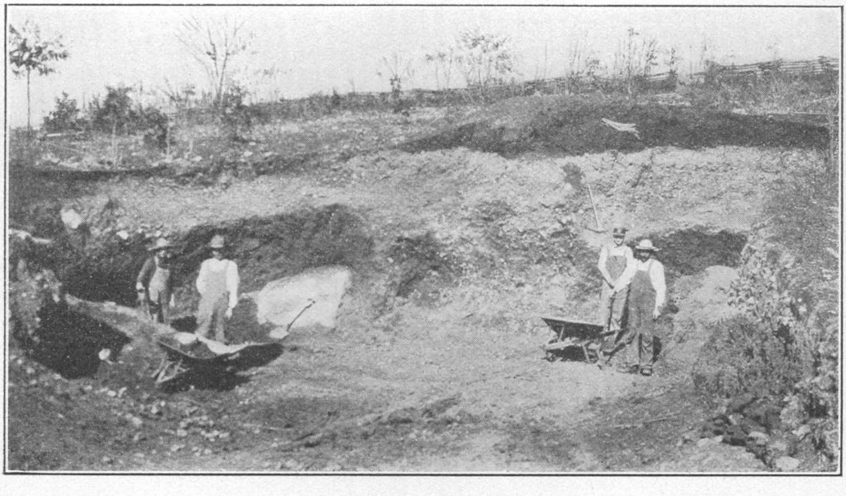
A. FEEDING WASH DIRT INTO SLUICE FROM BRIDGE AT CUTTER MINE.

Photograph by W. R. Crane.



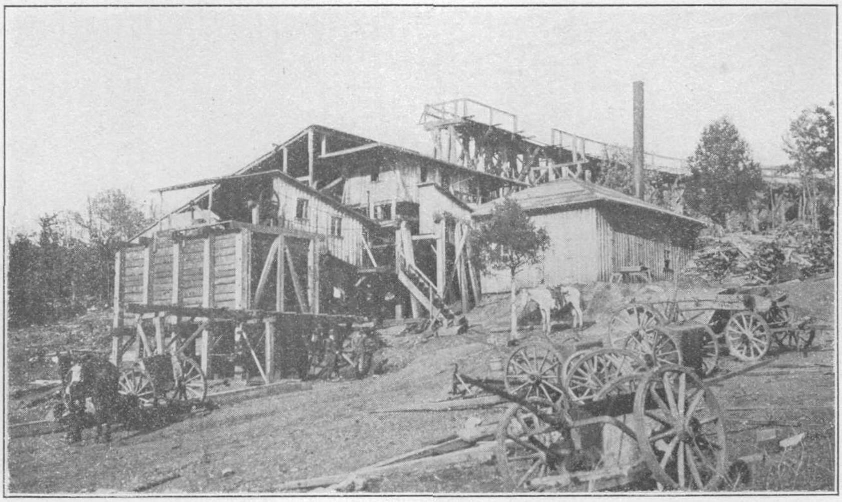
B. WASHING MANGANESE ORE IN SLUICE ON WEST LAFFERTY CREEK.

The ore being treated is from the Adler Hollow mine. Photograph by W. R. Crane.



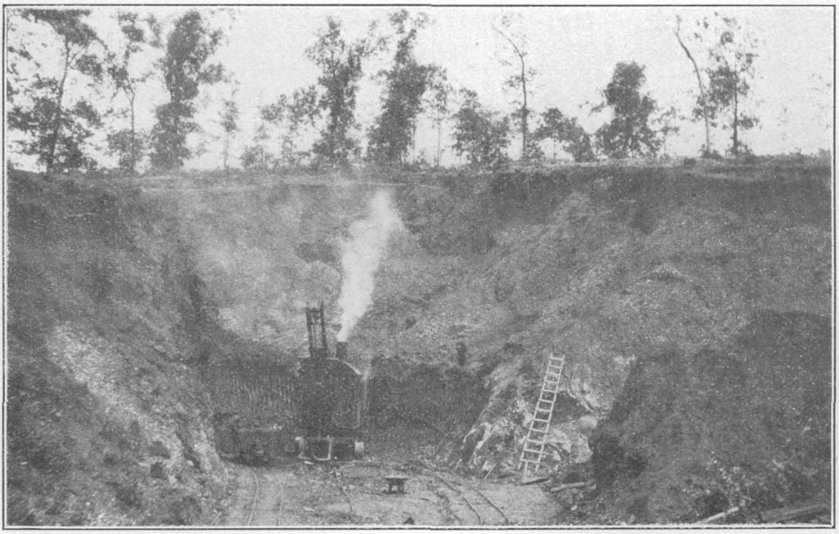
C. HAND MINING BY PICK AND SHOVEL IN OPEN CUT AT CUTTER MINE.

Photograph by W. R. Crane.



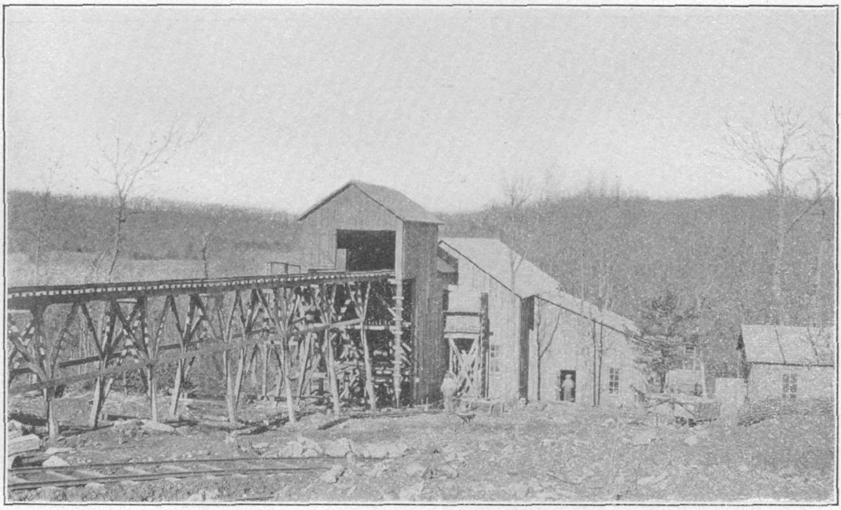
A. WASHING AND CONCENTRATING PLANT AT MONTGOMERY MINE.

Photograph by W. R. Crane.



B. SHOVEL OPERATING IN OPEN CUT AT MONTGOMERY MINE.

The ladder is leaning against a "horse" or pinnacle of limestone.



A. MODERN WASHER AND CONCENTRATOR AT DENISON MINE.

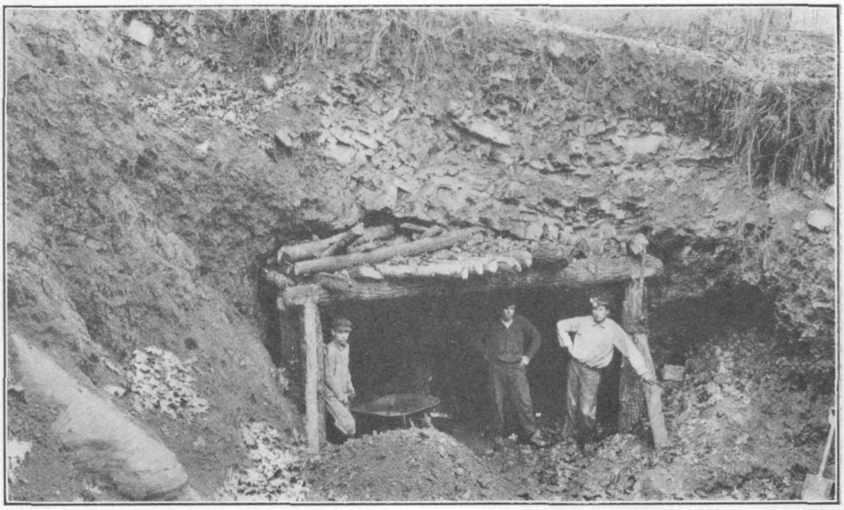
Photograph by W. R. Crane.

B. CLAY-FILLED SOLUTION CAVITY IN PLATTIN LIMESTONE AT DENISON MINE.

The clay contains manganese ore and has been partly removed from the cavity. Photograph by W. R. Crane.

A. PINNACLE OF PLATTIN LIMESTONE OVERLAIN BY A BED OF MANGANESE-BEARING CLAY AND THIS IN TURN BY NON MANGANESE-BEARING CLAY WITH CHERT FRAGMENTS, IN NORTH CUT AT POLK SOUTHARD MINE.

The manganese-bearing clay rests directly on the limestone and is therefore farther from the surface at the pit than it is on the crest of the pinnacle. Photograph by W. R. Crane.



B. VIEW AT OZARK MINE, SHOWING MANGANESE-BEARING CLAY LYING BETWEEN FOLDED AND SHATTERED LEDGES OF BOONE CHERT AND FERNVALE LIMESTONE.

Photograph by W. R. Crane.

The covering of phosphate rock has probably protected the underlying ledges of ore to a certain extent, and, although the ore may be somewhat more difficult to mine, on the other hand, it is less contaminated with clay, silica, and other impurities and requires less hand cleaning and sorting than ore that is otherwise situated.

The extreme irregularity of the limestone surface upon which the manganese ore lies prevents any attempt at systematic mining of the deposits in the limestone and shale.

Steam-shovel work is necessary if a large tonnage must be moved, as where a washing plant or concentrating mill is operated in connection with a mine. The only mines using steam shovels in the summer of 1918 were the Montgomery and Polk Southard, the former having one and the latter two shovels. (See Pl. XIV, *B*.) There were four other steam shovels in the district, and preparations were being made for installing several others. It is unnecessary to explain here the method of operating a steam shovel, as the clays, gravels, and chert fragments ordinarily encountered in the deposits are easily worked. It is, however, desirable to mention the one condition peculiar to the district, which will determine whether or not steam shovels can be employed; this is the irregularity of the bedrock. Steam shovels must operate on level ground, which they can not have where masses of rock, attached and unattached, together with pinnacles of relatively small section, extend vertically into the clay beds from a few feet to 25 or 30 feet. It is evident that only on the more extensive deposits can steam shovels be employed to advantage, and on these only until the irregularities of the bedrock are encountered. It is possible, of course, to extend the use of the shovel by blasting out the small irregularities, but the point is soon reached where the expense of blasting combined with the handling of the broken rock prevents its continuance.

Sluicing methods.—Sluices have been employed in the Batesville district as a means of handling ore alone and not as a method of mining, but a number of rather extensive operations have been planned in which hydraulic giants would be used for loosening and disintegrating the wash dirt and at the same time furnishing water for transporting the material to a washing plant. (See Pl. XIII, *B*.) Such an operation was planned by R. L. Dennison, an engineer for the Sand Field, Manganese Field, Ruminer Rough, and Barksdale mines near Anderson. Mr. Dennison is installing the plant and plans to hydraulic the clay, rock fragments, and manganese into a settling basin, the ore being removed from the basin by a conveyor, which would deliver it to a sluiceway. The partly cleaned ore would be discharged into logs at the foot of the sluiceway, passing which it would be hand picked, sized, and jigged preparatory to marketing. The character of the deposit and the lay of the ground on the property favor the installation of such a plant, supplemented with an ample supply of water near by and a proposed branch line of railroad on the property should insure the production of manganese at a low cost per ton.

Undoubtedly unexpected obstacles will be met, possibly requiring a material change in the method projected. Certain difficulties can be anticipated; thus it is not readily imagined how by the ordinary operation of a hydraulic giant clay and heavy masses of rock and ore can be removed from deep channels and solution cavities in limestone nor how the larger masses of rock and ore can be collected and discharged from the settling basin. Enormous quantities of water would be necessary to remove from the basin the great volume of clay and other material washed into it, and it is doubtful if there is a sufficient supply available.

Miscellaneous methods.—Grab buckets of the orange-peel type have been employed to a small extent, both in sinking shafts and excavating in open cuts, but have been discarded as unsuited to the work. Grab buckets were employed for a short time in shaft work at the Southern mine; also on a conveying line in open cuts at the Polk Southard mine.

Underground mining.—All underground work in manganese mines is done by drifting, the ore or wash dirt being mined at the face of the drifts. Operators plan where possible to run the development opening so as to reach the deposit at its lowest point in order that the work of mining may be carried on overhead rather than underfoot; where this is not possible both overhand and underhand work must be done.

Should the ore body extend above the opening drift it is mined by running another drift above the first one, the sets of the upper drift being supported by those below. In some places lagging must be employed to properly support the clay backs and walls of the drifts. This method of removing ore extending above the drifts may be continued to a height of several sets, the limit being five to seven, above which there is serious danger of collapse of the backs and walls.

If the ore body extends downward below the level of the opening drift it would be the safest practice to run a drift below the opening drift, placing the posts of the sets of the undercutting drift directly under the sills of the drift above.

In small, irregular deposits it is possible to remove all the ore to the height of 7 or 8 feet by drifting, but in wider deposits it is necessary to widen the face by skirting along the sides of the first drift run. When it becomes necessary to employ supports for drifts the side or skirting drifts are likewise provided with jamb sets, which are ordinary sets placed at the side of the sets of the opening drift. An ore body equal in width to six or eight sets can readily be mined by the employment of jamb sets.

The cost of drifting ranges from $1 to $1.50 per foot, untimbered; the cost of driving and timbering drifts is $2.50 to $4 per foot, depending on whether the timber can be cut on the property or must be purchased. The price paid for timber varies considerably, but ranges from about 10 to about 15 cents apiece for both sets and lagging.

Drainage, ventilation, lighting, etc.—Other operations incident to mining, such as drainage, ventilation, lighting, and handling, are usually as simple and crude as are the methods of mining and ordinarily present no serious or complicated problems.

The looseness of deposits of residual clays readily permits the escape of water, which causes much trouble in most mining work. Rarely is any trouble caused by the accumulation of water in underground workings for manganese in this district, but in open-cut work the bottoms of the pits often become choked with mud puddled by work done upon them. During wet weather water may collect in the pits, and unless they are self-draining it must be pumped out. As a rule much if not all of the trouble arising from accumulations of water can be obviated by proper methods of prevention, such as the use of intercepting ditches above and beyond the walls of the open cuts.

Ventilation is usually a matter of small concern, owing to the small scale of the operations. The practice of connecting underground workings so as to have openings at different levels, thus providing conditions favorable for natural ventilation, usually solves the problem of keeping the air fit to work in. When the workings become more extended some positive means of bringing air into them must be adopted, such as "sails" and furnaces, and in still more extended workings rotary blowers could be used to advantage.

Candles and acetylene lamps are commonly employed in underground work; in open cuts no artificial lighting is necessary, except when work is done at night. Acetylene flare lights have been used to advantage in large-scale open-cut operations, but it is doubtful whether there will ever be any great need for such equipment.

Handling materials.—Handling excavated materials is an important part of the mining operations, and is done by various methods. In open-cut work the excavated materials are largely handled in wheelbarrows on plank runways. Wheelbarrows are used in all small operations, and occasionally they are handled on fairly steep grades by two men, one pulling by a rope and the other pushing. It is needless to say that such a method of conveyance is both inefficient and expensive.

Cars are employed in many fairly large hand-operated open cuts and are used exclusively in connection with steam-shovel work, being moved by hand and by mules and in workings by engine and cable.

Owing to the common practice of following deposits downward within the pit, considerable depth of open-cut work often results, which requires the waste and wash dirt to be hauled up slopes of various grades. A level approach and entrance to the open cut should be maintained if the location of the deposit does not absolutely prevent this.

Sluices are used in a few workings for moving wash dirt from the pit to the washing plant. When the wash dirt handled contains a fair proportion of coarse ore or rock the sluice serves as a very efficient cleaning device and at the same time handles the material at a small cost. Wooden box sluices of V or square section are commonly used, and a pipe line delivers carrying water to the upper or feed end. The sluices may be fed by shovel or by scrapers operating on bridges built across the pipe line. (See Pl. XIII, *A*.)

The cost of producing manganese during 1918, although it varied considerably, particularly with respect to labor and supplies, was between $12 and $15 per ton for the bulk of the ore f. o. b. cars at the shipping point. In certain localities as high as $35 and $40 a ton has been paid for mining alone.

PREPARATION OF MANGANESE ORE.

GENERAL FEATURES.

The methods employed in cleaning and concentrating manganese ores and the scale of the operations depend largely upon the size and character of the deposits worked. The ore-bearing clays are more largely worked than the Fernvale limestone and Cason shale and produce all of the ores that are washed and otherwise treated immediately after their removal from the workings.

The deposits in the Fernvale limestone and Cason shale may be composed of hard ore or of soft or wad ores and may be of considerable size. The deposits of wad are generally of low grade and present rather unusual problems in washing and concentration; as yet no serious attempt has been made to utilize them commercially.

The principal difficulty met with in planning the treatment of ore or wash-dirt coming from the ore-bearing clays is the uncertainty of a regular and uniform output from the mines. Next in importance to the features of the supply is the character of the manganese ore and the proportion of ore to waste, such as clay, sand, iron oxide, etc. The kind of ore best adapted to washing and concentration is the nodular or pebble form of small size, following which in ease of treatment is the granular form, which is usually of convenient size for log washing and subsequent jig work. The kidney, dornick, and massive ores require reduction before they can be successfully treated by logs and on the picking belt, but owing to the size of the masses and the purity of many of them, it is often possible to make a high percentage extraction prior to treatment in logs and jigs.

Owing to the variable conditions mentioned, there is a tendency to limit the equipment for treating manganese to a minimum both with regard to kinds and number of parts employed, and irrespective of the desirability of a small equipment. Poor and imperfect cleaning and excessive losses of ores usually result from the curtailment of equipment. This curtailment is not always due to a wish to limit the first cost but more often to a lack of definite knowledge regarding proper methods of treating manganese ores, which leads to the following of a previous practice, however poor it may be. It is therefore very important that the layout of a standard plant which incorporates all useful and desirable parts of the best practice to be found in the country be given here.

The preparation of manganese ores consists of two distinct operations—(1) dry mining, (2) washing and concentration.

DRY MINING.

Dry mining is not a method of taking ore out of the ground. It is a method of cleaning the ore, and consists of screening the wash dirt as it is mined. Not all wash dirt is adapted to dry mining, as certain clays are wet and sticky and some occur in large masses, making their separation from the mineral by screening practically impossible. Dirt that can be best treated by dry-mining methods is dry and granular, breaking up readily and separating from the mineral with little or no effort.

The dry-mining method is far from satisfactory at best, and is scarcely ever employed in operations of much size, except as a temporary expedient, as in the preparation of ores prior to the erection of a washing plant. In small-scale operations, carried on where the deposits are small or by parties who have not enough funds to equip the mine properly for economical extraction and preparation of the ore, such a method may be permissible. Further, deposits situated at considerable distance from a water supply may require dry mining if they are to be worked at all, but in any case the method is wasteful, the loss of fine ore frequently amounting to 25 to 35 per cent of the recoverable mineral in the bank.

On the other hand, the high-grade manganese occurring in solution cavities can be cleaned by hand with or without screening, but in such deposits the bulk of the ore is of fair size; however, even under the most favorable conditions considerable loss results.

The percentage of manganese in the wash dirt is the controlling factor in dry mining. Dirt having less than 10 per cent of mineral can not be successfully separated by screening unless the bulk of the mineral is of large size.

WASHING AND CONCENTRATION.

The principal considerations affecting the employment of washing and concentrating methods in the treatment of manganese ores are the quantity of wash dirt available, the percentage of manganese in the dirt, and the water supply. No plant should be erected until the available supply of ore has been determined within reasonably close limits; failure to test a property adequately before erecting a plant shows lack of good judgment and business acumen. Although ore may be mined and hand picked under certain conditions of occurrence, even when the proportion of ore to clay is 1 to 50, or 2 per cent, yet the excavation must be done on a large scale by mechanical means and the bulk of the ore must be in fairly large masses. Log washers and jigs can not readily treat materials that are leaner than 1 to 35, and preferably they should be 1 to 10, or 10 per cent, which is a fair average for wash dirt treated.

The design of a plant for the proper treatment of any mineral must be based upon the following points: The nature of the mineral and its physical characteristics; its mode of occurrence, the associated minerals and inclosing rock formations; the practice previously followed, if there has been any; and of somewhat less though of considerable importance, the local conditions, such as lay of ground, water supply, and timber for construction and other purposes.

The manganese ores in a district may differ widely in character, and considerable difference may be noted in ores from openings on the same property. The mineral may be dense and hard, or porous and hard, or porous and soft. The specific gravity also varies considerably, ranging from 3.5 to nearly 5; the average for the greater part of the mineral treated is between 3.5 and 4. The small rounded or granular pieces can be treated without difficulty, but fine material and large masses require special treatment.

The minerals associated with manganese are chert and iron oxide, principally limonite; barite occurs rarely. As the oxides of iron and manganese have nearly the same specific gravity it is practically impossible to separate them mechanically, consequently it is common practice to hand pick the ore coming from the finishing apparatus when a product low in iron is desired. As a rule, however, no attempt is made to separate the small amount of iron present in ores coming from the ordinary manganese deposit. The specific gravity of compact chert is about 2.60–2.65, but much of the chert that occurs with manganese deposits, particularly the sands resulting from the decay of limestone and other formations, is rough and porous and has a specific gravity of 1.8 to 2. It is evident, then, that the average specific gravity of manganese is about twice that of chert, the principal impurity that must be separated from it, which is ample to allow of clean and rapid separation.

Existing practice in the treatment or cleaning of manganese ore has a wide range, from fair to very bad, but as a whole it would fall in the lower part of the range. New plants are modeled after those that are operating, apparently on the assumption that because a plant is in operation it must be doing good work, which is often far from being true. However, the essential principles of a prevailing practice are very likely to be sound and particularly adapted to the special conditions in the district and are therefore worthy of careful consideration and adoption, at least in part.

The practice of cleaning manganese ores followed in the Batesville district can hardly be considered standard except in its general outline, which is the use of grizzlies, log washers, screens, and picking belts, with a growing tendency toward employing jigs. Rarely, however, are plants constructed for and fully equipped with the apparatus that has proved satisfactory in operation on manganese ores, and a number of plants are operating with the irreducible minimum of equipment, namely, a log washer and screen or hand jigs alone. The practice is very simple and may be outlined as follows:

Wash dirt to 1:

1. Grizzly, size 5 by 6 feet, 10 to 14 railroad rails spaced 4 inches: Oversize, waste rock thrown on dump, lump ore reduced by sledging to size that will pass through grizzly to 2; undersize to 2.

2. Double log washer, 28 feet long, slope 1 inch to 1 foot: Discharge to 3; overflow to 4.

3. Revolving screen, 6 feet long by 30 inches in diameter with three-fourths inch perforations: Oversize to 5; undersize to 6.

4. Waste bank.

5. Picking belt, 22 feet long by 24 inches wide: Ore to 7; waste to 4.

6. Harz jig, 4 cells, size of cells 32 inches by 42 inches: Gate discharges to 7; hutches to 8.

7. Finished ore bin.

8. Harz jig; 2 cells, size of cells 28 inches by 36 inches: Gate discharges to 7; hutches to 7; tails to 4.

A similar equipment, somewhat more specialized, was employed at the Eureka Manganese & Mining Co.'s plant at the Montgomery mine, but certain changes have been made in it, including particularly the addition of several Harz jigs. The mill as remodeled has not been operated, so that the flow sheet given below represents the work done during the summer of 1918. (See Pl. XIV, *A*.)

Wash dirt to 1:

1. Grizzly, railroad rails spaced 4 inches: Rock to dump; manganese lump reduced by sledge, goes with undersizes and clays to 2.
2. Log washer, 30 feet long, slope 1 inch to 1 foot: Discharge to 3; overflow to stream.
3. Jacketed screen, 7½ feet long by 4 feet in diameter; two sections of screening surfaces, first one-sixteenth inch mesh, second one-half inch mesh: Oversize of one-sixteenth inch section to one-half inch section, undersize to 4; oversize of one-half inch section to 5, undersize to 6.
4. Settling boxes: A low-grade highly siliceous product is obtained.
5. Picking belt, 30 feet long by 28 inches wide: Rock to dump; manganese to 7.
6. Richards pulsating jig, size 12 by 12 inches: Hutch product to 7; overflow to 4.
7. Finished ore bin.

More than two jigs are seldom employed in the washing plants for manganese ores, and in many plants only one jig is used. Revolving screens or trommels are commonly used, but flat screens are occasionally employed; in either case it is the exception to find more than one size of opening used, which ranges from three-quarters of an inch to 1¼ inches. The wide range in the size of the material fed to the jigs from such screens renders good separation next to impossible. Few of the products of the jigs are clean; the greater part require extensive hand picking to complete their preparation, which could be obviated by simply rerunning the hutches of the rougher jigs. Fairly clean products could then be made on the second or cleaner jigs. If only one jig is employed little or none of the jig products is suitable for market. Fairly close sizing would make a great improvement in the work done by the jigs and would reduce the expense of preparing the ores by eliminating hand picking.

Probably a dozen hand jigs have been in operation in the district at different times, but with them as with the power jigs incomplete separation of waste materials was the almost universal rule owing to little or no attention being paid to sizing of the feed.

One of the best equipped and most modern plants in the district is at the Denison mine. (See Pl. XV, *A*.)

Manganese ores can readily be cleaned by washing and jigging and with only slight change in the present practice. The flow sheet of a plant properly arranged, which can, therefore, be called a standard plant, is given below:

Wash dirt to 1:

1. Grizzly, 2 to 4 inch spaces between bars: Oversize, rock to 2, manganese by sledge to 3; undersize to 3.
2. Rock dump.

3. Log washer, double log, 20 to 30 feet long, slope 1 inch to 1 foot: Discharge to 4; overflow to 5.

4. Revolving screen, cylindrical or conical, perforation or mesh one-half inch and three-sixteenths inch: Oversize, everything above one-half inch to 6; undersize, one-half inch to three-sixteenths inch to 7; under three-sixteenths inch to 8.

5. Mud or settling pond.

6. Picking belt: Rock to 2; manganese to 9.

7. Rougher jig, four cells: Gate discharges to 9; hutches, first to 9; second, third, and fourth to 10.

8. Sand jig, three cells: Gate discharges to 9; hutches to 9 or 10.

9. Finished ore bin.

10. Cleaner jig, three cells: Gate discharges to 9; hutches to 9 or 11.

11. Shaking table: Finished product to 9; tails to 5.

A standard washing plant, equipped as indicated in the above flow sheet, may be called a single washer or unit and has a capacity of 40 to 50 tons of finished ore per 10 hours. By a single washer is not meant a single log, but a single washer with double logs. Although single logs do good work, yet in such a plant as that outlined above a double log should be employed. An increase in the capacity of such a plant, aside from a small increase that might be gained through crowding, would require a doubling, trebling, or quadrupling of most of the equipment listed, and would effect a corresponding increase in the volume of wash-dirt treated.

The sizes of the various machines of a standard plant are indicated in the flow sheet, and their adjustments and the sizes of the screens required for the proper operation of the plant are given below.

The number of revolutions of logs ranges from 12 to 15 per minute. The amount of water required ranges from 50 to 75 gallons per minute. The capacity is 40 to 50 tons per 10 hours. The horsepower required to drive the logs is between 20 and 25.

The number of revolutions of screens ranges from 15 to 20 per minute, being approximately the same for cylindrical and conical screens of 36 and 48 inches diameter. The power required for driving varies somewhat with the feed and the size of material handled but is about 1 horsepower. The capacity of the screens of the sizes given ranges between 45 and 55 tons per 10 hours for the smaller and 50 to 75 tons for the larger. The length of screen for the ordinary material treated should not be less than 60 inches nor more than 72 inches, unless a larger number of sizes is desired, in which case it might be better to shorten the separate screening surfaces than to unduly increase the length of the whole screen.

The sizes of picking belts that are commonly employed and have proved satisfactory for the usual range of work done are from 30 feet long by 18 inches wide to 50 feet long by 30 inches wide. The speed of the picking belt ranges from 50 to 60 feet per minute. The capacity is limited by the character of the work done. If the material sorted is largely ore, and the waste rock is fairly coarse, the capacity is large; also if the percentage of ore is small and the individual pieces are large. On the other hand, if the ore and waste are about equal in amount and there is a wide range in sizes, the capacity may be small. Occasionally two picking belts are used, one for the coarse, the other for the finer materials, but this practice is not desirable.

The following data are necessary for the proper adjustment and operation of jigs:

Specifications for jigs.

	Width (inches).		Length (inches).	
Size of sieve compartments	20–24		30–38	
Size of plunger compartments	18–22		30–38	
	1st cell.	2d cell.	3d cell.	4th cell.
Size of sieve openings, in fractions of an inch:				
Rougher jig	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{3}{16}$
Sand jig	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{8}$
Cleaner jig	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{8}$
Length of stroked jigs, in inches:				
Rougher jig	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{1}{4}$
Sand jig	1	1	$\frac{7}{8}$	$\frac{7}{8}$
Cleaner jig	1	1	$\frac{7}{8}$	$\frac{7}{8}$
Number of strokes per minute:				
Rougher jig	150	150	150	150
Sand jig	200	200	200	200
Cleaner jig	200	200	200	200

Power for 4-cell jig, 2.5 to 3.0 horsepower.
Power for 3-cell jig, 2.0 to 2.5 horsepower.
Hydraulic water pipes, main pipe 2 inches, branch pipes 1 inch.
Amount of water used per jig, 350 to 400 gallons per minute.
Height of tailboard or dams, $3\frac{1}{2}$ to $4\frac{1}{2}$ inches.
Slope of bed (sieve) should not exceed 1 inch to length of bed; for heavy mineral bed should be level. Slope should be against movement of mineral.
Drop between tailboards or dams, 1 inch.
Height of gate discharge above bed, 2 to $2\frac{1}{2}$ inches, which must be varied to suit conditions and character of material treated.

Jigs must be fed regularly to enable them to work at full or large capacity; therefore jigs receiving the feed directly or indirectly from logs usually do unsatisfactory work, for the feeding is irregular and does not permit the maintenance of a bed of uniform depth. Further, the feeding of mixed materials, part sandy and part clayey, also renders it difficult to keep a full bed; clayey ores, as they tend to clog the jig beds, are preferably cleaned by trommels and jets of water.

If the plant is suitably arranged practically all the materials treated may be handled by gravity, but in some circumstances elevators are advantageous, for although increasing the cost of equipment and the expense of operation they make it possible to have more of the apparatus on the same level and therefore more accessible. Elevators are particularly useful in handling the hutches from the rougher and sand jigs to elevate them to the cleaner jig. Should it be found desirable to employ a shaking table for reworking the hutch products from the cleaner jig, an elevator should be used to convey them also.

It is doubtful whether tables can be used to advantage in the preparation of the usual run of manganese ore, as outlined above. There is, however, a well-defined field for them in treating certain ores, such as the low-grade deposits in the Cason shale and the ores in which fragments and pebbles of chert are embedded.

Largely because of an inadequate supply of water, a number of attempts have been made to clean manganese ores by dry methods. Probably the most extensive and elaborate equipment is that of the Manganese Development Co. installed at the Southern mine. It is proposed to separate the ore from the clay and rock fragments by passing the material, as excavated, through a revolving drum, in which it is thoroughly dried and the clay is pulverized. On being discharged from the drum the fine material is removed by a revolving screen, which is a continuation of the drum, and the coarse manganese and waste then pass to a picking belt, where final separation is made. The smaller sizes of ore are to be treated on hand jigs. This plant has never been operated on a commercial scale, hence no definite statement can be made regarding its practicability.

The water supply for manganese washing and concentrating plants is of considerable importance. Many of the workable properties are at considerable distance from an available supply. Water is usually conveyed from the pumping plant to the washer by a line of 3-inch to 4-inch pipe, which is sufficiently large for a standard plant. The conservation of water by passing it through settling or impounding ponds usually solves the problem of water supply where the quantity of living water is small. Once a plant has been put in operation the addition of 25 per cent of the total consumption not only provides for the loss by wastage but supplies the needed amount of clean water for those parts of the process that require it.

GENERAL SUMMARY OF CONDITIONS AFFECTING CONCENTRATION.

The same care that has been shown to be necessary in prospecting and mining should be exercised in planning the erection of a washing or concentrating plant, and the factors that have to do with successful operation must be duly considered.

The principal considerations affecting the cleaning of ores include the character and grade of the ore, the recoverable percentage of mineral, the relative values of crude and cleaned ore, and the basis upon which royalty is paid.

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In addition to the clays and other waste materials considerable silica is associated with manganese ores. The silica may be "free" or "attached"; the former can be readily removed by washing operations, but the latter is attached to or embedded in the ore and can be separated, if at all, with difficulty.

High-grade ores, particularly if they come from the mine in large masses, and soft ore, as wad, should receive the minimum amount of treatment that will effect proper cleaning. Low-grade ores usually require much more treatment than the high-grade ores, and the amount of effort and consequent expense required to increase the value depend largely upon the constituents responsible for the diminished grade. Soft ore, or wad, although of high grade is difficult to clean without great loss, due to fines, and the difficulty is increased when much fine sand is mixed with the clays and ore.

The recoverable percentage of mineral in the wash dirt depends largely upon the character of the material. As a rule the larger the pieces of ore and the higher the grade the more readily is the separation from wastes effected, owing probably to the smoothness of the surfaces. Nodular and button ore of small and fairly uniform size is readily washed and jigged, but fragments broken from large masses and rough particles, resulting from the decay of limestone and possibly from the partial solution of the manganese, are very difficult to clean satisfactorily. Certain clays are readily broken up and separated from the manganese, whereas others become pasty on the addition of water and adhere tenaciously to the particles of mineral.

The relation between the value of crude ore and that of cleaned ore may be the deciding factor in determining whether or not a concentrating plant should be erected. A considerable tonnage of low-grade ores was shipped from the Batesville district during 1917 and 1918 and sold at a low price, simply because there was a market for it. It is a question whether such ores could not have been raised in grade by concentration so as to bring a price that would warrant the erection of a concentration plant. The question was not answered by a trial, because of the uncertainty as to the extent of the deposits and the period in which schedule prices would be maintained. It was not deemed advisable to go to any considerable expense on a venture that was largely experimental, especially as no assurance could be had regarding the future market.

The grade of ore upon which royalties are assessed has been the cause of considerable trouble in different districts, but in the Batesville district during 1918 royalties were paid on all ores coming within the schedule, unless otherwise specified. In future high-grade ores only will be subject to royalty charges.

Careful mining of high-grade ores in well-tested properties will be necessary in future operations in the district. The material mined will require either close hand picking or concentration in well-designed plants in order to produce a high-grade ore, low in silica and phosphorus. With a dependable output of such ore the manganese industry may be continued for many years.

MINES AND PROSPECTS.

By Hugh D. Miser.

SHARP COUNTY.

M'LEOD PROSPECT.

The McLeod prospect is on the southeast slope of a ridge on the C. C. McLeod tract, 3½ miles northeast of Cave City. It comprises two very small pits which have been dug in surficial materials consisting largely of chert fragments and pebbles. Both pits reveal brown iron oxide, and in addition to this oxide one pit reveals a small quantity of manganiferous iron oxide. Iron oxide also crops out at a few places on the slope. The crest of the ridge at this locality is capped by a bed of chert fragments and pebbles, which are doubtless underlain by clay, and the clay is in turn underlain by the St. Peter sandstone or the Joachim limestone.

MOBLEY PROSPECT.

The Mobley prospect, not visited by the writer, is on the Mary Mobley tract, 4½ miles east of Cave City. S. O. Johnson, who has done some prospecting on the tract, says that he has taken a few tons of low-grade manganese ore out of the openings. Mr. Johnson at the time when the writer conferred with him (May 18, 1918) was planning to do further work.

COCHRAN PROSPECT.

The Cochran prospect is on the Powell Cochran estate, 3½ miles northeast of Cave City. Two pits—one 12 feet deep and the other 4 feet deep—were dug in 1916 in red manganese-bearing clay on the north slope, near the crest of a ridge. The total depth of the clay was not determined as neither of the pits was dug entirely through it. The occurrence of an outcrop of the Joachim limestone in a gully somewhat lower on the slope and 100 yards northwest of the pits indicates that the clay rests upon this limestone. The St. Peter sandstone, which underlies the Joachim limestone, is exposed on the steep slope, at the north edge of the field that lies north of the pits.

The ore was not observed in place in the clay, as the pits had caved badly at the time of visit (May 17, 1918), but on the dumps a considerable quantity of light earthy manganese oxide in fine angular fragments was seen. No analyses of the ore are available, but it probably contains a high percentage of silica and alumina and a low percentage of manganese.

M. A. ALDRIDGE PROSPECT.

The M. A. Aldridge prospect is three-fourths of a mile west of Cave City and is on the M. A. Aldridge tract, which comprises the SE. ¼ SW. ¼ and the SW. ¼ SE. ¼ sec. 18, T. 15 N., R. 5 W. It consists of two very small pits, which have been recently dug in clay on the gentle west slope of a hill. Fragments of brown iron oxide and a small quantity of manganese oxide were observed on the dumps at the time of visit (May 16, 1918). Although most of the manganese oxide is intimately mixed with the iron oxide some is free from it. The thickness of the clay has not been fully determined. It probably overlies the Plattin limestone, of which there are no exposures near the pits but there are some in the vicinity.

K. D. ALDRIDGE PROSPECT.

The K. D. Aldridge prospect is on the K. D. Aldridge tract in the NW. ¼ SW. ¼ sec. 18, T. 15 N., R. 5 W., 1¼ miles west of Cave City. Work was done at this locality in 1917, and 15 to 20 tons of "lump" manganese ore is said to have been shipped. The openings consist of a few pits and cuts as much as 12 feet deep, near the top of a gravel-covered hill. After they pass through a few feet of gravelly loam they enter a red clay. The manganese ore includes porous to compact psilomelane and soft brown earthy wad, which were found in both small and large fragments from the surface to the bottoms of the openings. The total depth of the clay has not been determined, as none of the openings passed through it and reached the underlying limestone, which is probably the Plattin limestone.

The presence of fossil casts in some pieces of the manganese ore suggest that it is a residue from the decomposition of a fossiliferous limestone—presumably the Fernvale limestone—which may once have occurred in this part of the region but which has since been decomposed and eroded, leaving its more resistant components. This assumption is supported by the occurrence at this locality of boulders and fragments of porous brown chert like those found in the residual clay of the Fernvale limestone farther southwest in the Batesville district.

MATLOCK MINE.

The Matlock (usually pronounced Medlock) mine is on land owned by Boyd Matlock, in the SE. ¼ sec. 13, T. 15 N., R. 6 W., 1½ miles west of Cave City. It has been operated by several lessees, beginning in 1916, but most of the work on it has been done by George Brewer. Altogether 200 tons of "lump" manganese ore have been mined and hauled to Pfeiffer, a distance of 10 miles, whence it was shipped.

The workings, which are pits and cuts as much as 18 feet deep, have been dug here and there over several acres in a field that is on and near the crest of a low eastward-trending ridge. They penetrate a dark-red manganese-bearing clay, whose superficial parts contain chert fragments and pebbles. The clay is overlain in places by pockets, known as "bars," several feet thick, some of which are composed almost entirely of chert fragments and others of sand and chert pebbles. The chert fragments were derived from the Boone chert, which once occurred over all this part of the region, but which has long since been entirely eroded, leaving only small areas of fragments, which have settled below the original position of the formation. The pebbles were derived from an extensive gravel bed of Upper Cretaceous or later age, which, like the Boone chert, has been completely eroded, except in small areas.

The red clay rests upon a sticky yellow clay, and this in turn rests upon the Plattin limestone, which is exposed in a near-by gully and which is said to have been struck in some of the openings. The yellow clay is a residue from the decay of the Plattin limestone, but the occurrence in the red clay of fragments and boulders of porous chert like those that occur in the residual clays of the Fernvale limestone farther south and southwest shows that a part of the red clay at this locality is a residue from the decay of the Fernvale limestone. Not only this limestone but the Kimmswick limestone and much of the Plattin limestone have been removed, leaving only their insoluble components, and while this process was going on the resistant Boone chert, which overlay the limestones, gradually settled below its original position.

The manganese ore consists mainly of psilomelane and hausmannite, which are more or less intimately mixed, and it occurs as both fine particles ("wash ore") and large masses ("lump ore"), which are found in leads and pockets in different parts of the red clay from the surface to the bottoms of the openings but usually in greatest quantity near the chert and the sand and gravel bars. Some of the boulders and fragments of porous chert in the clay have been partly replaced by manganese oxide. Although the "wash ore" observed on the dumps occurs in considerable quantity, only the "lump ore" has been mined. The largest yield thus far (May 16, 1918) obtained from any single pocket is said to have been 30 tons. Ore has been found over several acres, but the openings show that it occurs in greatest quantity in about 2 acres. Like some of the chert in the red clay, it is presumably a residue from the decomposition of the Fernvale limestone. The ore that has been shipped is said to have averaged about 48 per cent of manganese. The following analysis is of a carload of ore shipped from this mine in 1917 to the Tennessee Coal, Iron & Railroad Co.:

Analysis of manganese ore from the Matlock mine.

Manganese (Mn)	45.84
Iron (Fe)	4.77
Phosphorus (P)	.19
Silica (SiO_2)	5.40
Alumina (Al_2O_3)	2.73

STORY MINE.

The Story mine consists of a number of openings in the NE. ¼ NE. ¼ sec. 24 and the SE. ¼ SE. ¼ sec. 13, T. 15 N., R. 6 W., 1½ miles west of Cave City. It was formerly owned by J. G. Story but is now owned by a firm in Chicago. It was first operated by W. H. Denison and H. H. Anderson, beginning in 1916, and was later operated by Henry Clark. The total production before the time of visit (May 17, 1918) was 150 tons of ore, which is said to have averaged 48 per cent of manganese. The ore was hauled to Pfeiffer, a distance of 10 miles, whence it was shipped.

One of the main openings is a cut 25 feet long, 15 feet wide, and 10 feet deep, which has been made in a field on the west slope and near the crest of a hill in the NE. ¼ NE. ¼ sec. 24. It reveals chert fragments, derived from the Boone chert, on its south side and red clay on its north side. Manganese and brown iron oxides, more or less intimately mixed, occur in both large and small masses in the clay and in the cherty material. Much of the material contains chert fragments. Other though smaller openings show similar ore for a distance of one-eighth of a mile east of this cut. The ore at all these openings would be classed as a manganiferous iron ore or ferruginous manganese ore. It is not a residue from the decomposition of the Fernvale limestone and Cason shale, as are most of the manganese ores of the Batesville district, but it has apparently been formed rather recently in the clay and chert débris. The depth and extent of the ore-bearing clay and chert have not been fully tested. Although no limestone is exposed in the vicinity the clay and chert probably overlie the Plattin limestone or Joachim limestone.

Many pits and cuts as much as 15 feet deep have been made in an area of about 3 acres, in a field on the crest of a very low, well-rounded hill, in the SE. ¼ SE. ¼ sec. 13, just north of the openings described above. They have been made by means of picks, shovels, plows, and scrapers in a red clay and red sandy clay and in red sand in which there are a few chert fragments and boulders. Chert pebbles and fragments are present in the surficial parts of the clays. The manganese ore consists of hausmannite and compact steel-blue psilomelane and occurs as fine particles ("wash ore") and as boulders, some weighing as much as 1,000 pounds, in the clays from the surface to the bottoms of the workings, but the greatest quantity of "wash ore" was taken from the bottom of the largest cut. The ore that has been shipped included only the larger masses, which could be freed from the clays by hand picking. The firm that had purchased the property was planning at the time of visit to erect a washing plant to recover the "wash ore."

Like the manganese ore at the Matlock mine and the K. D. Aldridge prospect the ore at the openings just described is a residue from the decomposition of the Fernvale limestone. A few fragments of porous ferruginous chert derived from the Fernvale limestone occur at this locality. The depth and extent of the ore-bearing clays have not been fully determined. Only one opening is reported to have passed through the clays and encountered the underlying limestone, which is either the Joachim limestone or the Plattin limestone.

INDEPENDENCE COUNTY.

JACKSON PROSPECT.

The Jackson prospect, not visited by the writer, is on the W. M. Jackson farm in the northwest corner of sec. 19, T. 15 N., R. 5 W., 1½ miles west of Cave City. A pile of about 500 pounds of manganese ore, which had been taken in 1916 from three small pits, was examined at Mr. Jackson's house. It consisted of irregular-shaped fragments, some weighing several pounds, of hausmannite and steel-blue psilomelane.

WOODYARD PROSPECT.

The Woodyard prospect, not visited by the writer, is on the Thomas Woodyard tract in the NE. ¼ sec. 19, T. 15 N., R. 5 W., half a mile or more southwest of Cave City. It consists of two very small openings, which are said to show manganese ore.

BALL MINE.

The Ball mine is on a tract of land owned by Warren Ball, which comprises the NE. ¼ NE. ¼ sec. 4 and the NW. ¼ NW. ¼ sec. 3, T. 14 N., R. 5 W. It is half a mile south of Cura Creek, 2 miles east of the village of Hickory Valley, and 6 miles northeast of Pfeiffer. It was operated from 1914 to 1916 by Henry Clark, who hand sorted and shipped only the "lump ore," and it was next operated by the Ozark Mining Co., which installed a small washing plant. In 1918 the mine was re-leased to Shepherd & Wilson, who operated the small washing plant that had been erected by the Ozark Mining Co. The various lessees are reported to have mined and shipped before the time of visit—May 18, 1918—65 carloads of manganese ore. By November, 1918, Shepherd & Wilson had partly completed a 250-ton washing plant. equipped with jigs and crushing machinery, but the lack of market for domestic manganese ores at that time soon stopped work on the property.

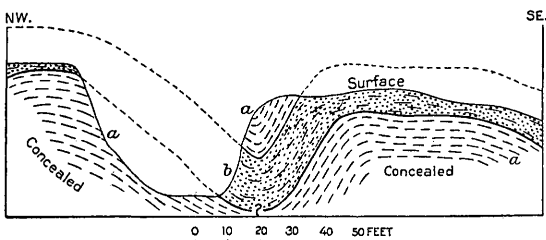

FIGURE 7.—Sketch section in a part of the Ball mine, illustrating the occurrence of the ore-bearing clay bed. The dashed lines represent the probable former extent of the ore-bearing clay. *a*, Non ore-bearing clay; *b*, ore-bearing clay.

The manganese ore has been mined in large open cuts as much as 30 feet deep over an area of 1½ acres on a gentle southeast slope. It occurs in a bed several feet thick composed of clay, sandy clay, and friable sandstone. Some of these materials are red or yellow, but most of them are brown. This bed has been derived from the weathering of the Cason shale. It is shown by the openings to be fairly continuous in the worked area, and although it once lay in a nearly horizontal position, it now dips at different angles at different places (see fig. 7) but in general dips to the southeast, toward the base of the hill. The manganese-bearing bed is underlain by yellow ocherous clay, which contains a few thin beds of soft friable sandstone and lenses of chart as much as 18 inches thick. These underlying beds are presumably derived from the weathering of the Kimmswick and Plattin limestones, which are exposed on the hill slope between the mine and Cura Creek half a mile to the northeast.

In consequence of the decomposition and partial removal of the limestones, the overlying Cason shale and higher beds have settled below their original positions. The manganese-bearing bed is in places overlain by a bed a few feet or more thick composed of red and yellow clays in which angular chert fragments and boulders are embedded. These overlying materials have been derived by weathering from the Boone chert, which caps many of the hills in the vicinity of the mine, and they have settled below the original position of the Boone chert. Some fragments of ferruginous chert found near the base of these overlying materials contain well-rounded pebble-like masses (*Girvanella*) about an inch in diameter, and they look as if they might represent a silicified phase of the basal bed of the St. Clair limestone, which at places, as at the Cason mine, contains such masses.

The manganese ore occurs as thin lenses and veins and as small masses which are rather uniformly disseminated through the weathered Cason shale, much of which it has replaced. Manganese oxides have partly replaced also some of the chert both above and below the Cason shale. Most of the ore is psilomelane, but part is manganite; some of it has a botryoidal form; and a small part of it contains grains of quartz sand. At the west end of the main cut it contains enough iron to be classed as a manganiferous iron ore. A few "buttons" of manganese oxide like those at the Cason and Montgomery mines, also a few "buttons" of iron oxide, are found here and there in the weathered Cason shale. The outlines of similar-shaped "buttons" were observed in some masses of psilomelane; the psilomelane in these masses has replaced the parts of the Cason shale adjacent to the "buttons." Tests are said to show that the concentrates obtained from the ore-bearing material on the dumps, from which the "lump ore" has been hand picked, bear the ratio of 1 part of concentrates to 4 parts of this material, and that the concentrates obtained from ore-bearing material as it comes from the mine bear the ratio of 1 to 3. The marketed manganese ore is stated to have had an average manganese content of 38 per cent and an average iron content of 8 per cent; but the silica content, as is indicated by a few analyses given below, is high. The treatment of the ore in the new plant, which is equipped with jigs and crushing machinery, was expected to reduce materially the silica content. The analyses given below are of carload lots of manganese ore shipped from this mine. The first seven analyses are of ore mined in 1917 by the Ozark Mining Co. and shipped to the Tennessee Coal, Iron & Railroad Co., and the others are of ore mined by Henry Clark.

Analyses of manganese ore from the Ball mine.

	1	2	3	4	5	6	7	8
Manganese (Mn)	33.51	36.79	19.85	20.53	19.26	38.83	12.87	44.24
Iron (Fe)	6.15	6.14			12.27	4.04	17.82	3.80
Phosphorus (P)	.13	.13	.17		.22	.13		
Silica (SiO_2)	25.86	20.13			41.55	9.56		
Alumina (Al_2O_3)	3.57	3.74			4.98	2.96		

Analyses of manganese ore from the Ball mine—Continued.

	9	10	11	12	13	14	15	16
Manganese (Mn)	44.24	43.01	38.42	37.41	37.10	38.30	38.30	36.10
Iron (Fe)	3.90	....	4.00	....	5.36	5.75	5.70	6.30

	17	18	19	20	21	22	23	24
Manganese (Mn)	39.60	38.80	39.40	36	36.70	38.30	39.40	39.20
Iron (Fe)	6	6.75	5.45	7.20	6	7.20	6.10	6

	25	26	27	28	29	30	31
Manganese (Mn)	36.50	32.70	36.05	39.10	33.92	36.35	34
Iron (Fe)	6.10	12.15	7.05	5.05	....	....	7.35

At the time of visit the ore was being mined with picks and shovels and conveyed in tramcars to the small near-by washing plant, which was equipped with a trommel screen and jigs. Water was being obtained from a small spring branch at the base of the hill, but plans were being made to obtain a more adequate supply from Cura Creek.

MILLIGAN PROSPECT.

The Milligan prospect, owned by H. L. Remmel, was not visited by the writer. According to report no work has been done on it during the last 25 or 30 years. Penrose supplies the following description of this prospect:[73]

The Milligan tract is in 14 N., 5 W., section 6, the northeast quarter of the northwest quarter, on the northern escarpment of the hills that lie at the headwaters of Cave, Coon, and North Dota creeks. A few scattered fragments of manganese ore lie on the slopes, associated with loose chert and masses of St. Clair [Fernvale or Kimmswick] limestone. Frequently loose masses of a bright, glossy iron ore (limonite), of a brown or black color, occur with the manganese.

ELIZA PATTERSON PROSPECT.

The Eliza Patterson prospect is in the NE. ¼ sec. 1, T. 14 N., R. 6 W., 1¼ miles west-southwest of Hickory Valley. The principal opening is a shaft 10 feet or more deep, on the top of a hill, and it was partly filled with water at the time of visit (May 9, 1918). The material on the dumps and that exposed above the water in the shaft consisted of red and brown clays, parts of which contain many angular fragments of chert. Irregular masses and veins of brown iron oxide and ferruginous manganese oxide occur both in the cherty clay and in the clay that is free from chert. These oxides have replaced the clays, and parts of the masses and veins therefore in-

[73] Penrose, R. A. F., jr., Manganese—its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, p. 239, 1891.

clude chert fragments. Veinlets of barite, which occur as needle-like radiating crystals, were observed in some pieces of the oxides on the dump. The shaft was dug in 1917, and a small quantity of manganese ore is said to have been sold.

A few very shallow pits have been dug through a surficial bed of chert fragments and pebbles and then into red clay at other places on this tract. Two small piles of psilomelane were observed near some of the pits.

The extent of the manganese-bearing clays at this locality has not been fully tested, but the absence of limestone exposures near the openings suggests that considerable clay overlies the limestone.

MILLIGAN-PERRIN PROSPECT.

The Milligan-Perrin prospect is in the northern part of sec. 11, T. 14 N., R. 6 W., one-fourth of a mile south of Coon Creek and 3½ miles north-northwest of Pfeiffer. The first work at this locality was done about 30 years ago; the next was done by W. H. Denison in 1917. At the time of visit (May 8, 1918) work was being done by George Milligan and Frank Perrin, the owners. Some ore has been removed from the openings and shipped, but the quantity is not known.

A number of pits and cuts, none of which exceed 9 feet in depth, have been dug in chocolate-colored manganese-bearing clay, whose surficial portion contains chert fragments and pebbles. The clay and the manganese ore are a residue from the decomposition of the Fernvale limestone, of which there are exposures both on the surface and in some of the openings. The ore consists mainly of psilomelane and hausmannite and occurs as small pieces and large irregular masses, not only in the clay but also in the Fernvale limestone. At some places it is associated with considerable red iron oxide and ferruginous manganese oxide.

SCHLIEPER MINE.

The Schlieper mine is on the headwaters of Cave Creek, in the SE. ¼ NE. ¼ sec. 11, the E. ½ SE. ¼ sec. 11, the SW. ¼ NW. ¼ sec. 12, and the NW. ¼ SW. ¼ sec. 12, T. 14 N., R. 6 W., 3¼ miles north of Pfeiffer. It was operated about 30 years ago by E. H. Woodward & Co., who, according to M. W. Reves, an old resident of the region, mined several hundred tons of manganese ore. At that time the property was known as the Privet tract. Work has been done recently by Gus Schlieper, the owner, and 36 tons of ore had been mined and marketed before the time of visit (May 6, 1918). Since the writer left the region in June, 1918, the property has been sold to the Oklahoma-Kansas Mining Co., which has done very little or no work on it.

The openings are small and are scattered along the hollow at the head of Cave Creek for a distance of almost half a mile.

A few pits and shafts as much as 23 feet deep are on the gentle east slope just west and south of Mr. Schlieper's house. They pass through 2 to 4 feet of surficial cherty loam and next penetrate brown clay, the upper part of which contains fragments of brown porous chert. The surficial chert has been derived from the weathering of the Boone chert, which caps the hills in the vicinity, but the brown porous chert and the clay containing it have been derived from the weathering of the Fernvale limestone. Any undecomposed parts of this limestone that may still exist at this locality are probably overlain by considerable clay, for none of the limestone is exposed on the surface and none was found in the openings. The full thickness and areal extent of the clay have not been determined. The manganese ore consists of masses of psilomelane, some weighing as much as 700 pounds, which are irregularly distributed through the clay and through a part of the surficial loam. Pyrolusite also occurs in the clay but in quantity far too small to be of economic importance. Some of the psilomelane has partly or entirely replaced many of the fragments of porous chert. The following analysis, supplied by S. W. Deener, was made of a sample of ore collected at this place by William Rock:

Analysis of manganese ore from the Schlieper mine.

[C. A. Graves, analyst.]

Manganese (Mn)	63.81
Iron (Fe)	2.18
Phosphorus (P)	.128

The old openings known as the Privet mine are on the east side of the narrow valley, about a quarter of a mile south of those described above. They are badly caved, but work has been done in some of them recently and a few new openings have been made in the vicinity. They consist of open cuts and pits only a few feet deep and are in brown, red, and yellow clays, whose surficial portion contains chert fragments. Although a few outcrops of the Fernvale limestone occur in the vicinity, this limestone has doubtless undergone considerable decomposition, thus yielding large quantities of clay, but the thickness and areal extent of the clay have not been determined. The manganese ore, which consists mainly of psilomelane and hausmannite, occurs irregularly distributed through the clay as fine particles ("wash ore") and larger masses ("lump ore"). Only the "lump ore" has been mined and shipped.

A shaft 37 feet deep has been dug near the base of the hill on the east side of the valley, about one-eighth of a mile south of the Privet mine. Water which rose in the shaft to a depth of 17 feet stopped further work in it. A brown ore-bearing clay was found on one side of the shaft and a mass of chert fragments on the other side. The shaft is said to have yielded 600 pounds of "lump ore" before it was abandoned.

OZARK MINE.

The Ozark mine, also known as the Brack Gray mine, is composed of three groups of workings on the headwaters of Cave Creek, 3½ miles north of Pfeiffer. Part of the land on which the mine is situated is described by Penrose[74] as the Edward Hunt tract. Mining was done at one of these groups of workings about 30 years ago by the Keystone Manganese & Iron Co., which mined and shipped one or two carloads of ore, and mining was also done at that time at another group by E. H. Woodward & Co., who mined and shipped two carloads of ore. The next work was done by Brack Gray, beginning in 1916, and the production by him before the time of visit (May 6, 1918) was about 100 tons. After the time of visit the mine was sold to the Ozark Manganese Co., of Superior, Wis., which operated it for a few months in 1918.

One group of workings is in and near the head of a hollow in the SW. ¼ NE. ¼ sec. 11, T. 14 N., R. 6 W. The hills on either side of the hollow are capped with the Boone chert, and their slopes are strewn with débris from it at least a few feet deep. The discovery of manganese ore in the brown clay beneath the chert débris was made in one of several sink holes that caved in May 8 or 9, 1882. Several shafts as much as 55 feet deep were sunk by the Keystone Manganese & Iron Co. near the caved-in sink hole, and a few pits and one shaft have been dug recently near the shafts and others at a locality 300 feet northeast of them. Some of the pits passed through only loose chert débris 2 to 4 feet thick before they reached the brown manganese-bearing clay, but other pits and the shafts passed through 5 to 30 feet of the Boone chert in steeply dipping layers before they penetrated the manganese-bearing clay. The clay is a residue from the decomposition of the Fernvale limestone, the only observed exposure of which was in one of the shafts. The decomposition of this limestone has formed hollows and underground channels in it, as is attested by the sink holes, and this removal of supporting material has caused the Boone chert to settle so as to conform with the irregular though clay-covered surface of the limestone. One sink hole on the top of the hill shows that the Fernvale has undergone decomposition not only in the hollow but in the hills as well. The depth and areal extent of the manganese-bearing clay have,

[74] Penrose, R. A. F., jr., op. cit., pp. 237–238.

however, not been fully determined. The manganese ore observed at the time of visit consisted of psilomelane and hausmannite and smaller quantities of wad. It occurs in the ore-bearing clay and its surficial cherty portion as slabs and irregular masses ranging from fine particles ("wash ore") to boulders said to weigh 300 pounds. After the larger pieces have been picked out by hand the clay is allowed to dry on the dumps and is screened by means of a screen with ⅝-inch perforations to recover the pieces of ore above that size.

The second group of workings, which consists of pits, cuts, and shafts, has been dug over an area of about 1 acre in the bottom and at the base of the slope on the east side of the hollow in the S. ½ NW. ¼ sec. 11, T. 14 N., R. 6 W., almost half a mile west of the workings described above. The Boone chert caps the hills on either side of the hollow. Débris a few feet thick that is derived from it covers the slopes, and wash, also derived from it, has filled the bottom of the hollow to a depth of probably 20 feet. Manganese ore at this locality was first discovered in brown clay in the bottom of a well beneath this chert filling. The openings made by E. H. Woodward & Co. and Brack Gray yielded ore from similar clay. The clay is a residue from the decomposition of the Fernvale limestone, and although none of this limestone is exposed on the surface a few masses of it were found in the openings. The manganese ore consists mainly of psilomelane and hausmannite and occurs as both "lump ore" and "wash ore." Most of the ore shipped from this locality has been "lump ore" that has been hand picked from the clay. The clay after the picking still contains considerable "wash ore," and it is dried and screened in order to recover some of the smaller pieces of ore. Some of the psilomelane contains cracks lined with a film of velvety wad and a small quantity of it has a botryoidal form. A pocket containing 1 or 2 pounds of pyrolusite was observed in the clay at one place. The largest mass of ore thus far discovered is said to have been a ledge 6 feet thick and 20 feet long, which yielded 2 carloads of ore.

The third group of openings, which is farther south, was not visited.

Photographs that have been supplied by W. R. Crane show the manganese-bearing clay lying between the Fernvale limestone and the folded and shattered ledges of the Boone chert and also show the occurrence of large irregular masses of manganese ore in the clay at this mine. (See Pls. IX, *B*, and XVI, *B*.)

The first analysis given below is of a carload of ore shipped from the Ozark mine in 1917 to the Tennessee Coal, Iron & Railroad Co., and the other analyses represent the composition of six carloads of ore that was mined and shipped in 1918 by the Ozark Manganese Co. to the Tennessee Coal, Iron & Railroad Co.

Analyses of manganese ore from the Ozark mine.

	1	2	3	4	5	6	7
Manganese (Mn)	44.03	54.97	50.78	46.38	46.47	48.36	51.59
Iron (Fe)	7.76	3.51	6.93	....	9.17	6.98	4.60
Phosphorus (P)	.25	.15	.092	....	.096	.50	.15
Silica (SiO_2)	7.82	4.85	4.67	5.41	5.39	3.37	6.86
Alumina (Al_2O_3)	3.39	1.94	2.64	....	3.72	2.71	2.31
Moisture	....	5.29	2.73	7.00	7.63	9.88	9.50

SEARCY MINE.

The Searcy mine, also known as the Trent mine, Bill-Jim mine, and Adler mine, is on the headwaters of Cave Creek, in the SE. ¼ SE. ¼ sec. 10 and the NE. ¼ NE. ¼ sec. 15, T. 14 N., R. 6 W., 3 miles north-northwest of Pfeiffer. It was worked between 1881 and 1887 by E. H. Woodward & Co.,who sunk two large pits to a depth of 20 feet and a shaft to a greater depth.[75] The production by this company is reported to have been 1,200 tons of "lump manganese ore." The mine was next operated for a few years in the nineties through shafts by Simon Adler, who mined and shipped 200 tons of "lump ore." The next mining was done by N. A. Adler, the present owner, beginning in 1916. The production in 1916 was 325 tons, and in 1917 it was 850 tons. Most of this production was "lump ore," but part of it was dry screened and part was concentrated at a small washing plant which is just below the Searcy Spring, southeast of the mine. In the spring of 1918 the mine was leased to the Oklahoma-Arkansas Oil & Mining Co., and was soon re-leased to the Bill-Jim Mineral Co., which erected a log washer. The mine was not operated, however, by the latter company, but later in 1918 it was re-leased to Logan Rives, who operated it for a short time.

The workings, which consist of many shallow pits and cuts, tunnels 200 to 300 feet long, and shafts as much as 60 feet deep are on the west side of a southward-trending valley, and although they are not represented on the accompanying map on account of their badly caved condition at the time of visit (May and June, 1918) most of them are situated within the areas represented as containing proved manganese deposits. (See fig. 8.) The workings penetrate a chocolate-brown manganese-bearing clay after they pass through a yellow cherty loam a few feet to many feet thick. This clay is said to average 15 feet over the ore-bearing area on the hill north-

[75] Penrose, R. A. F., jr., op. cit., pp. 232–234.

west of the washer and 5 or 6 feet thick in the larger of the two ore-bearing areas south of the washer. The clay and the ore that it contains are a residue from the decomposition of the Fernvale limestone. The surface of the limestone overlain by the clay is very

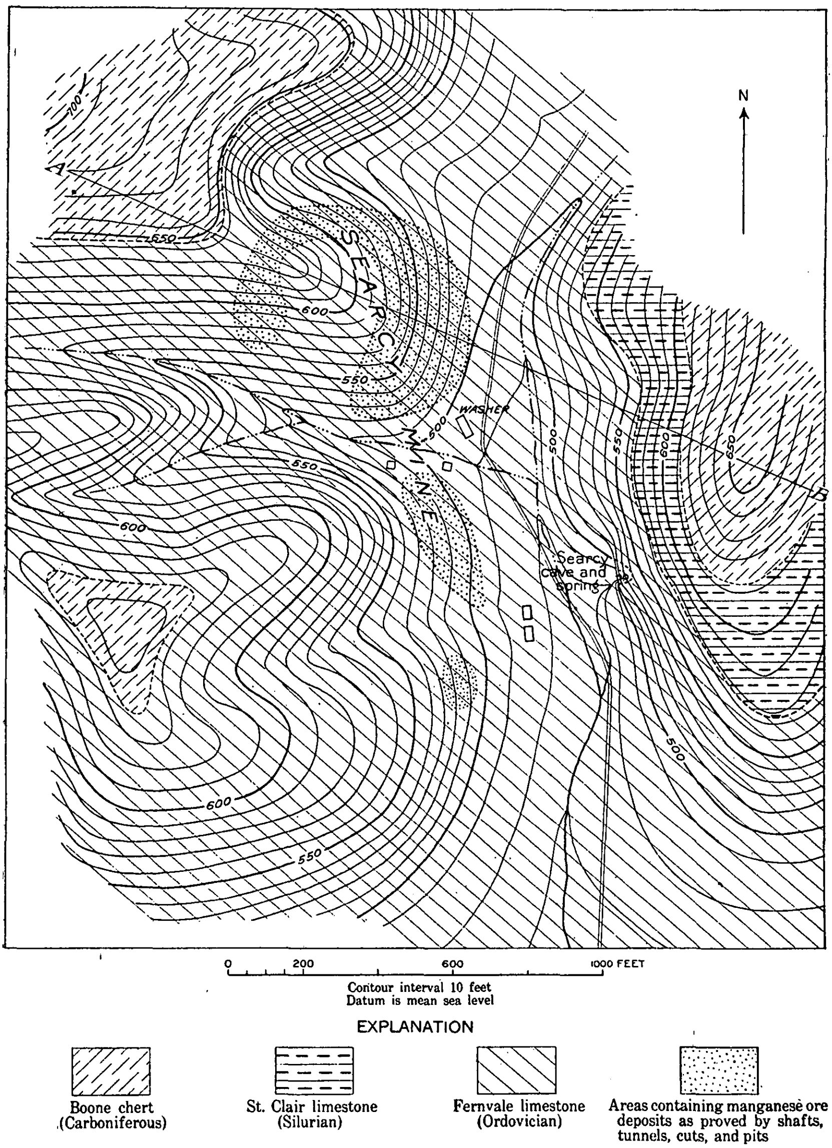

FIGURE 8.—Geologic map of Searcy mine. Surveyed by H. D. Miser with plane table and telescopic alidade in June, 1918. *A, B,* Line of section in figure 4 (p. 62).

irregular. The ledges and boulders of the limestone revealed in a few of the openings are gray for the most part, but in places they are purplish red, and some of the limestone contains seams and nodules of manganese oxides from one-third of an inch to 3 inches thick.

The occurrence of the manganese ore in the limestone and in the overlying residual clay is represented in figures 4 and 9.

Although the Fernvale limestone is thus deeply decayed on the west side of the valley, it is but little decayed on the east side, where it is exposed in bluffs and over most of the adjoining hill slopes. The Searcy Cave, from which the Searcy Spring issues, is in this limestone. On the east side of the valley the limestone is everywhere gray, and neither it nor its scanty residual clay contain any visible quantity of manganese oxide. Furthermore, the Fernvale on the east side of the valley is overlain by 50 feet of pinkish-gray St. Clair limestone, whereas the St. Clair is apparently absent on the west side of the valley. The Boone chert caps the hills near the mine, and much of it, especially on the west side of the valley, occurs as loose débris on the slopes or as steeply dipping broken beds that have settled below their original position to conform with the irregular clay-covered surface of the limestone.

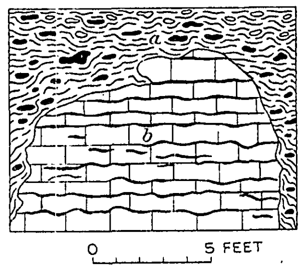

FIGURE 9.—Section showing manganese ore in Fernvale limestone (*b*) and in the overlying residual clay (*a*) at the Searcy mine. The unshaded masses in the clay, near the top of the section represent chert fragments. (After Penrose.)

Manganese ore has been proved by prospecting and mining to occur in minable quantity in the three areas represented on the map (fig. 8). Although much prospecting has been done outside these areas, no other deposits or extensions of the proved deposits have been found, which may be due in part to the shallowness of the pits and shafts. The ore consists of psilomelane and smaller quantities of hausmannite and manganite and occurs as small and large masses irregularly distributed through the clay. Most of the masses are irregular in shape; only a few have a botryoidal form. The smallest pieces, "wash ore," a fraction of an inch in diameter, form a considerable portion of the ore-bearing clay. The larger masses, "lump ore," some of which have been found weighing 8 to 10 tons, have been sorted out, and many of the smaller ones, more than half an inch in diameter, have been separated from the clay and from the finer particles by dry screening. Some of the ore-bearing clay ("wash dirt") from which the "lump ore" had been hand picked has been shipped without treatment, and some was, in 1917, treated in a small washing plant that was equipped with a trommel screen. Two grades of concentrates, classed as "washed ore" and "tailings," were obtained at the washing plant. No records were kept to show the ratio of material treated to the concentrates recovered. The following analyses represent the composition of carload lots of these different classes of ore:

Analyses of manganese ore from the Searcy mine.

	1	2	3	4	5	6	7	8	9	10
Manganese (Mn)	52.71	21.22	24.64	46.61	45.46	40.17	40.03	39.49	47.40	52.23
Iron (Fe)	4.15	8.83	12.5	6.70	5.05	8.83	9.86	10.34	7.02	4.25
Phosphorus (P)	.131	....	....	.27	.13	.16	.29	.32	.18	.22
Silica (SiO_2)	3.20	....	....	6.33	13.78	12.05	10.50	10.02	7.14	5.38
Alumina (Al_2O_3)	....	....	....	2.92	2.64	5.26	4.89	4.75	4.76	2.62

	11	12	13	14	15	16	17	18	19	20
Manganese (Mn)	49.02	48.06	48.13	47.24	48.96	53.05	48.68	48.20	47.65	47.47
Iron (Fe)	4.72	4.80	5.37	5.91	7.45	13.57	3.71	4.68	4.85	5.53
Phosphorus (P)	.15	.26	.22	.18	.32	.15	.14	.22	.27	.30
Silica (SiO_2)	8.54	6.59	7.02	6.43	5.31	4.33	5.22	4.40	6.10	5.17
Alumina (Al_2O_3)	3.16	3.06	2.89	2.76	3.07	2.63	2.48	2.91	2.97	3.24

1. "Lump ore" shipped in 1897 to the Carnegie Steel Co.
2. "Wash dirt" from dumps.
3. "Tailings" from washer, shipped in 1917 to the Tennessee Coal, Iron & Railroad Co.
4. "Washed ore" from washer, shipped in 1917 to the Tennessee Coal, Iron & Railroad Co.
5–8. "Screened ore" shipped in 1917 to the Tennessee Coal, Iron & Railroad Co.
9–20. "Lump ore" shipped in 1917 to the Tennessee Coal, Iron & Railroad Co.

MATHENY MINE.

The Matheny mine is on the north side of Cave Creek, near the line between secs. 11 and 14, T. 14 N., R. 6 W., 2¾ miles north of Pfeiffer. The land is owned by Mrs. E. Diener, and work has been done by I. J. Matheny, the lessee, beginning in February, 1918. About 30 tons of manganese ore had been shipped before the time of visit (May 10, 1918).

A cut trending northwestward and one trending northeastward, each 75 feet long, which connect in a T, have been excavated to a maximum depth of 12 feet in yellow, red, and brown clays on a gentle south slope, and a tunnel 10 feet long has been driven in similar clays in the side of one of the cuts. Many pebbles and fragments of chert occur in the surficial parts of these clays, and a few chert fragments occur in other parts of them. Masses of psilomelane which range in size from fine particles to boulders weighing 500 pounds are irregularly distributed through the clays from the surface to the bottom of the workings and how much deeper they extend has not been determined. Although the clays are a residue from the decomposition of limestone no limestone was found in the workings, and none is exposed near by on the surface except to the southeast, in the north bank of Cave Creek, which is 55 feet below the bottom of the cut. Wad is associated with the psilomelane, and some of the chert fragments in the clays have been partly replaced by manganese oxide.

DUNEGAN PROSPECT.

The Dunegan prospect is on a steep northwest hill slope on the south side of Cave Creek, in the SW. ¼ NE. ¼ sec. 14, T. 14 N., R. 6 W., 2½ miles north of Pfeiffer. Some work was done here 25 or 30 years ago. Later work has been done at several times, beginning in November, 1917, by different persons, including J. G. Keppler, I. J. Matheny, and D. C. Dunegan, who is the present owner and operator. The production by these operators is said to have been 30 tons before the time of visit (May 10, 1918).

The workings consist of several shallow pits and cuts and a drift 30 feet long. They extend along the hill slope for about one-eighth of a mile and have been dug in chocolate-colored clay, whose surficial portion contains chert fragments and pebbles.

The clay is a residue from the weathering of the Fernvale limestone, of which exposures are common both on the surface and in the workings. The manganese oxides, wad and psilomelane, are found in the clay, and manganese oxide has partly replaced a few large boulders of porous chert.

BALES MINE.

The Bales mine is 2¼ miles north-northwest of Pfeiffer and consists of two groups of openings on a tract of land which comprises the W. ½ NW. ¼ sec. 13, and the SE. ¼ NE. ¼ sec. 14, T. 14 N., R. 6 W. It was operated about 1909 by the Oliver Iron Mining Co., the owner, and the production at that time is reported to have been 200 tons of manganese ore. The mine has been idle since then.

Only one of the groups of openings was visited by the writer. It comprises pits, cuts, a tunnel 50 feet or more long, and a shaft 20 feet deep connecting the back end of the tunnel with the surface. These openings have been made within about an acre on the southeast point of a low southeastward-trending spur. After they passed through the surficial chert débris, which is shown in the shaft to be 10 feet thick, they penetrated a dark-colored porous, soft though firm wad, through which irregular masses of braunite are scattered. The wad shows a thickness of about 15 feet in the shaft and in the tunnel. In fact, most of the tunnel and side drifts are in it. It would likely contain between 20 and 30 per cent of manganese after the larger masses of braunite were separated from it.

MOYER MINE.

The Moyer mine is on the south side of Cave Creek, in the SW. ¼ sec. 14, T. 14 N., R. 6 W., 2¼ miles north-northwest of Pfeiffer. It was worked on a small scale 25 to 30 years ago, and it was next worked in 1916 by S. N. Givens, who mined 30 tons of manganese ore. Since 1916 it has been worked by A. W. Moyer, the owner, who had mined 50 tons of ore before the time of visit (May 10, 1918). Since the time of visit the mine has been purchased by P. J. Concannon, who did some work in it but shipped no ore.

The openings, which are small pits and cuts, short tunnels, and shafts as much as 35 feet deep, have been dug here and there over an area of about 5 acres on the lower part of a steep southwest hill slope. After they pass through a few inches to 15 feet or more of chert débris or of chert in steeply dipping layers they penetrate red and chocolate-colored clays, through which masses of manganese oxides varying in size from fine particles to boulders weighing 500 pounds are irregularly distributed. The clays as well as the manganese oxides are a residue from the decomposition of the Fernvale limestone, which is not exposed on the surface but which was found in some of the openings. They contain a few boulders and ledges of porous brown chert, which are partly replaced by manganese oxide. The marketed manganese ore comprised a high-grade ore, consisting mainly of psilomelane but partly of hausmannite, both hard minerals, and a low-grade ore, consisting of the soft mineral, wad.

SILBERSTEIN PROSPECT.

The Silberstein prospect consists of pits and cuts made at different places on the Mrs. Searcy tract, in sec. 14, T. 14 N., R. 6 W., 2¼ miles north-northwest of Pfeiffer. It was being operated at the time of visit (June 26, 1918) by E. A. Silberstein, the owner. The production before that time is said to have been 25 tons of manganese ore.

An east-west cut 100 feet long and a few feet deep has been dug in chocolate-colored manganese-bearing clay, on the northwest slope of a hill, in the NE. ¼ SW. ¼ sec. 14. This clay contains large and small masses of hard and soft manganese oxides, and it overlies the irregular surface of the Fernvale limestone, which is revealed at places in the cut. Several other openings as much as 20 feet deep have been made on the southwest slope of a hill in the NE. ¼ SW. ¼ sec. 14, and they have yielded ore similar to that at the cut described above. These openings are just northwest of the Moyer mine. A pit by the roadside, southeast of the last-described openings, reveals the presence of chocolate-colored manganese-bearing clay. Several very shallow pits have been dug in cherty manganese-bearing clay, on the west point of a hill near the east side of the Mrs. Searcy tract, but the clay is probably thin, as outcrops of the Fernvale limestone are numerous. The ore observed at these pits at the time of visit consisted of small fragments of braunite.

The openings described above prove the presence of manganese ore on this tract, but further prospecting will be required before any reliable estimate of available tonnage can be made.

J. A. REVES MINE.

The J. A. Reves mine is on the south side of Cave Creek, in the NW. ¼ sec. 23, T. 14 N., R. 6 W., 2 miles north-northwest of Pfeiffer, and is on land whose agricultural right is owned by J. N. Smith and whose mineral right is owned by J. A. Reves. It was operated between 1890 and 1895 by M. W. Reves for the Keystone Manganese & Iron Co., which mined and shipped 300 tons of hand-picked "lump" manganese ore that is said to have contained between 45 and 48 per cent of manganese. It then lay idle until April, 1918, when work was begun by J. A. Reves, who had mined only a few tons before the time of visit (May 10, 1918).

The workings, which consist of shallow pits, have been dug in brown and red manganese-bearing clays over an area of a few acres. On the east hill the clays are overlain by a few feet or more of chert either as loose débris or as steeply dipping layers, and they overlie the irregular surface of the Fernvale limestone, of which there are a few exposures in the vicinity of the workings. On the west hill, where most of the shipped ore has been mined, the chert overburden is thinner, and exposures of the Fernvale limestone are more numerous. The manganese ore occurs as both small and large masses irregularly distributed through the clays. Many of the masses are compact and hard and include psilomelane and hausmannite; but some of them consist of soft though firm wad, are porous, and contain considerable clay.

HENLEY MINE.

The Henley mine is in the S. ½ NW. ¼ sec. 14, T. 14 N., R. 6 W., 2¾ miles north-northwest of Pfeiffer. It was worked about 30 years ago by the American Manganese Co. and the Keystone Manganese & Iron Co. The quantity of ore mined and shipped by these two companies is not known. The next work was begun in May, 1917, by A. S. Wilson, who was succeeded in the fall of 1917 by the Batesville Commercial Mining Co. The operator at the time of visit (May 10, 1918) was George Reves, but he has since been succeeded by Barbee & Malsbury. The total production from May, 1917, to May, 1918, is said to have been about 25 tons.

The workings are on steep south and west hill slopes. Those on the south slope are shallow cuts and inclined drifts as much as 30 feet long and are partly in clay and partly in chert overlying the top of the Fernvale limestone. They are all about 150 feet above Cave Creek, and they extend along the slope for a distance of almost

500 feet. The Fernvale limestone is exposed in some of them, and it is overlain by 6 to 12 inches of chocolate-colored clay, which in turn is overlain by a few inches to 3 feet of shaly red, yellow, and brown clay. These clays are in part a residue from the decomposition of the Fernvale limestone and in part from the decomposition of a bed of shale overlying it, and they contain pockets and lenses of psilomelane, hausmannite, and wad. The ore-bearing clays and the overlying Boone chert dip in different directions at different places, to conform with the irregular limestone surface that has been produced by the partial decomposition of the limestone. At one place 1 to 2 feet of the highest part of the Fernvale limestone has been largely replaced by iron and manganese oxides.

The largest opening on the west slope of the hill is 75 feet long north and south and reveals the following section:

Section in cut at Henley mine.

	Ft.	in.
Boone chert:		
Thin beds of chert lying horizontal	12	
Yellow platy clay with a thin layer of greenish-gray earthy limestone at the base	2	
Conglomeratic ferruginous earth; rests upon slightly irregular surface of Fernvale limestone	1	4
Fernvale limestone:		
Rusty limestone; contains thin seams and irregular masses of manganese oxides	Few feet.	

Four or five carloads of manganese ore is said to have been mined and shipped from this cut about 30 years ago, but no work has been done in it recently. The ore was mined from clay, and both clay and ore are obviously residues from decomposition of the Fernvale limestone.

Several badly caved pits and shafts farther north and lower on the slope of the west hill show the occurrence of manganese ore in both small and large masses in clay which is overlain by considerable chert débris that has rolled or settled down the slopes.

The following analyses, supplied by E. A. Silberstein, the trustee of the mine, show the composition of samples of the manganese ore from the openings on the south slope of the hill:

Analyses of manganese ore from Henley mine.

[C. A. Graves, analyst.]

	1	2
Manganese (Mn)	55.65	41.56
Iron (Fe)	2.30	8.86
Phosphorus (P)	.107	.187
Silica (SiO_2)	6.20	4.15

1. Selected specimen.
2. Average sample from seven pits.

G. A. WILSON MINE.

The G. A. Wilson mine, formerly known as the Lone Star mine, is in the NW. ¼ NW. ¼ sec. 14, T. 14 N., R. 6 W., 2¾ miles north-northwest of Pfeiffer, and is just north of the Henley mine. It was operated 30 years ago by the American Manganese Co., and a few years later by the Keystone Manganese & Iron Co., both of which shipped several hundred tons of hand-picked "lump" manganese ore. Work has been done at different times in recent years by several persons, but the quantity of ore mined by them has been small.

The workings are on a steep west hill slope and extend from the base of the hill 100 feet or more up the slope. They consist of one large cut, several small cuts, and a few shafts as much as 27 feet deep, all badly caved at the time of visit (May 10, 1918). They penetrate manganese-bearing clay, which is overlain by a few inches to several feet of chert débris. Although this clay and the manganese ore it contains are residues from the decomposition of the Fernvale limestone no exposures of this limestone are observed in the openings, and none occur on the surface near them. The manganese oxides observed on the dumps are psilomelane and hausmannite, which occur in particles a fraction of an inch in diameter ("wash ore") and in larger masses.

M. W. REVES PROSPECT.

The M. W. Reves prospect is on the north side of Cave Creek, in the N. ½ sec. 15, T. 14 N., R. 6 W., 2¾ miles north-northwest of Pfeiffer. A few very shallow pits have been dug in cherty, clayey loam on and near the south point of a hill, and from them altogether not more than 2½ tons of manganese ore have been taken out and shipped. If they had been dug deeper they would have doubtless penetrated manganese-bearing clay that is free from chert fragments. The presence of only a few outcrops of the Fernvale limestone on the slopes and of a sink hole on the crest of the hill indicate that this limestone has undergone extensive decomposition, which has yielded a considerable quantity of such clay. The few pieces of manganese oxide found on the dumps at the time of visit (May 14, 1918) consisted of hausmannite, psilomelane, and soft though firm wad.

G. D. REVES TRACT.

The G. D. Reves tract comprises the N. ½ NE. ¼ sec. 22, part of the NE. ¼ NW. ¼ sec. 22, and part of the S. ½ SE. ¼ sec. 15, T. 14 N., R. 6 W., 2½ miles northwest of Pfeiffer. No prospecting has been done on the tract, but pieces of steel-blue psilomelane, some of which weigh 3 or 4 pounds, have been found on the edge of a low terrace on the north side of Cave Creek. These pieces, like the chert fragments and pebbles which occur in the loam underlying the terrace, were carried to their present position by Cave Creek when its channel was higher than it is now.

Small masses of iron oxide were observed by the writer on the surface on the hill slopes south of Cave Creek, but no manganese oxide was observed. The hills are capped by the Boone chert, and the Fernvale, Kimmswick, and Plattin limestones are exposed at a few places on the slopes, but at most places they are overlain by clay whose surficial portion contains chert fragments.

OLIVER IRON MINING CO.'S PROSPECT.

The Oliver Iron Mining Co.'s prospect is on the north side of Cave Creek, 2¾ miles northwest of Pfeiffer and is in either the NE. ¼ NW. ¼ Sec. 22 or the SE. ¼ SW. ¼ sec. 15, T. 14 N., R. 6 W. It consists of a few badly caved shallow cuts and some shafts, as much as 60 feet deep, dug many years ago at different places over an area of about an acre on the lower part of the east slope of a hill. They penetrated a chocolate-colored clay which is overlain at the surface by chert débris. This clay is a residue from the weathering of the Fernvale limestone and possibly the Kimmswick and Plattin limestones, but none of these limestones are exposed on the surface near the openings. The only manganese ore observed at the time of visit consisted of fine particles of psilomelane and hausmannite, which occur in considerable quantity in the clay.

MARTHA THOMPSON MINE.

The Martha Thompson mine is in the SW. ¼ SW. ¼ sec. 15, T. 14 N., R. 6 W., on the east slope of a hill north of Cave Creek, 3 miles northwest of Pfeiffer. It was first worked 30 years ago by M. W. Reves, who says that he mined and shipped nine cars of manganese ore, and it was next worked by Capt. Vance, beginning in the fall of 1917, but the production by him before the time of visit (May 11, 1918) was only 12 tons. The workings consist of a few shallow pits and cuts that have been dug in chocolate-colored manganese-bearing clay. This clay lies in channels and hollows in the Fernvale limestone, of which there are a few exposures, and is overlain by a few inches to several feet of chert débris. Manganese ore occurs in the clay both as fine particles and large masses. The larger masses have been hand picked from the clay and shipped, but the smaller particles have been left in the clay on the dumps. The small particles observed at the time of visit consist mainly of psilomelane and hausmannite.

CLIMER PROSPECT.

The Climer prospect consists of three openings made in 1917 by Captain Vance on a northeast hill slope in the NW. ¼ SW. ¼ sec. 15, T. 14 N., R. 6 W., 3 miles northwest of Pfeiffer. One of the openings, a shaft, passed through 5 feet of clay containing chert fragments and then penetrated to a depth of 20 feet a chocolate-colored clay in which masses of hard manganese oxide are said to have been found. A north-south cut 30 feet long and a tunnel 10 feet long running from the south end of the cut have been dug in mealy manganiferous brown to black clay (wad), which is mixed with much red clay and many chert fragments at and near the surface. Another cut 20 feet long is in similar manganiferous clay (wad), which is concealed at the surface by red clay containing chert fragments. Masses of hard manganese oxides were found in the manganiferous clay. Most of these masses observed on the dump at the time of visit (May 11, 1918) were composed mainly of compact psilomelane, but some of them are porous and contain considerable clay. Manganese ore is said to have been plowed up in a field on the hill slope below the openings.

The absence of limestone exposures on the surface in this vicinity and the fact that no limestone was found in the openings suggest that the underlying limestone is concealed by a thick covering of clay, but prospecting has not been extensive enough thus far to determine its depth and areal extent or the quantity of manganese ore it contains.

WALTER CHINN PROSPECTS.

The Walter Chinn prospects are on the Walter Chinn tract, 2½ miles west-northwest of Pfeiffer, which comprises the W. ½ NW. ¼ sec. 22, T. 14 N., R. 6 W. Some work was done on this tract 15 to 20 years ago and some within the last few years, but very little altogether. A cut a few feet deep has been dug recently in chocolate-colored clay on the gentle south slope of a hill north of Cave Creek, and it is said to have yielded a ton of "lump" manganese ore. The total depth of the clay is not known, for the cut and a few old badly caved cuts near by do not appear to have passed entirely through it. No limestone is exposed in the vicinity of the cuts, but the occurrence of outcrops of the Fernvale limestone at about the same elevation a quarter of a mile northeast and almost half a mile southwest suggests that this limestone underlies the clay. The clay is overlain by a cherty loam which in places is several feet thick.

A northwestward-trending cut 60 feet long and a few feet deep is on the southwest side of a small hollow one-eighth of a mile south of

Cave Creek and 140 feet above the creek. It has been blasted in horizontal rock beds, of which the following section was measured:

Section in cut on Walter Chinn tract.

	Feet.
Boone chert:	
Massive chert interbedded with a small quantity of clay	6
Red clay containing a few chert layers	1½–2½
Hard, compact, greenish-gray limestone	Few inches–2½
Weathered shale; contains nodules that appear to be phosphatic	Few inches.
Fernvale limestone:	
Cross-bedded gray limestone; contains very small pockets and lenses of manganese oxide near the top; at the northwest end of the cut the limestone is red and contains red iron oxide and hausmannite and thin veins of calcite	4

The hausmannite and iron oxide mentioned in the above section have only partly replaced the Fernvale limestone, and for this reason fragments of these oxides contain more or less calcium carbonate. After almost one carload of manganese-bearing limestone had been quarried the manganese content of the limestone became too low for further mining to be profitable. The manganese-bearing limestone at this locality is similar to that at the W. A. Chinn cut, which is described on pages 130–131.

O'FLINN PROSPECT.

The O'Flinn prospect is on the T. J. Walbert tract, in the SW. ¼ NE. ¼ sec. 22, T. 14 N., R. 6 W., 2¼ miles northwest of Pfeiffer, in a depression on the southwest slope of a hill. The depression is circular, from 150 to 200 feet in diameter, and is surrounded by steep slopes except on its southwest side. A few tons of ferruginous manganese ore have been removed from shallow pits. Some of these pits reveal 3 feet or less of brown weathered Cason shale which contains "buttons" and shaly masses of ferruginous manganese oxide and iron oxide and some pits reveal ledges of the Fernvale limestone that are blackened with asphalt and that contain veinlets and small pockets of asphalt. A soft manganese oxide found in one pit contains many doubly terminated quartz crystals which are a fraction of an inch in their longest dimension.

A shaft at this locality is described by Penrose as follows:[76]

A shaft was once sunk in the St. Clair [Fernvale] limestone here in search of gold and silver but has been abandoned. It is now mostly filled with water but is said to be 103 feet deep. Many masses of a pink St. Clair [Fernvale] limestone, containing inclusions of red and green clay and cavities lined with crystalline quartz and white calcite, are on the dump. Veins of calcite also traverse the limestone bed, but the rock from which the gold and silver is

[76] Penrose, R. A. F., jr., Manganese—its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, pp. 231–232, 1891.

said to have been taken is a hard, massive, dun-colored quartz, of a somewhat granular structure, frequently containing small cavities lined with red, transparent quartz crystals. This rock is said to have lain almost horizontally and to have been 18 inches in its thickest part. It probably represents a lenticular bed in the St. Clair [Fernvale] limestone.

The Fernvale limestone crops out in heavy ledges on the steep hill slopes that partly surround the circular covelike depression at this locality, and the Kimmswick and Plattin limestones crop out as heavy ledges on the steep slope and in the bluff southwest of it. The Cason shale described above is present only in the depression, and as it occurs lower than the beds of Fernvale limestone exposed on the hill slopes that partly surround the depression it is not in place. Both it and possibly some of the limestone beneath it apparently represent the roof of an old cave that has fallen in.

WALBERT MINE.

The Walbert mine is 2 miles northwest of Pfeiffer, on the T. J. Walbert tract, which comprises the S. ½ NE. ¼ and the SE. ¼ NW. ¼ sec. 22, T. 14 N., R. 6 W. Work has been done here beginning in August, 1917, by Capt. Vance and later by the Vance Mining Co., of which Capt. Vance became a member. The production before the writer's visit (May 13, 1918) was two cars of manganese ore, one of which, according to Capt. Vance, contained soft low-grade ore with 30 per cent of manganese and the other a hard high-grade ore with 55 per cent of manganese.

The mine consists of two openings; one of these, a cut by the roadside at the base of a steep hill slope, has a face 15 feet high at its inner end, and a shaft 30 feet deep has been sunk from it. The cut and shaft together reveal a thickness of 25 feet of brown to black soft, friable, mealy manganiferous clay (wad), through which hard, compact masses composed mainly of psilomelane are scattered. The firmer and more earthy parts of this clay and the masses of hard manganese oxides are hand picked during mining and are shipped separately as low-grade and high-grade ores, respectively. The clay is overlain at the surface by a few feet of red loam containing chert fragments, and on one side of the cut it is overlain by a pocket of quartz sand in which there are pebbles and fragments of chert. The following analysis, supplied by Capt. Vance, represents the composition of a 10-pound sample of the hard ore from this locality:

Analysis of manganese ore from the Walbert mine.

[Roger Brown, analyst.]

Manganese (Mn)	59.04
Iron (Fe)	1.19
Phosphorus (P)	.113
Silica (SiO_2)	.82
Aluminum (Al)	1.13

Another cut, having a face of 10 feet, is on the hill slope 400 feet northwest of the one just described. It reveals 3 to 4 feet of surficial cherty loam, below which is a manganiferous clay (wad) and masses of hard manganese oxides, whose character and occurrence are the same as they are in the cut and shaft to the southeast, except that much braunite in fine crystals is disseminated through parts of the clay at this locality. An analysis of a sample of this clay, furnished by Capt. Vance, shows that it contains 35.65 per cent of manganese.

A few very small pits that have been dug on the hill slope between the two cuts just described reveal the presence of chocolate-colored manganiferous clay.

Although no limestone is exposed on the surface or in the openings at this locality the elevation and character of the manganiferous clay indicate that the clay overlies the Fernvale limestone, from which it has been derived by weathering. The total thickness of the clay and its areal extent have not been determined.

ADLER MINE.

The Adler mine, also known as the Section Sixteen mine, consists of a number of openings at places in and near sec. 16, T. 14 N., R. 6 W., 3½ miles northwest of Pfeiffer and 5½ miles north of Batesville. A little work was done here about 30 years ago by E. H. Woodward & Co., and 15 tons of ore is said to have been mined and shipped.[77] It has been operated from time to time within the last 20 years—first by Simon Adler, the former owner, and later by N. A. Adler, the present owner—and has produced several hundred tons of manganese ore. Since the time of visit (June, 1918) the National Manganese Co., the present lessee, is reported to have installed a steam shovel to mine the larger pieces of ore, and will also determine the available quantity of fine ore that can be recovered by means of a washing plant.

The Adler mine is in a rough, hilly area not unlike most of the surrounding region in which manganese deposits are found. The hills are capped by the Boone chert, and at different places on their slopes the Plattin, Kimmswick, and Fernvale limestones are exposed. These rocks have disintegrated more or less at different places, leaving their residual materials on their irregular surfaces. The clays that are residual from the limestones are overlain by chert fragments, derived from the Boone chert, or by pockets of sand and by many well-rounded pebbles. Some of the clay, as shown by the presence of manganese "buttons" in it, is a residue

[77] Penrose, R. A. F., jr., op. cit., p. 232.

from the decomposition of the Cason shale, but this shale is not present everywhere in this vicinity. Although most of the manganese ore that has been shipped has been mined from these clays, ore has been quarried from beds near the top of the Fernvale limestone. The ore in the clays and much of the clays themselves are residual from the weathering of the Fernvale limestone and Cason shale, and the ore found in clays that rest upon the Plattin and Kimmswick limestones has simply settled farther down the hill slopes than the ore that is in the clays that rest upon the Fernvale limestone.

Several cuts as much as 20 feet deep have been made on the east and west sides of a hollow on or near the south line of sec. 16, half a mile north of Cave Creek, and one tunnel 30 feet long has been driven here. They penetrate chocolate-colored clays, in which both large and small masses of manganese oxides occur. These clays overlie the Fernvale, which is exposed both in the openings and on the surface. Some of this limestone contains enough manganese to make mining profitable, and such material is known as "rock." Fragments of this material observed on the dump at the time of visit (May 13, 1918) contained a brown translucent manganese silicate, which has not yet been identified. A small quantity of white barite occurs as large crystals in some of this mineral. A pile containing about 1,000 pounds of "lump ore," which had been hand picked from the clay, was observed at the time of visit; it consisted of irregular slabs of coarsely granular hausmannite and a small quantity of psilomelane.

A number of other openings are on the points of 3 or 4 hills farther north and northwest. They penetrate to a depth of several feet red and brown clays, in which hard oxides of manganese usually occur as irregular masses, both large and small, but in some of the openings the clays contain "buttons" of psilomelane like those at the Cason and Montgomery mines. The gentleness of some of the hill slopes and the absence of limestone outcrops on them suggest that the manganese-bearing clays may occur in considerable quantity in these slopes. Most of the clays overlie the Plattin limestone, of which there are many exposures on the lower parts of the slopes, and although the Kimmswick and Fernvale limestones are not exposed some of the clays probably overlie these limestones.

According to N. A. Adler, 15 tons of hand-picked "lump ore" with 50 per cent of manganese and 55 tons with 33 per cent of manganese was shipped from this mine in 1915; in 1916 the production was 90 tons with 50.69 per cent of manganese; and in 1917 it was 100 tons averaging 47 per cent of manganese and 150 tons with less than 40 per cent of manganese. In addition, 100 tons of manganese-bearing limestone was shipped during these years. The following analyses, supplied by Mr. Adler, are of carload lots of manganese ore from this mine:

Analyses of manganese ore from the Adler mine.

	1	2	3	4	5	6	7	8	9	10
Manganese (Mn)	51.51	52.13	56.03	57.20	58.697	51.35	36.15	30.90	29.16	21.52
Iron (Fe)	2.40	3.70	1.20	2.01	1.417	3.91	10	9.11		
Phosphorus (P)	.137	.176	.132	.120	.094	.16	.54			
Silica (SiO_2)	7.30	4.55	2.05	1.70	.75	3.35	8.50	7.51		
Alumina (Al_2O_3)						2.77				
Calcium carbonate ($CaCO_3$)							25.30			
Moisture	1.30		.70		1.25		2.10			

1-3. "Lump ore" shipped in 1897 by Simon Adler to the Carnegie Steel Co.
4. "Lump ore" shipped in 1899 by Simon Adler to the Carnegie Steel Co.
5. Two cars of "lump ore," shipped in 1901 by Simon Adler to the Carnegie Steel Co.
6. "Lump ore" shipped in 1917 by N. A. Adler to the Tennessee Coal, Iron & Railroad Co.
7. Ore known as "rock," shipped by N. A. Adler.
8-10. Low-grade soft ore shipped by N. A. Adler.

W. A. CHINN CUT.

The W. A. Chinn cut is on the W. A. Chinn tract, in a hollow on the north side of Cave Creek, in the NE. ¼ sec. 21, T. 14 N., R. 6 W., 3 miles west-northwest of Pfeiffer. The mine was operated by S. W. Deener in 1915 and by W. H. Denison and N. A. Adler in 1916. The total production by these operators was 400 tons.

The cut is on a steep slope on the east side of the hollow and 60 feet above the bottom of the hollow; it is a few feet deep and 125 feet long north and south. It was blasted in rock beds which lie horizontal, and it reveals the following section:

Section in W. A. Chinn cut.

	Feet.
Boone chert:	
Thick-bedded gray chert and cherty gray limestone	3
Fine-grained gray limestone; contains small nodules of phosphate rock	3
Platy red and green shale; contains soft dark-colored pebble-like masses, which may be phosphatic	Few inches to 1
Fernvale limestone:	
Ferruginous and manganiferous fossiliferous limestone; red in parts and dark gray in others. Calcareous oolites and pebbles occupy small fissures and pockets in the upper part of the limestone	7

Hausmannite and a smaller amount of iron oxide have partly replaced the Fernvale limestone. These minerals in places form only a small part of the rock and in others form the larger part of it, but no specimens were found that were entirely free from calcium carbonate. One specimen observed at the time of visit contains a pocket 1 inch in its longest dimension, composed of white barite and pink fine-grained manganiferous calcite (manganocalcite). The parts of the limestone that contained the largest percentages of manganese have been quarried and shipped. Of the beds exposed in the cut in 1918, a 2-foot bed at the top of the limestone reveals the most hausmannite. The analyses given below are of carload lots of manganese ore shipped from this mine. No. 3 is said to represent approximately the average composition of the marketed ore.

Analyses of manganese ore from the W. A. Chinn cut.

	1	2	3
Manganese (Mn)	17.24	36.15	24.65
Iron (Fe)	7	10	9.20
Phosphorus (P)	.44	.54	.58
Silica (SiO_2)	3.60	8.50	4.90
Calcium carbonate ($CaCO_3$)	52.70	25.30	32.83
Moisture	1.60	2.10	.60

A. R. CHINN PROSPECT.

The A. R. Chinn prospect is on a steep west slope, on the point of a hill just south of Cave Creek, in the SE. ¼ sec. 21, T. 14 N., R. 6 W., 2¾ miles west-northwest of Pfeiffer. Work at this locality was done 25 to 30 years ago, again in 1898, and next in 1916 and 1917. The owner, A. R. Chinn, reports that altogether about 30 tons of manganese ore have been removed from the openings and shipped. The openings are shallow pits which have been dug in pockets of clay from points near the base of the hill to 120 feet above the base. The clay contains fragments of braunite and a few fragments of psilomelane and overlies the Fernvale limestone, of which there are many outcropping ledges and boulders. Lenses of braunite 2 inches or less thick are common in the upper part of the Fernvale limestone. The presence of calcite and of the casts of fossils in some of them show that the braunite has replaced parts of the limestone, and the similarity of the fragments of braunite in the clay to those in the limestone indicates that they were once embedded in the limestone but have been freed from it by weathering.

BAXTER PROSPECTS.

The Baxter prospects consist of two groups of openings, made in 1917 and 1918 by George Baxter, the owner. One group, which includes three very small pits, is on a north hill slope in the N. ½ SE. ¼ sec. 28, T. 14 N., R. 6 W., 2½ miles west of Pfeiffer. These pits are in a chocolate-colored clay, which contains chert fragments at and near the surface, and from them 4 or 5 tons of hand-picked manganese ore is said to have been taken and marketed. The other openings are about a mile farther north, on a steep north hill slope just south of Cave Creek, in the SE. ¼ sec. 21, T. 14 N., R. 6 W. They have been dug a few feet deep in a manganese-bearing clay and are said to have yielded 10 or 12 tons of hand-picked manganese ore.

The total thickness of the manganese-bearing clays at these two localities has not been tested. At the second locality described they rest upon the irregular surface of the Fernvale limestone, of which there are exposures near the pits, and they also probably overlie this limestone at the first locality, though no limestone is exposed there.

COLLINS PROSPECT.

The Collins prospect consists of several very small pits situated here and there on both sides of a southwestward-trending hollow for a distance of about a quarter of a mile in the NE. ¼ sec. 28, T. 14 N., R. 6 W., 2½ miles west of Pfeiffer. The pits were made in 1917 and 1918 by Isaac Collins, the owner of the land, and are said to have yielded 10 tons or more of hand-picked manganese ore. They are in a chocolate-colored clay, which contains fragments of manganese oxides and chert. Some of them are in clay that surrounds masses of the Fernvale limestone; others were not dug deep enough to reach this limestone. The small pieces of manganese oxides found on the dumps at the time of visit (May 13, 1918) were made up largely of psilomelane, hausmannite, and wad.

BURGE MINE.

The Burge mine is on land belonging to Mrs. S. E. Burge, in the SW. ¼ SW. ¼ sec. 28, T. 14 N., R. 6 W., 3 miles north of Batesville, and is near the head of a hollow which is drained by a wet-weather branch flowing into Polk Bayou about a mile away. Mining was begun here in 1916, and the operator at the time of visit (March 21, 1918) was J. A. Finster, who reported that the equivalent of 4 or 5 carloads of manganese ore had been mined and hauled to Pfeiffer and Batesville, where it was shipped.

The mine is made up of openings extending along both sides of the hollow for about three-eighths of a mile, but most of them are on the south side of the hollow. The deposit that is being worked is in the residual clay of the Fernvale limestone, exposures of which are found in the lowest 50 feet of the hill slopes. The Fernvale was also found beneath 27 feet of clay and chert débris in a drill hole in the bottom of the hollow. The Boone chert, which caps the hills in the vicinity, appears to rest directly upon the Fernvale limestone. The ore-bearing clay is red and chocolate-colored and sticky; its surficial portion is mixed with chert that has rolled down the slope; and it rests upon the irregular surface of the hard, unaltered limestone. It has been found in shafts to extend to a depth of 45 feet, and one tunnel penetrated it for 200 feet.

The manganese ore is mainly compact hard psilomelane, though other manganese minerals including hausmannite and braunite are present. It occurs in irregular fragments ranging in size from fine particles to masses weighing 1 ton. It contains a small quantity of white barite but not enough to injure its market value. Some of the ore has partly replaced masses of chert which are residual from the Fernvale limestone, and such ore is too siliceous to be of value.

RUTHERFORD MINE.

The Rutherford mine, owned by W. A. Rutherford, is 3 miles north of Batesville. It was operated about 30 years ago, and although the total production at that time is not known the shipment of two carloads of manganese ore from this property is mentioned by Penrose,[78] who described the mine as the "John B. Skinner tract." The next work was done by various lessees, beginning in 1916, who mined and marketed 100 tons of lump ore before June, 1918.

The workings consist of four or more groups of shallow pits and cuts and a few short drifts. Most of them are on the points of hills and are on either side of narrow hollows, the main one of which is drained by a wet-weather branch southwestward into Polk Bayou. Those farthest west are about half a mile from Polk Bayou, and those farthest east are about 1½ miles from it.

The manganese ore occurs in the Fernvale limestone and its residual clay but in minable quantity in only the clay. The Fernvale limestone is exposed at many places in the lower 100 feet of the slopes, but it is generally concealed by its residual clay or by débris from the Boone chert above. The ore-bearing clay is red or chocolate-colored and sticky, rests in channels and pockets in the limestone, and is probably nowhere more than a few feet thick. It contains irregular fragments of ore from small particles to masses weighing several hundred pounds and fragments of chert that have been derived from the Fernvale limestone and the Boone chert. Wherever the chert from the Fernvale is present some of it is partly or entirely replaced by manganese oxide.

The ore is chiefly psilomelane with subordinate amounts of wad and possibly braunite, and that recently shipped contained, according to N. A. Adler, the buyer and shipper of the ore, from 48 to 50 per cent of manganese. The first two analyses given below represent the composition of two carloads of manganese ore shipped from this property about 30 years ago,[79] and the third analysis one carload of ore shipped in 1917 to the Tennessee Coal, Iron & Railroad Co.

[78] Penrose, R. A. F., jr., Manganese—its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, pp. 217–219, 1891.

[79] Idem, p. 219.

Analyses of manganese ore from the Rutherford mine.

	1	2	3
Manganese (Mn)	38.30	39.35	48.65
Iron (Fe)	8.45	5.30	3.30
Phosphorus (P)	.380	.217	.21
Silica (SiO_2)			4.46
Alumina (Al_2O_3)			2.54

CASON MINE.

LOCATION, HISTORY, AND PRODUCTION.

The Cason mine, owned by Mrs. K. P. Gregory, is in the S. ½ SW. ¼ sec. 34, T. 14 N., R. 6 W., 3 miles northeast of Batesville and half a mile north-northwest of a siding on the spur of the Missouri Pacific Railroad that runs to Pfeiffer. It is in the southern border of the Batesville district, in a rough hilly region whose relief ranges from 360 to 610 feet above sea level. (See fig. 10.) The ore is mined from the Cason shale in four radiating cuts—North cut, East cut, South cut, and West cut—which are near the base of the hill slopes, and is hauled in wagons to the above-mentioned siding for shipment.

The Cason mine was operated on a small scale about 30 years ago by the Keystone Manganese & Iron Co., but beginning in 1904 it has been operated almost continuously by various firms and persons. The following table, compiled from information furnished by the operators to the Mineral Resources branch of the United States Geological Survey, shows the names of the operators, the composition of the ore, and the production by years:

Production of ferruginous manganese ore from the Cason mine.

Year.	Long tons.	Operators.	Composition.
1904	600	(a)	
1905	3,321	(a)	
1906	8,900	Frisco Ore Mining Co	23-25 per cent Mn.
1907	4,133	do	
1908	4,066	do	
1909	3,325	do	
1910	5,030	do	20-25 per cent Mn.
1911	2,177	do	20 per cent Mn, 10 per cent Fe.
1912	1,332	do	20 per cent Mn, 10 per cent Fe.
1913	9,500	Batesville Manganese Co	16-24 per cent Mn, 7-10 per cent Fe.
1914	1,900	do	
1915	2,400	do	18 per cent Mn, 7-10 per cent Fe.
1916	[b] 3,645	do	
1917	5,374	W. H. Denison for Manganese Development Co.	22 per cent Mn, 8 per cent Fe, 26 per cent SiO_2.
1918	5,618	do	11.07-19.47 per cent Mn, 6.08-7.69 per cent Fe, 0.30-.42 per cent P, 32.32-37.61 per cent SiO_2.
	61,321		

[a] Name of operator not known.
[b] Total production of district. Includes several hundred tons from other mines.

ROCK FORMATIONS.

The rock formations in the vicinity of the mine are well exposed and are briefly described here, the oldest first, but the Cason shale, all parts of which contain manganese minerals, will be described under the heading "Occurrence and character of the ore" (pp. 139–142).

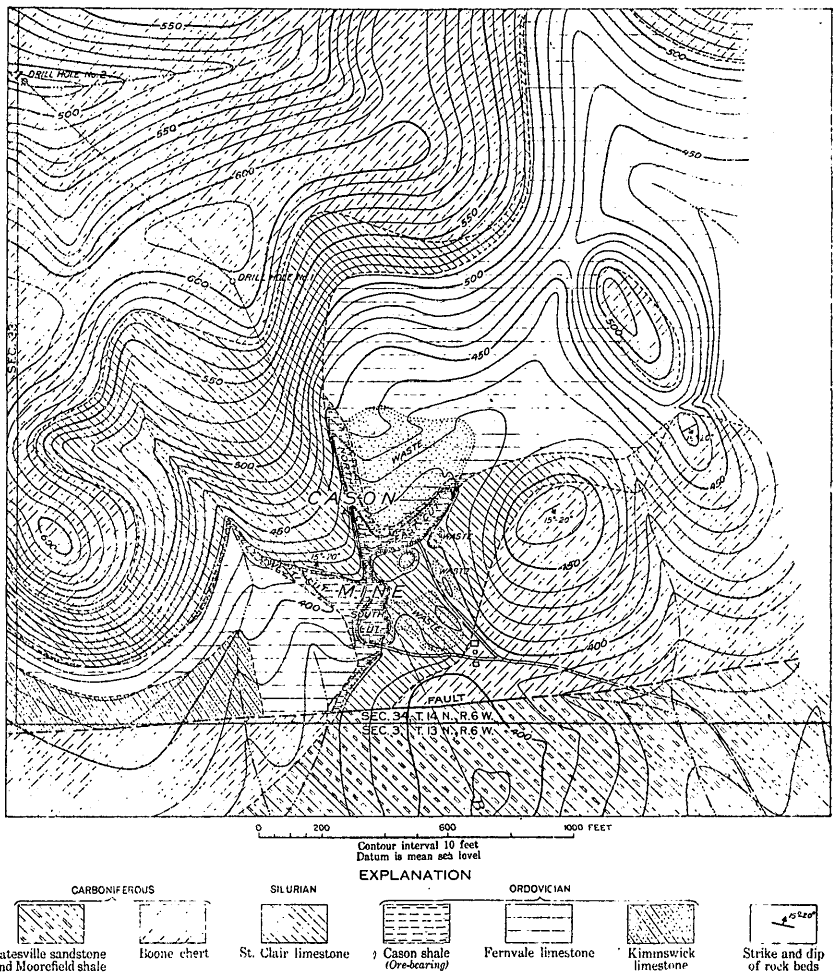

FIGURE 10.—Geologic map of Cason mine. Surveyed by H. D. Miser with plane table in March, 1918. *A–B*, Line of section in figure 11.

The upper part of the Kimmswick limestone is exposed on the south slope of the hill, west of the mine.

The Fernvale limestone, a pinkish-gray or gray coarsely granular limestone, is exposed both northeast and southwest of the mine, but some of the best exposures are in the cedar glade just northeast of the mine. It is about 30 feet thick southwest of the mine, whereas northeast of the mine 75 feet of the formation is exposed without the base being revealed.

The Cason shale, the next formation, is described on pages 139–142.

The St. Clair limestone is a massive pinkish-gray or gray fossiliferous granular but partly compact limestone. On the hill above the mine it is about 90 feet thick and on the hill west of the mine it is 100 feet thick, but it thins out entirely east and northeast of the mine and west of the area shown on the map. It is 55 feet thick in drill hole No. 1 and is absent in drill hole No. 2. It rests upon the Cason shale where that is present, and where the Cason is absent it rests upon the Fernvale limestone. These two formations, so far as their relations can be determined from the excellent exposures in the mine, are conformable. The character of the base of the St. Clair limestone in the North Cut is shown in the following section, but it varies somewhat from place to place, owing in part to different stages of weathering and in part to the original differences in the beds from place to place.

Section in North cut at Cason mine.

	Feet.
St. Clair limestone:	
Pinkish-gray granular fossiliferous limestone containing a few gray scattered pebble-like masses (*Girvanella*) about 1 inch in diameter. Dendrites are present on the surface of some of the numerous fossils	Several.
Red limestone like that above, except that it contains a few "buttons" of manganese oxide in its lower, shaly part. This limestone is not a separate bed but is a colored phase of the limestone described above	1–3
Calcareous hard red shale: contains a few "buttons" of manganese oxide. Appears to grade into the overlying limestone bed; not mined	1¼
Cason shale:	
Red sandy shale; contains manganese "buttons"; mined. Within 2 inches of its top there is a lenticular horizontal vein 1 inch thick and 2 feet long of white barite and pink manganiferous calcite (manganocalcite). The 1 or 2 feet of still lower shale that rests upon the Fernvale limestone is not mined	7

The pebble-like *Girvanella* mentioned in the above section are a conspicuous feature of the lower few feet of the St. Clair limestone. (See Pl. VIII.) They range from one-eighth of an inch to 1½ inches in diameter, they show concentric banding, and many contain angular fragments of gray earthy phosphatic material in their centers. The minerals in them are crystalline and as may be inferred from the character of the specimens and the analyses given below contain calcium, manganese, and magnesium carbonates and barium sulphate. Some of the carbonates may be chemically combined. They also contain considerable pyrite as fine crystals and as small irregular replacement masses. In weathered limestone ledges they have a red color, resembling that of the red "buttons" in the Cason shale that are described on pages 140–142, and on the weathered surface they change to a ferruginous manganese oxide. In some of the limestone many of the *Girvanella* have been partly or wholly removed through solution, leaving cavities. One observed pebble-like mass is crystalline barite.

Analysis of pebble-like Girvanella from St. Clair limestone.

[R. C. Wells, analyst.]

Manganese (Mn)	5.94
Iron (Fe)	1.56
Silica (SiO_2)	.29
Alumina (Al_2O_3)	4.06
Lime (CaO)	42.80
Magnesia (MgO)	.87
Barium (Ba), SO_4, CO_3	Present.

The black manganese "buttons" in the base of the St. Clair are fossil *Girvanella* that have been replaced by manganese oxide. It is assumed that they were once nearly spherical like the pebble-like masses higher in the St. Clair, and that the flattening of the "buttons" is due to the effect of pressure upon the shaly limestone in which they occur.

Manganese oxide is also present as thin films and dendrites in the lower part of the St. Clair limestone. Yellow and brown clays that occur in joints in the lower beds of the St. Clair limestone contain buckshot-like concretions of manganiferous iron oxide. A mass a few inches across of dark-brown manganese oxide in which there are a few crystals of manganese oxide is in red clay lying beside a boulder of the St. Clair limestone that is in place near the west end of the West Cut. Its position indicates that the St. Clair limestone is the source of its manganese.

Minute quantities of galena occur in the cavities left by the solution of the fossil *Girvanella* and in fine veins in the parts of the limestone that still contain the *Girvanella*. The largest mass of galena found in quarrying this limestone is reported to have been the size of a man's fist.

Gray laminated sandy clay was found in drill hole No. 2. The fossils in this clay indicate that it is an altered phase of the Chattanooga shale, and the position of the laminae in the drill cores shows that it dips at high angles. This shale and the overlying Boone chert have slumped or settled into channels or hollows formed by solution in the Fernvale limestone.

The Boone chert, owing to its resistant nature, forms the crests of the hills in the vicinity of the mine. In part of the area shown on

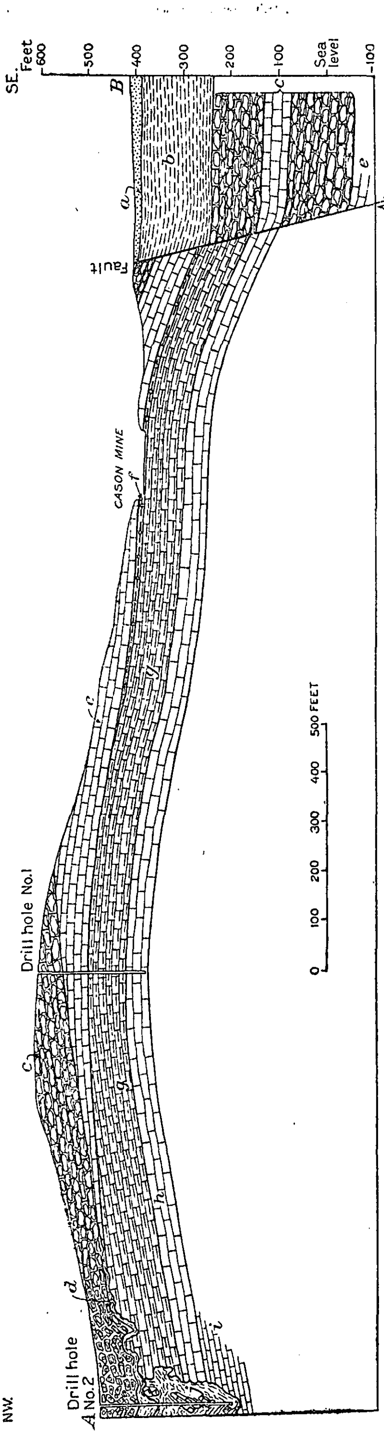

FIGURE 11.—Structure section through the Cason mine along line A–B in figure 10. *a*, Batesville sandstone; *b*, Moorefield shale; *c*, Boone chert; *d*, Chattanooga shale; *e*, St. Clair limestone; *f*, Cason shale; *g*, Fernvale limestone; *h*, Kimmswick limestone; *i*, Plattin limestone.

the map (fig. 10), it rests upon the St. Clair limestone, but in other parts of this area, where the St. Clair is absent, it rests upon the Fernvale limestone.

The Moorefield shale, although not anywhere exposed, probably underlies the surficial material on the northwest slope of the low southwestward-trending ridge that is just south of the mine. The Batesville sandstone caps this ridge and is the surface rock in the low-lying area east of it.

The above-described rocks lie flat or dip at low angles in the area shown on the map (fig. 10), but south of the mine they are broken by a normal fault with a north of east trend and a downthrow of perhaps 400 feet on its south side. (See Fig. 11.) The rocks just north of the fault dip 15° to 20° southeastward, toward the fault, whereas beyond the crest of the ridge northwest of the mine they dip at a low angle to the northwest. An anticline therefore occurs at this locality. Its axis trends northeastward along the crest of the ridge north of the mine. The rocks in the mine lie in a shallow syncline on the southeast side of the anticline. The axis of the syncline trends northwestward. The St. Clair limestone and Cason shale in the West cut, which is on the west side of the syncline, dip 15° to 20° into the hill (north-

northeast) and in the North cut, which is on the east side of the syncline, they dip at about the same angle to the southwest. Two or three faults with a downthrow of 5 feet or less were visible near the middle of the mine at the time of visit.

OCCURRENCE AND CHARACTER OF THE ORE.

The marketable ore, as previously stated, occurs in the Cason shale. All the Cason shale at this locality contains some manganese, and half or more of it contains enough manganese for it to be mined and shipped without treatment. There are several deposits in the Batesville district whose manganese and manganiferous ores are obtained from weathered phases of this shale, but of the few deposits where such ores are found in the hard unweathered shale the one at the Cason mine is by far the most important both in scientific interest and in the quantity of marketed ore and available ore in reserve.

The extent of the Cason shale was not definitely determined, as soil and rock fragments conceal it or its horizon at most places, but it probably thins out to the west, north, and east, as shown on the map (fig. 10), and it perhaps extends southward to the fault, south of which the shale, if present, is possibly 400 feet below the surface. The shale is absent in drill holes Nos. 1 and 2. The area underlain by the unmined shale is therefore comparatively small; it is at least 3 acres and may be 6 acres or more. The shale ranges in thickness from a feather edge to about 10 feet. The contact between the Cason shale and Fernvale limestone, as shown by exposures in the North cut, is irregular, indicating an unconformity between them. The Cason shale was therefore deposited upon an irregular surface, and this probably accounts for a large part of the variation in the thickness of the shale.

The Cason shale is red, hard, platy, sandy, and slightly calcareous, but its original color, a greenish-gray, is retained by as much as 3 feet of the top of the shale in the bottom of the syncline, near the junction of the cuts. An analysis of the greenish-gray shale from which the "buttons" described below were removed is as follows:

Analysis of greenish-gray Cason shale from Cason mine.

[R. C. Wells, analyst.]

Manganese (Mn)	5.87
Iron (Fe)	4.98
Silica (SiO_2)	32.73
Alumina (Al_2O_3)	8.22
Lime (CaO)	14.22
Magnesia (MgO)	3.38
Barium (Ba), SO_4, CO_3	Present.

Flattened pebble-like or concretion-like masses, known as "buttons," lie parallel with the bedding and are more or less uniformly distributed through the shale in all parts of the mine. Most of them are from half an inch to 1 inch in their longer diameter and from one-fourth of an inch to one-half an inch thick. A few of the "buttons" in the greenish-gray shale are gray but parts of some are reddened. Other "buttons" in both the greenish-gray and red shales are red, whereas in much of the red shale they are composed of hard black manganese oxides. Analyses of the red and black buttons follow:

Analyses of "buttons" from the Cason shale, Cason mine.

	1	2
Manganese (Mn)	5.85	50.41
Iron (Fe)	3.08	7.56
Phosphorus (P)		.06
Silica (SiO_2)	2.73	12.67
Alumina (Al_2O_3)	5.68	1.37
Lime (CaO)	29.85	2.09
Magnesia (MgO)	1.45	
Barium (Ba), SO_4, CO_3	Present.	

1. Red "buttons"; R. C. Wells, analyst.
2. Black "buttons"; R. N. Brackett, analyst; analysis from Penrose, R. A. F., jr., op. cit., p. 221.

The red and greenish-gray "buttons" presumably contain manganese, iron, calcium, and magnesium carbonates and barium sulphate, though a few of the gray ones are composed largely of barite (barium sulphate). The black "buttons" are chiefly compact psilomelane, but some consist entirely of a ferruginous manganese oxide. Short lenses 1 to 2 inches thick of psilomelane and ferruginous manganese oxide lie parallel with the bedding in some parts of the mine.

The gray, red, and black "buttons" have obviously had the same origin. A number of the red "buttons" were examined by E. O. Ulrich, and he states that they are fossil algal growths belonging to the genus *Girvanella*. Many of the "buttons" contain centers of chert and earthy material. They were all probably gray and nearly spherical at one time, like the *Girvanella* in the St. Clair limestone (see Pl. VIII), but by the oxidation of the iron and manganese minerals and the replacement of some of their other constituents by iron and manganese oxides they have changed in color from gray through red to black and by the effect of pressure they have been flattened. (See Pl. X, *A*.) Specimens which illustrate the changes in color may be found in the North and West cuts and near their junction. It is expected that the black manganese "buttons" will become less abundant and the "buttons" of other colors more abundant as the shale is followed into the hills. If so, the manganese content of the shale will decrease likewise.

The relations of the red and greenish-gray shales and the red and black "buttons" near the junction of the several cuts are shown in figure 12.

Although manganese is present in all the "buttons" and in the shaly matrix surrounding the "buttons," it does not occur in sufficient quantity to permit profitable mining except in the shale carrying the "buttons" of black manganese oxides. The black "buttons" generally make up about one-third of the rock mass, but in some places they make up more than half of the rock mass and in others they form such a small part of the rock mass that such rock has to be discarded as waste. The shale that contains enough black

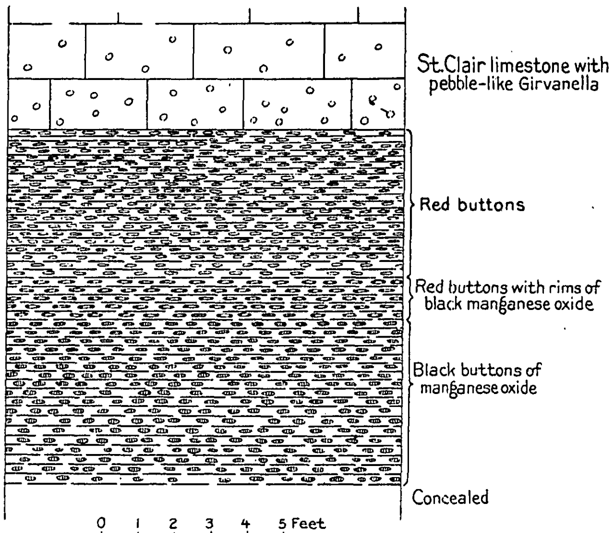

FIGURE 12.—Section near central part of Cason mine, showing the relations of the red and green shales in the Cason shale and the relations of the red, black, and partly blackened buttons. Heavy ruling represents red shale and light ruling green shale.

manganese "buttons" to be classed as ore is said to range in thickness from 3 to 8 feet and to average about 5 feet.

In the middle and northern parts of the North cut all the "buttons" consist of manganese oxides, whereas at the south end of this cut the black "button"-bearing shale is overlain by 5 feet of shale with red and partly blackened "buttons," and in the West cut the black "button"-bearing shale is overlain by 2½ feet of shale with red "buttons." In the North cut the shale is hard and unweathered, but in the other cuts it in places has weathered to yellow and green laminated clays, in which the numerous "buttons" and few lenses of manganese oxide are preserved. Much of the ores shipped in the past consisted of this weathered material, but now only the hard unweathered ore-bearing rock is shipped. In parts of this clay the "buttons" are soft from weathering and consist of ferruginous manganese oxide, and the clay in places contains thin horizontal lenses of this oxide. This clay is not shipped.

The shale bearing manganese "buttons" apparently does not extend beyond the wet-weather stream at the northwest end of the West cut. A pit west of this stream reveals a few feet of pebbly phosphatic sandstone, which contains only stains of manganese oxide. Some of the pebbles are red and resemble the red "buttons" in the Cason shale at the mine.

A few veins of calcite half an inch or less thick cut the Cason shale near the middle of the mine, and as noted in the section on page 136 a lenticular horizontal vein 1 inch thick and 2 feet long of white barite and pink manganiferous calcite (manganocalcite) is near the top of the shale in the North cut. D. F. Hewett, of the United States Geological Survey, who visited the mine in 1917, found specimens of shale that contain films and crystals of arsenopyrite.[80] Films of barite occur in cracks in parts of the shale.

The manganese content of the ore shipped from the Cason mine has ranged from 14 to 28 per cent, the average being about 20 per cent. The average analyses for a number of years are given in the table on page 134.

Penrose [81] in describing the ore taken out during the early attempts to work the deposit says:

> The amount of this ingredient [phosphorus] is variable, sometimes being under the maximum allowed, but generally, so far as tested, going above it, and at times amounting to from 2 to almost 4 per cent. * * * Analyses of the ore and inclosing sandstone together have shown the presence in certain cases of 3 to 4 per cent of phosphorus, and some analyses of the buttons alone have shown over 1 per cent. Hence sometimes at least, the inclosing rock contains more phosphorus than the ore, while the ore alone is sometimes low enough in phosphorus to allow it to be marketed and sometimes is too high.

MINING.

The Keystone Iron & Manganese Co. shipped the ore as it occurred in the surficial clay but made an unsuccessful attempt to improve its quality by washing it. Much of the ore shipped by the other operators was the soft surficial material, which was shoveled into wagons without treatment and hauled to the railroad. The ore being mined at the time of visit (March, April, and May, 1918) was the hard, unaltered shale. It was simply quarried by blasting after the overburden of St. Clair limestone was removed. The limestone overburden was as much as 15 feet thick at some places, and its thickness will increase as the ore bed is followed away from the outcrop. The

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[80] Personal communication.

[81] Penrose, R. A. F., jr., Manganese—its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, pp. 220–222, 1891.

limestone was broken up into fragments about a foot or less across and was shipped to points along the Mississippi, where it was used for riprap. The only machinery then used at the mine was a gasoline engine, an air compressor, and one or two hand drills.

CHAMPLAIN PROSPECT.

The Champlain prospect consists of several shallow pits in sticky chocolate-colored clay on a steep east hill slope, on the west side of Polk Bayou and from 30 to 40 feet above this stream, 2½ miles north of Batesville. The first work at this locality was done early in 1918 by J. W. Hampton, and he was followed by J. B. Champlain, who began work about March 1, 1918. The clay is a residue from the decay of the Fernvale limestone, which is exposed at a number of places in the pits and on the surface. It lies in pockets and channels in this limestone and is overlain by as much as 4 feet of chert débris, which is derived from the Boone chert exposed higher on the hill.

The manganese ore consists of hard psilomelane and a smaller quantity of braunite and occurs in the clay as irregular masses ranging from fine particles to boulders weighing 200 pounds. Much of it contains casts of fossils like the fossils in the Fernvale limestone, showing that the ore once occurred in the limestone as a replacement material. In fact, specimens of ore-bearing limestone showing the various stages of replacement were observed. An analysis of a sample of ore from this locality, furnished by Mr. Champlain, showed 56.32 per cent of manganese and 2.40 per cent of iron.

About 5 tons of "lump ore," which had been picked out by hand, was on the dump at the time of visit (March 19, 1918), but no shipments had been made. Plans were being made to mine the ore by hydraulic methods.

J. W. GREENFIELD PROSPECT.

The J. W. Greenfield prospect is on the south point of the hill on which the Champlain prospect is situated, on land belonging to J. W. Greenfield. A few very small pits had been made near the base of the hill prior to the time of examination (March 19, 1918), and two piles of manganese ore, containing together about 300 pounds, were near the pits. Although some of the manganese ore is found on the surface, most of it is in dark clay occupying shallow fissures and pockets in the Fernvale limestone, of which there are many outcrops. This limestone is here overlain by the St. Clair limestone, and the St. Clair is in turn overlain by the Boone chert. The top of the Fernvale limestone is very rusty from the presence of iron oxide, and in places it contains some manganese oxide.

The manganese ore is psilomelane and braunite and occurs in irregular porous pieces, which do not exceed a few pounds in weight. It extends up the hill slope to about 60 feet above Polk Bayou.

WEAVER-DOWDY PROSPECT.

The Weaver-Dowdy prospect is near Blowing Cave, on Polk Bayou, 3½ miles north of Batesville, and is on the Weaver-Dowdy tract, which comprises the SW. ¼ SE. ¼ sec. 29 and the NW. ¼ NE. ¼ sec. 32, T. 14 N., R. 6 W. Very little work had been done at this locality at the time of visit (March 25, 1918), and probably not more than a few tons of manganese ore had been mined and marketed. The prospect at that time was being worked by J. C. Shepherd, who had leased it.

The prospect consists of several openings, some of which are on the slope above Blowing Cave, and others are on the southwest point of a hill to the south. The openings, which include small pits and cuts and one tunnel 15 feet long, are in sticky chocolate-colored ore-bearing clay and in a cherty soil a few feet thick that overlies the clay. This clay lies in basins and channels in the Fernvale limestone, from which it is residual, but it does not occur in great quantity, as the slope is steep, and exposures of the Fernvale are numerous.

The ore is fairly hard manganese oxide and is in irregular fragments, some weighing as much as 100 pounds or more. The ore that has been placed by itself on the dumps has been saved by hand picking, and the finer ore has been left in the clay.

W. L. GREENFIELD MINE.

The W. L. Greenfield mine, which is on land belonging to W. L. Greenfield, is in the SW. ¼ sec. 29, T. 14 N., R. 6 W., on the west side of Polk Bayou, 3½ miles north of Batesville. Anthony Simmons mined half a car of ore at this locality in 1888, and Mr. Greenfield has done work recently, beginning in 1916.

The mine consists of two groups of openings. One of these groups is in the lowest hundred feet or so of the north hill slope, a short distance west of the mouth of the stream whose main source is Stark Spring. This group comprises several very small pits, which have been made within an area not exceeding a quarter of an acre. They pass through a thin surficial covering of chert fragments derived from the Boone chert and penetrate light to dark brown ore-bearing clays that are residual from the Fernvale limestone, of which only a few exposures occur in the vicinity. These clays rest upon the irregular pockety and channeled surface of this limestone, and although their thickness consequently varies from place to place none of the pits have passed through them.

The second group of openings is in an area on the southeast slope of the above-mentioned hill. It extends up the slope 125 feet from the bottom land along Polk Bayou and northeastward along the slope for 300 feet. The openings are pits and tunnels, the pits being 20 feet or more deep and the largest tunnel, of which there are four, being 40 feet long. After they penetrate a cherty loam, usually 2 to 6 feet thick, derived from the weathering of the Boone chert, they pass into a chocolate-colored sticky clay, in which the manganese ore occurs. This clay has been derived through weathering from the Fernvale limestone, of which some ledges and horses are found in the openings, and although the clay is shown to be 20 feet or more thick in places it probably does not average more than a few feet thick.

The manganese ore is in masses whose usual range of weight is from 1 to 50 pounds. The larger masses are hard manganese oxide, but the smaller ones are soft, though they are firm enough to keep from falling to pieces while they are being mined and shipped. The ore marketed before the time of visit (March 21, 1918) amounted to about 60 tons, which is said to have contained between 30 and 35 per cent of manganese, but this production does not include the half car of ore mined in 1888 by Anthony Simmons. Since the time of visit some ore has been produced from the mine by T. F. Adams.

SIMMONS PROSPECT.

The Simmons prospect, which was not visited by the present writer, is in the bluff on the west side of Polk Bayou, in the NE. ¼ NW. ¼ sec. 29, T. 14 N., R. 6 W., just north of the mouth of the stream draining the hollow in which the Allen and Roberts mines are situated. The deposit opened by this prospect is described by Penrose[82] as follows:

> The manganese occurs in an elongated pocket in the St. Clair [Fernvale] limestone, striking N. 18° W. across the almost horizontal bedding of the rock. The pocket dips almost vertically but has a slight inclination to the east and is 2 to 3 feet in width. The ore is in the form of seams and pockets varying from 1 inch to 2 feet in thickness and is associated with an indurated brownish-red clay containing many rounded fragments of a massive red or gray calcareous rock, one-quarter to 1 inch in diameter. The latter look like fragments of the limestone strata that often occur at the base of the chert. The ore varies much in character—from crystalline to a massive, botryoidal, or stalactitic variety. The sides of the deposit are very irregular, with "feeders" running off in various directions, but the contact with the country rock is sharp and well defined. The latter is a coarsely crystalline limestone of a pink or purplish-brown color and contains many small masses and interbedded lenses of manganese ore. These become more and more numerous as the sides of the main ore deposit are approached.

[82] Penrose, R. A. F., jr., op. cit., pp. 225–226.

The deposit runs diagonally up the slope of the bluff and has been opened at various places for 75 yards along its course. It seems probable that it occupies a cavity made by water along a crack or joint and filled up with residual clay and ore from the part of the limestone that has been dissolved as well as by limestone pebbles from above.

Work was done at this locality in 1918 by the Polk Bayou Mining Co., which produced a small amount of ore.

ALLEN MINE.

The Allen mine is on a small tributary of Polk Bayou, in the W. ½ NW. ¼ sec. 29, T. 14 N., R. 6 W., 4 miles north of Batesville. It was worked in 1889 by Skinner & Abbot and then lay idle until 1917, when mining was resumed by other parties. The owners and operators at the time of the writer's last visit to the locality (June 27, 1918) were Messrs. Alnutt and Purse.

The workings are shafts and pits dug here and there on the steep slopes on either side of a southeastward-trending hollow for a distance of half a mile near the Stark Spring and within 120 feet above the bases of the slopes. They penetrate the residual clay of the Fernvale limestone, exposures of which are found at many places from the stream to 130 feet up the slopes. This clay, which contains the manganese ore, is red or chocolate-colored and sticky and lies in pockets and channels in the limestone or surrounds limestone horses and hence varies greatly in thickness from place to place. One or more of the shafts, however, have passed through 30 feet of it. It is usually concealed by chert fragments that have rolled down the slopes from the outcrops of the Boone chert, which at this locality overlies the Fernvale limestone, and its surficial parts contain chert fragments from the same source.

The manganese ore is mainly psilomelane with some braunite or hausmannite, and occurs in irregular pieces, ranging in size from fine particles to boulders weighing 8 tons. The manganese minerals are intimately mixed, and some specimens were found that contain a very small quantity of barite. Manganese and iron oxides are disseminated through some of the exposed Fernvale limestone, and give those parts of the limestone a brown color.

Most of the ore that has been marketed consisted of fragments an inch or more in diameter and of boulders. At the time of the writer's last visit to the locality a hand jig was being successfully used to separate the fine ore from the clay and chert. The stream from Stark Spring flows in the hollow containing the openings and affords an abundant supply of water for hand jigs or a washing plant. The quantity of ore shipped from this locality is not known, but it exceeds 100 tons, and analyses of samples are said to show that its percentage of manganese varies from 42 to 60.

ROBERTS MINE.

The Roberts mine, described by Penrose[83] under the name Maxfield tract, is in the NE. ¼ sec. 30, T. 14 N., R. 6 W., and about one-eighth of a mile northwest of Stark Spring. It was worked in 1889 by Skinner & Abbot, in 1916 by Walbert & Deener, and beginning in February, 1918, it has been worked by the Polk Bayou Mining Co., the present owner of the property, but some work was done here in 1915 or 1916 by Coleman & Grefenkamp.

The openings, which are small pits or tunnels, have been dug near the base of the hill slopes in a strip extending 1,000 feet along both sides of a hollow, but most of them are on the southwest side. After they passed through 2 to 6 feet of cherty loam derived from the Boone chert they penetrated the sticky reddish-brown ore-bearing clay. This clay is seen in places to be as much as 8 feet thick, and it rests upon the uneven surface of the Fernvale limestone, from which it is residual. In addition to the ore it contains masses of the Fernvale limestone and fragments of the Boone chert. In the few places where the limestone is exposed it is brown from the presence of fine particles of iron and manganese oxides.

Most of the manganese ore is psilomelane, but part of it is braunite, and it occurs as irregular masses ranging from the size of a pea or less to boulders weighing 500 pounds. The larger part of it is compact, but some masses are porous, and others contain pockets of calcite half an inch or less in their longest dimension.

The entire production of the mine is not known. Penrose,[84] however, stated that several carloads were mined in 1889 by Skinner & Abbot, and he quoted 26 analyses of carload lots of manganese ore shipped from the property. The recent production has been much less than this amount. Analyses of picked samples of ore from this mine are said to show from 53 to 57 per cent of manganese, but the following 26 analyses, which represent the composition of carload shipments of ore, show that the average manganese content is much less.[85]

Analyses of manganese ore from the Roberts mine.[a]

	1	2	3	4	5	6	7	8	9
Manganese (Mn)	44.69	41.08	43.12	42.74	31.90	24.31	24.50	27.49	29.57
Iron (Fe)	9.18	10.75	12.50	4.95	11.20	21.63	28.72	23.40	23.40
Phosphorus (P)	.319	.467	.339	.385	.347	.252	.226	.405	.452
Silica (SiO_2)	3.23	....	1.54	10.41	20.50	14.82	5.22	7.08	5.10
Moisture	....	....	....	....	....	....	....	....	19.0

a Analyses 3, 4, and 5 were made by the North Chicago Rolling Mill Co. and the remainder by the Illinois Steel Co. of Chicago.

83 Penrose, R. A. F., jr., op. cit., p. 225.
84 Idem, p. 225.
85 Idem, p. 224.

Analyses of manganese ore from the Roberts mine—Continued.

	10	11	12	13	14	15	16	17	18
Manganese (Mn)	31.56	26.82	27.55	30.55	33.21	30.55	31.35	37.59	34.38
Iron (Fe)	21.47	24.42	24.00	21.70	18.80	21.70	20.70	12.70	17.70
Phosphorus (P)	.385	.273	.268	.328	.194	.328	.581	.357	.476
Silica (SiO_2)	6.75	6.33	7.46	6.48	6.05	6.48	4.49	5.56	4.03
Moisture	16.40	16.20	15.50	15.00	15.10	15.00	14.50	18.20	21.50

	19	20	21	22	23	24	25	26
Manganese (Mn)	36.05	37.27	28.69	33.80	34.03	36.18	35.40	36.86
Iron (Fe)	15.50	15.30	23.00	16.85	11.20	14.70	15.70	15.20
Phosphorus (P)	.279	.481	.788	.596	.732	.608	.735	.585
Silica (SiO_2)	4.87	4.55	5.42	5.70	3.65	3.97	4.35	3.68
Moisture	18.30	21.10	20.00	19.10	16.30	18.50	16.30	12.00

Several tons of ore was shipped by Coleman & Grefenkamp from this mine for use as chemical ore. The results of its use are not known, but analyses of samples collected by other parties show that the percentage of manganese dioxide is too low for the ore to be classed as a chemical ore.

DEENER PROSPECT.

The Deener prospect, owned by S. W. Deener and leased by the Vance Mining Co., is in the south border of the SE. ¼ sec. 19, T. 14 N., R. 6 W., 4½ miles north by west of Batesville. It is just north of the Roberts mine and in the same hollow with it. Work was begun here in May, 1918, and 14 or 15 tons of manganese ore had been removed from the openings before the time of visit (June 27, 1918). The hill slopes in this vicinity are covered with chert débris several feet deep, which overlies the ore-bearing clay. This clay in turn overlies the Fernvale limestone, from which it and the manganese ore have been derived by weathering.

A shaft 16 feet deep has been sunk on the west slope of the hill. A drift 18 feet long that has been run from the bottom of the shaft shows a pocket of porous manganese ore 5 feet thick, extending its entire length. The Fernvale limestone was encountered in the bottom of the shaft and near the end of the drift. A second shaft, 75 feet north of the one just described, is 16 feet deep and was sunk 2 feet in porous manganese ore without passing through it. A cut with a face of 8 feet has been made 75 feet west of the first shaft and lower on the hill slope. It reveals a pocket of ore, which in places attains a thickness of 4 feet. About 200 yards north of the cut a third shaft had been sunk 8 feet in loose iron-stained chert débris at the time of visit.

The pockets of ore mentioned above are not solid but consist of irregular masses of psilomelane and hausmannite ranging in size from fine particles to boulders that weigh as much as 2½ tons. The deposit at this locality is promising and deserves further prospecting.

BUTTON MINE.

The Button mine is in the NW. ¼ SE. ¼ sec. 24, T. 14 N., R. 7 W., 2½ miles northeast of James and 4 miles southeast of Cushman. It was worked about 30 years ago and a production of 300 tons of manganese ore is mentioned by Penrose.[86] It has been worked also within the last few years by the Polk Bayou Mining Co., of Batesville, Ark., but the quantity of ore shipped was not learned.

The workings are several small pits scattered over the upper part of the southeast slope of a hill which is capped by 20 feet or more of the Boone chert. The red and dark-brown ore-bearing clay a few feet thick overlies the irregular surface of the Fernvale limestone, of which outcrops are common, and the clay is overlain by surface débris a few inches to several feet thick, composed of chert fragments and pebbles. Both the ore and the clay are residues from the decomposition of the Fernvale limestone. The workings were badly caved at the time of visit (April 17, 1918), and the ore could not be examined in place. Piles of ore found on the dumps consist of small pieces of steel-blue psilomelane.

W. W. ALLEN MINE.

The W. W. Allen mine, described by Penrose[87] under the name "Castile tract," is on a northeastward-trending spur on the west side of Polk Bayou, in the SW. ¼ sec. 18, T. 14 N., R. 6 W., 4 miles east-southeast of Cushman. It was worked about 30 years ago by Skinner & Abbot. The total amount of ore shipped by them is not known, but Penrose mentions the production of two carloads. The next mining was done in 1917 by S. W. Deener, and in 1918 the mine was worked by J. C. Shepherd, who was succeeded by the Leader Mining Co., of which Mr. Shepherd became president. A washing plant was erected on this property by Mr. Shepherd, and it was operated for a short time, beginning in September, 1918.

Shallow pits and cuts have been dug here and there in red to brown manganese-bearing clays over a few acres on the east point and crest of the above-mentioned spur, which rises 175 to 200 feet above Polk Bayou. These clays are mixed at the surface with chert and sandstone fragments and chert pebbles, and they occupy pockets and channels in the Plattin, Kimmswick, and Fernvale limestones, of which outcrops are numerous.

The manganese ore consists of compact irregular masses of psilomelane and hausmannite ranging in size from fine particles to boulders that weigh a few hundred pounds or more. Before the installation of the washer only the larger masses, which were hand

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[86] Penrose, R. A. F., jr., op. cit., p. 228.
[87] Idem, pp. 226–227.

sorted from the clay, were shipped. The following analyses represent the composition of two carloads of manganese ore mined at this property by Skinner & Abbot.[88]

Analyses of manganese ore from the W. W. Allen mine.

	1	2
Manganese (Mn)	55.45	57.13
Iron (Fe)	2.95	1.89
Phosphorus (P)	.117	.078
Silica (SiO_2)	5.60	.539
Moisture	1.30	1.30

CRISWELL PROSPECT.

The Criswell prospect, not visited by the writer, is described as follows by Penrose.[89]

The Criswell tract is in 14 N., 7 W., section 24, the northeast quarter of the northeast quarter. This property is on the west side of Polk Bayou, and about 1½ miles above the mouth of Sullivan Creek. The ore is associated with the characteristic purplish-red clay and overlies the surface of the Izard limestone. The St. Clair [Fernvale] limestone is not seen here but is exposed half a mile to the west in the head of a ravine, and it is probable that it underlies some of the chert-covered area in the western part of the property. No mining has been done, but about 1 ton of ore has been collected on the surface and piled up.

Work was done at this locality in the spring of 1916 by Shell, Kennard & Smith. None was being done at the time of the writer's visit to this part of the region on April 17, 1918.

SHAW MINE.

The Shaw mine, which is on land owned by Halsell & Stafford, of Oklahoma City, is on Shaw Hill, on the west side of Polk Bayou, 3 miles east of Cushman. Work has been done at times, beginning in 1916, by W. H. Denison, who had mined and shipped 69 tons of manganese ore before June, 1918. The workings consist of a large number of very shallow pits grouped at several places on the hill slopes. They penetrate surficial material consisting of chert pebbles and fragments, among which are masses of iron and manganese oxides, and some of them pass through this material into chocolate-colored manganese-bearing clay. The clay overlies the Plattin limestone, of which there are many exposures in parts of the prospected area. Very little ore was seen on the dumps at the time of visit (April 19, 1918). The larger pieces that were taken from the openings had been hauled to Cushman and shipped.

WACO PROSPECT.

The Waco prospect, controlled by the Waco Manganese Co., of Batesville, Ark., is on the T. S. M. Patterson tract, just east of

[88] Penrose, R. A. F., jr., op. cit., p. 227.
[89] Idem, p. 226.

Polk Bayou, in the northern part of sec. 18, T. 14 N., R. 6 W., 4 miles east by south of Cushman. No prospecting or mining had been done on the tract when the writer was in this vicinity, June 7, 1918, but he was told that manganese ore had been found on the surface at several places. As shown on the map (Pl. I) this tract is in an area where the Plattin limestone is the surface rock formation. In the fall of 1918 the above-named company operated a washing plant for a short time.

DENISON MINE.

The Denison mine, also known as the Patterson mine, Skinner-Abbot mine,[90] and John B. Skinner mine,[91] is on the east side of Polk Bayou, 4 miles east of Cushman. The tract on which it occurs comprises 60 acres in the SW. ¼ SW. ¼ sec. 7 and approximately the W. ½ NW. ¼ NW. ¼ sec. 18, T. 14 N., R. 6 W.

The mine was operated by Skinner & Abbot from 1888 to 1891, inclusive. Although much of the manganese ore shipped by them was "lump ore" that had been hand sorted from the inclosing clays, some of the ore consisted of concentrates that had been freed from the ore-bearing clay in a washing plant on Polk Bayou, half a mile from the mine. The production by Skinner & Abbot is not known, but Penrose gives 13 analyses, which he says represent as many carload shipments from this property. The mine was next operated, in 1916, by N. W. Keith, the owner at that time, who mined 4½ carloads (about 120 tons) of "lump ore." Walter Denison, jr., purchased the property in 1917 and mined eight carloads (254 tons) of "lump ore." In 1918 the Oklahoma-Kansas Mining Co., of which O. M. Bilharz is president, purchased the property and erected a washing plant known as the Bilharz washer. (See Pl. XV, *A*.) The washer was completed about November 1, 1918, but it has never been operated.

The workings, which are pits, cuts, and shafts, the shafts being as much as 35 feet deep, have been made here and there over an area of 15 to 20 acres on the crest and north slope of a hill. Those on the crest penetrate sticky chocolate-colored clay, and those on the slope penetrate sticky red and yellow clays. These clays, as revealed in most of the workings, contain masses of manganese ore, and parts of them contain chert pebbles and fragments and limestone fragments. They overlie the Plattin limestone and in places fill hollows, cavities, and channels a few feet or more wide and 35 feet or more deep in this limestone (Pl. XV, *B*, and fig. 13.) This limestone is exposed at many places, and the Kimmswick limestone, which rests upon

[90] Harder, E. C., Manganese deposits of the United States, with sections on foreign deposits, chemistry, and uses: U. S. Geol. Survey Bull. 427, p. 112, 1910.

[91] Penrose, R. A. F., jr., op. cit., pp. 240–242.

the Plattin, is exposed in and near an old cut that was made by Skinner & Abbot on the crest of the hill. Many of the channels in the limestone are joints that have been widened by the dissolving of the limestone on either side of them. The relations of the manganese-bearing clay to the underlying limestones at this cut are shown in figure 13. A large part of the clay is obviously residual from the Plattin and Kimmswick limestones, but much of it, as well as the manganese ore, is residual from the Fernvale limestone, which has been completely decomposed. Most of the ore has settled by gravity to its present position, but part of it has been carried there as wash.

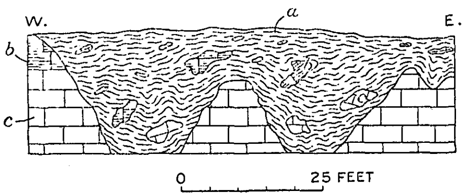

FIGURE 13.—Section at Denison mine, showing manganese-bearing clay (*a*) in hollows in the surface of the Plattin limestone (*c*) and Kimmswick limestone (*b*). (After Penrose.)

The ore occurs in irregular masses, which range in size from fine particles to boulders weighing as much as 300 pounds. Most of these masses are compact, and they consist of massive granular braunite, hausmannite, and steel-blue psilomelane, which are more or less intermixed. The ore at places has been found to extend from the surface to the bottom of the workings, but the full depth everywhere and the total areal extent of the ore body have not been determined. The following analyses are of carload lots of manganese ore shipped from the Denison mine:

Analyses of manganese ore from the Denison mine.

	1	2	3	4	5	6	7
Manganese (Mn)	55.68	53.66	51.86	42.77	56.10	57.01	57.41
Iron (Fe)	2.00	2.50	7.80	5.50	2.61	2.05	1.62
Phosphorus (P)	.172	.209	.141	.523	.075	.072	.100
Silica (SiO_2)	....	....	....	....	5.44	5.33	6.00
Moisture	....	....	....	....	.60	.80	1.00

	8	9	10	11	12	13	14
Manganese (Mn)	55.70	56.75	57.39	38.49	56.65	58.31	58.68
Iron (Fe)	1.85	2.19	1.55	8.80	1.68	1.33	1.70
Phosphorus (P)	.078	.068	.074	.115	.066	.064	....
Silica (SiO_2)	6.71	5.49	5.46	19.96	5.55	5.78	5.21
Moisture	.80	.20	.10	7.00	.80	.90	....

	15	16	17	18	19	20	21
Manganese (Mn)	57.85	55.24	58.00	54.33	58.28	57.85	56.56
Iron (Fe)	1.45	2.15	2.15	2.88	....	1.31	1.86
Phosphorus (P)	....	.15	.15	.18	....	....	.092
Silica (SiO_2)	6.65	3.92	3.92	9.51	....	5.67	5.76
Alumina (Al_2O_3)	....	2.06	2.06	....	....	....	1.52

1-13. From Penrose, op. cit., p. 242.
1-4. Shipped to the North Chicago Rolling Mill Co.
5-13. Shipped to the Illinois Steel Co.
14-21. Mined by Walter Denison, jr.

MARSHALL MINE.

The Marshall mine is on the Mrs. J. Marshall tract, in the NW. ¼ SW. ¼ sec. 7, T. 14 N., R. 6 W., 4 miles east of Cushman, and consists of pits and cuts a few feet or more deep within an area of about 3 acres in the hollow north of the Patterson mine. Work has been done recently, and about 50 tons of manganese ore are said to have been mined and shipped. The ore is like that at the Denison mine and is in red and yellow clays that overlie the Plattin limestone, of which exposed ledges are common, or that fill channels in the limestone.

R. T. PATTERSON MINE.

The R. T. Patterson mine is in the SW. ¼ sec. 7, T. 14 N., R. 6 W., 4 miles east of Cushman. It is in the hollow north of the Denison mine and is east of the Marshall mine. It was operated in 1916 and 1917 by R. T. Patterson, the owner, who mined 50 tons of manganese ore.

Pits and shafts as much as 20 feet deep have been dug in red and yellow clays in an area of about 2 acres on the south side of the wet-weather stream that drains the hollow. These clays overlie the Plattin limestone and fill channels in it as they do at the Denison and Marshall mines. The manganese ore is similar to that at the two mines just named.

JOHN PATTERSON PROSPECT.

The John Patterson prospect, owned by the Liberty Manganese Co., of Chicago, Ill., is in the NE. ¼ SE. ¼ sec. 7, T. 14 N., R. 6 W., 4½ miles east of Cushman. Many pits as much as 6 feet deep were dug in 1917 by Mr. Patterson in a draw on the gentle southeast slope of a hill, and they yielded 20 tons of "lump" manganese ore. The above-named company did a small amount of work in 1918 and obtained 3 tons of ore. Pockets of red waxy ore-bearing clay have been penetrated by the pits and lie between ledges and boulders of the Joachim and Plattin limestones, which are exposed over much of the surface.

The manganese ore is found in this clay from the surface to the bottoms of the clay pockets. Small pieces of ore found on the surface indicate that it occurs over a much larger area than the 1 acre in which the pits have been dug. It consists of irregular compact masses of hausmannite and steel-blue psilomelane and is a very high grade of ore; apparently it would contain between 55 and 60 per cent of manganese in carload lots. Some masses of red iron oxide are also present in the clay. Mr. Patterson states that one man with pick and shovel can mine an average of 400 pounds of ore each day.

Although the masses of manganese ore are in clay that overlies the Joachim and Plattin limestones they are a residue from the decomposition of the Fernvale limestone, which has been entirely eroded from this locality, and they have been brought to their present position by gravity or by streams or by both agencies.

G. W. W. PATTERSON PROSPECT.

The G. W. W. Patterson prospect is in the SW. ¼ NE. ¼ sec. 7, T. 14 N., R. 6 W., 4¼ miles east of Cushman. Two very small pits have been dug recently in a red clay that contains chert fragments and pebbles, and from them a few hundred pounds of both hard and soft manganese oxides were removed. The manganese-bearing clay, whose depth and areal extent are yet to be determined, rests upon the Plattin limestone, of which there are a few exposures near the pits.

BELL HILL PROSPECT.

The Bell Hill prospect is on Bell Hill, in the NW. ¼ NE. ¼ sec. 7, T., 14 N., R. 6 W., 4½ miles east of Cushman. Considerable prospecting was done early in 1918 by S. B. McConnico to determine the size and character of the ore body. The Liberty Manganese Co., of Chicago, Ill., of which Mr. McConnico became a member, has leased the property from John Patterson, the owner, and after the writer departed from the region in June, 1918, this company began the erection of a washing plant, on which work was stopped in November, 1918. No ore has been shipped from this property.

The openings, which are pits, cuts, and shafts, some shafts being 30 feet or more deep, have been dug here and there in red and brown clays in an area of a few acres on the northeast and southeast slopes of the hill. These clays are overlain by more or less surficial material, consisting mainly of chert fragments and pebbles, and they were at no place passed through by the openings. There are no exposures of limestone on the hill slopes near the openings, but exposures of the Plattin limestone near the base of the hill and on the west slope indicate that the clays penetrated by the openings overlie this limestone.

More than half of the openings yielded no manganese ore, and less than half of the others yielded manganese and ferruginous manganese ores in quantity that is sufficient to yield a profit even when high prices are paid for manganese. Further prospecting may, however, reveal extensions of the ore deposit. The ore is mostly in small irregular fragments; some of it is soft but firm and parts of it contain grains of quartz sand. No analyses are at hand, but the concentrates that would be recovered from the ore dirt examined by the writer would be ferruginous and hence would be likely to have a high silica content.

PERRIN MINE.

The Perrin mine is on the east side of Sullivan Creek in the SE. ¼ sec. 8, T. 14 N., R. 6 W., 4½ miles northwest of Pfeiffer. It was first worked about 30 years ago, when, as stated by Penrose,[92] 40 tons of ore were taken from one pit. It was next worked in 1916 and 1917 by Frank Perrin, and at the time of visit (May 8, 1918) it was being operated by the Ozark Mining Co., the present owner. The total production before the time of visit is not known, but it probably exceeded 100 tons.

The workings, which consist of shallow pits and cuts and shafts as much as 25 feet deep, are in the bottom of a short hollow and on the hill slopes at the head of it. Those on the hill slopes pass through a surficial bed from a few inches to several feet thick, composed largely of chert fragments and pebbles, and then penetrate red and reddish-brown clay to a depth of as much as 20 feet, whereas those in the bottom of the hollow are in pebbly clay, which lies between ledges and boulders of limestone and which at most places is only a few inches thick. Manganese oxides are irregularly distributed through the clays just described, and these oxides are found in small quantity in the surficial cherty bed on the hill slope. Although the workings show that the clays underlie an area of several acres their depth in this area has not been fully tested. The clays are a residue from the decomposition of the Cason shale and the Fernvale, Kimmswick, Plattin, and Joachim limestones. As there are no exposures of the Cason shale and none of the Fernvale and Kimmswick limestones in either the workings near the top of the hill or on the surface, these formations are probably largely, if not completely, decomposed, but there are many exposures of the Plattin and Joachim limestones, especially in the bottom of the hollow.

The masses of manganese oxides, which range in size from fine particles ("wash ore") to boulders weighing as much as 500 pounds, once formed a part of the Fernvale limestone and possibly the Cason shale. From these formations they were set free by decomposition and erosion, and they settled by gravity down the hill slopes to their present position, but some of them, including those in the bottom of the hollow, were carried to their present position as wash by streams. The manganese ore on the hill slopes consists of two grades, of which one, known as soft ore, is composed of soft earthy though firm wad, and the other, known as hard ore, is composed of psilomelane and hausmannite. The ore in the bottom of the hollow consists entirely of psilomelane and hausmannite. Mining thus far is said to have shown twice as much soft ore as hard ore. "Buttons" of red iron oxide, which have been derived from the weathering of the

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[92] Penrose, R. A. F., jr., op. cit., p. 236.

Cason shale, are common though not abundant in the manganese-bearing clays. The following analysis, supplied by Capt. Vance, represents the composition of a carload of ore shipped by him from this mine in 1918 to the Southern Manganese Corporation:

Analysis of manganese ore from the Perrin mine.

Manganese (Mn)	41.00
Iron (Fe)	9.80
Moisture	8.52

Another car of ore shipped from this mine by Mr. Vance is said by him to have contained 53 per cent of manganese.

KELLEY PROSPECT.

The Kelley prospect, which is in the SW. ¼ sec. 9, T. 14 N., R. 6 W., is just east of the Perrin mine. A small amount of work has been done by means of pits and cuts by A. J. Kelley, the owner. The character of the manganese ore and its occurrence at this prospect are the same as those of the ore in the workings on the hill slopes at the Perrin mine.

HAIGWOOD PROSPECT.

The Haigwood prospect is in the NW. ¼ SE. ¼ sec. 9, T. 14 N., R. 6 W., 4 miles northwest of Pfeiffer. Work has been done here by J. W. Haigwood, the owner, beginning in 1917, and before the time of visit (May 13, 1918) he had mined and marketed 30 tons of hand-picked manganese ore. The openings, which are pits and cuts as much as 18 feet deep, have been dug along an east hill slope for a distance of 150 to 200 yards. They penetrate chocolate-colored and black clays, which are overlain at the surface by a few inches to several feet of chert fragments and pebbles. Steel-blue psilomelane, some of which is compact and some porous, occurs disseminated through the clays as irregular-shaped masses, ranging in size from fine particles to boulders of 100 pounds. The depth and areal extent of the manganese-bearing clays have not been fully tested. None of the openings have been dug deep enough to reach the underlying limestone. The only limestone that crops out in the vicinity is the Plattin limestone, which is exposed on the slope above the openings that are farthest north.

J. B. THOMPSON PROSPECT.

The J. B. Thompson prospect is on the west side of a northward-trending hollow, in the NE. ¼ sec. 9, T. 14 N., R. 6 W., half a mile south of Coon Creek, and 4 miles northwest of Pfeiffer. Some work was done here 25 to 30 years ago and a little was done in 1917 by J. B. Thompson, the owner, who mined and marketed 5 tons of hand-picked manganese ore. The workings consist of a few very small pits and of a shallow cut in the bottom of which a shaft 27 feet deep has been dug. They penetrate a chocolate-colored manganese-bearing clay, which is overlain by surficial material from a few inches to 5 or 6 feet thick, composed largely of chert fragments; but a mass of sand containing chert pebbles extends to the bottom of the shaft on one side of it, whereas chocolate-colored clay occurs on the other side of the shaft. Only a very small quantity of manganese ore had been removed from the other workings. The Plattin limestone is exposed on the hill slope below the main cut and south of it. No limestone exposures were observed on the slope above the workings.

WILDCAT PROSPECT.

The Wildcat prospect, also known as the William Reves prospect, is on the north slope of the ridge forming the divide between Coon and Cave creeks, in the SW. ¼ NW. ¼ or the NW. ¼ SW. ¼ sec. 10, T. 14 N., R. 6 W., 3¾ miles northwest of Pfeiffer. It is on land owned by Halsell & Stafford, of Oklahoma City. It was worked in 1917 by W. H. Denison, who mined and shipped 22 tons of "lump ore."

The workings, consisting of pits, shafts, and tunnels—some made recently and some many years ago—were badly caved at the time of visit (May 8, 1918), so that the ore-bearing clay in place could not be examined very well. The clay as it is revealed in the workings and on the dumps is part reddish brown and part chocolate-colored; it is overlain by a few inches to 4 feet of cherty loam, and it has been penetrated to a depth of fully 10 feet. Although its areal extent has not been fully determined, the workings and surficial materials indicate that it underlies at least 2 acres. There are no limestone exposures in the vicinity, and apparently only a very small amount of the Fernvale limestone was found in the workings. A fragment of this limestone observed on one of the dumps has fine particles of manganese oxide disseminated through it.

The manganese ore occurs as fine particles ("wash ore") and as slabs and irregular-shaped boulders ("lump ore") and consists mainly of compact steel-blue psilomelane but partly of hausmannite, either in separate masses or intimately mixed. Some of the slabs of ore on the dumps show a roughly banded arrangement of these minerals, and a few such slabs contain crystals of white barite. (See Pl. X, *C*.) Red iron oxide in small quantity is found in the clay associated with the manganese ore.

HUNT HOLLOW MINE.

The Hunt Hollow mine, owned by William Einstein, is in Hunt Hollow in the SE. ¼ NW. ¼, the NE. ¼ SW. ¼, and the NW. ¼ SE. ¼ sec. 10, T. 14 N., R. 6 W., 3½ miles north-northwest of Pfeiffer. A small amount of work was done about 30 years ago, and the next work was done by the Vance Mining Co., the present lessee, beginning in 1917. At the time of visit (May 21, 1918) this firm had mined and shipped 80 tons of manganese ore containing 52 per cent of manganese and 140 tons of manganese ores containing 22 per cent of manganese.

The mine consists of two groups of workings, one of which is at the head of Hunt Hollow and the other a quarter of a mile farther north, on the east slope and north point of a hill. The workings at the head of the hollow are on an east and southeast slope and include one tunnel 30 feet long, a shorter tunnel, one cut, and a shaft 27 feet deep. They passed through a few inches to a few feet of surficial material, composed mainly of chert fragments and pebbles, and then penetrated for several feet red, yellow, and dark-brown manganese-bearing clays. The depth and extent of these clays had not been proved at the time of visit. The only limestone exposures in the vicinity at that time were one mass of Fernvale limestone and two masses of Kimmswick limestone. The manganese ore is mainly compact steel-blue psilomelane, but partly hausmannite and braunite, and it occurs as fine particles and as lumps and slabs, irregularly distributed through the clay. The largest slab thus far found weighed more than 3 tons. The presence of tabular casts in some of the ore suggests that they once contained barite, which occurs in a number of deposits in the region.

The workings on the east slope and north point of the hill farther north comprise several shallow pits and cuts and one tunnel. They have been dug in chocolate-colored manganese-bearing clay whose surficial portion is mixed with chert fragments and pebbles. Although the clay has been penetrated to a depth of 10 to 15 feet, its total thickness and areal extent have not been determined. The presence of several large outcrops of the Plattin limestone in the vicinity indicates that the clay overlies this limestone. Much mealy wad and many fragments of psilomelane, hausmannite, and braunite occur in the clay. The 140 tons of manganese ore (wad), containing 22 per cent of manganese, that has been shipped from this mine was obtained from the tunnel at this locality. Some fragments and boulders of fossiliferous chert taken from the tunnel were partly to wholly replaced by psilomelane. They were once a part of the Kimmswick limestone or Fernvale limestone and were set free by the decomposition of the limestone.

SMITH PROSPECT.

The Smith prospect, which is owned by L. H. Smith and G. W. Smith, is in Hunt Hollow, about one-fourth of a mile south of Coon Creek, in the NE. ¼ sec. 10, T. 14 N., R. 6 W., 4 miles north-northwest of Pfeiffer. Work was done here in 1918 by L. H. Smith and about 2 tons of hand-picked manganese ore had been taken out before the time of visit (May 7, 1918) and hauled to Pfeiffer, where it was shipped. The principal opening is a cut 15 feet long and a few feet deep that was dug near the base of a hill slope on the east side of Hunt Branch, a small stream said to run the year round. The cut is in chocolate-colored manganese-bearing clay, which is overlain in a part of the cut by a bed 6 feet thick composed of well-rounded chert pebbles. The manganese ore, which consists largely of psilomelane, occurs in the clay as masses weighing 15 pounds or less. The fine particles of ore ("wash ore") forms a considerable part of the ore-bearing clay, and at the time of visit Mr. Smith was planning to separate some of it from the clay by dry screening. The other workings include an old badly caved cut higher on the slope than the one just described and a shaft 10 feet or more deep, in a bed of chert fragments and pebbles on the top of the hill to the east. The depth and areal extent of the ore-bearing clay have not been determined. There are no outcrops of limestone in the vicinity, but outcrops of the Plattin limestone at the mouth of Hunt Hollow, less than one-fourth of a mile away, suggests that the ore-bearing clay overlies this limestone.

M'GEE MINE.

The McGee mine consists of pits and cuts 10 feet or less deep scattered over an area of about half an acre, on and near the crest of a hill on the north side of Coon Creek, in the SE. ¼ SE. ¼ sec. 3, T. 14 N., R. 6 W., 4 miles north-northwest of Pfeiffer. It was worked about 30 years ago by E. H. Woodward & Co., who mined and shipped one carload of ore,[93] and it has been worked recently by W. A. Hamer, who mined 300 tons of ore during the first 9 months of 1918. The openings are in a surficial loam 2 feet thick, composed mainly of chert fragments, and in red clay below the loam. The crest of the hill south of the openings is capped by a bed of chert fragments at least several feet thick. Psilomelane, manganite, wad, and some iron oxide, all more or less intimately mixed, occur as fine particles and masses a few feet across in both the clay and the surficial material. Iron oxide cements together some of the chert fragments, and manganese oxide has coated many chert fragments and

[93] Penrose, R. A. F., jr., Manganese—its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, pp. 238–239, 1891.

penetrated them along cracks. The manganese ore at this locality would be classed as a ferruginous manganese ore. Considerable silica in the form of sand grains occurs in parts of the manganese ore. If the sandy ore can not be avoided in mining the silica content of the marketed ore will be high. Sufficient prospecting has not, however, been done here to prove fully the size and character of the ore deposit. No limestone has been found in the openings, but further prospecting will show that the deposit overlies the irregular surface of the Plattin limestone, of which large exposures occur just north of the present openings.

A. G. GRAY MINE.

The A. G. Gray mine, owned by A. G. Gray, is about one-fourth of a mile north of Coon Creek, in the NE. ¼ SE. ¼ sec. 3, T. 14 N., R. 6 W., 4¼ miles north-northwest of Pfeiffer. The workings, which are shallow pits, have been dug through an east-west distance of about one-eighth of a mile, on and near the top of a hill at the head of the hollow that trends southward and passes just east of the McGee mine. Some of them were dug 25 or 30 years ago, and the recent ones were dug in 1918 by W. A. Hamer, the present lessee, who had mined and marketed 60 tons of ore before June 30, 1918. The openings penetrate but do not pass through the brown manganese-bearing clay, which is overlain on the slopes and on the crest of the hill by a surficial layer a few inches to a few feet thick of chert fragments and pebbles. Although no limestone is exposed on the surface near the openings and none was found in them the ore-bearing clay probably overlies the Plattin limestone, which is exposed not far away to the southeast and southwest.

The manganese ore consists of steel-blue psilomelane and of wad. Some masses of psilomelane weigh as much as 100 pounds or more. Both are irregularly distributed through the clay. Besides the manganese ore the clay contains nodules and slabs of chert which are partly to entirely replaced by manganese oxide. This chert and much of the clay as well as the manganese ore are a residue from the decomposition of the Fernvale limestone, but some of the clay is doubtless a residue from the decomposition of the Kimmswick and Plattin limestones.

W. T. GRAY MINE.

The W. T. Gray mine, owned by W. T. Gray, is on and near the divide between Barnitz Creek on the north and Coon Creek on the south and is 4½ miles north-northwest of Pfeiffer. It was worked 25 to 30 years ago by J. B. Gray and H. M. Hodge, and most of the ore shipped by them was hand-sorted "lump ore," but some material was hauled to the washer operated by Skinner & Abbot, on Sullivan Creek, 2½ miles west, where the smaller particles ("wash ore") were recovered from the clay. The next mining was done by W. T. Gray, beginning in August, 1917. The total production of the mine before the time of visit (May 7, 1918) is reported to have been about 375 tons. Since then considerable systematic prospecting has been done by Dwight E. Woodbridge.

The workings consist of many pits and cuts as much as 30 feet deep that have been dug here and there over 100 or more acres in the W. ½ NW. ¼, the NW. ¼ SW. ¼, and the NW. ¼ SW. ¼ SW. ¼ sec. 2 and the SE. ¼ NE. ¼ sec. 3, T. 14 N., R. 6 W. Most of the tract thus worked is gently rolling but part is rough hilly land, and the greater part of the tract has been cleared and cultivated. Rock exposures are common on parts of the tract but are absent from much of it. The rocks here exposed are limestones, which are overlain by a surficial bed composed of their residual clays and chert, chert fragments and pebbles, quartz sand, and masses of manganese oxides.

The Fernvale limestone is exposed as rusty boulders and ledges at many places on the surface and in the workings on the crest of the hill and on the hill slopes west and northwest of the main cut, which is in the SW. ¼ NW. ¼ sec. 2. This is the youngest limestone exposed in the vicinity, but a shaft near the crest of the hill southwest of the main cut encountered masses of the St. Clair limestone. A "button" of iron oxide found on the dumps together with the broken fragments of this limestone suggests that the Cason shale also underlies the crest of the hill. The Kimmswick limestone which lies beneath the Fernvale limestone, is nowhere exposed, but the Plattin, the next lower limestone, is exposed at many places on the hills south and east of the main cut and at a few places north of the main cut and along the small stream that flows northward just east of this cut. The Joachim limestone, which is below the Plattin, is exposed at a few places in the SE. ¼ NE. ¼ sec. 3, about one-fourth of a mile west of the main cut. The exposures and low dips of these limestones indicate that the mine lies in a shallow syncline. The accompanying section (fig. 14) illustrates the structure of the limestones and their relations to the overlying surficial material at this locality.

The main cut, dug in 1917 and partly caved at the time of visit (May 7, 1918), is 180 feet long, 8 to 20 feet wide, and 30 feet deep at the deepest place and trends S. 60° W. into a gentle east slope. It is entirely in surficial material, which consists of lenses and pockets of sand, beds of chert, manganiferous clay (wad), and chocolate-colored cherty clay. The cherty clay occurs in and near the bottom of the cut and contains masses of hard manganese ore, whereas the others are more or less intermixed and interbedded and occur at and near the surface. The chert, manganiferous clay, and cherty clay are for the most part residual products of the decomposition of the Fernvale limestone, but the sand was carried by streams and deposited on the surface of this limestone or in underground channels in it before the limestone was decomposed. Although the two sections given here show the character of these materials in parts of the cut, other sections made elsewhere would be quite different. The first section, made at the east end of the cut, is of beds of fairly uniform thickness that dip 45° N. 20° E., and the second section, made on the north side of the cut, is of beds which not only vary in thickness but are abruptly cut off on the east—possibly by a fault in the surficial material.

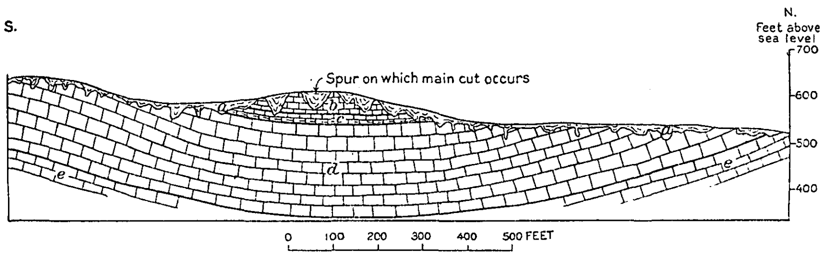


FIGURE 14.—North-south section through the W. T. Gray property, showing the structure of the rocks and the relations of the ore-bearing surficial material to the rocks. *a*, Surficial ore-bearing material; *b*, Fernvale limestone; *c*, Kimmswick limestone; *d*, Plattin limestone; *e*, Joachim limestone.

Section at east end of the main cut at the W. T. Gray mine.

	Feet.
Chert	3–5
Black manganiferous clay (wad), classed as low-grade manganese ore, which at this locality contains 20 to 25 per cent of manganese	7
Interbedded chert and clay	10
Black, porous, light, soft though firm earthy material, classed as second-grade manganese ore, which at this locality contains 30 to 35 per cent of manganese	2½
Black manganiferous clay (wad), classed as low-grade ore	1
Chert fragments and clay.	

Partial section on north side of the main cut at the W. T. Gray mine.

	Feet.
Black manganiferous clay (wad), classed as low-grade manganese ore	2–4
Interbedded chert and clay	4
Black manganiferous clay (wad)	3½
Red clay interbedded with black manganiferous clay (wad)	Few.
Yellow quartz sand containing some chert fragments and pebbles	2–5
Chocolate-colored clay containing both fine particles and boulders of hard manganese oxides. This is in bottom of cut.	

A bed of sand 8 feet thick is revealed at the surface on the north side of the cut near its west end, but a shaft 15 feet north of the exposure shows it to be 15 feet thick.

The manganese ore that was mined from this cut and shipped in 1917 was hand sorted and comprised three grades, which were shipped separately. The production of these several grades is stated by Mr. Gray to have been 55 tons of "first-grade" ore, containing 50 per cent of manganese in carload lots; 35 to 40 tons of "second-grade" ore, containing 30 to 35 per cent of manganese in carload lots; and 200 tons of "low-grade" ore, containing between 20 and 25 per cent of manganese. The "low-grade" ore is black manganiferous clay (wad), and the "second-grade" is a black, light, porous, soft though firm wad with small particles of hard manganese oxide scattered through it. The high-grade ore consists of compact steel-blue psilomelane, with which small quantities of hausmannite are mixed, and occurs as fine particles ("wash ore") and slabs and irregular masses weighing as much as 2 tons. Most of the "first-grade" ore has been found in the chocolate-colored clay in the bottom of the cut. Much of the "first-grade" ore occurs in the "second-grade" ore but very little occurs in the "low-grade" ore. The ore at the other workings consists largely of compact steel-blue psilomelane. Some of the chert found in the manganese-bearing clay on this property has been partly to wholly replaced by manganese oxide.

A cut 18 feet wide, 25 feet long, and 15 feet deep has been dug 300 feet east of the main cut and on the east side of the small northward-flowing stream. It reveals brown clay and black manganiferous clay (wad), also pockets as much as 10 feet thick of yellow sand in which there are a few angular fragments and pebbles of chert. Although these clays are overlain by the sand they in places extend upward to the surface. An old shaft a short distance east of this cut is said to have yielded a carload of high-grade ore 25 years ago.

On the low hill just west of the main cut ore was mined 25 years ago from clay lying between exposed boulders and ledges of the Fernvale limestone, but only a little mining has been done on this hill recently.

A few pits that have been dug in gravelly surface loam in an area of 2 or more acres in the NW. ¼ NW. ¼ sec. 2 are said to show that manganese ore in fine particles and larger masses extends from the surface to a depth of 4 feet. Two boulders of ore said to have been found in this area many years ago were together the size of a bale of cotton, and a boulder of ore weighing 1,000 pounds was found in 1917 in plowing the land.

A cut has been dug to a depth of 15 feet in red and chocolate-colored clays in the SE. ¼ NE. ¼ sec. 3, just west of the 40-acre tract on which the main cut is located. Hard manganese oxides were found in the chocolate-colored clay in both fine particles and boulders weighing as much as 1 ton, and masses of the oxides weighing a few pounds or less were observed at the time of visit in the beds of gullies. Systematic prospecting which was done in 1918 over part of this 40-acre tract and part of the 40-acre tract on the east by Dwight E. Woodbridge proved the presence, he states, of a large tonnage of high-grade manganese ore.

Considerable "wash ore" may be seen in the clay now lying on the dumps of both old and recent pits and cuts on the hills west and southwest of the main cut. The larger masses of ore were hand picked from the clay and shipped. Some of the clay removed from the workings contains fragments of chert that have been partly or entirely replaced by psilomelane.

On the east side of the hollow east of the McGee mine, in the NW. ¼ SW. ¼ SW. ¼ sec. 2, a cut has been dug in red and yellow clays, in which veins and irregular masses of manganese oxides (psilomelane and manganite) and iron oxide have been found. Ore mined at this locality would be classed as a ferruginous manganese ore, as the manganese and iron oxides are intimately mixed.

The following are analyses of samples from three carloads of ore, shipped by J. B. Gray to Carnegie Bros. & Co.[94]

Analyses of manganese ore from the W. T. Gray mine.

	1	2	3
Manganese (Mn)	50.81	46.36	49.36
Iron (Fe)	2.90	8.53	5.97
Phosphorus (P)	.126	.128	.156
Silica (SiO_2)	2.50	4.25	3.90
Moisture	....	2.50	5.50

UNITED STATES-CANADIAN MANGANESE CO.'S PROSPECT.

The United States-Canadian Manganese Co.'s prospect, also known as the Weaver prospect, is in the NE. ¼ NE. ¼ sec. 3, T. 14 N., R. 6 W., 4½ miles north-northwest of Pfeiffer, but other parts of the company's land, including the NW. ¼ NE. ¼ sec. 3 and the S. ½ SE. ¼ sec. 34, T. 15 N., R. 6 W., have been prospected. Prospecting at the locality first named was begun in 1917 by persons who in 1918 organized the above-named firm and at the time of last visit (June 4, 1918) further prospecting was being done and a dam was being built across the small northward-flowing stream to impound water for use in a washing plant to be built near by. The washing plant was nearly completed in November, 1918, when work on it was discontinued on account of lack of demand for domestic manganese ores.

[94] Penrose, R. A. F., jr., op. cit., p. 238.

Only a few tons of "lump ore" that was found during the prospecting has been sold.

The principal workings have been made within about 3 acres on the crest and gentle northwest slope of a hill. They consist of one cut 250 feet long, 25 feet wide, averaging 4 feet deep, another cut 118 feet long, 28 feet wide, averaging 2 feet deep, one shaft 50 feet deep, and a number of pits 4 to 8 feet deep. They have been made in red, yellow, and chocolate-brown clays, of which the layer 2 to 4 feet thick at the surface contains some chert pebbles and fragments. These clays are mainly a residue from the partial or complete decomposition of the Fernvale, Kimmswick, Plattin, and Joachim limestones. The first two of these limestones are apparently entirely decomposed, as there are no exposures of them either on the surface or in the workings, whereas the other two are only partly decomposed. Small boulders of the Plattin limestone were found in the shaft, and a few masses of it were found in the two cuts. This limestone is exposed at the surface near the dam, and the Joachim limestone is exposed farther north along the small stream.

The manganese ore consists of compact steel-blue psilomelane, hausmannite, and a smaller quantity of manganite and it is irregularly distributed through the red and chocolate-colored clays as fine particles ("wash ore") and as lenticular and irregular masses weighing as much as 300 pounds. A small quantity of red iron oxide in small pieces occurs also in the clays. The yellow clay, which lies next to the undecomposed limestone, does not contain any ore except near its contact with the other clays. Ore has been found in greater or less quantities not only in all the above-described openings but also in the bed of the stream above and below the dam and in gullies that trench the narrow flat through which the stream flows. The ore found in the larger gullies and in the stream bed is like that in the residual clays except that it has been transported by streams and deposited in their beds with many pebbles and fragments of chert. Its presence in the stream bed and gullies suggests that it underlies much of the level area or flat adjoining the stream, but neither the depth of this ore-bearing material nor its areal extent have been proved by prospecting.

E. W. ROACH PROSPECT.

The E. W. Roach prospect is in the NW. ¼ sec. 35, T. 15 N., R. 6 W., about one-fourth of a mile north of Barnitz Creek, and 1½ miles east-northeast of Sandtown. Work was done at this locality in 1917 by E. W. Roach, the owner, who mined and marketed 13 or 14 tons of manganese ore. The workings consist of one pit 8 feet deep and several smaller ones, which have been dug here and there over an area of about 1 acre in a nearly level tract. The largest pit has been sunk in a bed of yellow clay which contains many well-rounded pebbles. The clay contains also psilomelane, which has partly to entirely replaced much of the clay and has cemented many of the pebbles together. To separate the psilomelane from the clay and pebbles would require crushing and jigging, but the quantity of this mineral is too small to justify the installation of expensive machinery. A few pieces of manganese minerals were found on the dumps of the other pits.

The clay is obviously a residue from the decomposition of the limestones exposed near by, and the manganese was probably derived from the Fernvale limestone, of which a few loose boulders lie on the surface near the openings. The boulders are not in place but rest upon the weathered edges of the Plattin and Joachim limestones, which underlie a nearly circular area and dip at high angles toward its center. They lie therefore in a funnel-shaped syncline. The Plattin limestone, which is present in the center of the syncline, is brecciated in places, and its outcrop is 250 feet in diameter. Outside the Plattin limestone the Joachim is exposed in a narrow belt and outside this belt the St. Peter sandstone is exposed.

The manganese deposit and the boulders of Fernvale limestone are on and near the southwest edge of the syncline. The most plausible explanation for the peculiar occurrence of these boulders and the origin of the deposit is that masses of the Fernvale limestone fell or settled into an old sink or cave in the Plattin and Joachim limestones; that the pebbles were gradually washed from the surface into the sink hole or cave and were deposited in the clay as it accumulated in the bottom; and that the manganese was derived from the decomposition of the masses of the Fernvale limestone and was later deposited in the clay, partly or entirely replacing much of it.

HAWKINS MINE.

The Hawkins mine is half a mile southeast of Sandtown and 5 miles north-northwest of Pfeiffer, on a tract of land formerly owned by T. R. Hawkins but recently purchased by C. H. Plumb, who sold half of his interest to Paul Harding. This tract comprises the S. ½ SW. ¼ sec. 34, T. 15 N., R. 6 W., the NW. ¼ sec. 3, and the E. ½ sec. 4, T. 14 N., R. 6 W.

The mine was first operated in 1916 by Mr. Strahan, who mined 45 tons of manganese ore; some work was done later by Mr. Hawkins, who mined 15 tons of ore; and 43 tons was mined by Messrs. Plumb and Harding.

The workings, which are pits 15 feet or less deep, have been made on the slopes and crests of hills. Some of them pass through the surficial material, which consists mainly of chert pebbles and fragments, and penetrate red clay. Although most of the pits reveal ore the total depth and areal extent of the one or more ore bodies are yet to be determined. The presence of outcrops of the Plattin limestone at various places on the slopes indicates that the clay overlies this limestone. The Fernvale and Kimmswick limestones are nowhere exposed and have apparently been entirely removed by erosion.

The manganese ore consists of small nodular or botryoidal masses and large irregular masses, which are composed in part of psilomelane and manganite but in large measure of black earthy, soft though firm wad. In places the ore contains chert, pebbles, and fragments, in others it contains grains of quartz sand, and much of it is intimately mixed with brown iron oxide. The ore taken as a whole is a siliceous ferruginous manganese ore, but the grade can be improved by hand sorting and by avoiding the places where the silica and iron contents are highest. Samples of ore that have been analyzed are said to show a manganese content between 30 and 32 per cent.

The ore at this mine resembles that at the Chapel Hill and Roach mines, which are described on pages 167–168 and 169–171, respectively, and its origin is the same as that of the ore at those mines.

JEFF WEAVER PROSPECT.

The Jeff Weaver prospect consists of several pits and cuts a few feet deep on the north slope of a hill in the NW. ¼ SW. ¼ sec. 34, T. 15 N., R. 6 W., half a mile southeast of Sandtown and 5 miles north-northwest of Pfeiffer. The ore-bearing clay at this locality overlies the irregular surface of the Joachim and Plattin limestones, which are exposed at places on the slope. Manganese ore has been mined and hauled away from this prospect, but the quantity was not learned. The ore is similar to that on the Hawkins tract, which adjoins the Weaver property on the south.

CHAPEL HILL MINE.

The Chapel Hill mine, owned by the Cleveland Manganese Mining Co., is on the west and southwest slopes and on the crest of Chapel Hill, in the N. ½ SW. ¼ sec. 33, T. 15 N., R. 6 W., half a mile west of Sandtown, and 6¼ miles east by north of Cushman. The crest of the hill is about one-fourth of a mile west of Sullivan Creek and 240 feet above this stream. The mine was first worked by Skinner & Abbot about 30 years ago, and some of the manganese ore mined by them was treated in a washing plant on Sullivan Creek at the base of Chapel Hill, which they operated. A production of several hundred tons of manganese ore at that time is mentioned by Penrose,[95]

[95] Penrose, R. A. F., jr., op. cit., p. 247.

who described the property as the Morris tract. Very little mining has been done there during the last few years. At the time of visit work was being done by W. A. Hamer.

The workings include one shaft 25 feet or more deep and a few cuts 10 feet or less deep, which have been made in an area of perhaps 2 acres.

Chert fragments and pebbles cover much of the surface to a depth of 1 to 2 feet, but many of them are in the red clay found below the surficial layer, and in the shaft they extended to a depth of 25 feet. Most of the chert fragments have been derived from the Boone chert, but some of the chert in the clay is a residue from the decomposition of the Fernvale limestone, which once occurred at this locality but has been entirely eroded except its clayey and cherty constituents. Although part of the clay is residual from the Fernvale limestone, some of it is residual from the Kimmswick and Plattin limestones. The Plattin limestone is exposed on the slopes below the workings, but the Kimmswick limestone like the Fernvale has been entirely removed except its clayey constituents. The total thickness of the clay has not been determined, for none of the workings appear to have reached the underlying Plattin limestone nor has the areal extent of the clay been fully tested.

The ore is a ferruginous manganese ore, consisting of psilomelane, soft earthy though firm wad, and brown iron oxide. Most of it is in irregular masses, but some of it is in nodular or botryoidal masses, and many of the chert fragments derived from the Fernvale limestone have been partly or wholly replaced by manganese oxide. Some parts of the ore contain grains of quartz sand and other parts contain chert fragments and pebbles. Most if not all of the masses of ore at this mine are not residual from the Fernvale limestone and Cason shale, as is most of the ore in the Batesville district, but were formed in the clay, which the ore has partly or wholly replaced.

POOL PROSPECT.

The Pool prospect is three-fourths of a mile northwest of Sandtown and is on the A. N. Pool tract, which comprises the NW. ¼ NW. ¼ sec. 33 and the S. ½ SW. ¼ sec. 28, T. 15 N., R. 6 W. A few pits 4 feet or less in depth have been dug recently by Mr. Pool and C. H. Palmer on two hills on this tract. They are in red clay, much of which contains chert fragments and pebbles and masses of manganese ore. The occurrence of exposures of the Joachim limestone in the vicinity indicates that the clay overlies this limestone, but none of the pits have been dug deep enough to reach the limestone.

The manganese ore, which is like that at the Roach, Hawkins, and Chapel Hill mines, occurs as both large and small masses of irregular and botryoidal shapes. Some of the ore contains sand and chert pebbles and fragments, part of it is intermixed with iron oxide, and much of it is soft and earthy. By careful hand sorting a fair grade of ferruginous manganese ore can be obtained. Altogether about 15 tons of ore had been mined and marketed before the time of visit (June 4, 1918), and 40 tons is reported to have been mined before June 30, 1918.

ADLER-SOUTHARD MINE.

The Adler-Southard mine, not visited by the writer, is on a tract of land owned by N. A. Adler, in the SW. ¼ sec. 29, T. 15 N., R. 6 W., 1¼ miles northwest of Sandtown and 6 miles east-northeast of Cushman. Work on this tract has been done from time to time by various lessees, who mined 25 tons of manganese ore in 1916, little if any in 1917, and 25 tons in the first 6 months of 1918. This ore is a ferruginous manganese ore, and Mr. Adler reports that it had an average manganese content of 24 per cent.

ROACH MINE.

The Roach mine, owned by the Cleveland Manganese Mining Co., is on Roach Hill, in the SE. ¼ sec. 31, T. 15 N., R. 6 W., 4¾ miles east by north from Cushman. It was operated first about 30 years ago, but the production if any is not known. It was next operated from April, 1916, to March, 1917, by W. H. Denison, who mined and shipped 191 tons of manganese ore. A little work was being done at the time of visit (June 4, 1918) by the Manganese Development Co., and after that the mine was leased to James A. Welch, who began to build a washing plant but did not complete it.

The workings are on the crest of the hill and on its north and west slopes as far as 50 feet below the crest. The earlier workings were open cuts 10 feet or more deep, but the recent ones include shafts as much as 27 feet deep. They are in red and chocolate-colored clays, which are overlain by a surficial bed 2 to 3 feet thick composed mainly of chert pebbles and fragments, but many chert pebbles and fragments are present in the clays several feet below the surface. The clay also contains small and large masses of manganese ore. Although the depth and extent of the ore-bearing clay have not been fully determined, it is in places at least 27 feet thick and perhaps underlies a few acres. None of the workings appear to have passed entirely through the clay to the underlying limestone, which is either the Joachim limestone or Plattin limestone. The Joachim limestone and the St. Peter sandstone are exposed on the slopes below the workings, but no outcrops of the Plattin limestone were observed on that part of the slopes. Outcrops of the Plattin, however, were observed on the crest of the hill just south of the workings, and they appear to mark the southern boundary of the ore body. The occurrence of these outcrops on the crest of the hill, at or near the level of the highest workings, indicates that the concealed limestone surface upon which the ore-bearing clays rests is irregular. (See fig. 15.)

The manganese ore occurs in irregular masses, some as much as several feet across, and in small pieces, many of which have a botryoidal shape. The large masses are composed mainly of a soft, earthy, compact black wad but partly of psilomelane, manganite, and iron oxide, and they are cut by many joints whose faces are black and show deeply striated slickensides. Many chert pebbles and fragments are found in parts of such masses. Boulders of brown iron oxide but none of manganese ore were observed on the surface. The manganese ore shipped from this locality down to June

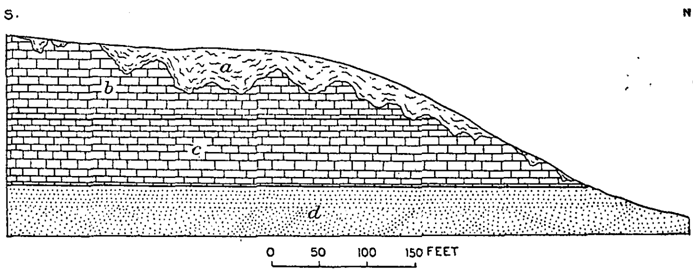


FIGURE 15.—Diagrammatic section at the Roach mine, illustrating the relation of the clay (*a*), much of which contains manganese ore, to the Plattin limestone (*b*), Joachim limestone (*c*), and St. Peter sandstone (*d*).

4, 1918, was hand-sorted "lump ore." The 191 tons of ore that was shipped by Mr. Denison is said to have averaged 17 per cent of manganese.

The following analysis shows the composition of a sample of the black earthy wad from this locality:[96]

Analysis of wad from the Roach mine.

[R. N. Brackett, analyst.]

Manganese (Mn)	14.57
Iron (Fe)	10.84
Silica (SiO_2)	37.77
Alumina (Al_2O_3)	9.87
Water	12.82

The masses of manganese ore at this mine are not residual from the Cason shale and Fernvale limestone, as is most of the ore of the Batesville district, but manganese in solution has been introduced

[96] Penrose, R. A. F., jr., Manganese—its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, p. 246, 1891.

into the clay by ground water, from which the present manganese oxides were deposited, partly or entirely replacing the clay. The wad represents parts of the clay that have been only partly replaced by manganese oxide, whereas the psilomelane and manganite represent parts of the clay that have been entirely replaced.

MONTGOMERY MINE.

The Montgomery mine is on the southwest slope of a hill, about four-fifths of a mile east of Polk Bayou and 7 miles east-northeast of Cushman. It was formerly worked as two cuts, the one on the west having been known as the Baxter mine and the one on the east as the Montgomery mine. Although these two cuts have been enlarged and connected by recent mining, they are still distinct and are herein described as the Baxter cut and Montgomery cut respectively. (See fig. 16.) The west part of the present mine—the part that includes the Baxter cut—is on the east border of the NW. ¼ SW. ¼ sec. 32, T. 15 N., R. 6 W., and is owned by C. A. Montgomery and J. P. Montgomery, whereas the east part of the mine—the part that includes the Montgomery cut—is on the west border of the NE. ¼ SW. ¼ sec. 32, T. 15 N., R. 6 W., and is owned by J. P. Montgomery. The line separating these two tracts runs north through the center of the mine.

Both of these old cuts were operated about 30 years ago. The Baxter cut was operated by John B. Skinner & Co., who conveyed the manganese ore on a tramway to Sullivan Creek, a distance of about a mile, where it was crushed and washed in a series of jigs.[97] Penrose mentions a production of 350 tons from this cut. Little if any more mining was done at this locality until May, 1917, when the Eureka Manganese & Mining Co., of which W. H. Denison is president and W. H. Beatty is manager, reopened the cuts and started the operation of a washing plant located near them. This company mined, milled, and shipped about 3,600 tons of manganese ore during 1917 and 1918.

The manganese ore is disseminated rather uniformly through a bed of red to brown clay, which is a residue from the decomposition of the Cason shale and possibly of a part of the Fernvale limestone. The distribution of this clay as well as that of the other rock formations in the vicinity is represented in fig. 16. This clay is concealed at the surface by a bed 1½ to 5 feet thick, which is composed of angular chert fragments and well-rounded chert pebbles, some as much as 4 inches in their longest diameter. The Joachim and Plattin limestones, of which there are many exposures, are concealed at most places by clay, soil, and chert débris consisting of both

[97] Penrose, R. A. F., jr., op. cit., p. 244.

angular fragments and well-rounded pebbles. Some of the chert fragments and pebbles are cemented together by iron and ferruginous manganese oxides on and near the crest of the hill, but most of them are loose. The chert fragments represent a part of the weathered Boone chert that has settled below the original position of this for-

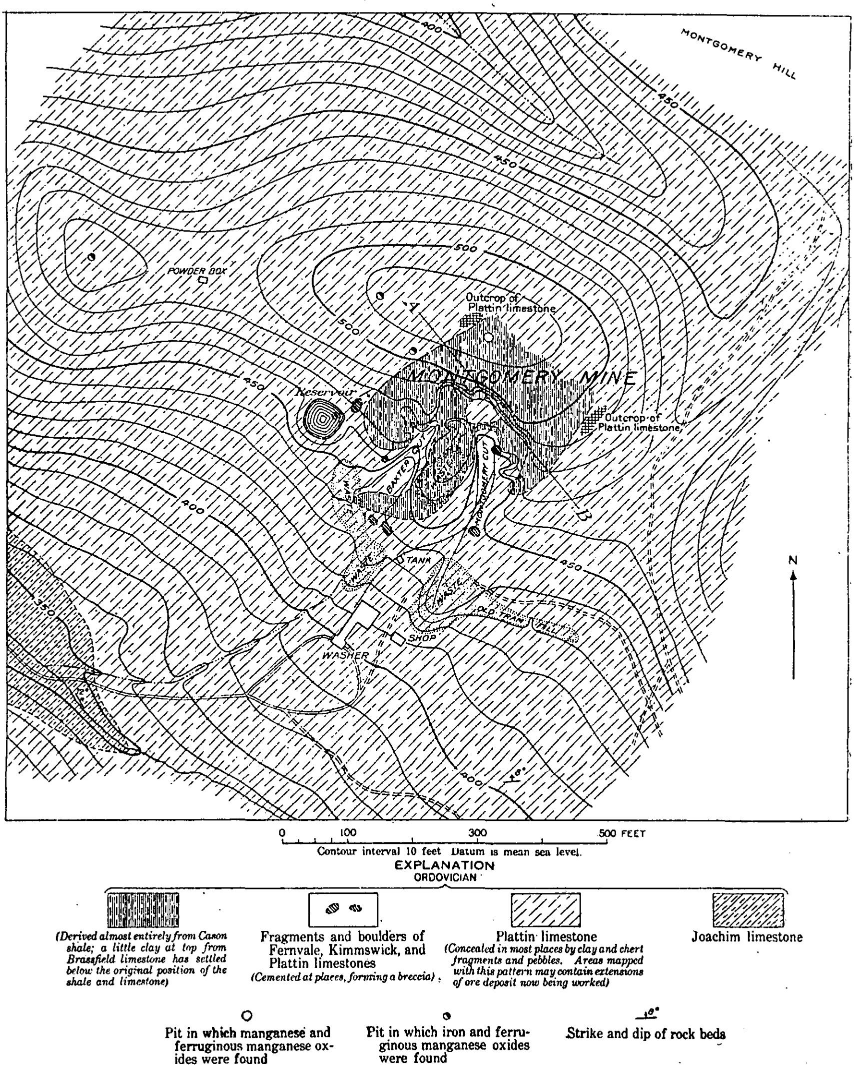


FIGURE 16.—Geologic map of the Montgomery mine. Surveyed by H. D. Miser with plane table in June, 1918. *A–B*, Line of section in figure 17.

mation, and the pebbles were once a part of the extensive gravel bed of Upper Cretaceous or later age that covered the region before the present valleys were carved by erosion. These surficial deposits may conceal parts of the known ore deposit or perhaps other deposits in the vicinity of the mine.

Although the ore-bearing clay occurs at and near the crest of the hill, it lies in a shallow northeastward-trending depression, varying from about 200 to about 250 feet in width in the Plattin limestone. (See fig. 17.) The extent of the depression toward the northeast has not been proved by prospecting, but its northwest and southeast borders are fairly well marked by outcrops of the Plattin limestone. The clay, as previously stated, is dark red and brown. In the lower parts of the cuts it is plastic and very tough, hence is hard to wash, whereas in the upper parts of the cuts it is less plastic and more earthy, making its washing easy. It ranges in thickness from a few feet to 47 feet. Part of this variation is due to the presence of three "horses" of non ore-bearing clay, which have been found to extend upward into it to within 15 or 20 feet of the surface. The greatest thickness of the ore-bearing clay is therefore in the depressions between the "horses."

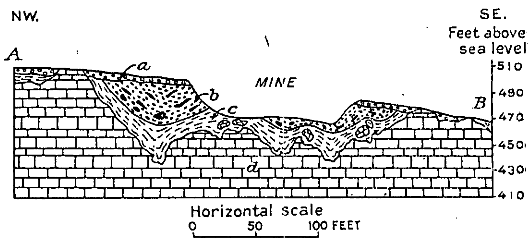


FIGURE 17.—Section along line A–B, figure 16, illustrating the occurrence of the manganese-ore deposit at the Montgomery mine. *a*, Chert fragments and pebbles; *b*, ore-bearing clay; *c*, non ore-bearing clay; *d*, Plattin limestone.

The "horses" beneath the ore-bearing clay are ridgelike and parallel, pitch to the southwest, and are as much as 45 feet wide at the base and as much as 30 feet high. They are composed for the most part of very sticky yellow, pink, red, and brown clays, which show slickensides and which contain thin sandy parallel plates, but they are composed in part of boulders and ledges of the Plattin, Kimmswick, and Fernvale limestones and of a few masses of chert that has replaced parts of one or more of these limestones. Thin veins of calcite cut the boulders of the Fernvale limestone, and some of them contain small quantities of psilomelane and other oxides of manganese, which were deposited later than the calcite, and some are said to contain small quantities of galena. Vein quartz and a few crystals of barite partly replaced by manganese oxide were found in blasting one of the masses of the Plattin limestone. The clays in these "horses" are the residue from the decomposition of the Plattin, Kimmswick, and Fernvale limestones. As the calcium carbonate of these limestones was removed through solution the overlying ore-bearing clay settled from its original position. The presence of large masses of limestone breccia—some composed of fragments of the Plattin limestone, some of both the Plattin and Fernvale limestones, and some of these two limestones and the Kimmswick limestone—at the mouths of the two cuts and in and near the reservoir and the fairly straight northwest and southeast boundaries of the ore-bearing clay suggest that at least a part of the settling of the ore-bearing clay may be attributed to the settling of the rocks between two nearly parallel faults on either side of the ore deposit. As there is no evidence of faulting along the small stream southwest of the mine it is believed that the brecciation of the limestones and at least a part of the settling of the ore-bearing clay are due to the falling in of the roof of an old cave.

The clays in and near the top of the workings contain fossil gastropods, brachiopods, cephalopods, and *Girvanella*, which consist of manganese oxide. These fossils, according to E. O. Ulrich, have been derived from the Brassfield limestone, which once overlay the Cason shale at this locality but which like this shale has been entirely decomposed, leaving only its residual clay and the above-mentioned fossils. The fossils were once composed of calcium carbonate, but, perhaps during the decomposition of the limestone, they were completely replaced by a hard manganese oxide, so that the form of the fossil shells is well preserved, although they now occur loose in the residual clays. Fossil gastropods, brachiopods, and cephalopods thus replaced by manganese oxide are, so far as the writer is able to learn, not found at any other locality in the United States. Some of the fossils are shown in Plate VII, *A*.

The manganese oxides, which are psilomelane, braunite, and manganite, usually more or less intermixed, occur disseminated through the above-described ore-bearing clay as irregular masses from the size of sand grains to that of boulders weighing 2 tons, as parallel layers or lenses a few inches thick, separated by various thicknesses of clay, and as buttons. (See Pl. XI and fig. 3.) The "buttons" are like the black manganese buttons at the Cason mine. They are 1½ inches or less in their longer diameter and one-third of an inch or less thick, and they lie with their longer diameters in the same plane, which is parallel with the bedding of the original unweathered shale. The layers or lenses of ore inclose "buttons" and thus appear to have replaced certain layers of the clay or shale. The "buttons" are hard and dense except for the cavities in some of them, whereas the lenses and irregular masses are hard and porous. The records of the mine indicate that the ore-bearing clay contains concentrates in the ratio of 3 parts of ore-bearing clay to 1 of concentrates and 6 of clay to 1 of concentrates and an average of 5 to 1. Irregular fragments and grains of a gray or white phosphatic rock, some of which is said to contain as much as 11 per cent of phosphorus, are disseminated through the ore-bearing clay in some parts of the deposit, especially the lower part. Most of them occur free in the clay, but some of them, together with greenish varieties of this rock, occur in some of the larger masses of manganese ore. Masses of ore containing much of this rock are not shipped because of their high phosphorus content.

Until May 28, 1918, the mining was done with pick and shovel, and the ore was conveyed from the cuts to the washer in small tram cars which were pushed by hand. On that date a Thew steam shovel, with a ⅝-yard dipper and larger cars drawn by mules, were installed. (See Pl. XIV, *B*.) The washing plant at present (June, 1918) operates only about 6 hours a day, because of the inadequate supply of water, and produces 100 tons of concentrates a week. Water for it is pumped from Polk Bayou through 4,500 feet of 4-inch pipe to the reservoir, which is 210 feet above the bayou. The reservoir has since been enlarged so as to contain sufficient water for a 10-hour working day. The output of the plant on the basis of a 10-hour run each day was expected to be 150 tons or more each week. The concentrates are hauled by wagon to Cushman, a distance of 7 miles, at a cost of $4.50 a ton. The equipment of the washing plant at the time of visit (June, 1918) included a McLanahan-Stone standard 2-log ore washer, a Richards jig, and a combination screen and sizing drum. (See Pl. XIV, *A*.) The flow sheet of the washing plant is described on pages 97–98 by W. R. Crane.

Prior to the time of examination the ore was separated into two grades—"tailings," which passed through a screen with ⅛-inch perforations, and "mine-run ore," which did not pass through such a screen. The "mine-run ore" shipped before April 1, 1918, averaged 40.21 per cent of manganese, 7 per cent of iron, and 17 per cent of silica, but soon after the installation of the Richards jig the manganese content was increased to 44.30 per cent and the silica was decreased to 13 per cent. More thorough jigging, which was expected of the 3-cell jigs installed since June, 1918, may have reduced the silica content still more.

The "mine-run ore" averages about 0.40 per cent of phosphorus, and the ore that is in pieces more than half an inch in diameter contains about 0.20 per cent of phosphorus. This difference in the phosphorus content is due to the presence of pieces less than half an inch in diameter of phosphatic rock, which have not been entirely separated from the ore. Although grains of phosphatic rock occur in some of the ore more thorough jigging will free the ore from most of the phosphatic rock, as this rock has a much lower specific gravity than the manganese ore. The ore that is free of phosphatic rock has a low phosphorus content, as shown by the fact that some carload lots of "lump ore" contained as low as 0.09 per cent of phosphorus. Some of the first cars shipped by the Eureka Manganese & Mining Co. were not properly prepared for the market and contained as high as 1.87 per cent of phosphorus. The tailings constitute one-eighth of the production of the mine. The 10 cars thus far (June 22, 1918) shipped ranged from 27.55 to 31.48 per cent of manganese and averaged 28.84 per cent of manganese and 7 per cent of iron. The following analyses represent the composition of three carloads of manganese ore mined in the Baxter cut by Skinner & Abbot and shipped to the Illinois Steel Co.[98]

Analyses of manganese ore from the Montgomery mine.

	1	2	3
Manganese (Mn)	55.60	47.70	45.77
Iron (Fe)	8.78	4.77	4.67
Phosphorus (P)	.149	.284	.342
Silica (SiO_2)	24.58	10.98	14.06
Water	9.80	9.20	8.20

MONTGOMERY HILL MINE.

The Montgomery Hill mine is on a knob known as Montgomery Hill, which is just northeast of the Montgomery mine. It is on land owned by J. P. Montgomery, which has been leased to the Eureka Manganese & Mining Co. Surficial material composed of chert pebbles and fragments caps the crest of the knob and covers its slopes. A number of pits as much as 10 feet deep which have been dug on the slopes pass through this material and penetrate a red ore-bearing clay. The clay as revealed in the pits is at least a few feet thick and in places attains a thickness of 10 feet, and it underlies an area of at least 1 acre and perhaps 3 acres more. The Plattin limestone underlies this hill, although there are no exposures of it near the pits, and it is probably separated from the ore-bearing clay by a greater or less thickness of clay that does not contain any ore.

The ore is a ferruginous manganese ore similar in character and origin to that at the Roach mine and is apparently present in the ratio of 1 part of ore to 5 parts of ore-bearing clay. Part of the ore is earthy and soft, though firm; some of it contains chert fragments; and most of its masses are irregular in shape, but some are botryoidal. Analyses of samples of the ore are said to show that it contains between 32 and 34 per cent of manganese. The "lump ore" has been mined and shipped and is in much smaller quantity than the "wash ore."

SIS CLARK MINE.

The Sis Clark mine is 5 miles east by north from Cushman and is on a tract of land owned by Mary J. Clark, which comprises the N. ½ NW. ¼ sec. 5, T. 14 N., R. 6 W., and the SE. ¼ SW. ¼ sec. 32, T. 15 N., R. 6 W. The mine, which is in the NW. ¼ NW. ¼ sec. 5,

[98] Penrose, R. A. F., jr., op. cit., p. 245.

was first worked by Skinner & Abbot about 30 years ago. Part of the ore mined by them was hand sorted, but some of the ore dirt was hauled in wagons to the tramroad connecting the Montgomery mine with its washing plant on Sullivan Creek, and it was thence conveyed to the washing plant where the ore was recovered by washing. The total production at that time is not known, but Penrose[99] mentions the production of 90 tons of manganese ore. The mine was next operated in 1915 by Coleman & Grefenkamp, who mined 40 tons of high-grade manganese ore, and since then it has been operated at times by W. A. Hamer. Most of the work by Mr. Hamer was done in 1917, when he mined 80 tons of high-grade ore and 500 tons of low-grade ore. Since the time of visit (June 7, 1918) the mine has been leased to J. C. Shepherd and R. A. Baker, who mined several carloads of low-grade manganese ore before the end of the year.

The recent workings consist of about 17 cuts and shafts, and from these 250 to 300 feet of tunneling has been done. Ten of the openings, the deepest being 32 feet, have been made here and there over an area of about 7 acres on and near the crest of an east-west ridge. They all penetrated red and chocolate-colored manganese-bearing clays after they passed through a surficial bed of chert fragments and pebbles, and none of them passed entirely through the clay. The other openings, of which the deepest is 22 feet, have been made here and there over an area of about 13 acres farther south. They penetrated the ore-bearing clay, which lies beneath a surficial bed 6 to 8 feet thick that is composed mainly of chert fragments and pebbles, but none of them passed entirely through the clay.

The information at hand supports the inference that the ore-bearing clay underlies the whole of the 7-acre and 13-acre tracts, but the quantity of ore on them can not be accurately estimated until after systematic prospecting and sampling have been done. Several of the openings encountered boulders of the Plattin limestone, but none of them encountered solid ledges of any limestone. The Fernvale limestone, from which most if not all of the ore has been derived, has been removed by erosion from the two tracts, and the Kimmswick limestone has also been removed, so that the ore-bearing clay everywhere rests upon the Plattin limestone. Channels and hollows separated by pinnacles doubtless mark the surface of this limestone.

The manganese ore consists of two grades, known as low grade and high grade. They are intermixed, and the low-grade ore is in greater quantity than the high-grade. One shaft, from which 200 tons of ore were removed, showed a ratio of 3 tons of low-grade

[99] Penrose, R. A. F., jr., op. cit., p. 243.

to 1 ton of high-grade ore. The low-grade ore is an earthy, porous, brown, and soft but firm wad, and it is hand sorted from the inclosing clay. The 500 tons of it mined in 1917 by Mr. Hamer had, he states, an average content of 30 per cent of manganese, 14 per cent of iron, and 8 per cent of silica. The analyses of four carload lots that were shipped to the Tennessee Coal, Iron & Railroad Co. are given below. The high-grade ore consists of steel-blue psilomelane and a smaller quantity of hausmannite and occurs in irregular masses ranging in size from fine particles to boulders, the largest of which thus far found is said to have measured 20 feet long, 4 to 10 feet wide, and 2 to 5 feet thick and to have weighed 22 tons. The concentrates of hard ore recovered by Skinner & Abbot from the wash dirt, were found, it is stated, in the ratio of 1 ton of concentrates to 3 tons of wash dirt, but most of the wash dirt observed by the writer will not yield such a large proportion of concentrates. The 80 tons of high-grade ore mined by Mr. Hamer in 1917 had, he states, an average content of 48 per cent of manganese, 8 per cent of iron, and 4 per cent of silica.

Analyses of low-grade manganese ore from the Sis Clark mine.

	1	2	3	4
Manganese (Mn)	35.23	30.36	31.87	30.39
Iron (Fe)	9.82	9.82	9.82	13.47
Silica (SiO_2)	13.88	13.88	13.88	13.78

SIS CLARK CORNER PROSPECT.

The Sis Clark Corner prospect is about one-fourth of a mile southwest of the Montgomery mine, on the southern border of the SW. ¼ SW. ¼ sec. 32, T. 15 N., R. 6 W. It is on land that is owned by C. A. Montgomery and J. P. Montgomery and has been leased by the Eureka Manganese & Mining Co. Shallow pits and cuts have been made in red and chocolate-colored manganese-bearing clays over an area of about 2 acres, and two grades of ore like those in the Sis Clark mine, which adjoins this 2-acre tract, were found. The full thickness of the ore-bearing clay has not been determined.

GALLOWAY MINE.

The Galloway mine is in a hilly but gently rolling region, 5 miles east by north from Cushman, and it adjoins the west side of the tract on which the Sis Clark mine is situated. It was formerly owned by J. M. Galloway, but at the time of visit (June 5, 1918) it was owned by J. D. O'Gara.

A few pits and shafts as much as 20 feet deep have been made on and near the crest of a well-rounded hill in the northeast corner of the NE. ¼ NE. ¼ sec. 6, T. 14 N., R. 6 W. They penetrate red and chocolate-colored manganese-bearing clays the surficial portion of which contains chert pebbles and fragments. The clays were nowhere entirely passed through, and no limestone boulders were found in them. Exposures of the Plattin limestone on the slope south of the openings indicate that the clays rest on this limestone, and although this part of the tract has not been fully prospected a considerable thickness of ore-bearing clay appears to underlie about 7 acres on the crest of the hill. The manganese ore consists of two grades resembling those at the Sis Clark mine. The low-grade ore is wad, and the high-grade ore consists of large and small masses of steel-blue psilomelane and a less quantity of braunite and hausmannite. Some wash ore is found here, but the percentage of it that can be recovered from the inclosing clay has not been determined.

Several pits a few feet deep have been made on Peach Orchard Hill, a well-rounded hill southwest of the openings described above, and they reveal the presence of manganese-bearing clay beneath a surficial bed 5 to 6 feet thick of chert fragments and pebbles. Manganese ore of good quality, including both "wash ore" and "lump ore" were found, but the extent and depth of the deposit are yet to be determined. The Plattin limestone probably underlies the ore-bearing clay.

Several pits as much as 15 feet deep have been made in a triangular wooded tract of 5 acres on the crest of a well-rounded hill, on the east side of the NE. ¼ NE. ¼ sec. 6. The red to black ore-bearing clays, which were penetrated but not passed through, are in places overlain by masses several or many feet thick, composed of chert fragments and pebbles. Such masses are known as flint or gravel bars. The clay probably overlies the Plattin limestone as it does at other places on the Galloway tract. Much black wad, which is said to contain 35 per cent of manganese, occurs at this locality, but there are also masses of hard manganese ore occurring both as "wash ore" and "lump ore."

DEAD TREE HILL PROSPECT.

The Dead Tree Hill prospect, owned by J. P. Montgomery and C. A. Montgomery and leased by the Eureka Manganese & Mining Co., is on Dead Tree Hill, in the southeast corner of the SE. ¼ SE. ¼ sec. 31, T. 15 N., R. 6 W., 5 miles east by north of Cushman. It consists of a number of pits and shafts as much as 27 feet deep, which have been dug here and there in red and chocolate-brown manganese-bearing clays on the well-rounded crest of the hill. Although the crest of the hill has not been thoroughly prospected, a considerable thickness of these clays apparently underlies an area of about 8 acres. This area adjoins the north side of the 7-acre ore-bearing tract in the northeast corner of the land on which the Galloway mine is situated. The clay is concealed by a bed of chert pebbles and fragments, which at most places does not appear to be more than a few feet thick. Masses of the Plattin limestone were found in some of the openings, and a few masses of this limestone are exposed on the surface. The Fernvale limestone has been completely removed by erosion, and only one boulder of the Kimmswick limestone was observed, which indicates that this limestone has been almost entirely eroded. The manganese ore, of which only a small quantity has been mined and shipped, is like that at the Sis Clark and Galloway mines and the Sis Clark Corner prospect.

BARNETT MINE.

The Barnett mine is in a gently rolling hilly area, 5 miles east by north from Cushman, and is just south of the Galloway and Sis Clark mines. Most of the work at this mine was done in 1917 by George L. Barnett and N. Barnett, who mined 135 tons of manganese ore. The mine was formerly owned by H. L. Barnett, but at the time of visit (June 5, 1918) it was owned by J. D. O'Gara.

A cut 20 feet deep, 20 feet wide, and 30 feet long has been made in ore-bearing clay, in the SE. ¼ NE. ¼ sec. 6, T. 14 N., R. 6 W. The clay as revealed in the cut is overlain by a surficial rocky loam as much as a few feet thick, which is composed mainly of chert fragments and pebbles, and its base was not reached in the cut. The production of this cut has been 100 tons of low-grade and 10 to 15 tons of high-grade manganese ore. Another cut, 22 feet deep, 10 feet wide, and 20 feet long, has been made in black and red ore-bearing clays east of the above-described cut, in the northwest corner of the S. ½ SW. ¼ NW. ¼ sec. 5, T. 14 N., R. 6 W., and it has yielded 15 tons of low-grade and 10 tons of high-grade manganese ore. As in the other cut, the base of the clay was not reached. Very small pits have been made at other places.

The ore-bearing clay penetrated by the above-described openings probably underlies a few acres, but systematic prospecting and sampling will be required to determine the full depth of the clay and the tonnage of ore. The occurrence of a few outcrops of the Plattin limestone on the gentle hill slopes near the pits and below the cuts indicates that the ore-bearing clay rests on this limestone.

The manganese ore resembles that at the Sis Clark, Galloway, and Dead Tree Hill mines. It consists of the two grades of ore mentioned above, and although they are more or less mixed they have been hand sorted and shipped separately. The low-grade ore is soft, mealy, porous brown wad and is reported to contain about 30 per cent of manganese. An analysis of one carload of it that was shipped to the Tennessee Coal, Iron & Railroad Co. showed manganese (Mn), 29.33 per cent; iron (Fe), 13.75 per cent; and silica (SiO_2), 15.16 per cent. The high-grade ore consists of irregular masses of psilomelane ranging in size from fine particles to boulders that weigh 3 tons, and carload lots of it will apparently contain close to 50 per cent of manganese.

MONTGOMERY PROSPECT.

The Montgomery prospect consists of a few small pits on a west hill slope, on the east side of Polk Bayou and is on land owned by J. P. Montgomery, in the NE. ¼ SW. ¼ sec. 31, T. 15 N., R. 6 W. The hill is capped by a thick bed of chert fragments, and such fragments cover most of its west slope. The pits, which are badly caved, reveal an earthy soft though firm ferruginous manganese ore, but further prospecting will be required to determine the quantity of it.

The rock exposures indicate that the pits lie between two normal faults 250 feet apart, which trend east, and that the rocks in the belt between the two faults have settled about 100 feet. (See fig. 18.) The Joachim and Plattin limestones are exposed on the slope below the pits, and at one place the top of the St. Peter sandstone is exposed at the water's edge of Polk Bayou below the pits, but north and south of the pits beyond the belt that has settled by faulting outcrops of the St. Peter sandstone occur on the hill slope as far as 100 feet above Polk Bayou.

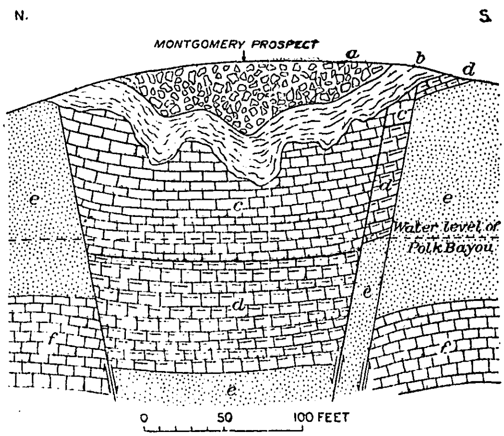


FIGURE 18.—North-south section at the Montgomery prospect. *a*, Fractured chert; *b*, residual clay; *c*, Plattin limestone; *d*, Joachim limestone; *e*, St. Peter sandstone; *f*, magnesian limestone.

REED MINE.

The Reed mine, 3½ miles east-northeast of Cushman, was not visited by the present writer. It is described as follows by Penrose:[1]

The I. N. Reed tract is in 15 N., 7 W., sec. 36, the SE. ¼ SW. ¼, and is a quarter of a mile southeast of the Pritchett tract. The hill on which it is

[1] Penrose, R. A. F., jr., Manganese—its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, p. 254, 1891.

situated is heavily capped with chert, but to the north it slopes off gently to a hollow that separates it from the last-named place. The ore-bearing clay is exposed on this slope and overlies the Izard [Plattin] limestone. From here the deposit runs south under the chert that caps the hill. The ore is of a massive black variety and is associated with red and brown clay and angular fragments of chert. Several openings have been made, and 200 tons of ore are said to have been mined.

C. C. JOHNSON PROSPECT.

The C. C. Johnson prospect is in the SW. ¼ SW. ¼ sec. 36, T. 15 N., R. 7 W., 3¼ miles east-northeast of Cushman. Prospecting has been done at this locality by C. C. Johnson, the owner, who mined and marketed several tons of lump manganese ore. In April, 1918, the prospect was leased to C. H. Edge, who later became a member of the Loyalty Mining Association. This firm operated the property on a small scale and shipped very little if any manganese ore. Several pits and shafts as much as 14 feet deep had been dug before the time of visit (April 22, 1918) on and near the east end of a hill and in a saddle between this and another hill farther west. They penetrate a brown clay whose surficial portion contains chert fragments and pebbles. Neither the depth nor the areal extent of the clay has been determined by prospecting. That the clay overlies the Plattin limestone is indicated by the presence of a number of outcrops of this limestone in the vicinity, and the clay doubtless extends through the hills beneath the chert capping on their crests.

Manganese oxides, of which psilomelane is in greatest quantity and wad, braunite, and hausmannite in less quantity, occur in the clay and surface material as irregular masses ranging in size from fine particles ("wash ore") to boulders. The largest boulder thus far found (April 22, 1918) is said to have weighed 3 tons. Films of manganese oxide coat many of the chert fragments and pebbles. Some openings reveal considerable "wash ore," and some reveal very little or none of it.

PRITCHETT PROSPECT.

The Pritchett prospect, 3¼ miles east-northeast of Cushman, was not visited by the present writer. Penrose[2] describes it as follows:

The Pritchett tract is in 15 N., 7 W., sec. 36, the NW. ¼ SW. ¼, and sec. 35, the SE. ¼ SE. ¼. Manganese ore, associated with red clay, has been found on this property, overlying hills of Izard [Plattin] limestone. Frequently bodies of chert form prominent knobs on the hills, and fragments of it overlie the surface of the ore-bearing clay on the slopes. Underneath this loose material, at a depth of from 2 to 10 feet, ore has been found in masses from 1 to 12 inches or more in diameter. It is of the usual hard, black variety and is gener-

[2] Penrose, R. A. F., jr., op. cit., pp. 253–254.

ally crystalline. Sometimes it occurs as a cement, binding together fragments of chert. Several small prospect pits which have been sunk show manganese in greater or less quantities.

FORTUNE PROSPECT.

The Fortune prospect, which is on land owned by W. N. Fortune, is on the south side of Prairie Creek, in the NW. ¼ SW. ¼ sec. 11, T. 14 N., R. 7 W., 2 miles east of Cushman. Work was done at this locality in 1917 by Mr. Fortune, and 40 tons of manganese ore are said to have been mined and shipped.

The workings are pits as much as 15 feet deep, dug here and there over 2 acres, in a saddle in the ridge. They all penetrate dark-brown clay in which there is a considerable quantity of mealy wad and some irregular masses of steel-blue psilomelane and braunite. The dark-colored surficial loam, 2 feet thick, contains chert pebbles and fragments and masses of ore. The largest boulder of ore thus far found (April 17, 1918) weighed between 200 and 300 pounds. White barite in slender needles lines cavities in a few pieces of ore observed on the dumps. Neither the extent nor the depth of the manganese-bearing clay at this prospect has been proved. No limestone was found in the workings, and there are no outcrops of it in the vicinity.

BROOKS HILL MINE.

The Brooks Hill mine, also known as the Brooks mine or Aydelott mine, consists of several groups of openings which have been made here and there on land owned by Doak Aydelott, 1 to 1¾ miles east-southeast of Cushman. It was first worked about 30 years ago and was next worked by W. H. Denison, the present operator and lessee, who began operations in July, 1916. Mr. Denison had mined and shipped before June, 1918, 1,252 tons of manganese ore with 40 per cent or more of manganese and 133 tons of ferruginous manganese ore.

The principal group of workings, from which most of the ore has been mined, consists of shallow pits, shafts as much as 55 feet deep, and drifts as much as 40 feet long scattered here and there over about 40 acres on the crest of a northeastward-trending ridge in the NE. ¼ NW. ¼ sec. 15 and the SE. ¼ SW. ¼ sec. 10, T. 14 N., R. 7 W. Chert débris, which varies in thickness from a few inches to 20 feet or more, is the usual surficial material on the ridge. It overlies the reddish-brown manganese-bearing clay, and the clay in turn overlies the irregular surface of the Fernvale limestone, of which there are exposures on the slopes on either side of the crest of the ridge. Some boulders and ledges of this limestone were found in the workings.

Parts of the clay contain both manganese ore and chert fragments. Some of these fragments are partly replaced by manganese oxide; and many of them, as well as some of the chert fragments overlying the clay, are coated with films of manganese oxide. Although the clay is widely distributed over the tract it varies in thickness from a few inches to 55 feet, and much of it contains no ore. The manganese ore is composed of psilomelane and a smaller quantity of hausmannite, which is intimately mixed with the psilomelane. These minerals are usually compact and are free from clay except on the surfaces of the masses, which are irregular in shape and range in size from fine particles to boulders weighing 500 pounds. All the marketed manganese ore from this group of workings, except four cars of concentrates and a few cars of unwashed ore-bearing clay, consisted of the larger masses that had been hand picked by the miners as they dug the clay from the "solid." The four cars of concentrates were recovered from clay which was hauled to Fortune or Scribner Spring, 1½ miles east-northeast of the mine, and there treated in a small washing plant equipped with a trommel screen with one-eighth inch perforations. The concentrates are said to have been recovered in the ratio of 1 part of concentrates to 7 parts of ore-bearing clay. One of the four cars of concentrates contained 33 per cent of manganese, another 36 per cent, another 46 per cent, and the fourth 48 per cent.

A few pits 5 to 20 feet deep are scattered here and there in a saddle between two hills, in the SW. ¼ NW. ¼ sec. 15, T. 14 N., R. 7 W., southwest of the above-described openings. The red to chocolate-colored ore-bearing clay extends from the surface to the bottoms of the pits, and none of them were dug deep enough to reach the underlying limestone. The production from these pits has been 30 tons of "lump ore," some masses of which weighed as much as 250 pounds.

A few pits, cuts, and drifts are on the north hill slope south of Prairie Creek, in the NW. ¼ SE. ¼ sec. 10, T. 14 N., R. 17 W., northeast of the main group of openings. The hill slope is covered with chert fragments and pebbles and blocks of sandstone. The workings reveal a large quantity of black earthy wad through which are scattered masses of hard manganese oxide. The production of these openings has been 175 tons of the larger masses of the hard oxides and one car of wad, which is said to have contained 29 per cent of manganese. The only limestone observed in the vicinity is Plattin limestone, outcrops of which are found below the openings.

Several shallow openings—some made recently and some about 30 years ago—are on the north slope of a ridge on the south side of Prairie Creek, in the NE. ¼ SE. ¼ sec. 10, T. 14 N., R. 7 W. There is little chert débris on the surface and only a few exposures of limestone. The openings are in red and brown clays, from which irregular masses of soft and hard manganese oxides, including psilomelane and wad, have been taken. A few small pits and cuts south of the openings described above have been dug on the south slope of the ridge, and they have yielded considerable earthy wad together with masses of psilomelane. The absence of limestone outcrops suggests that there may be an extensive deposit of ore-bearing clay on this slope. A few short drifts have been made on the north slope across the hollow south of the openings just described. They reveal a bed of wad 8 to 10 feet thick, through which masses of hard manganese oxide (psilomelane) are scattered. The wad does not lie horizontal but dips at different angles in different directions at the places where it could be observed. Both the wad and the hard ore were being mined and shipped at the time of visit (April 17, 1918), but they were separated by hand picking and shipped separately. The wad as shipped probably contained between 20 and 30 per cent of manganese, whereas the hard ore contained 45 per cent or more. The absence of limestone outcrops suggests that the Fernvale limestone is here deeply decayed and hence affords an extensive deposit of manganese-bearing clay.

Penrose[3] supplies the following description of the early workings at the Brooks Hill mine:

Three shafts, 35 feet, 36 feet, and 45 feet deep, respectively, have been sunk on the property, and it has been found that beneath the chert on the slopes of the hills the ore-bearing clay occurs to a considerable depth. Several drifts have also been made in the ore deposit.

Drift No. 1 runs into the side of a hill for 150 feet, showing a stiff red clay with angular chert and a little manganese ore. Immediately overlying the drift are 10 to 15 feet of chert, capping the hill. Drift No. 2 runs north under the chert into a deposit of dark chocolate-colored clay, containing both large masses of ore ("lump ore") and innumerable small particles ("shot ore"). The mixture of "shot ore" with its associated clay is said to contain 34 per cent of metallic manganese. A shaft 45 feet deep was sunk into this deposit without reaching the bottom.

Penrose also says,[4] "The dark-brown clay found in this mine has been successfully used in St. Louis in the manufacture of artificial brownstone and colored bricks, and several carloads have been shipped there for those purposes."

The analyses given below represent the composition of carload lots of manganese ore shipped in 1917 from the Brooks Hill mine to the Tennessee Coal, Iron & Railroad Co., but they do not include any analyses of the few cars of ferruginous manganese ore that have been shipped from this mine.

[3] Penrose, R. A. F., jr., op. cit., pp. 249–250.
[4] Idem., p. 251.

Analyses of manganese ore from the Brooks Hill mine.

	1	2	3	4	5	6	7	8
Manganese (Mn)	49.45	46.61	50.93	50.68	51.61	46.15	44.82	47.04
Iron (Fe)	5.19	7.16	4.58	4.86	3.50	7.35	8.20	7.20
Phosphorus (P)	.17	.24	.22	.20	.15	.26	.18	.16
	9	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Manganese (Mn)	48.55	47.70	47.08	51.82	51.02	46.09	47.29	43.37
Iron (Fe)	5.31	6.03	9.11	4.32	4.08	7.58	4.90	4.65
Phosphorus (P)	.14	.12	.17	.13	.13	.16	.12	.11

SHELL MINE.

The Shell mine is on the crest of a ridge, in the SW. ¼ SE. ¼ sec. 10, T. 14 N., R. 7 W., 1¼ miles east-southeast of Cushman, and is east of the main group of openings at the Brooks Hill mine. It was first operated in 1916 by Will Fortune, who mined only a small quantity of manganese ore, and it was next operated by T. F. Shell, the present owner and operator, beginning in 1917. The production before June, 1918, was 250 tons of manganese ore, which is said to have averaged 50 per cent of manganese.

The workings consist of several shafts as much as 75 feet deep and of drifts running from the shafts in various directions. Chert, which represents a part of the Boone chert that has settled or has been washed from its original position, covers the ridge to a depth said to average 8 feet. The manganese-bearing clay beneath the chert ranges in thickness from a few feet to more than 50 feet and is reddish brown, chocolate brown, and black. The clay penetrated by the workings contains a few masses of the Fernvale limestone, but there are no outcrops of this limestone on the surface. Although most of the shafts are confined to half an acre shafts at other places show that the manganese-bearing clay underlies several acres on the crest of the ridge. The manganese ore occurs in the clay as fine particles and irregular masses that are composed largely of psilomelane and hausmannite. Only such masses as could be hand picked from the clay have been shipped. A sample of the reddish-brown clay which originally contained both the larger masses and fine particles but from which the larger masses were hand picked is said to have contained 18.96 per cent of manganese. The black clay was found to be 56 feet thick in one shaft and 25 feet thick in another. An analysis is said to have shown that it contained 21.8 per cent of manganese.

KIMMER MINE.

The Kimmer mine, which is owned by the Cleveland Manganese Mining Co., is in the NE. ¼ SW. ¼ sec. 10, T. 14 N., R. 7 W., 1 mile east of Cushman, on a part of the land described by Penrose[5] as the Whitthorne tract. This mine was operated about 30 years ago and next operated by W. H. Denison, beginning in 1916. The marketed production by Mr. Denison before June, 1918, was 200 tons of high-grade manganese ore and 30 tons of ferruginous manganese ore.

The workings, which are pits and cuts only a few feet deep, are on the hill slopes on both sides of Prairie Creek. They were dug in a reddish-brown manganese-bearing clay whose surficial portion contains chert and sandstone fragments. This clay overlies the Plattin, Kimmswick, and Fernvale limestones, of which there are a few exposures in the vicinity, and its depth and areal extent have not been proved. The manganese ore consists largely of the oxides psilomelane, hausmannite, and wad, the first being in greatest quantity, and it occurs here and there in the clay as fine particles and as masses some of which weigh several hundred pounds. Fragments of red iron oxide also occur in the clay. The marketed ore consisted of the larger masses, which were freed from the clay by hand picking.

ROSEBOROUGH MINE.

The Roseborough mine, which is owned by Halsell & Stafford, of Oklahoma City, is on the north side of Prairie Creek in the SW. ¼ NE. ¼ sec. 10, T. 14 N., R. 7 W., 1 mile east of Cushman. It has been operated by W. H. Denison, beginning in 1917, and the production before June, 1918, was 150 tons of manganese ore.

The main group of workings consists of shallow pits, shafts ranging from 15 to 60 feet deep, and short drifts running from the shafts, occupying less than an acre in a saddle between two chert-covered hills. After the openings pass through a gray soil containing chert fragments and pebbles they enter the manganese-bearing clay, which is reddish brown and chocolate-colored and which in places shows slickensides. One shaft, however, passed through an exceptionally large thickness—35 feet—of chert in shattered layers. The chert fragments and layers represent a part of the Boone chert that has settled from its original position. Some sandstone ledges that were a part of the weathered Cason shale also occur in the workings, and they like the chert have settled from their original position. The manganese-bearing clay ranges in thickness from a few feet to 60 feet and lies in hollows in the Plattin limestone, of which there are exposures near by. A few boulders of this limestone and of the

[5] Penrose, R. A. F., jr., op. cit., pp. 251–253.

Kimmswick limestone are found in the clay in the workings. The manganese ore consists of both hard and soft manganese oxides, which occur in nearly equal quantity, scattered through the clay from the surface to a depth of 60 feet. Both varieties are mined, but they are separated by hand picking and shipped separately. The soft oxide is wad which is said to contain between 30 and 35 per cent of manganese, and the hard oxides, which are in irregular masses, some reaching 400 pounds in weight, include steel-blue compact psilomelane, hausmannite, and braunite. Carload lots of these hard oxides will average 45 per cent or more of manganese.

A few shallow pits have been made in manganese-bearing clay at other places on this property, but at only a few places has its depth been proved. It overlies the Plattin limestone, of which there are some outcrops, and it is usually overlain by or mixed at the surface with various quantities of chert fragments and pebbles. The manganese ore, part of which is found on the surface, is like that at the main group of openings.

BLAIR PROSPECT.

The Blair prospect, which was not visited by the writer, is described as follows by Penrose[6]:

> The Blair tract is in 14 N., 7 W., sec. 9, the SE. ¼. It comprises 160 acres at the head of one of the forks of Prairie Creek and three-quarters of a mile southeast of Cushman. The ore occurs in association with red clay, overlying the decayed slopes of the Izard [Plattin] limestone. A knob of chert caps the hill, and fragments of it have rolled down and mixed with the clay. Thirteen tons of ore are said to have been shipped, but very little work has been done.

C. W. MAXFIELD PROSPECT.

The C. W. Maxfield prospect is just south of the Rowe Field mine and is 1¾ miles east-northeast of Cushman. Prospecting was done here in 1917 and earlier by C. W. Maxfield. Shallow openings and several deep gullies in this vicinity reveal several feet of pebbly red clay overlying reddish-brown and chocolate-brown clays. Small pieces of manganese oxide were observed in the clays and were also observed in the gravels in the bottoms of the gullies at the time of visit (April 19, 1918).

ROWE FIELD MINE.

The Rowe Field mine is south of the east end of the Blue Ridge and is in the N. ½ SE. ¼ sec. 3, T. 14 N., R. 7 W., 1¾ miles east-northeast of Cushman. It was operated in 1909 and 1910 by the Martin Manganese & Mining Co., the owner, which by means of a steam shovel mined 200 tons of lump manganese ore, and it was next operated by

[6] Penrose, R. A. F., jr., op. cit., p. 253.

the Independence Mining Co., beginning in 1915, which had mined and shipped 100 tons of "lump" manganese ore before June, 1918.

The workings consist of shallow pits, shafts as much as 40 feet deep, and a cut 250 feet long, 20 to 50 feet wide, and 5 to 15 feet deep, which have been made here and there over several acres in and near a saddle between the Blue Ridge on the north and a low hill on the south. They penetrate to the above-mentioned depths red and brown manganese-bearing clays whose surficial portions contain chert fragments. The clays are residues from the decomposition of the Plattin, Kimmswick, and Fernvale limestones, but the only exposures of these limestones are a few boulders of the Kimmswick limestone and several boulders and horses of the Plattin limestone, which occur in and near the cut. Shattered and bent layers of chert as exposed in the cut overlie the clays at places. They represent the lower part of the Boone chert that has settled below its original position while the Fernvale and Kimmswick limestones were being carried away by solution.

The manganese ore occurs in the clay as irregular masses ranging in size from fine particles called "wash ore" to masses weighing 1 pound or more called "lump ore." It was found in all the openings examined but in different quantities at different places. The "lump ore" is mainly psilomelane, but part of it is wad, whereas most of the "wash ore" is ferruginous manganese oxide. E. C. McComb, of the Independence Mining Co., states that tests show that there are 1½ times as much "wash ore" as "lump ore" in the deposit and that much of the clay on being washed will yield concentrates in the ratio of 5 parts of clay to 1 part of concentrates.

BLUE RIDGE MINE.

The Blue Ridge mine is on the Blue Ridge, a nearly straight eastward-trending ridge almost a mile long, in the S. ½ NW. ¼ and the S. ½ NE. ¼ sec. 3, T. 14 N., R. 7 W., 1½ miles northeast of Cushman. The ridge is not uniform in height but contains a saddle near its middle. The saddle and the west part of the ridge, which attains an elevation of 848 feet above sea level, are represented on the accompanying map (Pl. XVII). The mine workings have been made not only on the west part of the ridge, as shown on the map, but also on the east end of the ridge.

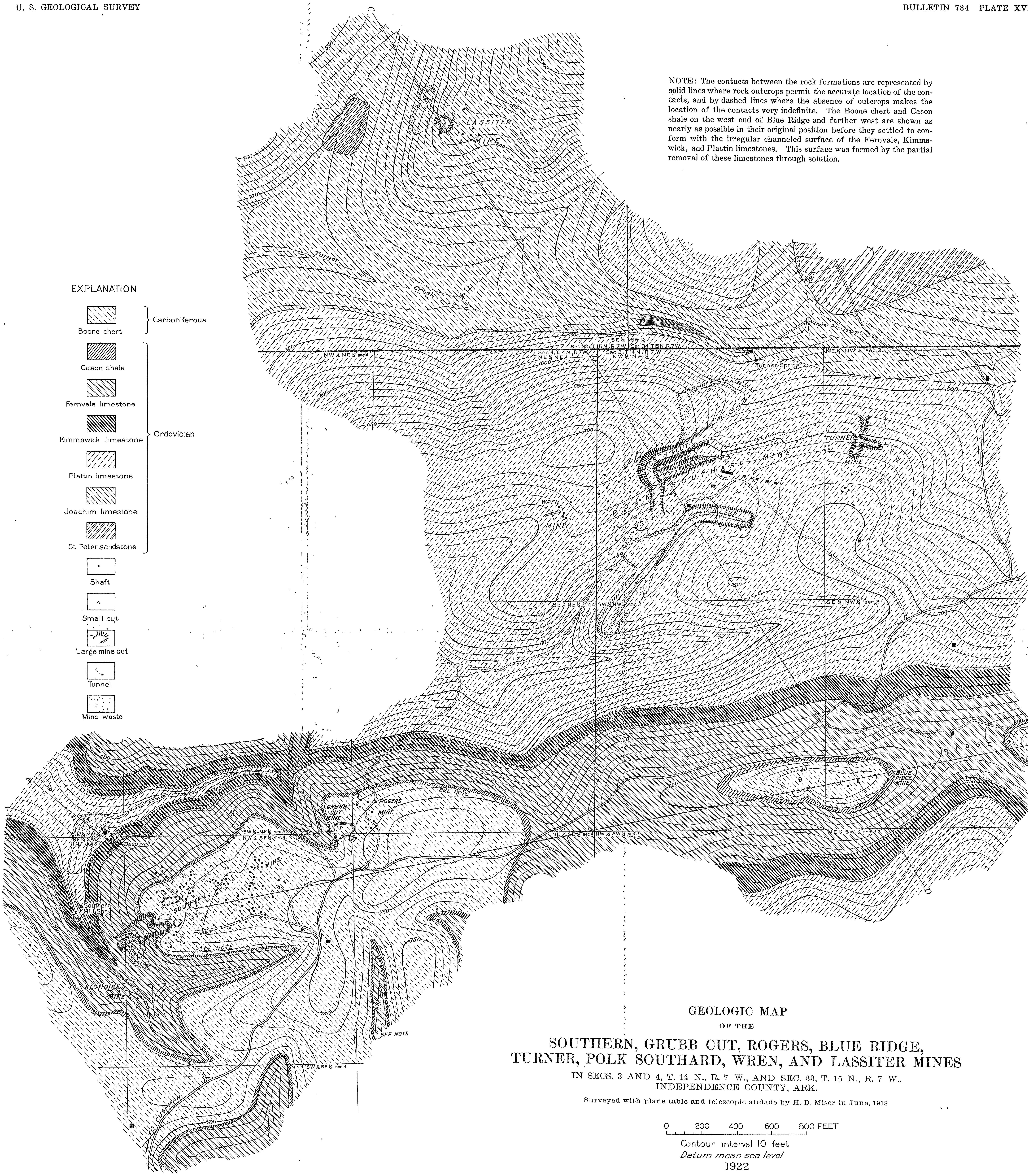
The mine was operated in 1909 and 1910 by the Martin Manganese & Mining Co., the owner, which mined and shipped 700 tons of ferruginous manganese ore. In recent years it has been operated by the Independence Mining Co., the present lessee, beginning in 1915, and the production of this firm before June, 1918, was 500 tons of ferruginous manganese ore.

The worked ore deposit on the west part of the Blue Ridge is mainly in the Cason shale but partly in brown clay overlying the top of the Fernvale limestone, whereas the worked deposit on the east end of the ridge is entirely in cherty surface loam and red clay which overlies the Fernvale limestone. The highest parts of the ridge are capped by as much as 30 feet of the Boone chert. The Cason shale, lying beneath the chert, is 8 feet thick where it is best exposed, in the workings on the west part of the ridge, but it is thinner farther east. The Fernvale limestone, in which there is a small quantity of chert, is exposed at many places in the saddle and together with the Kimmswick and Plattin limestone is exposed in heavy ledges on the south slope and at a few other places on the ridge. The Cason shale and Boone chert are in place except on the west end of the ridge. There they have settled into underground channels or hollows formed by solution in the Fernvale limestone. (See Pl. XII.) The small hollow-like reentrant on the south slope and near the crest of the ridge was formed in this way. Although the Cason shale and Boone chert may have settled as much as 20 feet or more at some places, they are represented on the map (Pl. XVII) in their original position as nearly as it can be determined.

Except for the displacement of the two formations mentioned above these and the other rock formations exposed on the Blue Ridge lie horizontally or nearly so. They, however, like the rocks at the Southern, Grubb Cut, Rogers, Wren, Polk Southard, and Turner mines lie in a broad eastward-trending syncline. (See Pl. XII, *B*.) On the south side of this syncline the St. Peter sandstone and Joachim limestone are revealed in an anticline in the southern part of sec. 3, T. 14 N., R. 7 W., and on the north side of the syncline these two formations are revealed in two domes just north of Turner Creek in secs. 33 and 34, T. 15 N., R. 7 W.

The workings on the west part of the ridge consist of open cuts and a tunnel on the hill slopes and a shaft on the crest. (See Pl. XVII.) The Cason shale, as revealed in the partly caved workings at the times of visit (April and June, 1918), is a bed 8 feet thick, composed of brown platy shale in its lower part and brown shaly sandstone in its upper part. Both the shale and sandstone are partly to wholly replaced by manganese and iron oxides. These oxides are shaly and porous, and the bed in the lower part of the shale from which they are mined is said to average 2 feet thick. Although some of these oxides were taken from the shaft on the crest of the ridge, E. C. McComb, of the Independence Mining Co., expresses the opinion that minable ore occurs in less quantity in and near the center of the ridge than at and near the surface on its borders. The small quantity of ore mined from the brown clay overlying the Fernvale limestone contains more manganese and less iron than the ore in the shale above.

NOTE: The contacts between the rock formations are represented by solid lines where rock outcrops permit the accurate location of the contacts, and by dashed lines where the absence of outcrops makes the location of the contacts very indefinite. The Boone chert and Cason shale on the west end of Blue Ridge and farther west are shown as nearly as possible in their original position before they settled to conform with the irregular channeled surface of the Fernvale, Kimmswick, and Plattin limestones. This surface was formed by the partial removal of these limestones through solution.



GEOLOGIC MAP

OF THE

SOUTHERN, GRUBB CUT, ROGERS, BLUE RIDGE, TURNER, POLK SOUTHARD, WREN, AND LASSITER MINES

IN SECS. 3 AND 4, T. 14 N., R. 7 W., AND SEC. 33, T. 15 N., R. 7 W., INDEPENDENCE COUNTY, ARK.

Surveyed with plane table and telescopic alidade by H. D. Miser in June, 1918

0 200 400 600 800 FEET

Contour interval 10 feet

Datum mean sea level

1922

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

Some of it is manganese oxide (psilomelane), but much of it is ferruginous manganese oxide.

The workings on the east end of the Blue Ridge are shallow pits and cuts which have been made in surficial cherty loam and the underlying red clay. Manganese ore in irregular masses is found in both the clay and the loam, but the depth of the deposit had not been determined at the time of visit.

The marketed ore from this mine was obtained for the most part from the Cason shale and is said by Mr. McComb to have averaged 17 per cent of manganese and 22 per cent of iron. The following analyses represent the composition of carload lots of ore shipped in 1917 from this mine. The first seven cars were shipped to the Central Iron & Coal Co. and the last four to the Sloss-Sheffield Steel & Iron Co.

Analyses of ferruginous manganese ore from the Blue Ridge mine.

	1	2	3	4	5	6	7	8	9	10	11
Manganese (Mn).......	17.73	23.49	18.97	18.02	17.56	13.18	24.19	14.00	19.50	14.08	14.20
Iron (Fe)..............	21.01	17.46	24.20	12.36	21.89	23.22	12.87	18.65	23.70	28.35	28.90

SOUTHERN MINE.

The Southern mine, also known as the Southern Hill mine, is on Southern Hill, in the NW. ¼ SE. ¼ sec. 4, T. 14 N., R. 7 W., 1¼ miles N. 30° E. of Cushman.

Of the early history of the mine Penrose[7] says:

> The Southern mine was first worked by E. H. Woodward & Co., between 1881 and 1885, during which time 2,500 to 3,000 tons of ore are said to have been mined. In October, 1885, the Keystone Manganese & Iron Co. began work on it, and from that time until December 31, 1890, they produced 14,489 tons of ore, making a total output since the first opening of the mine of from 16,989 to 17,489 tons. This production probably represents over half the total output of the State.

The Keystone Manganese & Iron Co., the owner of the mine, continued to operate it until about 1900, when this firm was dissolved and the ownership of the mine passed to Mrs. K. P. Gregory, who is the present owner. The next mining was done in 1916 and 1917 by W. H. Denison, who mined and shipped about 700 tons of ore. Very little ore was mined in 1918 before the writer finished his examination in June of that year. Since then the mine has been leased to M. A. Losee. The total production of the mine before 1919, according to Mr. Denison, has been 36,500 tons.

[7] Penrose, R. A. F., jr., Manganese—its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, p. 261, 1891.

The workings consist of two old cuts and many shafts, 192 shafts being shown on the accompanying map (Pl. XVII). Many of the shafts have been filled or partly filled with material taken from the adjoining ones, and the sides of the old cuts have badly caved, obscuring the relations of the ore deposit. The two depressions represented on the west part of the Southern Hill are due to the caving of material above areas that have been mined out. The mine was not worked during the writer's visit to the region, and none of the underground workings could be entered. The following description of the mine is, therefore, largely quoted and abstracted from Penrose.[8] The abstracted parts are slightly modified to accord with the present information regarding the mine and with the present knowledge of the geology of the region.

The Southern Hill, on which the mine is situated, is capped on its summit by a bed of the Boone chert, ranging in thickness from 20 to 60 feet. The ore-bearing clay is below this chert. The Fernvale and Kimmswick limestones, and perhaps the Cason shale, once occupied the position of the clay. The Cason shale, which if originally present probably did not exceed a few feet in thickness, has entirely decayed, and these two limestones, known as "gray rock," have mostly decayed and are now found in loose masses in the clay and as pinnacles extending upward into it. The hollows separating the pinnacles are doubtless wide and numerous, and many probably extend down to the Plattin limestone. The Boone chert is greatly disturbed and dips at various angles from almost horizontal to almost vertical and is much faulted, jointed, and shattered throughout. Many of the loose fragments of it are much stained with manganese oxide on the outside, and many thin black films of manganese oxide penetrate the cracks of the whole bed. The disturbance of the chert has not been caused by an upheaval, as is generally supposed, but by the subsidence of the bed as a result of the decay and partial removal of the Fernvale and Kimmswick limestones, which once underlay it. The existence of the manganese-bearing clay is dependent on this decay of the Fernvale limestone, and therefore the breaking up of the chert bed is a proof of the presence of the ore and clay, provided of course that the original rocks contained materials for such a deposit.

The distribution of the rock formations, as shown on the accompanying map (Pl. XVII), represents not their present but their probable original position. The contact line representing the top of the Fernvale limestone has been arbitrarily drawn at the same elevation as the crest of the highest known pinnacle of this limestone found in the workings. The Boone chert has not only afforded loose

[8] Penrose, R. A. F., jr., op. cit., pp. 261–269.

débris which covers the slopes, but together with the weathered Cason shale it has settled into the hollows between the limestone pinnacles. (See Pl. XII, *A*.) The undecayed parts of the Fernvale and Kimmswick limestones are nowhere exposed at the surface; they are concealed by their residual clays but mostly by débris from the Boone chert. The only observed exposure of the Plattin limestone in the vicinity of the Southern Hill is at the west end of the old dam just north of the Southern Hill Spring.

The Southern mine, like the Blue Ridge mine just described, and like the Grubb Cut, Rogers, Wren, Polk Southard, and Turner mines, to be described later, lies in a broad eastward-trending syncline. On the south side of this syncline the St. Peter sandstone and Joachim limestone are revealed in an anticline in the southern part of sec. 3, T. 14 N., R. 7 W., and on the north side of it these two formations are revealed in two domes just north of Turner Creek in secs. 33 and 34, T. 15 N., R. 7 W.

A large number of shafts, ranging in depth from 20 to 132 feet, have proved a considerable thickness of manganese-bearing clay beneath the chert. Although most of the shafts have produced ore, the quantity from any single shaft is said not to exceed 200 tons. Many of the shafts have met loose masses of the Fernvale and Kimmswick limestones in the clay, and some have stopped on large bodies of limestone, which may be pinnacles rising from an undecomposed area of one of these limestones or from the Plattin limestone below. The clay varies greatly in thickness but is said to average about 25 feet.

The character of the manganese-bearing clay and its relations to the underlying and overlying rocks, and the occurrence of the manganese in it, are illustrated in Plate XII, *A*, and figure 19 and are further described by Penrose,[9] from whom the following is quoted:

> The clay that contains the ore at the Southern mine is a stiff red, brown, or almost black material, frequently containing many joints. The joints are due to the gradual sinking of the clay bed as it was formed from the limestone, and their faces are deeply grooved by slickensides, caused by the movement of one part of the clay against the other. The upper part of the clay contains fragments of chert, and the main chert bed itself often protrudes into it in angular "reefs." The clay bed is of a bright-red color in its upper part, but below it contains darker layers known as "black joint." The ore so far has been mined only in the upper clay, and until lately no work has been done in the "black joint." The color of this dark bed is due to manganese, and it is not impossible that further exploration may prove the existence in it of workable bodies of ore. The difference in the colors of the clay is entirely due to the difference in character of the insoluble material in the original limestone; and there is no reason why the ore should not be found in the dark-colored clay,

[9] Penrose, R. A. F., jr., op. cit., pp. 263–265.

though a practical test will be needed to demonstrate its presence or absence in workable quantities.

The manganese occurs in the clay in the form of pockets varying greatly in the amount of ore they contain. In some places only a few tons are found, while from others 500 tons or more have been taken. The pockets usually lie in the clay almost immediately under the chert; and this fact would suggest that the ore on this property originally occurred near the top of the St. Clair [Fernvale] limestone.

The ore is often found, as it is expressed, "bearing off from the steeply dipping chert." This can be explained in the following manner: The base of the chert penetrates the upper part of the clay bed in a very irregular manner, now running down into it for many feet, now receding, and often piercing a pocket of ore. In the process of mining such a pocket the ore, of course, ends abruptly where the chert cuts through it, but on the other side of the chert "reef" the continuation of the pocket may be found, unless indeed the chert penetrates the clay at the end of the pocket, leaving all of the ore on one side.

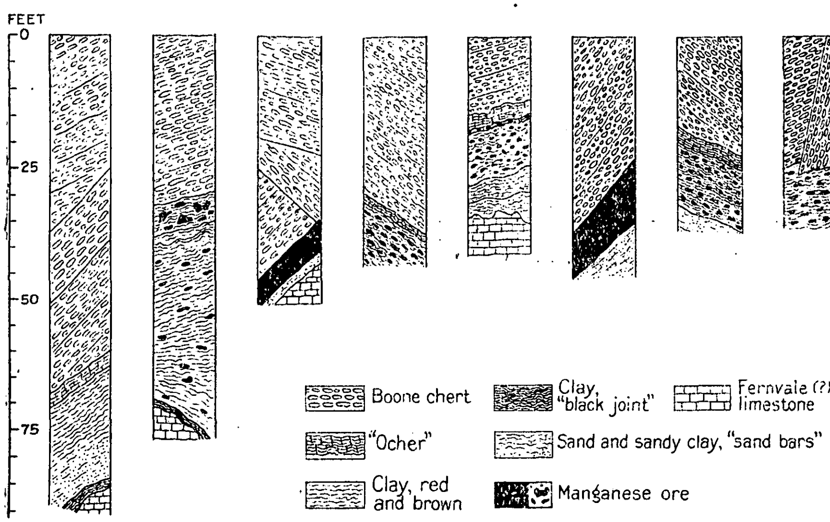


FIGURE 19.—Sections showing the occurrence of manganese ore in shafts at the Southern mine. (After Penrose.)

In sinking shafts through the chert on this property there is frequently found, just before the ore-bearing clay is reached, a yellow or brown siliceous material [probably the Cason shale] of a dry earthy appearance and from 6 inches to 3 feet in thickness, locally known as "ocher." This is considered a good indication that the ore-bearing clay is near, for the "ocher" occurs at the base of the chert, and clay containing a greater or less quantity of the ore occurs almost immediately under the chert.

Immediately below the ore at the Southern mine the shafts frequently come on to a deposit of sand or sandy clay, ranging in thickness from 4 to 20 feet, and averaging probably 8 feet. These deposits are called "sand bars," and vary from a loose, soft bed to a more compact and massive material. * * * It is generally found that in sinking through the sandy stratum a body of St. Clair [Fernvale and Kimmswick] limestone is struck, and therefore the shafts usually stop when the sandy deposits are met. Between the limestone and the sand there is very often a layer of dark-brown or black clay of the same character as the "black joint" described above and varying from a few inches to several feet in thickness. It represents the decomposition product of the surface of the mass of limestone and has originated in a manner similar to the rest of the clay in the ore-bearing deposit.

Material on the dumps, which is said to have been taken from the deposit of sand or sandy clay described above, consists of porous brown chert containing drusy quartz. Casts of certain fossils found in some of the chert indicate that the chert once occurred in the Fernvale limestone. Many doubly terminated quartz crystals an inch or less in their longest dimension occur on the dumps, associated with this cherty material. Many of them are transparent, but most of them are brown from minute inclusions of manganese oxide.

The ore found on this property occurs in loose masses which range in size from small particles, known as "wash ore," to masses weighing several tons. It is black, has a bright luster on fresh surfaces, and is generally of a crystalline structure. Parts of it contain transparent rhombohedral crystals of calcite or inclose cavities lined or partly filled with red or yellow clay. The cavities probably represent spaces formerly occupied by the calcite, which has decomposed and left the clay as a residue. The masses of ore found on the dumps by the present writer were composed of psilomelane and hausmannite and were similar to the manganese ore at the Grubb Cut, Rogers, Polk Southard, and Turner mines.

The quality of the ore, as determined from carload shipments, varies within the following limits: The percentage of manganese ranges from 41 to more than 56 per cent; the iron from 1 per cent to 9 per cent; the silica from 2 per cent to 6 per cent; the phosphorus from 0.16 per cent to more than 0.20 per cent; and the moisture from 2 to 7 per cent. Much ore has been shipped which contains less than 0.20 per cent of phosphorus. The following analyses represent the composition of carload lots of manganese ore shipped from this mine.

Analyses of manganese ore from the Southern mine.

	1	2	3	4	5	6	7	8
Manganese (Mn)	48.14	52.00	52.90	51.97	50.67	54.40	53.10	53.05
Iron (Fe)	5.50	5.67	3.59	4.05	4.26	2.69	4.22	3.78
Phosphorus (P)	.22	.23	.17	.22	.25	.22	.16	.20

	9	10	11	12	13	14	15	16
Manganese (Mn)	41.40	52.60	50.45	44.03	53.12	51.82	50.75	49.73
Iron (Fe)	6.06	8.62	8.41	9.11	2.30	3.40	4.27	2.15
Phosphorus (P)	.21	.48	.22	.25	.165	.193	.184	.166
Silica (SiO_2)	......	......	......	......	2.75	2.50	3.52	3.10
Moisture	......	......	......	......	4.40	5.10	5.40	7.28

Analyses of manganese ore from the Southern mine—Continued.

	17	18	19	20	21	22	23
Manganese (Mn)	51.77	49.60	45.66	42.64	47.927	48.183	53.685
Iron (Fe)	2.38	3.84	6.00	8.12	6.875	6.550	2.850
Phosphorus (P)	.128	.184	.236	.265	.197	.255	.186
Silica (SiO_2)	3.18	4.79	....	....	3.220	2.985	2.400
Moisture	1.68	3.88	....	....	6.490	7.179	4.229

1-12. "Lump ore" shipped in 1917 to the Tennessee Coal, Iron & Railroad Co.
13-17. From Penrose, R. A. F., jr., op. cit., p. 362; analyses were made under the direction of the Keystone Manganese & Iron Co. and were accepted by the Illinois Steel Co., the purchasers of the ore.
18. From Penrose, R. A. F., jr., op. cit., p. 362; analysis by Carnegie Bros. & Co.
19 and 20. Washed ore shipped in 1889 by the Keystone Manganese & Iron Co. to the Illinois Steel Co.
21. Analysis by A. S. McCreath of 5 cars of washed ore shipped in 1898 by the Keystone Manganese & Iron Co.
22. Analysis by A. S. McCreath of 3 cars of washed ore shipped in 1898 by the Keystone Manganese & Iron Co.
23. Analysis by A. S. McCreath of 15 cars of lump ore shipped in 1898 by the Keystone Manganese & Iron Co.

The following detailed analyses are of carload lots of ore shipped by the Keystone Manganese & Iron Co. from the Southern, Polk Southard, and Turner mines, the ores of which are similar and were mixed in the same carload lots:

Analyses of manganese ore from the Southern, Polk Southard, and Turner mines.

	1	2	3	4
Manganese (Mn)	45.04	48.22	56.36	53.37
Iron (Fe)	6.87	5.8	1.75	2.35
Phosphorus (P)	.227	.214	.126	.170
Silica (SiO_2)	6.28	3.05	1.71	2.80
Alumina (Al_2O_3)	3.06	2.87	2.16	3.24
Lime (CaO)	1.45	1.2	.90	.75
Magnesia (MgO)	2.45	.58	2.25	.65
Nickelous oxide (NiO)	.16	.00	.28	Trace.
Barium oxide (BaO)	4.17	2.79	3.02	2.94
Copper (Cu)	.028	Trace.	.016	Trace.
Arsenic (As)	Trace.	.012	Trace.	.019
Combined water	6.96	7.25	4.92	....
Moisture	6.00	6.00	2.00	10.00

1 and 2. Washed ore from the Southern and Polk Southard mines.
3 and 4. "Lump ore" from the Southern, Polk Southard, and Turner mines.

Doubtless considerable manganese ore still remains in the worked parts of the Southern Hill. It will be found lower than the old workings and probably in unworked ground farther east than the shafts shown on the map. Ore in paying quantities has not been found on the hill north of the Southern Hill nor on the ridge followed by the main wagon road south of the Southern Hill, but it has been mined from a group of shafts and cuts known locally as the Klondike mine on the hill southwest of the Southern Hill Spring and has been found in shafts on the crest of the hill. These openings, like the Southern mine, are on land belonging to Mrs. K. P. Gregory, and the ore deposit penetrated by them is similar to that on the Southern Hill.

Penrose[10] says:

The method of mining on the Southern Hill consists of a series of shafts with lateral drifts at desirable points. No machinery is used either in sinking or tunneling. Hoisting is done by hand windlasses or by "whips" worked by horses. Blasting is not always employed even in the chert, as that bed is so much shattered that shafts can sometimes be sunk through it with pick and shovel alone, but the use of dynamite is often necessary. The clay also can be worked with pick and shovel, but the employment of dynamite often hastens the work in loosening the bed and the masses of ore. Timbering is generally necessary, as the looseness of the chert bed and the tendency of the clay to cave in render an unprotected shaft dangerous. The shafts are small, and the timbering is cheaply done with roughly split logs. Frequently in wet weather the shafts are flooded with surface water, causing considerable expense and loss of time, but in fair weather few such difficulties are experienced.

The principle of work is to sink a shaft as cheaply as possible until a pocket of the ore is reached. After passing to the base of the ore, drifts are run out in various directions and the whole pocket removed. If in drifting and sinking still farther no more ore is found in the clay the shaft is abandoned and a new one sunk elsewhere. The distribution of the pockets of ore is very irregular; sometimes they are separated laterally by several hundred feet of barren clay, and at other times they come almost in contact with each other. Experience is said to show that as a result of this irregularity the small-shaft system is the cheapest and that it pays better to sink a large number of small shafts than to drift aimlessly around underground in quest of a new pocket of ore. Many shafts have been sunk in search of such pockets, and a large number of them have been successful.

The method of mining by a large open cut has been tried at the Southern mine, but it proved a failure on account of the expense of removing the heavy capping of chert. * * *

Penrose[10] describes as follows the water supply and the preparation of the ores by the Keystone Manganese & Iron Co.:

After the ore has been mined the larger masses are separated from the clay by hand and shipped without further preparation. This is known as "lump ore." The smaller ore and its associated clay, known as "wash dirt," contain from 10 to 25 per cent of ore. The material is carted to a large receiving bin and thence carried on an inclined tramway to the washer, which is of the kind often used for iron ores. The manganese is first dumped into a long trough filled with running water. A central shaft, armed with flanges arranged in the shape of a broken helix, revolves lengthwise in the trough, and gradually forces the ore to the other end. At the same time the beating and washing that the ore receives frees it from most of the adhering clay. At the end of the trough the ore passes over a screen, and the larger pieces are taken up on an apron belt and carried to the ore bin. A man stands by the apron to pick out the masses of rock and hard clay that are mixed with the ore. The ore that has passed through the screen is then sized by other screens and passed into jigs, where it is separated from the intermixed fragments of chert and from the clay that still adheres to it.

The most troublesome question at the Southern mine has been that of the water supply. The elevated position of the property renders it necessary to

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[10] Penrose, R. A. F., jr., op. cit., pp. 267–269.

get water either by pumping from one of the streams in the lower country or by boring a well. A small spring rises on the slope of the hill, but its discharge is small. In 1887 and 1888 a well was bored to a depth of 2,040 feet; and though a large supply was not obtained the water from it, with that saved from the spring by means of a dam, is now utilized to wash all the "ore dirt" that is mined. It is necessary, however, to be economical in the use of the water.

A section of the rocks passed through in the well mentioned above is given on page 45.

In recent years only the "lump ore" has been separated from the clay and shipped, and the clay has been left on the dumps.

GRUBB CUT MINE.

The Grubb Cut mine, which is owned by William Einstein, is in the SW. ¼ NE. ¼ sec. 4, T. 14 N., R. 7 W., 1¼ miles N. 30° E. of Cushman. It was operated about 30 years ago by the St. Louis Manganese Co. and was not operated again until 1917, when the Marqua Mining Co., the present lessee, began work. At the time of visit (April 12, 1918) the Marqua Mining Co. had mined and shipped several hundred tons of manganese ore.

This mine adjoins the Southern mine, and the occurrence and origin of its ore body are the same as those of the ore body at the Southern mine.

The workings include several shafts and the greater part of the Grubb cut. Formerly the entire cut, the tunnel at the Rogers mine, and a few near-by shafts were believed to be on land owned by Mr. Einstein, but a recent land survey established the boundary lines of Mr. Einstein's land as they are shown on Plate XVII.

The cut was formerly the main opening from which manganese ore was mined, but now the ore is being mined entirely from shafts and the cut is being filled with material taken from them. Penrose,[11] who visited the cut when it was fresh, supplies the following description of it:

The accompanying figure [fig. 20] shows a section across the main pit. At the base of the pit are two masses of St. Clair [Fernvale] limestone of a gray color, which lie horizontally and represent parts of the formation that have survived decomposition. Surrounding and overlying them is the manganese-bearing clay, overlain in turn by from 1 to 20 feet of chert.

Capt. Ed. Wilburn, superintendent of the St. Louis Manganese Co.'s mines, states that two shafts, now mostly filled up, were sunk here. One was 30 feet deep and was in the clay bed all the way; the other was 40 feet deep and was sunk in the bottom of a tunnel, which was itself 45 feet below the surface.

As will be seen in the figure, both the clay bed and the chert dip away from the underlying bodies of limestone, covering them in the form of a rough cone and pitching off from them in all directions. The position of the chert and

[11] Penrose, R. A. F., jr., op. cit., pp. 270–271.

clay is the natural result of their sinking over the unevenly decomposed surface of the limestone. * * * The chert is much shattered and broken, and near the clay bed it is deeply stained with manganese.

A great difference in the thickness of the Boone chert will be noted in the descriptions of the following shafts. Part of this difference is due to the unequal settling of the chert on the irregular surface of the Fernvale limestone. Shaft No. 3 penetrated the Boone chert to a depth of 72 feet without passing through it. A shaft which is south of No. 3 and which appears to have been filled up passed through Boone chert 60 to 65 feet thick and then penetrated clay to a depth of 35 to 40 feet. Drifts were run in the clay in every direction from the shaft. A drift running north 80 to 90 feet encountered "gray rock" (Fernvale limestone). The production of this shaft is said to have been several carloads. Shaft No. 4 passed through 52 feet of Boone chert and 27 feet of clay before it reached the Fernvale limestone. Drifts have been run in the clay in various directions from this shaft, and some of the drifts are in clay-filled solution channels in the Fernvale limestone. This shaft when it was examined (April 12, 1918) had produced 70 tons of manganese ore. Shaft No. 5 penetrated the Boone chert to a depth of 50 feet without passing through it. Shaft No. 1 was being sunk in the Boone chert at the time of visit (June, 1918). Shaft No. 2, an old shaft, apparently did not pass through the Boone chert.

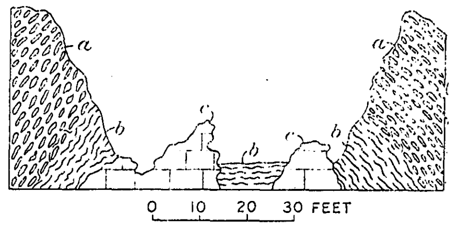

FIGURE 20.—Section through the Grubb cut, showing the decay of the Fernvale limestone, the formation of residual manganese-bearing clay, and the subsidence and tilting of the overlying Boone chert. (After Penrose.) *a*, Boone chert; *b*, manganese-bearing clay; *c*, Fernvale limestone.

The manganese ore is composed mainly of psilomelane and hausmannite, the psilomelane being in the greater quantity. It occurs in the clay both in small pieces ("wash ore") and in large irregular masses ("lump ore"), of which some have been found that weighed a few tons. The larger masses are hand picked ready for shipment before they are brought to the surface, and some of the smaller masses are picked from the dumps after the rains wash the clay from them.

ROGERS MINE.

The Rogers mine is in the southwest corner of the SE. ¼ NE. ¼ sec. 4, T. 14 N., R. 7 W., 1¼ miles N. 30° E. of Cushman, and is just east of the Grubb Cut mine. (See Pl. XVII.) Several shafts were made about 30 years ago, but they yielded no ore, for they were not sunk deep enough to strike the ore-bearing clay. One tunnel 75 feet long, also made at that time, yielded very little ore. The mine was next operated by R. S. Handford, beginning in December, 1916, and he was succeeded in October, 1917, by the Cushman Manganese Co., the present owner and operator, of which Mr. Handford is a member. The production by Mr. Handford was 112 tons of "lump" manganese ore and that by the Cushman Manganese Co., before June, 1918, was 188 tons of "lump" manganese ore and 8 carloads of "ore dirt" from which the lump ore had been hand sorted.

The workings consist of several shafts and one tunnel, none of which could be entered at the time of visit. (See Pl. XVII.) They are all in the Boone chert, and none of the old shafts and only two of the new shafts passed through the Boone chert into the ore-bearing clay. The deepest shaft, 96 feet deep, is said to have passed through 60 feet of the Boone chert and then 36 feet of ore and ore-bearing clay before it encountered the "gray rock." Drifts were run from this shaft into the ore-bearing clay, and they in places encountered "gray rock." The next deepest shaft is said to have passed through 60 feet of the Boone chert and 30 feet of ore-bearing clay.

The Boone chert not only caps the hill, but its débris covers the hill slopes, and the Cason shale, the Fernvale, Kimmswick, and Plattin limestones are nowhere exposed on the hill slopes in the vicinity of this mine, but "gray rock," which is either the Kimmswick limestone or the Fernvale limestone, was, as noted above, found in the deepest shaft.

The discussion of the origin of the ore-bearing clay, the relations of the clay to the overlying Boone chert and the underlying limestones, and the origin and character of the manganese ore at the Grubb Cut and Southern mines applies to the ore deposit at this mine and need not be repeated here.

The "ore dirt" shipped from this mine is stated to have averaged 25 per cent of manganese. The following analyses are of carloads of lump manganese ore shipped in 1917 to the Tennessee Coal, Iron & Railroad Co.:

Analyses of manganese from the Rogers mine.

	1	2	3	4	5
Manganese (Mn)	49.28	47.07	49.43	52.28	50.31
Iron (Fe)	5.30	8.08	4.34	4.04	4.85
Phosphorus (P)	.38	.38	.20	.59	.28
Silica (SiO_2)	6.52	6.52	5.80	9.56	6.10
Alumina (Al_2O_3)	2.62	2.62	2.64	2.96	2.97

POLK SOUTHARD MINE.

The Polk Southard mine, which is owned by the Martin Manganese & Mining Co., is in a saddle-like depression south of Turner Creek, in the NW. ¼ SW. ¼ sec. 3, T. 14 N., R. 7 W., 1½ miles N. 30° E. of Cushman. It was first operated about 30 years ago by the Keystone Manganese & Iron Co., which mined and shipped 3,500 to 4,000 tons of manganese ore, and it was next operated in 1909 and 1910 by the Martin Manganese & Mining Co., which mined and shipped 500 tons of ore. The Independence Mining Co., the present operator, began work in 1915 and had mined and shipped 1,500 tons of ore before June, 1918.

The workings include many shafts and three large cuts, which for convenience may be termed North cut, Middle cut, and South cut. These cuts and some of the shafts are represented on the map of the mine. (See Pl. XVII.) The cuts are in manganese-bearing clay, and all the shafts are said to have penetrated such clay, which proves that the ore body underlies an area of several acres.

The ore-bearing clay is sticky and is cut by joints whose faces are polished and are grooved by slickensides. Parts of it are red, other parts are chocolate-colored, and some of it at the top is yellow. The clay, as revealed in the North cut, lies in hollows as much as 20 feet or more deep in the Plattin limestone and overlies the limestone pinnacles separating the hollows. (See Pl. XVI, *A*.) No limestone is exposed in the Middle and South cuts nor on the surface near the openings, but the exposures of the Plattin limestone in the North cut, on the north slope north of the mine, and in the workings of the Turner mine on the east indicate that the ore-bearing clay everywhere rests upon the Plattin limestone. The surface of this limestone is doubtless irregular in all parts of this tract, hence the ore-bearing clay varies greatly in thickness, the minimum being a few feet and the maximum about 40 feet. (See Pl. XII, *B*.)

The clay is residual not only from the part of the Plattin limestone that has obviously been removed by erosion but also from the Kimmswick and Fernvale limestones, which were laid down over this locality but have been entirely decomposed. A part of it is perhaps derived from the Cason shale, which was probably once present at this locality. But the greater part of the clay as well as all the masses of ore is believed to be a residue from the decomposition of the Fernvale limestone. While these limestones and the Cason shale were being decomposed the overlying Boone chert settled to conform with the irregularities of the surface of the limestone. (See Pl. XII, *B*.) A few feet to 70 feet of this chert, which is now much shattered, overlies the ore-bearing clay; it is thickest in the hollows in the Plattin limestone and thinnest above the pinnacles of this limestone. Part of the overburden, however, is wash, consisting of red clay and chert fragments. Such wash is well exposed in the South cut.

Although manganese ore may be found in every pit or shaft in the above-described clay, it is by no means uniformly distributed through the clay but occurs as pockets scattered here and there. It consists of irregular masses of psilomelane and hausmannite, which range in size from fine particles to boulders weighing several tons. Tests are said to show that the "wash ore" and "lump ore" occur in equal proportions and that the ore-bearing parts of the clay will yield 1 ton of ore containing 45 per cent of manganese to every 4 tons of ore-bearing clay. The overburden and ore-bearing clay together are reported to average about 45 feet deep, and material which is handled by the steam shovels is reported to yield 1 ton of lump ore for every 50 tons of material handled. Much ore has been left in the bottom of the North cut, as it lies in hollows in the Plattin limestone and was therefore not removed by the steam shovel. If this ore were included the recovery of "lump ore" would probably be greater than 1 ton of "lump ore" for every 50 tons of overburden and ore-bearing clay. The steam shovels in the Middle and South cuts were removing the overburden at the time of visit and had reached the ore-bearing clay at only a few places.

The ore is similar to that at the Turner and Southern mines. In fact, some of the ores from these three mines were mixed by the Keystone Manganese & Iron Co. before they were shipped. Analyses of carload lots of both "lump" and "wash" ores that were thus mixed are given on page 196. The following analyses are of carload lots of "lump" manganese ore shipped from this mine by the Independence Mining Co. to the Miami Metals Co.:

Analyses of manganese ore from the Polk Southard mine.

	1	2	3
Manganese (Mn)	54.88	55.05	52.62
Iron (Fe)	2.31	1.98	2.83
Phosphorus (P)			.137
Silica (SiO_2)	2.18	1.49	3.26
Moisture	5.17	3.03	5.77

The Keystone Manganese & Mining Co. mined the ore by means of shafts and cuts, and it hand sorted most of the ore from the clay but concentrated some of the marketed ore in a small washing plant just below Turner Spring. The Martin Manganese & Mining Co. operated the mine by means of shafts, and the Independence Mining Co., the present operator, has mined ore in shafts and cuts. The work in the Middle and South cuts was being done at the time of visit by two steam shovels. The North cut had been made earlier by a steam shovel. The "lump ore" that was being mined by the steam shovels as well as that from the shafts was sorted by hand from the inclosing clay, and the "wash ore" was being left in the clay on the dumps, but at the time of visit a single-log washer was being erected at Turner Spring to recover the "wash ore" from the ore-bearing clay that had been placed on the old dump north of the mine and also the "wash ore" from the new cuts. Much of the clay on this old dump will yield 15 tons of "wash ore" for 100 tons of clay.

WREN MINE.

The Wren mine, also known as the Wren Hill mine, is on the G. T. Rogers tract, in the NE. ¼ NE. ¼ sec. 4, T. 14 N., R. 7 W., 1½ miles north-northeast of Cushman, and is on a hill west of the Polk Southard mine. (See Pl. XVII.) It was operated many years ago by means of shafts and cuts, and a little work has been done recently by the Cushman Manganese Co. Penrose[12] in describing the earlier workings says, "A number of pits show the presence of manganese ore in varying quantities, associated with red clay and overlain by from 2 to 8 feet or more of loose chert." The character and origin of the ore and the relations of the clay to the Plattin limestone are the same as they are at the Polk Southard mine.

TURNER MINE.

The Turner mine, owned by the Cleveland Manganese Mining Co., is on the north slope of a hill in the NE. ¼ NW. ¼ sec. 3, T. 14 N., R. 7 W., 1¾ miles N. 35° E. of Cushman. (See Pl. XVII.) Most of the work at this mine was done about 30 years ago, and the following description of it is quoted from Penrose,[13] who visited it at that time:

Something over 4,000 tons of ore are said to have been taken from the property, of which quantity from 500 to 1,000 tons were mined by E. H. Woodward & Co., and the rest by the Keystone Manganese & Iron Co. at different times between 1886 and 1890.

The ore is associated with red clay and directly overlies the decomposed surface of the Izard [Plattin] limestone. It is capped by the broken and disturbed remains of the chert bed, which varies from only a few scattered fragments to 20 feet in thickness. The St. Clair [Kimmswick and Fernvale] limestone has entirely decayed, and the clay and ore remain as the residual product. Even the Izard [Plattin] limestone * * * has been attacked by the surface waters, and deep hollows, separated by protruding knobs, have been formed in its surface. The ore-bearing clay has collected in these hollows and also covers the protruding knobs. A large part of the northern end of the hill has been

[12] Penrose, R. A. F., jr., Manganese—its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, p. 274, 1891.

[13] Idem, pp. 271–274.

excavated, and the rugged floor of Izard [Plattin] limestone has been exposed. * * * [See fig. 21.]

As would be expected in a deposit such as the one at the Turner mine the thickness of the clay is very changeable, varying from 4 to 40 feet or more. The bed is not so thick as in places like the Southern mine, where even less decay of the St. Clair [Fernvale and Kimmswick] limestone has gone on. In the parts of the Turner property where the chert has been almost entirely removed this difference in the thickness of the clay may be due to erosion by surface waters, but it is probably due mostly to the fact that the original limestone did not contain the material to form a thicker bed. The value of a deposit, however, does not depend alone upon the thickness of the ore-bearing clay, but on the percentage of the ore in that clay; and it often happens that a clay of great thickness does not contain a paying quantity of ore, while a much thinner bed may pay well. It is necessary, therefore, to make a special study of each locality in order to determine its value. The Turner mine is a case where a comparatively thin bed of clay contains large quantities of ore.

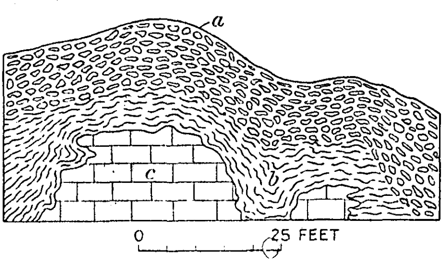

FIGURE 21.—Section at Turner mine, showing manganese-bearing clay (*b*) overlain by Boone chert (*a*) and occupying hollows in the decomposed surface of the Plattin limestone (*c*). (After Penrose.)

The mine was operated from April, 1916, to December, 1917, by W. H. Denison, who mined 90 tons of ore, and a little work was being done at the time of visit (June, 1918).

The manganese ore is like that at the near-by Polk Southard and Southern mines, and for this reason the Keystone Manganese & Iron Co., which operated these three mines at the same time, mixed at least a part of the ores from them. Analyses of two carload lots of lump ore mixed in this way are given on page 196.

LASSITER MINE.

The Lassiter mine, also known as the Lapham mine and the Section Thirty-three mine, is on land owned by William Einstein, in the SE. ¼ sec. 33, T. 15 N., R. 7 W., 2 miles N. 20° E. of Cushman. It was first operated about 30 years ago by the St. Louis Manganese Co.,[14] and was next operated by the Marqua Mining Co., the present lessee and operator, which began work in 1917 and had mined and shipped several hundred tons of high-grade manganese ore before the time of visit (June, 1918).

The workings are on a small terrace-like bench, on the southwest point of a hill, and include several pits, five shafts, of which the deepest is 90 feet deep, and a large cut, which had a face of 40 feet before it caved. (See Pl. XVII.) Although this bench is covered with

[14] Penrose, R. A. F., jr., op. cit., p. 275.

chert, which in most places conceals the ore-bearing clay, there are many exposures of the Joachim limestone on the slopes both above and below the bench and some masses of this limestone are revealed in the workings. The St. Peter sandstone is exposed in a small area stretching along the wet-weather branch that flows past the west base of the hill. This sandstone is exposed on the axis of a low eastward-trending anticline, and the Joachim limestone on either side of the axis dips at an angle of a few degrees away from it.

The chert covering as revealed in the workings varies in thickness from a few inches to 65 feet. Although most of the chert represents a part of the Boone chert that has settled and become much fractured as the underlying limestones were removed through solution, some of the chert appears to have been transported to its present position by water. Many boulders composed of chert pebbles and chert fragments cemented by brown iron oxides lie on the slope southwest of the mine.

The reddish-brown ore-bearing clay, parts of which contain many chert fragments, ranges in thickness from a few feet to more than 50 feet. One shaft is said to have been sunk to a depth of 50 feet in the clay without reaching the underlying limestone; work in this shaft was discontinued on account of the presence of water. Penrose,[15] who visited the mine when it was first worked, describes one shaft as follows:

> A shaft has been sunk into the "ore dirt" for 39 feet without reaching the underlying rock. At the bottom of the shaft a drift was run out to the northwest slope of the hill, a distance of 118 feet. The clay bed is continuous for the whole of this distance, and in many places contains manganese ore.

The ore-bearing clay lies in hollows in the Joachim limestone and overlies the limestone pinnacles between the hollows. (See Pl. XII, *B*.) Manganese ore has been found in much of it that was taken from all the openings within an area of about an acre, which is indicated on the map, and very little or none has been found in the pits outside this area. The manganese ore is mainly psilomelane, but some of it contains small quantities of hausmannite and possibly braunite. It occurs as fine particles, which appear to form fully one-tenth of the ore-bearing clay, and as larger irregular masses reaching a maximum weight of 9 tons. Thus far only the larger masses have been separated from the clay and shipped.

Masses of red iron oxide are commonly mixed with those of manganese ore near the surface but are said to be absent in the lower parts of the workings. Manganese oxide is present not only in the clay but it has also partly replaced many chert fragments, and it occurs as a film that covers the surface of many chert fragments.

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[15] Penrose, R. A. F., jr., op. cit., p. 275.

Most of the manganese ore, as well as much of the clay in which it is found, represents a residue from the decomposition of the Fernvale limestone, which was once present at this locality though at least 250 feet above the terrace-like bench.

CRIPPLE HILL PROSPECT.

The Cripple Hill prospect is on the south slope of a hill that is north of the Polk Southard mine, 2 miles north-northeast of Cushman. A few pits have been dug recently in a rocky clay, and between 12 and 15 tons of "lump" manganese ore are said to have been taken from them. The clay overlies the Plattin limestone, of which many ledges are exposed on the slope, and it probably does not occur in great quantity.

MAXFIELD PROSPECT.

The Maxfield prospect is in the NW. ¼ SE. ¼ sec. 34, T. 15 N., R. 7 W., 2½ miles northeast of Cushman. A few pits and shafts were dug on the southwest point of a hill by W. H. Denison, and only a very small quantity of manganese ore was found in them. They penetrate a yellow loam in which there are chert fragments and pebbles, and some of them pass through this loam and enter a light-brown clay. The only manganese oxide observed at the time of visit (April 22, 1918) was in very small pieces scattered through the brown clay. The clays at this locality overlie the Plattin and Joachim limestones, of which there are a few exposures near the openings.

SECTION THIRTY-FOUR PROSPECT.

The Section Thirty-four prospect, owned by William Einstein, is in a hollow and on an east hill slope in the SE. ¼ NE. ¼ sec. 34, T. 15 N., R. 7 W., 2¾ miles northeast of Cushman. Work at this prospect was done by the Marqua Mining Co., which is reported to have mined and shipped more than one carload of "lump ore" that contained 58 per cent of manganese. This ore was obtained by means of pits and shafts from one "pocket" of ore, and although further prospecting was done no other pockets were found. The few fragments of manganese oxides found on the dumps at the time of visit (April 23, 1918) were composed mainly of psilomelane but partly of hausmannite. The ore-bearing clay is reddish-brown and is overlain by red and yellow clays in which there are chert fragments. There are no exposures of limestone near the openings. In fact the only limestone observed at the time of visit was a few fragments of the Plattin limestone lying on a dump.

FRIDAY PROSPECT.

The Friday prospect, which is on land owned by E. Friday, consists of a few pits and shafts on a north hill slope just south of the Section Thirty-four prospect, in the NE. ¼ SE. ¼ sec. 34, T. 15 N., R. 7 W., 2¾ miles northeast of Cushman. About 15 tons of "lump" manganese ore was taken from the openings and shipped. The workings were caved badly at the time of visit (April 23, 1918), but the ore, as at the Section Thirty-four prospect, was probably obtained from clay that underlies the surface material, which is composed largely of chert fragments.

SIMPSON PROSPECT.

The Simpson prospect is on the south slope and near the crest of an eastward-trending ridge, in the NW. ¼ NE. ¼ sec. 33, 2½ miles north of Cushman, and is on land of which the mineral right is owned by N. A. Adler and the agricultural right by L. R. Simpson. In 1914 Mr. Handby mined here 10 tons of ore containing 55 per cent of manganese. This ore was taken from a cut 6 feet deep and 30 feet long, and it consisted of masses ranging in weight from 1 pound to 400 pounds. It was hand picked from a reddish-brown clay, which is overlain by 3 to 4 feet of red cherty loam. Other openings within less than 100 feet of the cut are a shaft 15 feet deep in cherty clay and loam practically barren of ore, a pit 8 feet deep in similar material, and a shaft 40 feet or more deep, which is said to have struck manganese ore at the bottom. The only limestone found in the workings was a boulder of pinkish-gray (Fernvale) limestone. A few outcrops of the Plattin limestone extend up the south slope to a point within about 50 feet of the south end of the cut.

HELMS PROSPECT.

The Helms prospect, which is just south of the Simpson prospect described above, is in the SW. ¼ NE. ¼ sec. 33, T. 15 N., R. 7 W., 2½ miles north of Cushman. A few shallow pits have been made by J. W. Helms, the owner, in yellow cherty clay on the south slope of a ridge. Several hundred pounds of manganese ore has been taken from the pits, and one boulder of ore weighing 300 pounds was found on the surface. A small pile of manganese ore observed on one of the dumps consisted of steel-blue psilomelane. Exposures of the Plattin limestone on the slope indicates that the clay overlies this limestone.

MOUNT ETNA MINE.

The Mount Etna mine, which is owned by William Einstein, is 2¾ miles north of Cushman. It was operated in 1917 by the Marqua Mining Co., and some manganese ore was shipped.

The workings consist of several pits, most of which have been dug within an area of about 1 acre on a gentle northwest slope, and they penetrate red, yellow, and brown manganese-bearing clays. These clays lie upon the irregular surface of the Fernvale limestone, which is exposed in the workings, and they are concealed by a thin covering of chert débris and large blocks of brown sandstone. The chert débris and the sandstone blocks represent parts of the Boone chert and Cason shale, respectively, that have settled down the slope below their original position. In the deepest pit, which is 20 feet deep, the clays range in thickness from 2 feet 8 inches to more than 4 feet and lie between a nearly vertical face of the Fernvale limestone and a heavy ledge of sandstone dipping 60° away from the limestone face. Irregular masses of red and brown iron oxides and soft though firm manganese oxide, some weighing as much as 75 pounds, are scattered through the clay. Some of these masses contain a high percentage of silica in the form of sand grains. The ore and the clay in which it occurs are apparently a residue from the decomposition of both the Fernvale limestone and Cason shale.

A few very small pits are near an outcrop of the Fernvale limestone on the slope farther west. They yielded a small quantity of high-grade hard manganese oxide as well as masses of brown and red oxides of iron.

J. R. DOBSON PROSPECT.

The J. R. Dobson prospect is on the J. R. Dobson tract, in the NE. ¼ sec. 29, T. 15 N., R. 7 W., 3½ miles north of Cushman. Prospecting at this locality was done in 1917 by the Magnolia Mining Co., and during the prospecting 16 tons of "lump" manganese ore was separated by hand picking from the ore-bearing clay and shipped. Of this production 12 tons contained more than 40 per cent of manganese and 4 tons less than 40 per cent of manganese.

Several pits and shafts as much as 60 feet deep have been dug on the east slope of a ridge and in a saddle near the crest of the ridge. They penetrate a red to dark-brown clay whose surficial portion contains chert fragments. The clay overlies the Joachim and Plattin limestones, of which there are some exposures in the workings and many near by. Both the Kimmswick and Fernvale limestones appear to have been entirely removed by solution. The chert which caps the ridge represents a part of the Boone chert that has settled from its former position as a result of the removal of these limestones. Masses of manganese oxides in the form of "wash ore" and "lump ore" were found in parts of the clay in some of the openings. They, together with fragments of red iron oxide, are mixed with pebbles in the bottoms of gullies on this property, and such material may underlie the alluvial cones near the base of the hill slope. Many of the chert fragments in the ore-bearing clay are stained with manganese oxide.

J. P. BARNES PROSPECT.

The J. P. Barnes prospect is on the south point of a ridge, on the north side of Pumpkin Creek, in the SW. ¼ sec. 32, T. 15 N., R. 7 W., 2 miles north by west of Cushman. The only opening at the time of visit (April 11, 1918) was a small pit that had been dug on the upper part of the hill slope. The slope where the pit was dug is gentle and is strewn with chert fragments and pebbles. No rock ledges are revealed on it, but heavy ledges of chert dipping at different angles are on the crest of the ridge, and many outcrops of the Plattin limestone are on the slope below the pit. The absence of exposures of the Kimmswick and Fernvale limestones, together with the occurrence of the displaced chert ledges on the crest, suggests that these limestones have been largely or entirely decomposed. If so the crest of the ridge is underlain by a considerable quantity of clay that may contain much manganese ore.

One ton of manganese ore has been taken from the pit and 2 tons or more have been picked up on the surface near the pit and at places near Mr. Barnes's house to the southwest. The ore that was seen on the surface at the time of visit is steel-blue compact psilomelane in masses ranging in size from fine particles to fragments that weigh a few pounds.

After the writer's visit the land on which the pit is situated was sold to P. D. McCormick, who dug three shafts and two cuts, in which the showing of manganese ore is said to have been good. The tract has since been sold to J. W. Williams and associates.

WOLFORD MINE.

The Wolford mine, which consists of several small pits within an acre on and near the crest of a hill, is in sec. 31, T. 15 N., R. 7 W., 3 miles northwest of Cushman. It was operated in 1917 by Jim Wolford, who mined three carloads of ferruginous manganese ore that contained about 17 per cent of manganese. Most of the pits are on the outcrop of the Cason shale. This formation does not here contain shale but consists of a soft yellow to red earthy, pebbly sandstone, in the lower part of which manganese and iron oxides are disseminated. Some of the richer parts of the sandstone appear to have been mined as ore. A chocolate-colored clay underlies the sandstone, but as the pits were badly caved at the time of visit (April 11, 1918) the presence or absence of manganese ore in it was not determined by the writer. One pit passed through chert ledges that dip 60° E. These ledges represent a part of the Boone chert that has settled from its former position as the limestones beneath it were removed by solution. The Cason shale has also probably settled below its original position. The only limestone exposed in the vicinity is the Plattin limestone.

NEILL PROSPECT.

The Neill prospect is on and near the crest of a ridge in sec. 31, T. 15 N., R. 7 W., 3 miles northwest of Cushman. A little work was done at this locality in 1917 by T. F. Shell, and some manganese ore was shipped, but the quantity was not determined. A few shallow pits and cuts are in brown manganese-bearing clay and in surficial chert débris, whose thicknesses were not determined as the workings were badly caved at the time of visit (April 11, 1918), but one of the pits that is highest on the ridge shows 10 feet of chert débris overlying the clay. This clay apparently rests upon the Plattin limestone, which is exposed near by, and it is presumably residual from the Fernvale limestone, although there are no exposures of this limestone in the vicinity.

The manganese ore consists of irregular masses of psilomelane scattered through the clay just described. The larger masses have been separated from the clay taken from the workings and have been shipped, whereas the smaller pieces, which appear to form from one-third to one-half of some of the ore-bearing clay, have been left in the clay.

CALAWAY PROSPECT.

The Calaway prospect consists of several very small pits and a cut 100 feet long near the top of a hill on the east side of East Lafferty Creek, 2 miles north-northwest of Cushman. Work was done at this locality in 1916 by W. H. Calaway, and 1½ carloads of ore, of which one-third was high-grade manganese ore and the rest ferruginous manganese ore, was shipped. The openings are on gentle west and southwest slopes and are in red manganese-bearing clay the upper few feet of which contains chert fragments. The clay was not seen in place as the openings had caved before the time of visit (April 9, 1918), but the occurrence of exposed ledges of Plattin limestone near the openings indicates that the clay rests upon this limestone.

The manganese ore that has been shipped consisted entirely of the larger masses. The smaller particles, which have been left in the clay on the dumps, are mainly manganese oxides but partly iron oxide.

STERRETT MINE.

The Sterrett mine is in the NE. ¼ SW. ¼ sec. 6, T. 14 N., R. 7 W., 2 miles northwest of Cushman. It was operated in 1896 by the Keystone Manganese & Iron Co., which shipped one car of manganese ore, and it was operated in 1916 and 1917 by T. W. Sterrett, the present owner, who mined and marketed three cars of manganese ore containing about 40 per cent of manganese.

The workings, which are pits, cuts, and shafts, are scattered over a few acres on and near the crest of a ridge. Although they were badly caved at the time of visit (April 9, 1918), the red ore-bearing clay could be seen lying between and over horses of the Kimmswick and Plattin limestones, none of which reached the surface. The clay is overlain by loose chert débris and by ledges of the Boone chert that have settled below their former position to conform with the irregular surface of the limestones. The chert ledges are much scattered and dip at different angles in different directions.

The manganese ore occurs in the clay as hard masses, both large and small. The larger ones—those 1 inch or more in diameter—have been separated from the clay by hand picking and shipped, whereas those less than 1 inch in diameter have been left in the ore-bearing clay, of which they form a considerable part.

SANDERS PROSPECT.

The Sanders prospect consists of a few shallow pits and cuts in a hollow in the SE. ¼ NW. ¼ sec. 6, T. 14 N., R. 7 W., just north of the Sterrett mine and 2 miles northwest of Cushman. Work was done here in 1916 by Ernest Sanders, the owner of the land, who mined and sold a few tons of manganese ore. The workings are in red clay, in which the manganese ore occurs as masses ranging in size from particles one-fourth of an inch or less in diameter to boulders. The clay overlies the Plattin limestone, of which there are a few outcrops, and its surficial portion contains chert fragments. The manganese ore at this locality is similar to that at the Sterrett mine.

MILLER PROSPECT.

The Miller prospect, which is on land that formed part of the W. H. Cole tract described by Penrose,[16] consists of several openings on and near the crest of the ridge on the south side of Pumpkin Creek, in the SW. ¼ NE. ¼ sec. 6, T. 14 N., R. 7 W., 2 miles northwest of Cushman. Some work was done here 30 years or more ago, and a very small pit, from which irregular masses of manganese ore were

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[16] Penrose, R. A. F., jr., Manganese—its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept., vol. 1, pp. 275–276, 1891.

removed, was being dug in cherty red clay at the time of visit (April 9, 1918). The thickness of the ore-bearing clay at this pit had not been determined. Outcrops of the Plattin limestone that are near by suggest that the clay overlies this limestone. Penrose,[17] who visited the old openings, describes them as follows:

Several small pits which have been dug show the presence of manganese ore in a red clay. The deposit is said to have been sunk into for 25 feet without reaching the bottom of the clay. The ore is of a hard, dark iron-gray variety, and often contains numerous cavities filled with earthy matter.

Fragments of St. Clair [Fernvale] limestone of a chocolate-brown color are frequently found in the clay, and it is probable that the main body of that rock still underlies the deposit, which is not so thick as it would have been had more of the limestone decayed. The clay bed, however, probably has a considerable lateral extent.

W. L. JOHNSON PROSPECT.

The Johnson prospect, described by Penrose[17] under the name "Thomas Cecil tract," consists of several small openings on the W. L. Johnson farm, which comprises the W. ½ NW. ¼ sec. 5 and the E. ½ NE. ¼ sec. 6, T. 14 N., R. 7 W., and is 2 miles northwest of Cushman. The work on this prospect has been done recently by Mr. Johnson, and about 10 tons of manganese ore containing 50 per cent or more of manganese has been mined and shipped. The manganese ore is mainly hard steel-blue psilomelane; the rest is wad. It occurs as fine particles and as boulders weighing as much as 300 or 400 pounds, and although some of it was picked up on the surface most of it was found in red or reddish-brown clay, which usually contains chert fragments and pebbles. One shaft 42 feet deep passed through 16 to 20 feet of barren chert débris and the rest of the distance in chert débris that is ore-bearing. The occurrence of a few exposures of the Fernvale and Kimmswick limestones and of many exposures of the Plattin limestone indicate that the ore-bearing material and other surficial material rest upon these limestones.

BOB WILSON PROSPECT.

The Bob Wilson prospect, which consists of several pits and shafts scattered over a few acres on the crest of a low ridge, is on the south side of Pumpkin Creek, in the northern part of sec. 5, T. 14 N., R. 7 W., 1½ miles north-northwest of Cushman. Work was done at this locality in 1916 by Corruthers, Enoch & Luckel, who mined and marketed half a carload of high-grade manganese ore. The openings had badly caved at the time of visit so that the thickness of the red and brown ore-bearing clay was not observed. Its thickness, however, varies greatly and appears to reach in places 10 feet or more. The clay is overlain by chert débris and rests upon the Fern-

[17] Penrose, R. A. F., jr., op. cit., pp. 275–276.

vale and Kimmswick limestones, of which there are a number of outcrops on the slopes near the crest of the ridge. Nothing could be determined concerning the quality of the manganese ore except from the finer particles that had been left in the clay. These consist of hard psilomelane of good quality.

PAGE MINE.

The Page mine consists of five shafts as much as 58 feet deep that have been sunk here and there in the SE. ¼ SW. ¼ sec. 4, T. 14 N., R. 7 W., three-fourths of a mile north of Cushman. The tract that includes the mine is owned by John Page, and the prospecting was being done at the time of visit (June, 1918) by R. S. Handford, of the Cushman Manganese Co. It is in a region whose surface is covered by a thick mantle of Boone chert, below which there are red and brown clays. No limestone is exposed in the vicinity, but the Plattin limestone was encountered beneath the clays in one of the shafts, and at other localities undecomposed parts of the Kimmswick and Fernvale limestones may be found later. The clays and the ore they contain have a similar origin to those at the Southern mine to the northeast.

Only a small quantity of manganese ore had been found at the time of visit but since then a workable deposit has been discovered and two carloads are reported to have been shipped from it. Some of the ore observed by the writer on the dump of one of the shafts is porous, and its cavities are lined with slender hairlike crystals of white barite.

CLUB HOUSE MINE.

The Club House mine, described by Penrose [18] under the heading "Matt. Martin tract," is in the NE. ¼ NE. ¼ sec. 8, T. 14 N., R. 7 W., half a mile north of Cushman. It was first operated by Skinner & Abbot about 30 years ago. The next work was done in 1909 and 1910 by the Martin Manganese & Mining Co. and the next by the Independence Mining Co., the present operator, beginning in 1915, but in 1916 some work was done by Denison & Adler. The production has been over 2,000 tons of manganese ore of the different grades described on page 215.

The workings consist of pits, open cuts, shafts, and tunnels scattered over a few acres on the east slope of the point of a hill and on the crest of the hill. They are partly in solid rock, but for the most part they are in surficial clay and chert débris derived from the four rock formations described below, of which there are many

[18] Penrose, R. A. F., jr., op. cit., p. 270.

exposures, both on the surface and in the workings. A section of the rocks at this locality follows:

Section at the Club House mine.

	Feet.
Boone chert:	
Massive and thin-bedded hard gray chert; the chert capping the crest of the hill is 50 feet thick	50
Cason shale:	
Sandy platy shale and shaly sandstone, part of which is yellow and part green; contains a few pebbles	2½
Shaly sandstone, largely replaced by porous red and brown iron oxides and manganese oxide	2
Fernvale limestone:	
Pinkish-gray granular cross-bedded limestone. Near the top it is rusty or dark gray from the presence of manganese and iron oxides. In one cut a bed of limestone 8 feet thick, lying at the top of the formation, was quarried and shipped as manganese ore; the rock shipped contained 12 per cent of manganese. The top of the limestone is irregular and is overlain by pockets of manganese oxide, ranging in thickness from a few inches to 2 feet or more	95
Kimmswick limestone:	
Fine-grained and compact light-gray massive limestone to base of hill	Several.

The manganese oxides mentioned in the section as occurring in the Cason shale and Fernvale limestone are the source of some of the manganese ore that has been mined, but the worked ore deposit is mostly in the reddish-brown residual clays of these two formations that are found at a lower elevation. Clays that are shown in figure 5 (p. 63) fill hollows in the Fernvale and Kimmswick limestones. They also overlie the limestone pinnacles between the hollows and partly or entirely fill caves in these limestones. They are overlain on the hill slope by different thicknesses of the Boone chert either as loose fragments or as shattered, steeply dipping ledges that have settled down the slope from their original position, as shown in the openings at and near the top of the hill. One shaft on the top of the hill passed through 30 feet or more of the Boone chert and entered a channel in the Fernvale limestone which was filled with ore-bearing clay. Shafts as much as 75 feet deep and tunnels and open cuts have been made in the ore-bearing clay on the slope of the hill, and a cave partly filled with ore-bearing clay was followed by a tunnel for 200 feet. A mass of white onyx marble several feet long and a foot thick lies along the contact of the Fernvale and Kimmswick limestones at the mouth of the cave. Ore-bearing clay has been mined in drifts from beneath ledges of the Fernvale limestone near the mouth of the cave, and since the mining has been done parts of the earthy roof of the drifts have caved in, leaving two small natural bridges of limestone. Limestone horses from around which the clay has been removed are excellently exposed in the open cuts. The hollows between these horses and the other channels in the limestone attain a width of 50 feet.

Manganese oxides, mainly psilomelane with minor quantities of hausmannite and wad, occur in the above-described clays as irregular masses ranging in size from fine particles to large boulders. The largest boulder thus far found weighed 10.2 tons. The greater part of the production of this mine—about 1,400 tons of ore, containing between 45 and 58 per cent of manganese—consisted of masses that were freed from the clay by hand picking, but some of the clay after being picked was washed by the Independence Mining Co. in a small washing plant below Phelps Spring, just northeast of the mine. The concentrates thus recovered aggregated 300 tons and contained between 42 and 44 per cent of manganese. Thirty cubic yards of clay—the quantity treated each day—yielded between 5 and 6 tons of concentrates. Besides the 300 tons just mentioned 200 tons of ore, containing 20 per cent of manganese and classed as "tailings," was recovered at the washing plant, and 167 tons of the ore-bearing Fernvale limestone described in the above section was quarried and shipped by Denison & Adler. The limestone thus shipped contained 12 per cent of manganese.

FELTS PROSPECT.

The Felts prospect is on land owned by the Cleveland Manganese Mining Co., in the NW. ¼ sec. 9, T. 14 N., R. 7 W., half a mile north of Cushman. The openings, which are shallow pits, are in the bottom of the hollow and near the base of the east hill slope on which the openings of the Club House mine occur. They have been made in red manganese-bearing clay that fills channels in the Plattin and Kimmswick limestones. Some boulders and ledges of these limestones protrude through the surficial material. The ore is like that at the adjoining Club House mine, but the quantity of ore is less than it is there.

Work was done here from April, 1916, to March, 1917, by W. H. Denison, who mined and shipped 36 tons of ore.

SECTION EIGHT PROSPECT.

The Section Eight prospect, owned by William Einstein, is in the SW. ¼ NE. ¼ sec. 8, T. 14 N., R. 7 W., on the south side of the head of the valley of Blowing Cave Creek, one-fourth of a mile west of Cushman. A few shallow pits and cuts were dug within an area of an acre or less in 1917 and 1918 by the Marqua Mining Co., the present lessee; and a small quantity of manganese ore was removed from them and shipped. After the openings pass through chert débris several feet thick they reveal masses of ferruginous Fernvale limestone surrounded by chocolate-colored clay, which is at places 15 feet or more thick, and they also reveal the Cason shale, which here contains beds of phosphatic sandstone as well as beds of shale.

The ore occurs as angular fragments scattered through the clay and as a bed a few inches thick lying upon the top of the limestone. It consists of the manganese oxides psilomelane and wad and red and brown iron oxides, which are more or less intimately mixed. The fragments containing the highest percentage of manganese can, however, be separated by hand picking from much of the iron oxides.

MEEKER MINE.

The Meeker mine, owned by the Cleveland Manganese Mining Co., is in sec. 8, T. 14 N., R. 7 W., on the south side of the head of the hollow in which Blowing Cave is situated, half a mile west of Cushman. It was operated 30 or more years ago, and in 1905 it was operated by W. H. Denison. Very little mining has been done since 1905. The marketed ore, which was a ferruginous manganese ore, is reported to have aggregated seven or eight carloads.

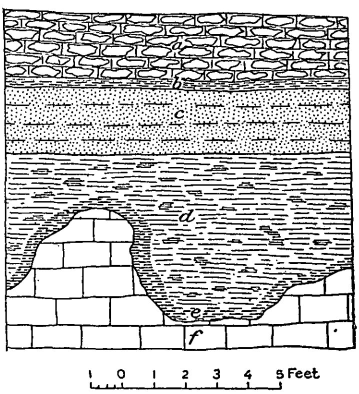

FIGURE 22.—Sketch showing occurrence of manganese ores at Meeker mine (after Harder). *a*, Boone chert; *b*, green shale or manganiferous clay; *c*, brown sandstone; *d*, manganese-bearing ferruginous shale; *e*, manganiferous clay or dark indurated siliceous layer; *f*, Fernvale limestone.

The openings consist of several open cuts and tunnels that have been made in the ore-bearing layer in the lower part of the Cason shale. The ore-bearing layer rests upon the irregular surface of the Fernvale limestone and ranges in thickness from a few inches to several feet. The following description of the succession of layers (fig. 22) is after Harder,[19] who visited the locality when the openings were fresh:

Boone chert.

Manganiferous clay 2 to 3 inches thick.

Green shale varying in thickness up to a foot or more. Absent in places.

Brown sandstone 2 to 3 feet thick.

Sandy manganese and iron oxide formation varying in thickness up to 6 feet or more. Locally the lower foot or two is hard and siliceous, while elsewhere there are 6 inches or a foot of manganiferous clay at the base.

Polk Bayou [Fernvale] limestone.

The manganese-bearing layer consists of thin horizontal layers of manganese and iron oxides, mainly the former, interlaminated with yellow and

[19] Harder, E. C., Manganese deposits of the United States, with sections on foreign deposits, chemistry and uses: U. S. Geol. Survey Bull. 427, p. 114, 1910.

red sandy material. The layers are generally crenulated and are one-sixteenth to one-half inch thick. The variations are generally abrupt and sharp, causing great irregularity. Locally large porous masses of manganese ore 4 to 5 inches thick are embedded in the low-grade laminated ore. They consist of dark-blue massive psilomelane, with a small amount of finely crystalline material in cavities. Many of the cavities are entirely or partly filled with calcite.

The ore-bearing layer is stated by Mr. Denison to contain 20 per cent of manganese and 25 per cent of iron.

R. W. REEVES PROSPECT.

The R. W. Reeves prospect consists of several very small pits in ore-bearing clay on a steep hill slope half a mile west of Blowing Cave and 1½ miles west of Cushman. The clay is concealed by soil and chert fragments and rests upon the irregular surface of the Plattin, Kimmswick, and Fernvale limestones, of which outcrops are numerous. The ore as revealed on the dumps consists of small masses of manganese and ferruginous manganese oxides. A ledge of ferruginous manganese ore like that at the Meeker mine may be expected in the lower part of the Cason shale, which overlies the Fernvale limestone. Very little or no ore had been hauled away from this locality at the time of visit (June 10, 1918).

JAKE COLE PROSPECT.

The Jake Cole prospect, which is on land owned by Jake Cole, is on the south side of Blowing Cave Creek, 2 miles west of Cushman. Work was done here by Mr. Cole in the spring of 1917, and several tons of manganese ore was hauled to Cushman, where is was sold.

The openings, which consist of several pits and shafts as much as 20 feet deep, are in a reddish-brown manganese-bearing clay. This clay overlies the Plattin and Joachim limestones, of which there are a few exposures, and it is generally concealed by chert and sandstone débris. In addition to the manganese ore the clay contains masses of red and brown iron oxides. The manganese ore is psilomelane, and most of it occurs in irregular masses ranging in size from those about an inch in their longest dimension to those weighing 150 pounds.

SAND FIELD PROSPECT.

The Sand Field prospect is on the east side of East Lafferty Creek, near the center of sec. 12, T. 14 N., R. 8 W., 2½ miles west of Cushman. Work was done at this locality in 1916 and 1917 by W. E. Barnes, the owner, and the quantity of manganese ore that has been mined and hauled to Cushman where it was shipped is reported to have been about 25 tons.

The main group of openings, which are pits and shafts, covers an area of one-fourth of an acre or less on a terrace that stands at an elevation of about 100 feet above East Lafferty Creek. This terrace is underlain by a gravel bed about a quarter of an acre in extent, and the gravel bed is in turn underlain by the St. Peter sandstone, which is well exposed at many places in the vicinity. The gravel bed, as shown by prospecting, is at places 32 feet thick and is composed mainly of chert fragments and pebbles but partly of masses of manganese ore. Its materials were obviously carried to their present position by some stream that in the past flowed in a channel at the same elevation as the terrace; it is probably the remnant of an alluvial cone that once existed at the mouth of a hollow that was drained into East Lafferty Creek.

The manganese ore consists of psilomelane with smaller quantities of hausmannite, braunite, and wad and occurs disseminated through the gravel bed as fine particles and boulders, the largest of which so far found weighed 1,000 pounds. Thin coatings of manganese oxide have stained the chert fragments and pebbles, and some pieces of iron oxide are found in the gravel bed. The larger masses of ore were hand sorted and shipped, whereas the fine particles were left in the ore-bearing material on the dumps. It is said that a wagon load (about 3,000 pounds) of this discarded material was washed and from it 300 or 400 pounds of concentrates was obtained.

A number of pits 3 feet or less deep, which have been dug on the slope 300 or 400 feet northeast of the deposit described above, have yielded fragments of manganese ore. The ore at this locality is in surficial material composed of sand and chert fragments that lie upon the St. Peter sandstone.

A knob capped with chert fragments and pebbles is one-eighth of a mile east of the above-described terrace deposit and at the same elevation. A shaft was sunk to a depth of 39 feet into the material capping this knob, but only stains of manganese oxides that occur on the chert fragments and pebbles were found.

TOSH HILL PROSPECT.

The Tosh Hill prospect, which is owned by William Einstein, is on the west end of Tosh Hill, in the SE. ¼ sec. 12, T. 14 N., R. 8 W., 2½ miles west of Cushman. Very little work has been done at this locality. Part of it was done about 30 years ago, and part of it within the last two or three years by the Marqua Mining Co.

Shallow pits and cuts penetrate red and brown clays that overlie the Fernvale, Kimmswick, and Plattin limestones, of which there are many exposures, and some of the openings pass through a surficial covering of chert débris before they reach the clays. The manganese ore consists of psilomelane and possibly braunite and occurs in these clays as irregular masses, ranging in size from fine particles to boulders. Some iron oxide is associated with the manganese and is either intimately mixed with it in the same masses or occurs as separate masses.

FRAZIER PROSPECT.

The Frazier prospect, which is on land owned by I. Frazier, consists of four or five small pits on the southwest slope of a small hill 2 miles west by south of Cushman. The prospecting was done in 1917 by Mr. Frazier, and only a few tons of manganese ore was hauled to Cushman, where it was sold.

The hill is capped by a few feet of loose chert fragments, below which the following section was revealed on the surface and in the pits:

Section at the Frazier prospect.

	Feet.
Cason shale:	
Ledge of yellow sandstone which is overlain by the chert that caps the hill; contains small pockets of brown and red iron oxides that have apparently replaced the sandstone; the lower 1 foot is phosphatic and contains ferruginous manganese oxide	4–5
Platy green shale whose base is conglomeratic; at its base there is a bed a foot or more thick of red and brown iron oxides and manganese oxides	5+
Fernvale limestone:	
Gray limestone whose relations to the bed of iron and manganese oxides above are not revealed	5–6

The manganese and iron oxides that have been removed from the pits are from the bed of these oxides at the base of the Cason shale and from clays that fill shallow channels in the Fernvale limestone. They are intermixed, and the iron oxides are as abundant as the manganese oxides, but they can be partly freed from one another by hand picking.

HIGHTOWER PROSPECT.

The Hightower prospect is on the W. M. Hightower tract, in the NE. ¼ NW. ¼ sec. 18, T. 14 N., R. 7 W., 1¾ miles west by south of Cushman. A few pits as much as 8 feet deep have been dug near the wagon road that crosses this tract. The pits and the cistern 12 feet deep at Mr. Hightower's house have penetrated red and brown clays in which irregular fragments of manganese oxide mixed with some iron oxide have been found. These clays and the manganese and iron oxides are residual from the decomposition of the Fernvale limestone, and they are partly concealed by masses of phosphatic sandstone derived from the Cason shale and by ledges of the Boone chert that have settled below their original positions while solution channels were being formed in the Fernvale limestone. There are no exposures of this limestone near the pits, and none were observed in the vicinity except at places one-fourth of a mile west of the wagon road.

The manganese ore that has been mined is in irregular masses ranging in size from fine particles to boulders weighing 200 pounds, and as a rule it can be freed by hand picking from the iron oxide. The only reported production from this prospect is 5 or 6 tons that was mined and marketed in 1916.

F. M. BARNES PROSPECT.

The F. M. Barnes prospect is on the F. M. Barnes tract, in the SE. ¼ NE. ¼ sec. 14 and the S. ½ NW. ¼ sec. 13, T. 14 N., R. 8 W., on the southeast side of East Lafferty Creek, 3 miles west-southwest of Cushman. Work has been done here by Mr. Barnes, beginning in 1917, and a small quantity of manganese ore has been shipped. Since the time of visit (April 10, 1918) the tract has been purchased by E. Fleming L'Engle and D. E. Woodbridge.

The workings, which are a few shallow cuts and pits, have been made on the outcrop of the Cason shale and in a thin mantle of chocolate-colored clay overlying the upper part of the Fernvale limestone, of which there are many exposed ledges. Some are on a steep hill slope in a small hollow, and the rest are on the southwest point of a hill that is east of the mouth of the hollow. Iron oxide, ferruginous manganese oxide, and manganese oxides occur as a 19-inch ledge and as thin lenses in the Cason shale; also as irregular fragments in the chocolate-colored clay. The first two oxides predominate in the shale, whereas the manganese oxides, which include both hard and soft oxides, are most abundant in the clay. One sample collected from the ledge of ferruginous manganese oxide is reported to have contained 16 per cent of manganese, and another sample from it is reported to have contained 19 per cent of manganese. This ledge is well exposed in one cut, where the following section was made, but its presence or absence at other localities has not been determined by prospecting.

Section in cut at F. M. Barnes prospect.

	Ft.	in.
St. Clair limestone:		
Gray fossiliferous limestone	4+	
Cason shale:		
Massive and thin-bedded ferruginous sandstone	7–8	
Sandy and shaly ferruginous manganese oxide	1	7
Green phosphatic sandstone		8
Platy gray shale containing a few thin lenses of iron oxide	3	
Fernvale limestone:		
Rusty limestone separated from the Cason shale by a foot or more of chocolate-colored clay, which is a residue from the decomposition of this limestone. The top of the limestone is irregular.		

W. C. COLLIE MINE.

The W. C. Collie mine is 3½ miles west-southwest of Cushman and consists of two groups of openings on the W. C. Collie tract, which embraces the NW. ¼ NW. ¼ sec. 13 and the NE. ¼ NE. ¼ sec. 14, T. 14 N., R. 8 W. One of these groups is on the southeast side of East Lafferty Creek, and the other is on the northwest side of the creek. The mine has been operated by W. C. Collie, the owner, beginning in 1917, and the production before the time of visit (April 10, 1918) was 130 tons of manganese ore, which is reported to have averaged 38 per cent of manganese. One carload of ore taken from the west side of the creek is said to have contained 45 per cent of manganese.

The workings on the southeast side of the creek are shallow cuts and pits, which are scattered here and there through an east-west distance of 100 yards on a steep north hill slope. They are in chocolate-colored clay, which overlies the upper part of the Fernvale limestone and extends down into it in channels and pockets as much as 15 feet deep. This clay contains chert fragments in its surficial part and also contains irregular masses of psilomelane, which range in size from minute particles to boulders weighing 100 pounds. Only the larger masses are removed from the clay. The smaller pieces make up more than half of the clay found on some of the dumps, but the steepness of the slope and the presence of many outcrops of the Fernvale limestone, both on the slope and in the workings, indicate that the ore-bearing clay is not in great quantity.

The workings on the west side of the creek are on the steep east slope and the crest of a southward-trending ridge. They consist of shallow cuts and pits and a few shafts, the deepest of which is 32 feet deep. The highest of the openings are 300 feet above the creek. They pass through a surficial covering of chert débris and then penetrate a reddish-brown clay, in which the manganese ore is found. This clay varies from a minimum thickness of a few inches to a reported thickness of 32 feet. It overlies the Fernvale, Kimmswick, and Plattin limestones, exposures of which are numerous on the east slope but few on the crest. Although the chert débris is found everywhere on the surface it is thickest on the crest of the ridge. The manganese ore occurs as fine particles and as boulders, some weighing as much as 1,800 pounds. The larger masses are removed from the clay by hand picking, the smaller ones, which form a considerable part of some of the clay, being left.

GEORGE MINE.

The George mine was not visited by the present writer but was described as follows by Penrose:[20]

The George tract is in 14 N., 8 W., sec. 11, the SW. ¼ NE. ¼, the W. ½ SE. ¼, and the NE. ¼ SE. ¼. It belongs to the Keystone Manganese & Iron Co. and is situated less than a mile above the confluence of the two main branches of Lafferty Creek. A few small pits have been sunk on the top of a hill and show the presence of manganese ore associated with red clay. A hundred and ninety-three tons of ore are said to have been taken from this property. The clay deposit is covered by from 10 to 40 feet or even more of chert. Numerous masses of St. Clair [Fernvale] limestone are associated with the ore, and the main body of the limestone is exposed on the hillsides in the vicinity. The amount of decomposition of that bed is thus shown to have been comparatively small, and the deposits of ore-bearing clay, at least in the part of the property where work has been done, will generally be found to be limited in depth as well as in lateral extent.

The property was worked in a small way in 1916 and 1917 by W. H. Denison and J. F. Barksdale, who mined and shipped 25 tons of manganese ore. A news item of October 19, 1918, says:[21] "Logan Rives and associates have installed a steam shovel and are securing a good production of high-grade nugget ore."

S. W. WEAVER MINE.

The S. W. Weaver mine is on a steep north hill slope on the southeast side of East Lafferty Creek in the SW. ¼ NE. ¼ sec. 14, T. 14 N., R. 8 W., 3½ miles west-southwest of Cushman. It was operated in 1917 by T. F. Shell, who mined and shipped one car of manganese ore, and it was being operated at the time of visit (April 10, 1918) by Dr. S. W. Weaver, the owner, but since then it has been sold to E. Fleming L'Engle and D. E. Woodbridge, who have operated it. The workings, which are cuts and short tunnels, have been dug for the most part in the manganese-bearing residual clays of the Fernvale limestone, and they are all near the top of the Fernvale limestone. The clay contains chert fragments at and near

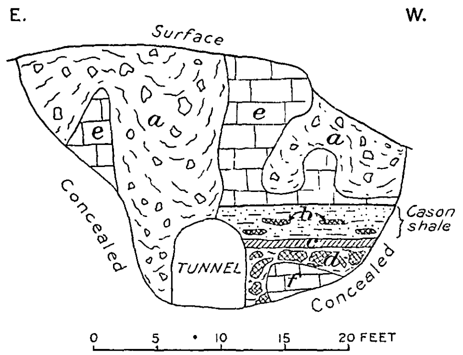

FIGURE 23.—Sketch section showing occurrence of iron and manganese oxides at the S. W. Weaver mine. *a*, Clay and chert fragments; *b*, iron and manganese oxides in Cason shale; *c*, red iron oxide; *d*, iron and manganese oxides in clay; *e*, St. Clair limestone; *f*, Fernvale limestone.

[20] Penrose, R. A. F., jr., Manganese—its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, pp. 278–279, 1891.

[21] Eng. and Min. Jour., Oct. 19, 1918.

the surface; it is in places overlain by cherty clays that have been derived from the weathering of the St. Clair limestone and the Boone chert; and it does not have a uniform thickness, as the top of the Fernvale limestone, upon which it rests, has been channeled by solution. Manganese ore together with much iron ore occurs as irregular masses in the clay or as a layer a few inches thick between the Cason shale and the Fernvale limestone. The manganese and iron ores are in places intimately mixed, but they can be separated fairly well. The marketed ore is said to have averaged about 40 per cent of manganese. Manganese oxide occurs not only in the residual clay of the Fernvale but a small quantity of it has blackened some of the residual clay of the St. Clair limestone. The accompanying sketch section (fig. 23) of the face of the cut at the portal of one of the tunnels illustrates the relations of the iron and manganese ores to the clays and rock formations.

MARTIN NO. 1 MINE.

The Martin No. 1 mine is in the SW. ¼ sec. 14, T. 14 N., R. 8 W., on the southeast side of East Lafferty Creek, 4 miles west-southwest of Cushman and 1½ miles southeast of Penters Bluff station. It has been operated at times by J. R. Martin, the owner, beginning in August, 1917, and the production before June, 1918, was 200 tons of manganese ore, carload lots of which contained an average of about 38 per cent of manganese.

The workings, which are pits and tunnels 30 feet or less in length, are distributed through a distance of 400 to 500 feet, along the base of a northwest hill slope, on the southeast side of East Lafferty Creek. Near the opening farthest southwest the following section, showing the position of the manganese ore bed, was measured in a low bluff that rises from near the edge of the creek.

Section of bluff at Martin No. 1 mine.

	Feet.
St. Clair limestone:	
Massive pinkish-gray or bluish-gray, compact to granular, fossiliferous limestone to top of bluff	12
Cason shale:	
Sandy shale that has been largely replaced by manganese, iron, and ferruginous manganese oxides	1½
Fernvale limestone:	
Rusty and gray limestone, the outcrop of which is a few feet above East Lafferty Creek.	

Although the Cason shale is exposed in the bluff it has been affected by weathering so that it has been largely replaced by the oxides noted in the section, but these oxides probably do not extend into the bluff more than a few feet from its face. Northeastward the Cason shale gradually rises higher above the creek level. Neither it nor the limestones between which it occurs are exposed for a few hundred feet northeast of the bluff; they are concealed by their residual clays and by chert débris that has rolled down the slope from the ledges of Boone chert. The openings, however, indicate that the beds gradually rise higher above the level of the creek in this direction. These openings penetrate brown clay 2 to 8 feet thick that overlies the uneven surface of the Fernvale limestone, from which most of the clay is residual. The masses of psilomelane range in size from fine particles to boulders weighing 500 pounds and are irregularly distributed through the clay, but only the larger ones are hand sorted from the clay that is mined.

MARTIN NO. 2 MINE.

The Martin No. 2 mine is in the NW. ¼ sec. 14, T. 14 N., R. 8 W., on the southeast side of East Lafferty Creek, 4 miles west-southwest of Cushman. It is northeast of the Martin No. 1 mine and is separated from it by an alluvial cone located at the mouth of a northwestward-trending hollow. It is on land of which the mineral right is owned by the Arkansas Fertilizer Co. and the agricultural right is owned by J. R. Martin. W. H. Denison, the operator at the time of visit, began work in 1917, and before June, 1918, had mined and shipped five cars of manganese ore, which averaged about 40 per cent of manganese.

The workings, which are shallow pits and tunnels 60 feet or less in length, extend along the west and northwest hill slopes for one-fourth of a mile. The chocolate-colored manganese-bearing clay is said to range in thickness from 2 to 12 feet; it overlies the uneven surface of the Fernvale limestone, of which there are many exposures on the hill slopes; and it is overlain by a cherty loam usually a few feet thick and by massive blocks of the St. Clair limestone which have broken loose from the parent ledge and settled down the slopes. The pit farthest southwest reveals 3 feet of the lower part of the Cason shale, which is much weathered. This part of the shale is composed of red shale and a green platy earth in which there occur irregular masses of iron and manganese oxides, a few "buttons" of iron oxide, and a layer of manganese oxide a few inches thick.

The ore that is being mined consists of irregular masses of psilomelane ranging in size from about 1 inch in their longest diameter to boulders weighing 500 pounds.

BUTTON PROSPECT.

The Button prospect, described by Penrose[22] under the heading "A. G. Pitman tract," is just northwest of the site of the old village of Phosphate and is on a hill on the west side of East Lafferty Creek, in the N. ½ sec. 14, T. 14 N., R. 8 W., 1½ miles east-southeast of Penters Bluff station. It is owned by the Arkansas Fertilizer Co. and at the time of visit (May 3, 1918) had been leased to R. S. Handford and J. C. Shepherd.

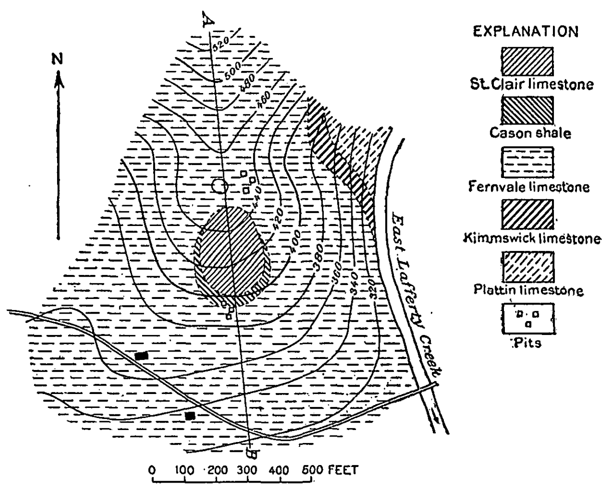

FIGURE 24.—Sketch map of the Button prospect. Elevations are above sea level and were determined by an aneroid barometer. *A–B*, Line of section in figure 25.

The workings, some of which are shown on the accompanying map (fig. 24), consist of several very shallow pits from which a small quantity of manganese ore had been mined. The Cason shale and a red clay that overlies the weathered edges of the Fernvale limestone on the steep hill slopes contain the manganese ore. The Cason shale underlies an area of about an acre on the south point of the hill. As represented on the accompanying map and section (figs. 24 and 25), it occurs between the Fernvale and St. Clair limestones, and both it and these limestones dip 10° to 12° to the south. The shale, however, thins out to the north, permitting the St. Clair limestone in places to rest upon the Fernvale limestone. The Cason shale was not seen in place at the time of visit, but prospecting since then has shown that it ranges from 2 to 4 feet thick on the south point of

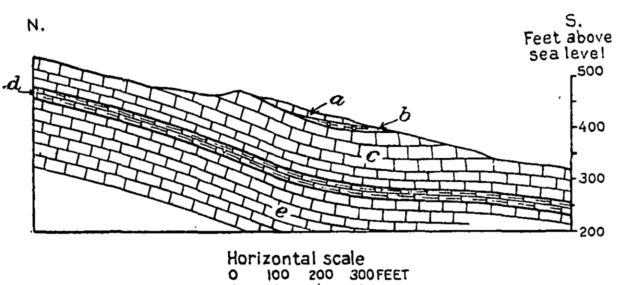

FIGURE 25.—Section at the Button prospect along line *A–B* in figure 24. *a*, St. Clair limestone; *b*, Cason shale; *c*, Fernvale limestone; *d*, Kimmswick limestone; *e*, Plattin limestone.

[22] Penrose, R. A. F., jr., op. cit., pp. 257–258.

the hill. It is a red platy, soft though firm shale, through which many "buttons" of ferruginous manganese oxide are disseminated. A small portion of the shale has been replaced by manganese oxide, as shown by the fact that masses of such oxides weighing a few pounds show the form of the original "buttons." The St. Clair limestone is a massive pinkish-gray fossiliferous limestone and is 10 to 12 feet thick, but its lowest bed, 3 feet thick, is a red platy earthy limestone that contains many "buttons" of ferruginous manganese oxide like those in the Cason shale. The hill on which the deposit occurs is a terrace-like bench and is capped by massive blocks of sandstone and chert. The south slope of the higher hill farther north is covered with pebbles, boulders, and small fragments of chert.

The red ore-bearing clay contains chert fragments, it varies in thickness from a few inches to a few feet, it has been found in pits on the slope east of the terrace-like bench, and it occurs at the surface over the entire south and southeast slopes below the outcrop of the Cason shale. There are, however, many and large exposures of the Fernvale limestone. The manganese ore in the clay consists in part of irregular masses composed of psilomelane, braunite, and ferruginous manganese oxide but is made up chiefly of manganese and ferruginous manganese "buttons" or their minute fragments. Most of the manganese "buttons" are psilomelane; the rest are psilomelane that contains minute crystals of braunite. All the "buttons" in this clay are obviously derived from the Cason shale. The absence of "buttons" of psilomelane in any part of the Cason shale along its outcrop and their abundance in the clay on the slope to the south suggest that they have been derived from a bed of psilomelane "button"-bearing shale that has been eroded.

The following analyses, supplied by Mr. Handford, represent the composition of the Cason shale and the manganese "buttons" in it and in the clay on the slopes:

Analyses of manganese ore from the Phosphate prospect.

	1	2	3	4	5	6	7
Manganese (Mn)	51.44	47.44	31.28	14.01	25.10	23.82	4.00
Iron (Fe)				26.44	21.92		
Phosphorus (P)	.166		1.676	.738		.723	
Silica (SiO_2)	10.73	10.41	12.86				

1-5, Crowell & Murray, analysts; 6, E. J. Ericson, analyst.

1, "Buttons" from clay on slope; they were picked from those that did not pass through a half-inch screen. 2, "Buttons" from clay on slope that did not pass through a half-inch screen: material for analysis not picked. 3-5, Samples were composed of pieces of ore that passed through a half-inch screen. 6, "Buttons" from the Cason shale. 7, Cason shale.

After the time of visit a small washing plant was erected and operated by Handford & Shepherd.

KIMBROUGH MINE.

The Kimbrough mine, which is owned by the Arkansas Fertilizer Co., is in a narrow valley, 4 miles west-southwest of Cushman. It was operated in 1917 by W. H. Denison, the lessee, who mined and shipped 3 cars—about 80 tons—of ferruginous manganese ore containing between 30 and 35 per cent of manganese. The workings are pits 14 feet or less deep, which have been dug in brown ore-bearing clay within a distance of one-fourth of a mile along the north side of the valley. This clay does not have a uniform thickness, as it rests upon the irregular surface of the Fernvale limestone, and it is concealed by chert débris. It has been followed for a short distance into the hills beneath the Cason shale, but it will not continue far, as it is simply a residue from the weathering of the above-named limestone.

The ferruginous manganese ore that has been mined and shipped was found as irregular masses scattered through the clay, and it was separated from the clay by hand picking. Mining is said to have been stopped, as the manganese content of the ore was becoming too low to yield a profit.

M'BRIDE MINE.

The McBride mine, owned by H. U. McBride, is in the north part of the NW. ¼ sec. 27, T. 14 N., R. 8 W., and consists of a number of openings extending for one-fourth of a mile on either side of a hollow that is drained by a wet-weather stream flowing west past Walls Ferry station. The openings farthest west are one-fourth of a mile east of this station. The mine has been operated on a small scale by R. S. Handford, beginning in 1917, and the production before June, 1918, was 125 tons of manganese ore averaging 41 per cent of manganese.

The openings are shallow pits, shafts 22 feet or less in depth, and drifts 15 feet or less in length, in the bottom of the hollow and at the base of the hill slopes, which are covered with chert débris to a depth of several feet. This chert has rolled or has been washed down the slopes from the Penters and Boone cherts exposed higher on the slopes. Although no limestone is exposed in this hollow, ledges of the Fernvale limestone and boulders of the St. Clair limestone in or near place were found in some of the openings. Red, yellow, and brown clays a few feet thick, which are overlain by the chert débris mentioned above, rest upon the channeled surface of the Fernvale limestone. The manganese ore occurs in these clays as irregular masses, ranging from fine particles to boulders weighing 2 tons, and is found at various elevations from the bottoms of the shafts 22 feet deep in the hollow up to the St. Clair limestone, which is 15 feet above the base of the hill slopes. It is associated with small quantities of iron oxide, and although the hard oxides psilomelane and braunite are present, most of the ore is a soft though firm oxide, which is probably wad. The ore is residual from the weathering of the Fernvale limestone, and some of it still retains calcite crystals.

HARVEY MINE.

The Harvey mine, which is owned by J. B. Harvey and operated by R. S. Handford, lessee, is on the north edge of the NW. ¼ NW. ¼ sec. 15, T. 14 N., R. 8 W., and is on a north hill slope just east of Penters Bluff station. Mining was begun here in the fall of 1917, and 3 carloads of manganese ore, amounting to 84 tons, had been mined and shipped before the end of June, 1918. The total production for 1918 is reported to have been about 6 carloads.

The openings are shallow pits and cuts that have been made here and there along the north hill slope in a distance of two-tenths of a mile from Penters Bluff station eastward. They were made in a brown ore-bearing clay, of which the surficial portion, 1 to 6 feet thick, contains chert fragments that have rolled down the slope from the cherty beds exposed higher on the hill. This clay is residual from the Fernvale limestone, which is exposed on the north slope near the station and has been reached in a few of the openings. The St. Clair limestone, 6 feet thick, is exposed above the openings, and at one place it is separated from the Fernvale limestone by 1 to 2 feet of clay, which is derived either from a thin bed of Cason shale or from limestone at the top of the Fernvale.

Manganese ore was found in all the openings but in least quantity in those farthest west. It consists of the manganese oxides psilomelane, hausmannite, and possibly braunite and a nearly equal quantity of ferruginous manganese oxide, and most of it occurs in the clay mentioned above, but some is found in the top of the Fernvale limestone. The ore in the clay consists of irregular compact and at some places shaly masses ranging in size from fine particles to boulders that weigh as much as 1,000 pounds. The ore in the limestone has replaced some of the limestone along cracks and bedding planes and makes up a large part of the rock mass. The parts of the limestone in which it is present are not pure but contain a fine to coarse-grained yellowish-brown manganese-bearing carbonate, of which an analysis follows:

Analysis of manganese-bearing carbonate from Fernvale limestone at the Harvey mine.

[R. C. Wells, analyst.]

Manganese (Mn)	35.50
Iron (Fe)	6.54
Silica (SiO_2)	1.51
Alumina (Al_2O_3)	2.06
Lime (CaO)	10.60
Magnesia (MgO)	.96

The analysis was made from a sample that was partly oxidized, but the chief constituents appear to be manganese, iron, and calcium carbonates, which are probably chemically combined. This mixed carbonate has entirely replaced parts of the limestone, and it has been partly oxidized and replaced by the manganese and ferruginous manganese oxides mentioned above. (See Pl. X, *D*.) Some of the resulting rock has been quarried and shipped as a low-grade manganese ore. A few boulders of ore that were mined near the surface appeared to consist entirely of manganese and ferruginous manganese oxides, but when they were broken open they were found to contain cores of the unaltered carbonate.

This deposit is one of the few deposits in the Batesville district that illustrate the origin of the manganese ore found in the residual clays of the Fernvale and lower limestones. The carbonate just described is presumably the form in which much if not all of the manganese ore that is derived from the upper part of the Fernvale limestone once occurred. Although it is probably present in the Fernvale limestone under all the hills of the region where this limestone has not been affected by weathering, it is not uniformly distributed through the limestone but occurs in scattered pockets, some large and some small. The manganese oxides associated with the carbonate simply represent oxidized portions of it and they probably do not extend far below water level. Masses of them are finally freed from the limestone by the removal of the calcium carbonate and are thus left loose in the residual clay of the limestone.

Of the first three carloads of ore that were shipped from this locality one contained 45 per cent of manganese and another 32.67 per cent of manganese. The analysis of the third car was not obtained by the writer. The following analyses of three samples from this mine were furnished by Mr. Handford:

Analyses of manganese ore from the Harvey mine.

[Crowell & Murray, analysts.]

	1	2	3
Manganese (Mn)	44.66	29.91	40.58
Iron (Fe)	7.83	15.75	6.30
Phosphorus (P)			.154
Silica (SiO_2)		15.75	

Since the time of visit (1918) some prospecting in a sink hole on Mr. Harvey's land south of the above described mine led to the discovery of a cave, of which the main cavern is approximately 200 feet long, 100 feet wide, and 60 feet high. Large boulders of ore are found not only in the clay in the bottom of the cave but also as a blanket "vein," 8 to 14 feet thick, in the walls on both sides of the main cavern. Prospecting indicates that the ore will probably extend the entire length of the cavern, but how far it extends into the limestone walls has not been determined. That the mouth of the cave had been open at one time and had been closed up with earth and stone from the top is said to be proved by the fact that bear tracks were still plainly visible in the moist clay of the floor.[23]

SOUTH HILL PROSPECT.

The South Hill prospect, owned by the Martin Manganese & Mining Co., is at the north base of an eastward-trending hill slope in the SW. ¼ SW. ¼ sec. 10, T. 14 N., R. 8 W., one-fourth of a mile east of Penters Bluff. It adjoins the Harvey mine. A few pits were dug in March, 1918, by the Independence Mining Co., and only a few tons of soft low-grade manganese ore, which was recovered by hand picking, was shipped. The pits are only a few feet deep and are in débris consisting largely of chert fragments that have rolled down the slope from the chert ledges exposed higher on the hill. By going deeper it is expected that the residual clays of the Fernvale limestone may be reached and a better grade of ore may thus be found. This limestone is exposed in the openings at the Harvey mine and on the slope farther west.

U. N. DOBSON PROSPECT.

The U. N. Dobson prospect is on the U. N. Dobson place, on the east side of West Lafferty Creek, and is on the north side of the first hollow south of Hankins Hollow, 1 mile east of Penters Bluff station. Work was done here in 1917 by Mr. Dobson, and a small quantity of manganese ore was removed from several shallow pits and cuts and was shipped. These openings were dug through a surficial covering of chert débris into pockets of ore-bearing clay that overlie the Fernvale limestone. The steepness of the slope and the abundance of limestone exposures suggest that the quantity of ore-bearing clay is small.

T. M. TATE MINE.

The T. M. Tate mine consists of two groups of openings 1 mile northeast of Penters Bluff station. It has been operated by T. M. Tate, the owner, beginning in 1917, and the production before the time of visit (April 4, 1918) was 300 tons of lump manganese ore, which is reported to have averaged about 40 per cent of manganese.

One group of pits is in the NE. ¼ NW. ¼ sec. 10, T. 14 N., R. 8 W., on the east point and southeast slope of a ridge that is on the west

[23] Baxter Bulletin, vol. 18, No. 4, Mountain Home, Ark., Jan. 24, 1919.

side of West Lafferty Creek. The pits are only a few feet deep and are in a chocolate-colored clay that fills shallow depressions and channels in the Fernvale limestone, of which there are many exposures, both in the pits and on the slope. The manganese ore is found in the clay as porous irregular, and at some places shaly masses, of which the largest on the dump at the time of visit weighed about 50 pounds. It is composed mainly of psilomelane with some wad and braunite, and it may occur associated with ferruginous manganese ore either in the same or in separate masses.

The second group of openings is in the NW. ¼ NE. ¼ sec. 10, T. 14 N., R. 8 W., on the south point of a ridge that is on the east side of Lafferty Creek. The main opening is a north-south cut 100 feet long and 12 to 15 feet deep, and from it a drift and a shaft have been dug. These openings are for the most part in reddish-brown clay, which overlies the Fernvale limestone. Besides masses of psilomelane the clay contains fragments of porous chert that have been set free from this limestone by weathering, and it is overlain by a few feet of chert débris derived from the Boone chert, which caps the ridge. An exposure in the north end of the cut shows 3 feet of sandy platy ferruginous weathered Cason shale resting on a ledge of brown limestone (Fernvale), in which there are small masses of manganese oxide. Both the psilomelane and the clay at this locality are residual from this limestone.

HANKINS HOLLOW MINE.

The Hankins Hollow mine consists of numerous openings in Hankins Hollow and on Hankins Hill southeast of it and is on land owned by J. J. Skelton in the NE. ¼ NE. ¼ sec. 10, the NW. ¼ NW. ¼ sec. 11, the SW. ¼ SW. ¼ sec. 2, and the NW. ¼ SW. ¼ sec. 2, T. 14 N., R. 8 W. This hollow trends southwest, and its mouth is 1 mile northeast of Penters Bluff station. The openings extend up the hollow from its mouth for almost three-fourths of a mile to Hankins Hill. The area in which this hill is located was described by Penrose[24] as the William Martin tract.

This mine was operated 30 or more years ago, one of the operators at that time being the Missouri Furnace Co. It was next operated by Mr. Skelton, beginning in 1915, but since June, 1916, it has been operated by Mr. Skelton and R. S. Handford, who had mined 400 tons or more of manganese ore before June, 1918.

Several rock formations, which lie horizontal or nearly so, are exposed in this vicinity, and the manganese ore is found in clays and wash that is associated with four of them—the Plattin, Kimmswick,

[24] Penrose, R. A. F., jr., Manganese—its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, pp. 280–281, 1891.

and Fernvale limestones and the Cason shale. The Plattin limestone crops out in heavy ledges and boulders along the steep hill slopes on either side of the hollow to an elevation of about 150 feet above its mouth, and the Kimmswick limestone, 20 to 25 feet thick, also crops out in heavy ledges. Exposures of the Fernvale limestone 115 feet thick are, however, not so abundant as those of the two limestones just named. At places its upper beds are brown from the presence of small quantities of manganese and iron oxides, and at places parts of them have been largely or entirely replaced by manganese oxide, which occurs in the limestone as irregular lenticular seams half an inch to 6 inches thick. The Cason shale, a few feet thick, is exposed in only a few of the openings. Elsewhere it is concealed by its residual clay, by massive blocks of the St. Clair limestone, and by chert débris from the Boone chert.

Although the Plattin, Kimmswick, and Fernvale limestones are exposed at many places they are overlain by greater or less quantities of red and chocolate-colored clays, whose surficial portions are mixed with chert fragments derived from the Boone chert. The clays are in greatest quantity on the parts of the slopes underlain by the Fernvale limestone. They not only overlie this limestone but extend down into it in pockets and channels that have been formed through solution. Wash that is composed largely of chert fragments but partly of manganese ore has accumulated in the bottom of the hollow and in ravines leading into it.

The openings, which are pits, short tunnels, and shafts, are in these clays and the chert wash. Most of them in Hankins Hollow are along its bottom and northwest side, and those on Hankins Hill are on its northwest slope. Some of the shafts are 35 feet deep, but most of the openings, which stop when rock ledges are encountered, are only a few feet deep.

The manganese ore occurs as irregular masses in the residual clays and wash that overlie the Plattin, Kimmswick, and Fernvale limestones. These masses consist mainly of psilomelane and hausmannite but partly of braunite, and they range in size from fine particles to boulders that weigh 1,800 pounds. Most of the ore is hard and compact, but much of it that is found in the clays overlying the Fernvale limestone, as on Hankins Hill, is soft. During the mining, which has been done by pick and shovel, the larger masses of ore are hand sorted from the clay and chert fragments, whereas the fine ore is left on the dumps. No attempt has been made thus far to recover this fine ore from the clay by washing, but the concentrates thus recovered would be a ferruginous manganese ore, as there are numerous fine particles of red and brown oxides of iron. The manganese ore is residual from the Fernvale limestone, and as erosion has progressed its masses have settled down the slopes, but much of it has been washed into the bottom of the hollow and into ravines on either side of the hollow.

The analyses given below represent the composition of carload lots of manganese ore shipped from the mine. The first four analyses are of ore from Hankins Hollow and the last five are of ore from Hankins Hill.

Analyses of manganese ore from the Hankins Hollow mine.

	1	2	3	4
Manganese (Mn)	54.00	56.00	55.68	56.31
Iron (Fe)	7.22	....	5.22	3.01
Phosphorus (P)	.22	.22	.30	.23
Silica (SiO_2)	6.96	....	3.43	5.05
Moisture	1.70	1.00	2.65	2.64

	5	6	7	8	9
Manganese (Mn)	34.98	40.46	36.42	41.82	41.20

SALT PETER HILL MINE.

The Salt Peter Hill mine is on Salt Peter Hill, on the west side of East Lafferty Creek, 3 miles west by north of Cushman. It is on land owned by W. E. Barnes, and it has been operated by him beginning in 1916. The total production of manganese ore before the time of visit (April 9, 1918) was not determined, but it exceeded 100 tons.

The mine consists of several groups of openings. One of these is in the head of Salt Peter Hollow, which is south of Salt Peter Hill; it is composed of one shaft 20 feet deep, a second shaft 22 feet deep, and a pit, all within an area 50 feet square. These openings passed through surface débris consisting of chert and sandstone fragments and then penetrated brown ore-bearing clay. The presence of a few fragments of the Fernvale limestone on the dumps indicates that ledges of this limestone were encountered in the openings. The manganese ore, some of which is marked with casts of fossils, is porous psilomelane, and most of it is in irregular masses that can be separated from the clay by hand picking. Red specular hematite is associated with the manganese ore, but the quantity of it is small.

A shaft 26 feet deep and a small cut are on the east slope of Salt Peter Hill near its crest. They are in a reddish-brown ore-bearing clay, which is concealed at the surface by chert débris and blocks of sandstone. The clay overlies the Fernvale limestone, which is exposed at a few places in the vicinity, but there was no evidence at the time of visit that this limestone had been found in the cut and shaft. The manganese ore is associated with iron oxide, from which it can be separated by hand picking.

Two cuts which are on the east slope of the hill below the shaft and cut described above have been dug in small pockets of red clay that overlie the Plattin limestone. Both iron and manganese oxides were found in the clay.

On the south slope of the hill there are said to be other openings, which were not visited.

Although the writer did not obtain any information regarding the quality of the ore that has been shipped, the ore observed by him at this locality is a ferruginous manganese ore.

EDWARDS MINE.

The Edwards mine is on the west side of East Lafferty Creek, 3 miles west-northwest of Cushman, and is on the R. P. Edwards tract, which comprises the W. ½ SW. ¼ sec. 1 and the SE. ¼ SE. ¼ sec. 2, T. 14 N., R. 8 W. It has been operated by Mr. Edwards beginning in 1917, and two cars of manganese ore, containing about 48 per cent of manganese, had been shipped before the writer's visit (April 9, 1918).

The principal group of openings is on the south side of the hollow west of Mr. Edwards's house. It consists of pits and open cuts a few feet deep that have been made within an area of 2 or 3 acres, but the dark reddish-brown ore-bearing clay in which they have been dug apparently underlies several acres. The total thickness of the clay is not known, but the absence of limestone exposures suggests that it has a considerable thickness. Only a small quantity of chert fragments is mixed with its surficial portion. Both iron and manganese oxides occur in the clay, but the manganese oxide, which is psilomelane, predominates. Only the larger masses of ore have been freed from the clay and shipped, whereas the smaller pieces, which are manganese oxides, have been left in the clay on the dumps, although they form a considerable part of it.

A few very small pits are in red clay on the north side of the hollow in which the openings just described are situated, and a few are in similar clay on the east slope of Salt Peter Hill southwest of Mr. Edwards's house. The ore visible on the dumps consists of iron and ferruginous manganese oxides.

ELLEN CLARK PROSPECT.

The Ellen Clark prospect is in the N. ½ SE. ¼ sec. 2, T. 14 N., R. 8 W., on a hill between West Lafferty and East Lafferty creeks, 3½ miles west by north of Cushman, and 2½ miles northeast of Penters Bluff station. It has been operated at times by R. S. Handford, beginning in 1916, who mined and shipped 30 tons or more of "lump ore" before June, 1918, but since then it has been operated by Logan Rives. Mr. Handford states that the ore—23 tons—which he mined in 1916 contained 52 per cent of manganese.

The openings that were visited by the writer are shallow pits in red manganese-bearing clay, on a gentle south hill slope on which there are a few exposures of the Fernvale limestone near the pits. The total depth of the clay had not been tested, for none of the pits appear to have passed entirely through it to the underlying Fernvale limestone. The only ore observed at the time of visit (May 22, 1918) was small pieces of psilomelane scattered through the clay on the dumps.

CUTTER MINE.

The Cutter mine is on Gray Hill, in the E. ½ NE. ¼ sec. 2, T. 14 N., R. 8 W., on the divide between West Lafferty and East Lafferty creeks, 3½ miles west by north of Cushman. It had been operated by Bill Thurlo before the time of visit, but since then it has been operated by the Standard Manganese Co. This company erected a washing plant near East Lafferty Creek and operated it for a short time in 1918.

The workings at the time of visit comprised several shafts 30 feet or less in depth and shallow cuts scattered over a few acres near the crest of a hill at the head of Adler Hollow, which is drained to the northwest into West Lafferty Creek. (See Pl. XIII, *C*.) They penetrate a chocolate-colored manganese-bearing clay, which at places reaches the surface but at others is overlain by a few feet of chert. The clay was not gone through at most openings, but in one pit it has been mined from around pinnacles of the Fernvale limestone. This limestone probably underlies all the clay at this locality. The manganese ore consists largely of psilomelane and hausmannite, which are more or less intermixed, and it occurs in irregular masses ranging in size from fine particles ("wash ore") to slabs and boulders ("lump ore"). Although most of it is found in the clay thin seams and fine particles occur in the limestone pinnacles in the pit mentioned above. "Lump ore" was apparently obtained from all the openings that were examined, but "wash ore" in fair quantity was found at only a few of them.

IZARD COUNTY.

ADLER HOLLOW MINE.

The Adler Hollow mine is in Adler or Pugh Hollow east of West Lafferty Creek, 2½ miles northeast of Penters Bluff station, and is on a tract of land owned by N. A. Adler that comprises the SE. ¼ SW. ¼ and the SW. ¼ SE. ¼ sec. 35, T. 15 N., R. 8 W. One shaft 85 feet deep is said to have been sunk at this locality 25 years ago. The next work was done by J. F. Barksdale and W. H. Denison, beginning in 1917, who mined and shipped 275 tons of hand-sorted manganese ore before June, 1918. The Everton Mining & Development Co., of Anderson, Ark., leased the mine in August, 1918, and erected an experimental washing plant, which was operated for a short time in that year. The marketed production by this company in 1918 was 16 tons.

The recent workings, which include shallow cuts and shafts as much as 24 feet deep, have been dug in brown ore-bearing clay and cherty surficial loam here and there over an area of 20 acres on the hill slopes and in the bottom of the hollow, but thus far the total depth and areal extent of the clay have not been determined. Only a small number of openings passed entirely through the clay and reached the underlying limestones, which, as shown by the few exposures in the openings and on the surface, are the Plattin, Kimmswick, and Fernvale limestones.

The manganese ore consists of two grades. One of these, the low grade, is soft earthy wad, and the other, the high grade, is mainly hard, compact steel-blue psilomelane, but part is hausmannite and braunite. Only the high-grade ore occurs in the bed of the wet-weather stream in the bottom of the hollow, where it has been mined to a depth of 4 to 10 feet, whereas both grades occur on the slopes and may be found in a single opening. The high-grade ore occurs in irregular masses, the largest of which thus far (May 22, 1918) found weighed 3,468 pounds, but one cut that was examined has yielded nearly spherical masses as much as a foot in diameter. Some of the hard ore contains the casts of fossils. The ore at this locality is a residue from the decomposition of the Fernvale limestone, and that on the slopes has settled below the level it occupied in the limstone, whereas that in the bed of the stream has been washed from the hill slopes on either side.

Of the above-mentioned production of 275 tons by Barksdale and Denison 75 tons was high-grade ore and the rest was low-grade. The manganese content of a carload of high-grade ore shipped to the Tennessee Coal, Iron & Railroad Co. was 50.16 per cent, and that of a carload of low-grade ore shipped to the American Steel Foundries was 32.50 per cent.

IZARD MINE.

The Izard mine, not visited by the writer, is on the hill south of the Adler Hollow mine and is on land owned by William Einstein. It was operated in October and September, 1917, by the Marqua Mining Co., which mined and shipped 3 carloads of manganese ore, containing 50 per cent of manganese.

PUGH MINE.

The Pugh mine is on the Mike Pugh tract, in the SW. ¼ SW. ¼ sec. 35, T. 15 N., R. 8 W., on the south side of Pugh or Adler Hollow, which is on the east side of West Lafferty Creek, and 2¼ miles northeast of Penters Bluff station. It is said to have been operated by Tom Coxey 20 to 25 years ago. Beginning in 1917 it has been operated at times by Mr. Pugh, who had mined and marketed 75 tons of "lump ore" before the time of visit (May 22, 1918). Later in 1918 it was operated by the Anderson Manganese Co., though the production by this company was small.

The workings consist of pits 8 feet or less deep that have been dug in brown clay and surficial cherty loam on a steep north hill slope just north of the Verna mine. The clay and surface loam overlie the Plattin limestone, of which there are exposures both on the surface and in the pits, but "gray rock," which is either the Fernvale or Kimmswick limestone, was found in the opening that is highest on the slope. One was not only taken from the pits, but it has been picked up also on the surface and in gullies. Most of it is psilomelane, but a part is hausmannite, the two being intermixed, and it occurs both as fine particles and as large masses that can be hand sorted from the clay.

VERNA MINE.

The Verna mine, which is owned by J. J. Skelton and operated by Mr. Skelton and R. S. Handford, is in the NW. ¼ NW. ¼ sec. 2, T. 14 N., R. 8 W., on the west point of a hill, 2¼ miles northeast of Penters Bluff station. It was first operated in 1917, and before the time of visit (May 4, 1918) 76 tons of lump manganese ore had been mined and shipped.

The openings are pits and cuts 10 feet or less deep, scattered here and there over about an acre on the west point of the hill, and they are between 200 and 300 feet above West Lafferty Creek, which flows past the west base of the hill. They are in a chocolate-colored clay, which contains chert fragments and masses of manganese oxide and which is overlain by a very thin covering of chert débris. The clay is residual from the Fernvale limestone, exposures of which occur on the surface and in the openings, and it fills channels in this limestone. These channels represent joints in the limestone that have been widened by solution, and they range from a few feet to 15 feet or more wide. The manganese ore that is mined is in irregular masses scattered through the clay and is composed of hard oxides of manganese, including psilomelane and braunite. Some masses of braunite contain calcite crystals, and manganese oxide coats many of the chert fragments. The manganese minerals are not only scattered through the clay, but veinlets and lenses of them a few inches thick are found in the Fernvale limestone at some places.

The manganese ore at this mine contains more manganese dioxide than is usually found in the ores in the Batesville district. As this fact was suspected during the mining, the ore was held at the mine until results of an analysis to determine whether or not it was suitable for chemical purposes could be learned. A sample to be analyzed was carefully selected from a 60-ton pile and sent by Mr. Handford to the Manhattan Electrical Supply Co., which reported that the ore contained 79 per cent of manganese dioxide but that it contained too much copper for the company's use. After the report of the analysis was received the ore was sold for metallurgical purposes.

The following analysis was made of a carload lot of manganese ore shipped from this mine:

Analysis of manganese ore from the Verna mine.

Manganese (Mn)	52.64
Iron (Fe)	4.48
Phosphorus (P)	.23
Silica (SiO_2)	6.59
Moisture	8.63

SKELTON HILL MINE.

The Skelton Hill mine is on land owned by J. J. Skelton, in the SW. ¼ NW. ¼ sec. 2, T. 14 N., R. 8 W., 2 miles northeast of Penters Bluff station. It has been operated by Mr. Skelton and R. S. Handford since 1917, and 100 tons of lump manganese ore had been mined and shipped before the writer's visit (May 4, 1918).

The openings, which are pits and shafts, are scattered over an area of three or four acres on a gentle hill slope, just northwest of a saddle between the crests of two hills. The highest opening is 350 feet above West Lafferty Creek, which is west of it. All the openings passed through a surficial covering consisting mainly of loose chert fragments, and then penetrated reddish-brown manganese-bearing clay, and some of them were continued downward in the clay until ledges of the Fernvale limestone were encountered. Both the clay and the ore were once constituents of the limestone and have been set free from it by weathering.

As there were only a few exposures of the Fernvale limestone at this locality it appears that this limestone has undergone deep weathering, thereby affording thick deposits of clay. The deepest shaft, 80 feet deep, is said to have passed through 6 to 8 feet of the surficial chert covering, then 70 to 75 feet of clay containing ore before it ended in a clay-filled pothole-like depression in the limestone. The chert on the slope and in the saddle represents the much broken-up beds of the Boone chert, which have settled from a position that was nearly level with the crests of the near-by hills, where the chert is in place.

The manganese ore occurs as fine particles and larger masses reaching the size of boulders, of which the largest thus far found weighed 4 tons. Most of the masses are irregular, but a few are botryoidal. They consist of psilomelane, but pyrolusite in minute quantities was observed in a few specimens. The following analyses represent the composition of three carloads of manganese ore shipped from the Skelton Hill mine:

Analyses of manganese ore from the Skelton Hill mine.

	1	2	3
Manganese (Mn)	49.30	50.97	54.35
Iron (Fe)	7.17	....	3.90
Phosphorus (P)	.11	....	.18
Silica (SiO_2)	3.99	....	8.46
Moisture	5.42	4.77	....

CLEVELAND MANGANESE MINING CO.'S PROSPECT.

There is a prospect on land belonging to the Cleveland Manganese Mining Co., in the southern part of sec. 2, T. 14 N., R. 8 W., near the head of Hankins Hollow, but it was not visited by the writer. W. H. Denison did work at this locality from April, 1916, to December, 1917, and mined 30 tons of manganese ore.

PITTMAN MINES.

The Pittman mines, which are on land owned by Mrs. Sallie Pittman, are in sec. 3, T. 14 N., R. 8 W., and are from 1½ to 2 miles northeast of Penters Bluff station. They include several mines on the east side of West Lafferty Creek and one mine on the west side of this stream.

The mines on the east side of the creek are in the NE. ¼ SE. ¼ and the SE. ¼ SE. ¼ sec. 3 and are on the slopes on both sides of a north-northeastward-trending ridge. The Keystone Manganese & Iron Co. mined and shipped ore from this part of the property 30 years or more ago. R. S. Handford, one of the next operators, began work in 1916, and before May, 1918, he and other operators had mined and shipped 380 tons or more of "lump" manganese ore from the openings on the east side of the creek.

A large number of pits, cuts, and shafts, the deepest of which are 20 feet deep, are in a saddle in the above-mentioned ridge and on its gentle north slope, the highest being about 300 feet above West Lafferty Creek. The openings pass through a few feet of cherty loam and then into reddish-brown manganese-bearing clay. This clay occurs in pockets and channels in the Fernvale limestone, part of which at this locality is rusty, and which is exposed at a few places on the surface and in some of the openings. One shaft 20 feet deep that is in the clay goes down part of its depth next to ledges of the Fernvale limestone. Irregular masses of manganese ore and some of iron are found in the clay; these are separated by hand picking. The manganese ore is psilomelane and wad, mainly the former, and is a fair grade of ore, but much of it is porous and some of it is siliceous. The siliceous ore consists of blocks of sandstone from the Cason shale that have been only partly replaced by manganese oxide. Forty tons of ore have been mined and shipped from this group of openings.

A cut and a number of small pits, known locally as the Hinkle mine, are on the west slope of the ridge a few hundred feet southwest of the openings described above. The pits have been made in clay-filled channels and pockets in the Fernvale limestone and the cut, which is 75 feet long north and south, has been made along the outcrop of the Cason shale and the topmost beds of the Fernvale limestone. The following section was made at this locality:

Section in cut at Hinkle mine.

	Ft.	in.
St. Clair limestone:		
Ledge of bluish-gray fine-grained to pinkish-gray coarse-grained fossiliferous limestone; contains dendrites, "buttons," and thin seams of manganiferous iron oxide in base	5	
Black clay that has apparently been derived from the overlying bed of limestone by weathering		3–12
Cason shale:		
Red shaly clay and hard shale; contains small quantity of soft manganese oxide and a few "buttons" of red iron oxide	1	
Clay with shaly iron oxide and "buttons" of iron oxide	1	
Fernvale limestone:		
Brown ledge of carbonate rock resembling the carbonate rock at the Harvey mine described on page 228; it probably contains carbonates of manganese, iron, and calcium but is partly changed to iron and manganese oxides. Several boulders of this rock are on the dump. Gray limestone that is typical of the Fernvale is exposed lower in the cut	1	6

The manganese ore mined at the Hinkle mine consisted of irregular masses of manganese oxides in the clay in the small pits and in the cut and of masses of these oxides that were blasted from the ledges at the top of the Fernvale limestone. As the ore was followed into the hillside the proportion of the manganese oxides to the unoxidized carbonate in the rock decreased and mining was discontinued. It is said that 200 tons of manganese ore was mined at this locality.

A number of cuts have been made on the south slope on the opposite side of the hill, east of the Hinkle mine. The cuts, which were badly caved at the time of visit (May 4, 1918), are in a chocolate-colored manganese-bearing clay and have followed it around massive blocks of the St. Clair limestone that have settled from the outcrop of this limestone above. Although there are no exposures of the Cason shale and none of the Fernvale limestone except below the cuts, the clay is probably residual from these two formations. All the larger masses of ore had been separated from the clay by hand picking before the time of visit and hauled away, leaving only the finer particles an inch or less in their longest diameter. The ore left in the clay is a ferruginous manganese ore, and the minerals that are represented in it include psilomelane, hausmannite, braunite, wad, and iron oxide. The production of this group of openings is said to have been 140 tons of manganese ore.

A large cut that was made 30 or more years ago by the Keystone Manganese & Iron Co. is on the southeast slope of the hill, northeast of the openings just described. This cut was made in chocolate-colored ore-bearing clay and reveals massive ledges of the Fernvale limestone. Considerable manganese oxide in fine particles is in the clay on the old dumps.

The Pittman mine on the west side of West Lafferty Creek is in the SE. ¼ NE. ¼ sec. 3, T. 14 N., R. 8 W., at the mouth of Cummins Hollow. It has been operated by R. S. Handford, beginning in 1917, and the production has been 200 tons of high-grade manganese ore. The mine, which consists of many shallow pits, is on a gently sloping alluvial cone at the mouth of Cummins Hollow. West Lafferty Creek flows in a sand-covered flat which adjoins the alluvial cone on the southeast. This cone occupies about an acre and is underlain by a bed of chert pebbles and fragments 4 feet or more deep that rests upon the Plattin limestone, which is exposed on the steep hill slopes on either side of the cone and in one of the pits. Masses of iron and manganese oxides, which occur separately, are scattered through this gravel bed. They, as well as the chert fragments and pebbles, have obviously been carried to their present position by the wet-weather stream draining Cummins Hollow, where masses of these oxides are present not only in the gravels in the stream beds but also in the superficial clays on the slopes on either side of the hollow.

The manganese ore consists of the minerals psilomelane, hausmannite, and braunite, and it occurs as irregular compact, hard masses that range in size from that of a pea or smaller to that of a cobble weighing 30 pounds. It has been mined and hand sorted from the gravel over about half an acre. Concentrates of the pebbles of ore 1 inch or less in diameter obtained by means of a hand jig are said by Mr. Handford to have averaged 27 per cent of manganese and 30 per cent of iron. The high percentage of iron is due to the large number of pebbles of iron oxides among those of manganese oxides. If the small pebbles of manganese oxides could be separated from those of iron oxides they would constitute a high-grade manganese ore.

The following analyses, supplied by Mr. Handford, are of carload lots of lump manganese ore shipped from the mine at the mouth of Cummins Hollow.

Analyses of manganese ore from the Pittman mine at the mouth of Cummins Hollow.

	1	2	3	4
Manganese (Mn)	52.28	52.84	55.28	51.62
Iron (Fe)	4.04	4.41	3.90	4.41
Phosphorus (P)	....	....	.28	....
Silica (SiO_2)	9.56	....	8.96	9.76
Moisture	1.40	2.12	1.40	5.73

CUMMINS HOLLOW MINE.

The Cummins Hollow mine, owned by the Martin Manganese & Mining Co., is on a tract of land comprising 239 acres lying along the north line of sec. 3, T. 14 N., R. 8 W., and is in Cummins Hollow, a southeastward-trending hollow on the west side of West Lafferty Creek, 1¾ miles north-northeast of Penters Bluff station. The mine was operated in 1849 and for a few years afterward by Col. Matt. Martin, who, according to E. C. McComb, mined and shipped probably as much as 500 tons of manganese ore by boats down White River to New Orleans and thence to England. It was operated in 1909 by the Martin Manganese & Mining Co., which mined 50 tons of ore, and was next operated, beginning in 1915, by the Independence Mining Co., the present lessee, which had mined and shipped 1,000 tons of ore before June, 1918. The ore thus far shipped consisted of "lump ore" that was sorted by hand from the clay and the rock fragments.

The workings, which are pits, cuts, and shafts, some as much as 15 feet deep, are located here and there over an area of about 25 acres on the hill slopes on either side of Cummins Hollow and in the bed of the wet-weather stream that drains it. They extend from nearly the level of West Lafferty Creek, which passes the mouth of the hollow, to an elevation of about 300 feet above it. They have been dug in red and black clays which contain masses of manganese ore, numerous fragments of chert, sandstone, and limestone, and many small particles of red iron oxide. These clays overlie the Plattin, Kimmswick, and Fernvale limestones, whose surficial boulders and exposed ledges occur over much of the surface, and they fill channels as much as 8 feet wide and irregular pockets in the limestones. They are at places only a few inches thick, but in some of the channels and at other places they are 15 feet or more thick. Some of the channels are straight and were formed by the solution of the limestone along joint planes.

The manganese ore consists of irregular compact masses ranging in size from fine particles ("wash ore") to larger masses ("lump ore"), some boulders of which weigh 5,000 pounds. It is composed of steel-blue psilomelane, granular hausmannite, and crystalline braunite. These minerals are generally intimately mixed, but some masses of ore are composed entirely of braunite. Barite is found in small quantity in a few masses. The ore is a residue from the decomposition of the Fernvale limestone, and some of it may have been derived from the weathering of shaly beds in the Cason shale, of which the only exposed beds are ledges of brown sandstone. In fact, a few lenses of manganese ore several inches thick that have not been set free by the decomposition of the Fernvale limestone are revealed on exposed ledges of this limestone. After the masses were set free from the inclosing rock, those on the hill slopes reached their present position by settling down the slopes or by being washed down the slopes by small streams, and most of the ore in the bed of the stream in the bottom of the hollow was washed from the hill slopes on either side of it. The ore has been proved by pits to extend over an area of about 25 acres, but the surface showings indicate that it will probably be found over an area of 50 to 60 acres in all. Considerable wash ore occurs in the clays, but the concentrates that would be recovered would be ferruginous manganese ore, owing to the presence of the fine particles of red iron oxide.

The first four of the following analyses are of carload lots of manganese ore shipped from this mine by the Independence Mining Co. to the Miami Metals Co., and the last analysis represents the average composition of 250 tons of ore shipped in 1918 by the Independence Mining Co. to the Miami Metals Co. One carload of ore that has been shipped from this mine contained 60.70 per cent of manganese.

Analyses of manganese ore from the Cummins Hollow mine.

	1	2	3	4	5
Manganese (Mn)	56.63	59.66	59.18	59.47	58.11
Iron (Fe)	1.49		2.52	1.51	1.63
Silica (SiO_2)	6.65		2.03	7.07	6.90
Moisture			3.10	.78	1.10

JOHNSON HILL MINE.

The Johnson Hill mine is in the southern part of sec. 34, T. 15 N., R. 8 W., on Johnson Hill west of West Lafferty Creek, 1 mile south of the village of Anderson and 2 miles northeast of Penters Bluff station, and is on land part of which was owned at the time of visit (May 23, 1918) by the United Phosphate & Chemical Co. and the rest by A. H. Taylor. Since then Mr. Taylor has sold his property to G. L. Bruner. The part of the property that comprises the SE. ¼ SE. ¼ sec. 34, T. 15 N., R. 8 W., was described by Penrose as the Anderson Mill tract, on which he states several carloads of ore are reported to have been mined in 1890 by C. F. Drake.[25] The present operators, W. H. Denison and J. F. Barksdale, have mined and shipped several hundred tons of ore within the last few years.

The workings consist of shallow pits that have been dug here and there over an area of perhaps 40 acres on the east and south slopes and on the crest of Johnson Hill and in the bed of the branch in the hollow south of the hill. The highest openings are 365 feet above West Lafferty Creek, which flows past the east base of the hill. They all penetrate red and brown clays in which chert fragments and large and small masses of manganese ore occur in greater or less quantities. These clays in most places are not more than a few feet thick, and they rest upon the irregular surfaces of the Plattin, Kimmswick, and Fernvale limestones, from which they are a residue through the process of weathering. Exposed ledges and boulders of the Plattin limestone are very abundant, whereas there are only a few exposures of the Kimmswick and Fernvale limestones. A few feet of weathered Cason shale are exposed in places on the crest of the hill.

The manganese ore consists of psilomelane, hausmannite, and braunite and occurs in irregular compact masses, ranging in size from fine particles ("wash ore") to boulders weighing as much as a few hundred pounds, but a small quantity of ore on the crest of the hill consists of "buttons" like those at the Cason and Montgomery mines, of botryoidal masses, and of other masses that show casts of fossils. Some of the Cason shale, which is exposed on the crest of the hill, as well as loose sandstone slabs derived from it, is partly replaced by manganese oxide. Associated with the manganese minerals there is a considerable quantity of red iron oxide, which occurs in fine particles free from manganese.

These iron and manganese minerals are a residue from the weathering of the Cason shale and Fernvale limestone, and masses of them have settled or have been washed down the slopes so that they are

[25] Penrose, R. A. F., jr., Manganese—its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, p. 285, 1891.

now found not only in the residual materials overlying these two formations but also in clays that overlie the Kimmswick and Plattin limestones. Much if not most of the ore in the bottom of the hollow south of Johnson Hill has obviously been washed from the slopes on either side.

The marketed ore has consisted of only the "lump ore" of high grade, which has been sorted by hand from the clay and chert fragments. Much "wash ore" is present in the clay, but as there is also a fairly large quantity of iron oxide the concentrates that would be recovered by washing would be ferruginous manganese ore.

The analyses given below are of carload lots of manganese ore shipped by W. H. Denison and J. F. Barksdale from the Ruminer Rough, Manganese Field, Sand Field, Barksdale, Earl Collie, and Johnson Hill mines. The ores from these mines are very similar and most lots were not kept separate when they were shipped. The first nine analyses are of carloads that were shipped to the Tennessee Coal, Iron & Railroad Co., and the last three are of carloads that were shipped to the Miami Metals Co.

Analyses of manganese ore from the Ruminer Rough, Manganese Field, Sand Field, Johnson Hill, Earl Collie, and Barksdale mines.

	1	2	3	4	5	6
Manganese (Mn)	54.51	50.16	56.43	56.47	55.41	52.43
Iron (Fe)	2.89	3.27	2.26	2.96	6.03	3.49
Phosphorus (P)	.17	.15	.18	.14	.13	.12
Silica (SiO_2)	7.00	8.54	6.15	5.63	9.90	6.86
Alumina (Al_2O_3)	2.00	3.16	2.55	1.87	2.89	2.51

	7	8	9	10	11	12
Manganese (Mn)	56.68	57.26	52.66	59.18	57.12	58.03
Iron (Fe)	4.04	4.85			2.31	1.31
Phosphorus (P)	.13	.08				.147
Silica (SiO_2)	9.56	6.10		6.48	6.24	7.58
Alumina (Al_2O_3)	2.96	2.97				

SKELTON-HANDFORD PROSPECT.

The Skelton-Handford prospect is in the SE. ¼ SW. ¼ sec. 3, T. 14 N., R. 8 W., 1 mile northeast of Penters Bluff station. The openings that were visited are on the east hill slope, just north of the T. M. Tate openings that are west of West Lafferty Creek. The few pits at this locality are very small and are in chocolate-colored manganese-bearing clays, which overlie the irregular surface of the Fernvale limestone. Large blocks of the St. Clair limestone that have settled down the slope a few feet partly conceal the clays. The ore is composed of manganese and ferruginous manganese oxides and occurs in irregular masses, many of which are shaly. Only a few tons of manganese ore has been hauled away from this locality, and, according to R. S. Handford, who did the mining, it contained about 40 per cent of manganese.

One hollow on this property where work has been done is said to have produced 5 or 6 tons of high-grade manganese ore, but the locality was not visited by the writer.

UNITED PHOSPHATE & CHEMICAL CO.'S MINE.

A mine on land owned by the United Phosphate & Chemical Co., formerly known as the Virginia Chemical Co., is situated on the northwest slope of the same hill as the Skelton-Handford prospect. It is composed of a number of shallow cuts and pits, which have been dug here and there over about an acre, and it has been operated by J. F. Barksdale and W. H. Denison, beginning in 1917. The ore at this locality is a ferruginous manganese ore and occurs as irregular masses in a chocolate-colored clay overlying the Fernvale limestone, of which there are many exposures. The clay is comparatively free from chert fragments and is not overlain by chert débris, which commonly overlies the ore-bearing clays of the district. One pit that was made in the weathered Cason shale revealed 2 feet of soft shale containing "buttons" of red iron oxide.

One car of ore, shipped from this mine to the Tennessee Coal, Iron & Railroad Co., contained 33.14 per cent of manganese, another car shipped to this company contained 31 per cent of manganese, and a third car, shipped to the American Steel Foundries, contained 20.62 per cent of manganese.

BREEDEN PROSPECT.

The Breeden prospect, which is on land owned by J. B. Breeden, is 1 mile north of Penters Bluff station. It consists of several shallow pits on the hill slope in and near the head of a hollow which is drained to the north. The pits are just south of those at the United Phosphate & Chemical Co.'s mine described above and have been made along the weathered outcrop of the Cason shale and in chocolate-colored clays that overlie the Fernvale limestone. Those in the Cason shale show 2 feet of soft shale containing "buttons" of red iron oxide and beneath this a bed 2 feet or less thick, composed partly of yellow and red clays but mainly of wad, psilomelane, and iron oxide. The bed containing the clay and these oxides rests upon the uneven surface of the weathered Fernvale limestone. These clays are derived in part from the weathering of the base of the Cason shale and in part from the weathering of the Fernvale limestone. Although some of the marketed ore has been obtained from the bed mentioned above, most of it consisted of lumps and boulders, some weighing as much as 450 pounds, that have been found in the clays overlying the Fernvale limestone. The manganese ore at this locality is associated with much iron oxide but is generally more free from it the lower the openings have been made on the slope.

The work on this property has been done by Mr. Breeden, beginning in 1917, and some ore has been shipped, but the quantity is not known.

SHAFT HILL MINE.

The Shaft Hill mine, owned by the Martin Manganese & Mining Co. and operated by the Independence Mining Co., is on a hill in the SW. ¼ sec. 10, T. 14 N., R. 8 W., one-fourth of a mile northeast of Penters Bluff station. Col. Matt. Martin mined the first manganese ore at this locality about 1850 and shipped it by barge from a landing at Penters Bluff to New Orleans, whence it was shipped by sea to England and to eastern ports of the United States. The next work was done in 1909 and 1910 by the Martin Manganese & Mining Co., which mined 50 tons of manganese ore but did not ship any of it. The mine then lay idle until 1915, when the Independence Mining Co., the present operator, began work.

The Plattin limestone is exposed at many places on the slope to a height within 60 feet of the crest of the hill, which rises 200 feet above the road in the valley on the south. A few feet of the base of the Kimmswick limestone is exposed on the slope, and a horse of it is exposed in a cut near the crest. These limestones are overlain by red ore-bearing clay, and this in turn is overlain by red clay or loam containing chert fragments. The ore-bearing clay, together with the manganese ore, is residual from the Fernvale limestone, which has apparently been entirely removed from this hill through solution, and it has settled upon the irregular surface of the two limestones named above. The cherty material is derived from the Boone chert and is much broken, for, like the underlying clay, it has settled below its original position. One cut and 25 shafts, none of which were entered at the time of visit (March 30, 1918), occupy about an acre of land on the crest of the hill. The shafts are 40 to 80 feet deep, and most of them are 20 feet apart; from them drifts as much as 35 feet long run in all directions. A shaft and a cut were being made on the northwest slope at the time of a later visit (May 25, 1918). The openings on the crest of the hill are said to have passed through 12 to 20 feet of cherty material before entering the underlying clay, and those on the northwest slope passed through only a few feet of such material. The clay in places has been penetrated to a depth of 60 feet, but only parts of it contain ore.

The manganese ore is mostly a soft though firm black oxide, but part of it is psilomelane, in which there are a few crystals of braunite, and it occurs both as irregular-shaped fine particles and as boulders, some weighing as much as 1,000 pounds. It is somewhat porous, but the clay generally does not enter the pores.

Most of the ore shipped from this locality was hand sorted from the clay and shipped without further treatment. The Independence Mining Co. has in this way produced 500 tons, which, according to E. C. McComb, owner and manager of the company, averaged 44 per cent of manganese, 8 per cent of iron, 4 to 5 per cent of silica, and less than 0.20 per cent of phosphorus.

A small washing plant, equipped with a trommel screen and a sluice trough 40 feet long, was erected by this company on the bank of White River, at Penters Bluff station, and was operated for some time before the writer's visit. Ore-bearing clay taken from the shafts was washed, and 150 tons of concentrates, averaging 33 per cent of manganese, were obtained. So much of the ore in fine particles was lost that 100 tons of the ore-bearing clay was shipped without treatment. This clay contained 20 per cent of manganese and 20 per cent of iron. The total recovery of concentrates from samples of the ore-bearing clay, as determined by tests made by Crowell & Murray, of Cleveland, Ohio, was 58.33 per cent, and the concentrates according to them contained 38.07 per cent of manganese.

The following analyses represent the composition of five carloads of washed ore shipped from the Shaft Hill mine to the Tennessee Coal, Iron & Railroad Co.

Analyses of ferruginous manganese ore from the Shaft Hill mine.

	1	2	3	4	5
Manganese (Mn)	27.05	32.42	32.67	32.32	31.53
Iron (Fe)	19.23	14.60	13.92	....	15.81
Phosphorus (P)	1.76	.53	.39	....	.63
Silica (SiO_2)	8.38	15.08	14.91	....	14.54
Alumina (Al_2O_3)	3.98	4.71	4.10	....	4.45

An unnamed mine owned by the Martin Manganese & Mining Co. and operated recently by the Independence Mining Co. is situated on a hill between Shaft Hill and White River, but it was not visited by the writer. The analyses given below are of carload lots of ferruginous manganese ore shipped from this mine by the Independence Mining Co. The first six analyses are of ore shipped to the Central Iron & Coal Co., and the last two are of ore shipped to the Sloss-Sheffield Steel & Iron Co.

Analyses of ferruginous manganese ore from an unnamed mine near the Shaft Hill mine.

	1	2	3	4	5	6	7	8
Manganese (Mn)	22.43	21.02	14.08	10.70	12.96	11.07	22.00	15.70
Iron (Fe)	11.50	12.19	12.24	31.23	14.58	16.07	20.00	18.75

UNITED PHOSPHATE & CHEMICAL CO.'S PROSPECT.

A prospect on land belonging to the United Phosphate & Chemical Co., formerly known as the Virginia Chemical Co., is in sec. 4, T. 14 N., R. 8 W., on the east side of Love Hollow and about half a mile north of the mouth of the hollow. Prospecting was done at this locality in 1917 by Louis and Theodore Weaver, and a few wagon loads of ore were hauled in 1918 to Williamson station, about 2 miles away, where it was shipped. The openings comprise several very small pits within an area of 2 or 3 acres. They penetrate a chocolate-colored clay as much as 4 feet thick, which is concealed by surface material consisting largely of fragments of chert from the Boone chert and of phosphatic sandstone fragments from the Cason shale. The clay is residual from the Fernvale limestone, which underlies the Cason shale, and it is apparently in small quantity, as there are many outcrops of the Fernvale limestone. Most of the ore observed at the time of visit (April 1, 1918) was a ferruginous manganese oxide, but part was psilomelane, and it occurs in the clay and overlying material. The Fernvale, from which it is residual, has a dark-brown color due to the presence of manganese and iron oxides in it.

LOVE PROSPECT.

The Love prospect, which is on land owned by W. J. Love, is in Love Hollow, in sec. 4, T. 14 N., R. 8 W., 2 miles northeast of Williamson station. No work has been done here except the collecting of fragments of manganese ore aggregating 1,000 pounds from the slope on the east side of the hollow. The ore is probably residual from the Fernvale limestone, which is exposed on the slopes on either side of the hollow.

WILLIAMSON–GULLEY PROSPECT.

The Williamson-Gulley prospect, which is on land owned by J. W. Williamson and Ransom Gulley, is on the east side of Lafferty Hollow, in the west part of sec. 5, T. 14 N., R. 8 W., about 1 mile northeast of Williamson. Prospecting was done here in 1917, and about 10 tons of manganese ore, which is said to have contained about 45 per cent of manganese, was removed from the openings and hauled to Williamson, whence it was shipped.

The openings, which are several shallow pits, have been dug on the south slope and west point of a hill, at an elevation of 200 feet above the wet-weather branch in Lafferty Hollow. They are in red, reddish-brown, and chocolate-colored clays that are found overlying the surface of the upper beds of the Fernvale limestone, which at this locality is overlain by the Cason shale, St. Clair limestone, and Boone chert, the first-named being the oldest and the last-named the youngest. Rusty ledges of the Fernvale limestone abound on the point of the hill, and very little clay is found on the surface there, whereas farther east on the hill the clay is thicker and the exposed ledges of this limestone are less numerous, but débris consisting largely of chert fragments from the Boone chert and phosphatic sandstone slabs from the Cason shale becomes thicker in this direction. A few small pockets and seams of psilomelane occur in the exposed ledges at the top of the Fernvale, and irregular fragments of this mineral occur in the clay.

H. M. TATE PROSPECT.

The H. M. Tate prospect consists of a few pits on the H. M. Tate tract, near the head of a hollow 2½ miles northeast of Williamson station. Manganese and ferruginous manganese oxides were found in a chocolate-colored clay which is overlain by a few feet of chert débris that has rolled down the hill from the Boone chert, exposed higher on the slopes. This clay and the ore in it are residual from the Fernvale limestone, of which heavy ledges are exposed in the largest pit, where a spring issues. Ore is said to have been mined and hauled away from this locality, but none has been hauled away recently.

W. K. TATE PROSPECT.

The W. K. Tate prospect is on land belonging to W. K. Tate, in sec. 33, T. 15 N., R. 8 W., 2½ miles northeast of Williamson station. Four very small pits were dug in 1916, in a field on a north hill slope. They passed through a gray cherty loam a few feet thick and then penetrated reddish-brown clay. This clay in two of the pits contains ferruginous manganese oxide and iron oxide in pieces an inch or less across, but in the other pits it contains none of these oxides. No rock ledges are exposed in the vicinity, and none were found in the pits, but the Fernvale limestone probably underlies the clay and other superficial materials.

About one-fourth of a mile farther west, on the same hill slope, two shallow pits 10 feet apart have been dug in a dark reddish-brown clay, which lies between exposed masses of the Fernvale limestone. Small pieces of psilomelane containing a minute quantity of manganite and of ferruginous manganese oxide were seen in the clay, but the quantity of these oxides in the clay removed from the pits is very small. The Fernvale is exposed at other places in this vicinity, and outcrops of the Plattin limestone occur in a small thicket 100 feet northeast of the pits. Doubly terminated quartz crystals that were shown to the writer are said to have been found on the surface at this locality.

HELM PROSPECT.

The Helm prospect, not visited by the writer, is on the T. M. Helm tract, in sec. 27, T. 15 N., R. 8 W., about 1 mile west of Anderson. Mr. Helm told the writer that he had dug one pit, from which he removed 1,500 pounds of manganese ore.

E. D. WINKLE PROSPECT.

The E. D. Winkle prospect, owned by E. D. Winkle, is in sec. 27, T. 15 N., R. 8 W., and is in a small saddle near the point of a hill west of West Lafferty Creek, one-fourth of a mile northwest of Anderson. Shallow pits have been dug recently in small pockets of black manganese-bearing earth, which lies around exposed ledges of the Fernvale limestone and which contains only a few chert fragments in its surficial portion. The Fernvale limestone is overlain on the hills on either side of the saddle by the St. Clair limestone. Very little manganese ore was observed at the time of visit, but 30 tons is said to have been mined and shipped.

C. L. SANDERS PROSPECT.

The C. L. Sanders prospect consists of two cuts on the south slope of the point of a hill, in sec. 27, T. 15 N., R. 8 W., about half a mile west-northwest of Anderson. The cuts were made in 1917 by C. L. Sanders, the owner, who obtained from them 30 tons of manganese ore, which he hauled to Cushman, where it was shipped. One of the cuts is very small. The other, which is higher on the slope, is 100 feet long and is said to have been 20 feet deep before it partly caved. In the upper part of the larger cut a few feet of brown crinoidal limestone, which is believed by the writer to be the St. Joe limestone member of the Boone chert, is exposed, and beneath it 3 feet of red and yellow ocherous laminated clay, which may have been derived from the Cason shale, are exposed. A boulder of the Fernvale limestone was revealed at one place, lying beneath the clay. Thin lenses and small pockets of manganese and iron oxides were observed in the clay, and at one place a lenticular mass of manganese oxide a few inches thick extends upward into the crinoidal limestone. Boulders of manganese ore are said to have been found in the clay, the largest weighing 800 pounds. One carload of ore from this prospect was shipped by W. H. Denison and J. F. Barksdale to the

Tennessee Coal, Iron & Railroad Co. and was found on analysis to have the following composition:

Analysis of manganese ore from the C. L. Sanders prospect.

Manganese (Mn)	45.82
Iron (Fe)	5.51
Phosphorus (P)	.38
Silica (SiO_2)	6.52
Alumina (Al_2O_3)	2.62

GROUP OF MINES EAST OF ANDERSON.

GENERAL FEATURES.

The Sand Field, Manganese Field, Ruminer Rough, and Barksdale mines are east of the village of Anderson and are on adjoining properties. The Ruminer Rough mine was operated 20 to 25 years ago by W. H. Denison, who mined and shipped 400 tons of manganese ore. All four mines have been operated by Mr. Denison and J. F. Barksdale, beginning in 1916. Their combined production in 1916 was 100 tons, in 1917 it was 240 tons, and in 1918 it was 200 tons before the time of visit (May 23). The production thus far consists entirely of manganese ore that has been sorted by hand from the inclosing clay.

These mines are on the south slope, on the west end, and at the south base of a low eastward-trending ridge more than a mile in length. Loose blocks of ferruginous sandstone that were once a part of the Cason shale—which, except for these blocks, has been completely eroded from the vicinity—cap the crest of the ridge. The Joachim, Plattin, Kimmswick, and Fernvale limestones are exposed in many heavy ledges on its gentle slopes, and the St. Peter sandstone is exposed in the valleys on either side of it. These limestones lie in a shallow east-west syncline half a mile wide, whose axis passes through Anderson.

The manganese ore is found in surface material overlying the St. Peter sandstone and in clays in channels and pockets formed by solution in the three limestones named above, and like most of the other manganese ore in the Batesville district it is a residue from the decomposition of the Fernvale limestone. It occurs in these clays and other surficial materials as irregular compact masses ranging in size from fine particles ("wash ore") to larger masses ("lump ore"), some boulders of which weigh 1,000 pounds. The "wash ore" and "lump ore," according to Mr. Barksdale, are present in equal quantities.

The ores from these mines consist largely of psilomelane and hausmannite, but partly of braunite and manganite. Some masses are composed of steel-blue psilomelane, others of steel-blue psilomelane and fine-grained to coarse-grained hausmannite, and still others of psilomelane and braunite. As the ore from each mine is very similar to that from the others, they have not been kept separate when shipped, and in some cars they have been mixed with the ores from the near-by Earl Collie and Johnson Hill mines. The analyses of carload lots of such mixed shipments are given on page 245. One carload of ore from the four mines here described contained 60.80 per cent of manganese.

SAND FIELD MINE.

The Sand Field mine, owned by W. F. Hamby, is in a nearly level part of a small valley, on the north border of the NE. ¼ NE. ¼ sec. 35, T. 15 N., R. 8 W. The workings are pits from 1 to 4½ feet deep, which have been made in a red sandy loam here and there over an area of about 2 acres. The loam overlies the St. Peter sandstone, of which there are large exposures in the vicinity, and it contains the manganese ore, which occurs in masses ranging in size from fine particles to pieces that weigh 25 pounds. Only the large pieces of ore have been separated by hand from the loam. An attempt was made to concentrate the ore by passing the dry ore-bearing loam through a trommel screen, but it was not successful.

MANGANESE FIELD MINE.

The Manganese Field mine is on the south slope of the ridge that trends eastward from Anderson and is just north of the Sand Field mine, described above. It is on a tract of land owned by J. F. Barksdale, which comprises the SE. ¼ SE. ¼ sec. 26 and the SW. ¼ SW. ¼ sec. 25, T. 15 N., R. 8 W.

The workings are pits 15 feet or less in depth and have been dug here and there over most of the tract. They penetrate red sandy loam, red clay, and black clay, which overlie the irregular surface of the Joachim, Plattin, Kimmswick, and Fernvale limestones or fill channels and pockets in these limestones. The ore is found from the surface to the bottoms of the pits, and it is in masses some of which weigh as much as 1,000 pounds.

RUMINER ROUGH MINE.

The Ruminer Rough mine is west of the Manganese Field mine and is on the west part of the ridge that trends east from Anderson. It is on a tract of land owned by Mr. Denison and Mr. Barksdale, which comprises the SE. ¼ SW. ¼ and the SW. ¼ SE. ¼ sec. 26, T. 15 N., R. 8 W. The manganese ore is mined by means of pits from clay that fills small pockets and channels in the Joachim and Plattin limestones. Ledges and boulders of these limestones occupy a large part of the surface, and as they make the ground exceedingly rough this area and other similar areas are known as "roughs."

BARKSDALE MINE.

The Barksdale mine is on the west end of the ridge just east of Anderson and is west of the Ruminer Rough mine. It is on a tract of land owned by Mr. Barksdale, which comprises the SW. ¼ SW. ¼ sec. 26, T. 15 N., R. 8 W. Exposed ledges and boulders of the Joachim and Plattin limestones occupy much of the surface here as at the Ruminer Rough mine. The manganese ore is found in clays that fill pockets and channels in these limestones, and it has been mined by means of pits.

EARL COLLIE MINE.

The Earl Collie mine is just east of Anderson and is on a 120-acre tract that adjoins the south side of the tracts on which the Barksdale and Ruminer Rough mines are situated. It was operated 20 to 25 years ago, when it produced 150 tons of "lump" manganese ore, and was next operated by Earl Collie, the owner, who began work in 1917 and who mined 30 tons of "lump ore" before the time of visit (May 23, 1918). In August, 1918, the property was sold to G. L. Bruner.

The workings, which are pits, have been dug here and there over a large part of the 120-acre tract, and manganese ore is said to occur over the entire tract. Ore in fragments, some weighing as much as 50 pounds, has been picked up on the surface in a field on the west part of the tract and has been mined by means of pits 4 feet deep in a sandy loam in and near a small stream that flows west. In the pits the ore is found usually at the base of the loam lying on ledges of the St. Peter sandstone and mixed with sandstone fragments. The ore, the sandstone fragments, and the sandy loam containing them have obviously been transported and deposited in their present position by the stream at this locality. Manganese oxide (wad) stains parts of the St. Peter sandstone and cements sand grains to the surfaces of many fragments of ore.

Most of the openings on this tract are in a gently rolling but rough area north of the above-mentioned field. There ledges of the Joachim limestone, which crop out over much of the surface, contain clay-filled channels, some as much as 5 or 6 feet wide, 100 feet long, and 15 feet deep. These channels were formed by the solution of the limestone along its bedding planes and joints, and many of them extend down to the St. Peter sandstone, which underlies the Joachim limestone. The clay that fills these channels and the scanty soil above it contains compact masses of manganese ore ranging in size from fine particles to boulders that weigh 100 pounds. The ore consists of steel-blue psilomelane, hausmannite, and braunite, which are more or less intermixed. It is similar to the ores obtained from other mines in the vicinity and has been mixed with them before being marketed. Analyses of carload lots of ores thus mixed are given on page 245.

The tract here described is on the south edge of the shallow east-west syncline that lies east of Anderson. The very low northward dip of the St. Peter sandstone toward the axis of the syncline is best revealed along the wagon road running down West Lafferty Creek south of Anderson.

CARAWAY PROSPECT.

The Caraway prospect, owned by Richmond Caraway, is in sec. 26, T. 15 N., R. 8 W., three-fourths of a mile northeast of Anderson, and is north of the Manganese Field mine. Work at this locality was begun in 1917 and thus far (May 22, 1918) only a few tons of manganese ore has been mined and shipped.

The workings, which are shallow pits, have been dug in clays that lie around the exposed ledges and boulders of the Joachim and Plattin limestones on a north hill slope and in surface wash that overlies the St. Peter sandstone along a small westward-flowing branch. The ore was generally found from the surface to the bottoms of the pits. It consists of steel-blue psilomelane, hausmannite, and braunite, and it occurs as both fine particles and larger masses, some of which weigh 200 pounds.

This prospect is on the north edge of the syncline extending eastward from Anderson. The St. Peter sandstone, which is exposed over large areas in the vicinity, dips a few degrees to the south.

L. J. WEAVER MINE.

The L. J. Weaver mine, which is owned by Mrs. L. J. Weaver, is on the east and north slopes and near the crest of Cave Hill, 1½ miles north-northeast of Anderson. The tract of land on which it is situated is in the E. ½ SE. ¼ sec. 23 and the NE. ¼ NE. ¼ sec. 26, T. 15 N., R. 8 W. The mine has been operated from time to time, beginning in 1916, by various persons, among whom were J. B. Hinkle, J. F. Barksdale, W. H. Denison, and J. E. Secrest. Although the total production is not known at least one car of ore is said to have been shipped. Pits and cuts, some as much as 25 feet deep, have been dug in brown manganese-bearing clay which overlies and fills pockets in the Fernvale limestone. They extend up the hill slopes to the St. Clair limestone, a few feet of which is exposed near the crest of the hill. The small pieces of ore observed in the clay on the dumps at the time of visit (May 23, 1918) consisted of soft though firm ferruginous manganese oxide. The car of ore mentioned above was shipped to the Tennessee Coal, Iron & Railroad Co., and was found on analysis to contain 36.17 per cent of manganese.

LEWIS PROSPECT.

The Lewis prospect is on the west slope and near the crest of Cave Hill, 1½ miles north-northeast of Anderson. A few small pits have been dug in red clay that overlies the Fernvale limestone, and they extend up the slope to the outcrop of the St. Clair limestone. The pits reveal a soft though firm ferruginous manganese ore like that at the L. J. Weaver mine, which is on the north and east slopes of the hill. The quantity of ore that has been removed and hauled away from this locality was not learned.

CAVE HILL MINE.

The Cave Hill mine is on and near the south slope of Cave Hill, on land owned by J. F. Barksdale, in secs. 23 and 16, T. 15 N., R. 8 W., 1¼ miles north-northeast of Anderson. It was operated in 1917 by Mr. Barksdale, who mined and shipped two or three carloads of manganese ore. Considerable ore is said to have been mined 20 to 25 years ago along a small stream on this property.

The openings that were visited are shafts on the east slope of the south point of Cave Hill. They passed through several feet of chert débris at the surface and then penetrated manganese-bearing clay. The occurrence of outcrops of the Plattin limestone near the shafts indicates that the manganese-bearing clay at this locality rests upon this limestone. Manganese ore was obtained not only from the shafts but is said to have been picked up on the surface. The ore observed on the dumps at the time of visit (May 23, 1918) consisted of small pieces of porous psilomelane.

T. C. WINKLE PROSPECT.

The T. C. Winkle prospect is on the T. C. Winkle farm, on West Lafferty Creek, 2½ miles above Anderson. A few pieces of hard manganese ore are said by Mr. Winkle to have been found on the stream flat bordering West Lafferty Creek and on the hill slope just east of the creek. Several pieces of such ore weighing 1 pound or less each were seen at Mr. Winkle's house; they consisted of steel-blue psilomelane in which there are crystals of braunite or hausmannite.

The St. Peter sandstone is exposed on the lower slopes of the hills on either side of the creek at this locality, and the Joachim and Plattin limestones are exposed on Pine Mountain, east of the creek, and on the hills west of the creek. Although no Fernvale limestone is exposed on this mountain nor on the above-mentioned hills, it once occurred on them and has been removed by erosion. While it was being eroded the pieces of manganese ore that are now found along the creek were set free from the limestone and were washed by streams to their present position.

H. J. RAY PROSPECT.

The H. J. Ray prospect is on land belonging to H. J. Ray, 2½ miles west-southwest of Mount Pleasant and 5½ miles northwest of Cushman. The work on this property was done by Mr. Ray beginning in 1916, and before the time of visit (May 23, 1918) he had mined and marketed 25 tons of manganese ore. Several pits as much as 8 feet deep have been dug in red and black clays near his house. These clays contain fragments of chert and limestone and masses of manganese ore, and they overlie the Plattin and Joachim limestones or fill shallow crevices between the many exposed ledges and boulders of these limestones. A pile of 1,000 pounds of ore ready to be marketed was observed in Mr. Ray's yard at the time of visit. It contained irregular compact masses of steel-blue psilomelane and granular hausmannite ranging from those half an inch in their longest dimension to those weighing several pounds, but some masses are said to have weighed 75 pounds. The manganese content of the ore thus examined was as high as any in the region—between 50 and 60 per cent.

M. E. WILSON PROSPECT.

The M. E. Wilson prospect consists of a few pits, 12 feet or less deep, on the north and northeast slopes of a hill in the NE. ¼ SE. ¼ sec. 13, T. 15 N., R. 8 W., 2 miles west-southwest of Mount Pleasant. M. E. Wilson, the owner, had mined and marketed 3 tons of manganese ore before the time of visit (May 30, 1918). The shallower pits have been dug in chert débris, but the deeper pits pass through it and penetrate brown clay. The occurrence of outcrops of the Plattin limestone on the crest and slopes indicates that the clay overlies this limestone. Manganese ore has been found at places in the surficial chert débris and in "leads" in the brown clay by the side of masses of chert, which are known as "flint bars." The ore observed on the dump at the time of visit was psilomelane, in which there was a small quantity of braunite.

BEVANS PROSPECT.

The Bevans prospect is on the east slope of the hill on which the M. E. Wilson prospect is situated and is in the NW. ¼ SW. ¼ sec. 18, T. 15 N., R. 7 W., 2 miles west-southwest of Mount Pleasant. A few shallow pits that have been dug at this locality passed through chert débris and penetrated manganese-bearing clay, but only a very small amount of psilomelane and manganite were found. The occurrence of outcrops of the Plattin and Joachim limestones in this vicinity indicates that the clay overlies these limestones.

M'CONNELL MINE.

The McConnell mine is 4 miles north-northwest of Cushman and is on a tract of land which comprises the SE. ¼ sec. 19 and the W. ½ SW. ¼ sec. 20, T. 15 N., R. 7 W. The agricultural right of this tract is owned by Norman Needham, and the mineral right is owned by the Cleveland Manganese Mining Co. The mine was first operated 30 years ago and was next operated in 1916 and later by W. H. Denison, who had mined and shipped 100 tons of manganese ore before the time of visit (May 30, 1918).

The workings, which are pits 8 feet or less deep, have been made at many places on the northwest slope of a ridge and in the beds of two wet-weather branches that run in shallow hollows near the base of the ridge. The pits on the slope penetrate red and brown manganese-bearing clays which contain chert fragments near the surface, but the pits in the beds of the branches are in wash which is composed mainly of fragments of manganese ore and chert. The thickness and extent of the manganese-bearing clays have not been fully determined. Although the Joachim and Plattin limestones, which the clays overlie, are exposed at many places very few, if any, of the pits on the slope have passed entirely through the clays. The Fernvale and Kimmswick limestones, and the Cason shale (if it was ever present in this vicinity), have probably been completely decomposed. Therefore, if large manganese deposits ever occurred in the Fernvale limestone and Cason shale they must now be looked for in the clays.

The manganese ore is distributed through the clays as irregular masses ranging in size from fine particles ("wash ore") to boulders that weigh 6 tons. There is considerable "wash ore" in places, but the recovered concentrates would be a ferruginous manganese ore. The "lump ore" contains 45 per cent or more of manganese and consists of psilomelane and braunite. Fine radiating needles of white barite line cavities in some of the ore.

KLONDIKE MINE.

The Fullbright mine, also known as the Klondike mine, is in the SE. ¼ SW. ¼ sec. 17, T. 15 N., R. 7 W., 1 mile south-southwest of Mount Pleasant and 5 miles north by west of Cushman. The agricultural right of the tract on which it is situated is owned by Tom Sipes, and the mineral right is owned by E. W. Buskett. The mine was operated in 1916 by Tom Fullbright, in 1917 by R. S. Handford, and in 1918 by Mr. Buskett. The total production before June, 1918, was 80 tons of manganese ore.

The workings are pits and cuts as much as 12 feet deep, which have been dug in red cherty manganese-bearing clay over 3 or 4 acres, on the crest and on the north and northeast slopes of a knob. Although none of the openings appear to have passed entirely through the clay to the underlying limestone the clay, according to Mr. Handford, averages about 6 feet thick. The only limestone observed in the vicinity consists of exposures of the Plattin limestone, which occur on the south slope of the knob. The elevation of these exposures and the absence of exposures of any younger limestones suggest that the Plattin limestone underlies all the clay on the knob.

The manganese ore is distributed through the clay as irregular masses which range in size from those a fraction of an inch in diameter to those weighing 50 pounds. The smaller particles, an inch or less in diameter and known as "wash ore," are in considerable quantity. Analyses of samples of the "wash ore" are reported to show that it contains from 28 to 35 per cent of manganese, and analyses of samples of the "lump ore" are reported to average about 45 per cent of manganese.

HADDOCK PROSPECT.

The Haddock prospect, owned by R. P. Haddock and leased to the Marqua Mining Co., is on a knob one-fourth of a mile west of the Klondike mine and 1 mile southwest of Mount Pleasant. Very little work has been done at this locality, and of the 12 tons of marketed manganese ore Mr. Turnbull mined the greater part in 1917. The openings are small pits, which have been dug in brown manganese-bearing clay on the crest of the knob. The full thickness of the clay has not been proved, as none of the pits have reached the underlying limestone, which is probably the Plattin limestone. The manganese ore observed on the dumps at the time of visit (May 30, 1918) consists of small irregular particles of psilomelane and some wad. Such particles, known as "wash ore," form a large part of the ore-bearing clay, but the concentrates that would be recovered by washing would probably be a low-grade manganese ore.

MOSER PROSPECT.

The Moser prospect is in the NW. ¼ sec. 17, T. 15 N., R. 7 W., three-fourths of a mile southwest of Mount Pleasant. In 1916 and 1917 J. W. Moser dug several pits on the south slope of a hill and picked up pieces of manganese ore on the surface. From these sources he obtained about 5 tons of ore, which he hauled to Cushman and sold. The ore-bearing area is underlain by a dark cherty loam, through which a few boulders and ledges of the Joachim and Plattin limestones protrude. On other parts of this tract the St. Peter sandstone is extensively exposed, and if any manganese ore is found in such areas the quantity will be very small.

The manganese ore is said to occur in masses, some weighing as much as 258 pounds. A pile of 1,200 pounds of ore ready to be marketed was observed near Mr. Moser's house at the time of visit. It contained irregular compact masses of steel-blue psilomelane through some of which crystals of braunite were disseminated.

L. B. RAY PROSPECT.

The L. B. Ray prospect is on the L. B. Ray tract, in the SE. ¼ sec. 7, T. 15 N., R. 7 W., 1 mile west of Mount Pleasant. Shallow pits have been dug recently in clay and surficial cherty loam at three places on the hill slopes on this tract. The total depth of the clay was not determined, as the pits were not dug deep enough to reach the underlying Joachim and Plattin limestones, of which there are a few exposures near by. Ferruginous manganese ore was found in some of the pits and high-grade manganese ore in others. Altogether 12 to 15 tons of manganese ore, some of which was picked up on the surface, is said to have been marketed before the time of visit (May 31, 1918). Since that time the Manganese Mining & Development Co. has done a small amount of work on this tract but has shipped very little or no ore.

HALL PROSPECT.

The Hall prospect, owned by E. D. Hall and now leased by the Marqua Mining Co., is on the top of a hill in the SW. ¼ sec. 8, T. 15 N., R. 7 W., three-fourths of a mile west of Mount Pleasant. A little work had been done by Mr. Hall, beginning in 1916, and he had picked up on the surface or mined from shallow pits 25 to 30 tons of manganese ore before the time of visit (May 31, 1918). Clay which contains chert fragments and large and small masses of hausmannite and steel-blue psilomelane was penetrated by the pits. The largest mass of ore thus far found weighed 800 pounds. The ore-bearing clay is probably nowhere more than a few feet thick, as outcrops of the Plattin limestone which it overlies are numerous.

O'GILSBY PROSPECT.

The O'Gilsby prospect is on the J. W. O'Gilsby tract, three-fourths of a mile west of Mount Pleasant. Manganese ore has been picked up on the surface and mined by means of shallow pits in sandy pebbly loam or in cherty clay along wet-weather branches and in the fields on this tract. The manganese ore at the pit farthest northwest is ferruginous, but at most other places it is of high grade, consisting of small masses of hausmannite and steel-blue psilomelane. Mr. O'Gilsby states that he has marketed altogether about 3 tons of ore. The cherty manganese-bearing clay generally overlies the Joachim and Plattin limestones, and the sandy pebbly loam in which some ore has been found occurs in the beds of small streams and overlies the St. Peter sandstone.

ANDERSON PROSPECT.

Three tons of manganese ore, it is reported, has been recently picked up on the surface on the Dan Anderson tract, half a mile southwest of Mount Pleasant, but no openings have been made. The St. Peter sandstone and the Joachim and Plattin limestones are exposed on this tract. Although fragments of manganese ore have been taken from the surface underlain by the St. Peter sandstone larger quantities of ore must be prospected for in clays that overlie the two limestones.

RUDOLPH PROSPECT.

The Rudolph prospect is on a tract of land just north of Mount Pleasant that is owned by the S. T. Rudolph heirs and E. A. Rudolph. Manganese ore is said to have been picked up on the surface and mined from many pits from time to time within the last 20 years. In 1917 the quantity of ore marketed was 10 to 15 tons. The ore is of a very high grade and consists of irregular compact masses of steel-blue psilomelane and coarsely granular hausmannite ranging in size from fine particles to boulders, of which the largest thus far discovered weighed 300 pounds. Sand grains have been cemented to the surface of some masses of ore.

A gray sandy loam, derived from the St. Peter sandstone, which it overlies, is the surface material over most of the tract, but ledges of the Joachim and Plattin limestones and clays and chert fragments which overlie the limestones occur on parts of the tract. The pits have been made at several places in the shallow surficial material, but not much ore has yet been found. If ore in larger quantity is present on the tract it is most likely to be found in the clay that overlies the Joachim and Plattin limestones. Two or three pits have been dug in this clay on a wooded hill half a mile north of Mount Pleasant, and although no ore was discovered in them it might be found in other pits on this hill, for ore has been picked up on the surface in a field on its south slope.

BONE PROSPECT.

The Bone prospect is on land owned by J. H. Bone and R. A. Bone, half a mile east of Mount Pleasant, and consists of a pit 5 feet deep, which has been dug in red clay. This clay contains chert fragments and a soft ferruginous manganese ore, which is reported to be in such quantity that one man can dig a ton of it in a day. Only one wagonload of it, however, has been mined and hauled away. The clay is probably residual from the Joachim and Plattin limestones, which are exposed at a few places in the vicinity. These limestones lie in a shallow eastward-trending syncline a few hundred feet wide, and the St. Peter sandstone is exposed on either side of it.

At one place in the bed of a branch east of the pit mentioned above many fragments of chert and sandstone and a few small particles of hard manganese oxide have been recently cemented together by iron oxide.

HENRY KING PROSPECT.

The Henry King prospect is on a hill on the Henry King tract, which joins the west side of the Bone tract, described above. No pits have been dug on this tract, but fragments of soft ferruginous manganese ore like that on the Bone tract were observed on the surface, and some ore will doubtless be found in the clay below the surface. This clay is largely if not entirely residual from the Joachim and Plattin limestones, which lie in the same syncline as the one that crosses the Bone tract.

W. D. LEWIS PROSPECT.

The W. D. Lewis prospect, not visited by the writer, is on the W. D. Lewis tract, 1 mile east of Mount Pleasant. No openings have been made on the tract, but 300 pounds of manganese ore is stated by Mr. Lewis to have been picked up on the surface.

HOLLAWELL PROSPECT.

The Hollawell prospect is on the W. S. Hollawell tract, three-fourths of a mile south of Mount Pleasant and 5 miles north of Cushman. A few openings were made 25 to 30 years ago, and work has been done from time to time within the last two or three years by Mr. Hollawell, the owner, and by several lessees, who altogether had mined and marketed 40 tons of "lump" manganese ore before the time of visit (May 30, 1918).

Shallow pits have been dug in red clay and surface loam, both of which contain manganese ore. Most of the pits are 4 feet or less deep and are scattered along a wet-weather branch, but one pit on the top of a low hill is 10 or 12 feet deep. The surficial parts of the clay contain chert fragments, and in places the clay is overlain to a depth of a few feet by such fragments. Although the full thickness of the clay has not been determined except on a small part of the tract, it is thickest on and near the crest of the hill and thinnest on the lower slopes, where there are many outcrops of the

Joachim and Plattin limestones. The Fernvale limestone—from which the manganese ore and part of the clay are a residue—and the Kimmswick limestone have apparently entirely decomposed, so that the clay everywhere overlies the Joachim and Plattin limestones.

Masses of hausmannite and steel-blue psilomelane, which range in size from fine particles to boulders weighing 100 pounds, have been found in the pits and at places on the surface over about 80 acres, but part of the ore removed from the pit on the top of the hill is wad.

E. WINKLE PROSPECT.

The E. Winkle prospect is on the Mrs. Enzie Winkle tract, three-fourths of a mile south of Mount Pleasant and 5 miles north of Cushman, which joins the Hollawell tract on the north and the King tract on the west. A few very shallow pits have been dug on the east slope of a hill whose slopes are covered with a bed of chert fragments, but they did not go deep enough to reveal more than 1 to 2 feet of the top of the manganese-bearing clay. The occurrence of outcrops of the Plattin limestone in gullies near the pits indicates that the clay overlies this limestone. A few small pieces of hard manganese oxide were observed at places on the surface, on the dumps of the pits, and in gullies on this tract. No manganese ore has been hauled away from this locality.

W. A. KING MINE.

The W. A. King mine is three-fourths of a mile south-southeast of Mount Pleasant and 5 miles north of Cushman. Work has been done here at times in the last 2 years by W. A. King, the owner, who had mined and marketed about 60 tons of lump manganese ore before the time of visit (May 30, 1918). Many pits 10 feet or less deep have been dug here and there over an area of a few acres on and near the northeast slope of a hill. They are in a surficial clayey loam which contains fragments of chert and manganese ore. This loam is only a few feet deep, and exposures of the Joachim limestone are numerous at the base of the hill, where most of the openings were made, but the loam is doubtless thicker on the hill slope, where there are only a few exposures of the Plattin limestone. The Fernvale and Kimmswick limestones are not exposed; they have probably been entirely decomposed.

The manganese ore consists of psilomelane and hausmannite in fine particles and in larger masses, some weighing several pounds. The ore at the base of the hill is compact, but some of it higher on the hill is porous. Many fine particles of iron oxide are present in the manganese-bearing loam.

STONE COUNTY.

G. F. FULTS PROSPECT.

The G. F. Fults prospect is on land owned by G. F. Fults and leased by the Stone County Mining Co., in the SE. ¼ sec. 21, T. 15 N., R. 9 W., on the south side of White River, about 1 mile south of Guion. Very little work has been done here, and no manganese ore has been shipped. The workings consist of two badly caved pits, one a few feet deep and the other 15 feet deep, that have been dug on the southeast slope of a hill. Red clay and yellow onyx marble were removed from the deeper pit, and about 50 pounds of manganese ore lying on the dump at the time of visit (May 28, 1918) was said to have been taken out. The ore consists of irregular compact masses of steel-blue psilomelane and granular hausmannite, which are intimately mixed. An outcrop of Kimmswick limestone near by suggests that the clay at this locality rests upon this limestone.

The other pit, lower on the slope, has been dug in a clay-filled crevice in the Plattin limestone. A few small pieces of manganese ore were observed on the dump.

A. T. FOSTER PROSPECT.

The A. T. Foster prospect, not visited by the present writer, is described by Penrose[26] as follows:

> The A. T. Foster tract is in 15 N., 9 W., the north part of section 34. It is * * * on Dry Creek, a tributary running north from the Boston Mountains into the White River. Fragments of a hard, massive black manganese ore have been found in association with a red clay, lying in cavities on the surface of the St. Clair [probably Fernvale] limestone, as shown in the accompanying figure [fig. 26]. Two small pits have been dug, but no ore has been shipped.

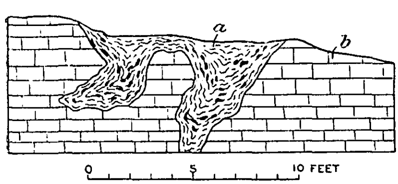

FIGURE 26.—Section on the A. T. Foster tract, showing the formation of manganese-bearing clay (*a*) by the solution of limestone (probably the Fernvale limestone) (*b*). (After Penrose.)

> The figure illustrates the dissolving action of surface waters on the limestone. They have gradually removed the carbonate of lime in the limestone, while the clay and ore, which were once distributed through that rock, have collected in the hollows thus formed. Fragments of ore are also seen on the slopes of the hill in several other places.

The present writer found small fragments of hard manganese oxide in a stream bed on land owned by A. T. Foster and leased by the Stone County Mining Co., in the S. ½ NE. ¼ sec. 28, T. 15 N., R. 9 W.

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[26] Penrose, R. A. F., jr., Manganese—its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, pp, 288–289, 1891.

ALEX FULTS PROSPECT.

The Alex Fults prospect is in a small hollow on the southeast side of Dry Creek, in the NW. ¼ sec. 33, T. 15 N., R. 9 W., south of White River and about 1¾ miles south of Guion. It is on land owned by Alex Fults, which has been leased by the Stone County Mining Co. Very little work has been done here, and no ore has been shipped. The workings consist of two or three very small pits, which have been made in a shallow black soil. Limestone ledges are exposed, both in the pits and on the surface. The lowest limestone exposed in the hollow is the Fernvale limestone, but above it there is about 10 feet of pinkish-gray fossiliferous St. Clair limestone, and above the St. Clair there is several feet of brown crinoidal limestone, which is perhaps the St. Joe limestone member of the Boone chert. The slopes above the crinoidal limestone are covered with chert débris.

A very small quantity of psilomelane has been found in the St. Joe (?) limestone and in the black soil which overlies it and which is apparently residual from the limestone. The psilomelane is disseminated through parts of the limestone as minute irregular-shaped particles and as larger masses, some of which are a few inches in their longest dimension.

CAGENS CREEK.

Manganese ore in masses weighing as much as 1,000 pounds is reported to occur on the surface along Gagens Creek for 1 to 1½ miles above its mouth, which is on the south side of White River, 2¼ miles southeast of Guion. Very little if any work has been done on this creek, and no ore has been shipped. This locality was not visited by the writer. The ore reported to have been found on this creek, like most of the ore in the Batesville region, is probably a residue from the decomposition of the Fernvale limestone.

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