MANGANESE DEPOSITS OF THE CADDO GAP AND DE QUEEN QUADRANGLES, ARKANSAS.

By Hugh D. Miser.

INTRODUCTION.

The high prices that are being offered for manganese ores have stimulated interest in the little-exploited manganese deposits of west-central Arkansas. These deposits are found at intervals in a belt 4 to

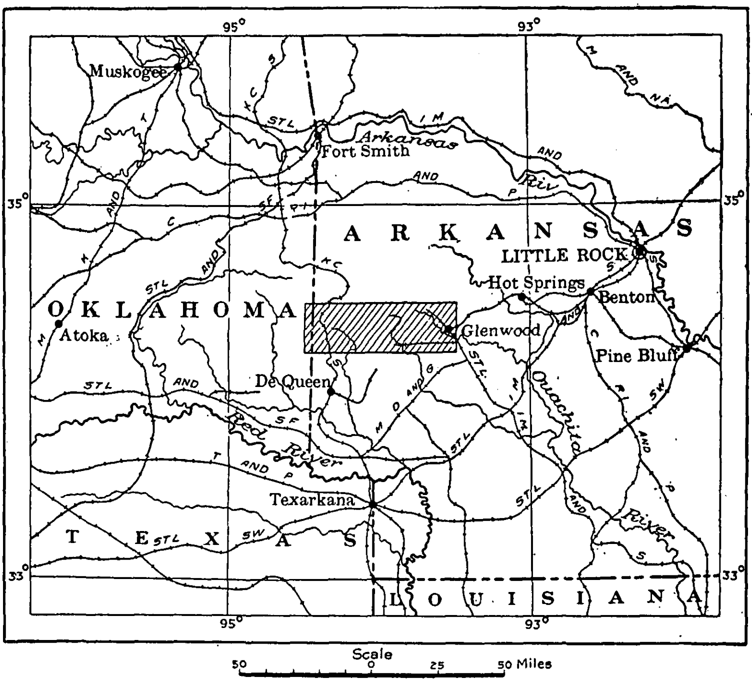


Figure 2.—Index map showing location of northern or mountainous parts of the Caddo Gap and De Queen quadrangles, Arkansas and Oklahoma.

12 miles wide, extending west-southwestward from Pulaski County, at the center of the State, to Polk County, on the west border. Recent exploitation, begun in 1915 and still in progress, is confined almost entirely to the mountainous districts in the northern parts of the

Caddo Gap and De Queen quadrangles, in western Arkansas. The location of the mountainous districts of these quadrangles is shown in figure 2. Aside from their economic features, these deposits are of scientific interest, as they occur mainly at two definite horizons in the Arkansas novaculite, which is closely folded.

Below is given a list of papers treating of the manganese deposits of west-central Arkansas and the adjoining part of Oklahoma and some of the more important papers on the geology of the region:

Owen, D. D., Second report of a geological reconnaissance of the middle and southern counties of Arkansas, 1860.

The region containing the manganese deposits is described, but the existence of the deposits is not mentioned. The analyses given, however, show manganese in the soils and in some of the spring waters. An analysis of manganese ore from Batesville, in northern Arkansas, is given.

Anon., Age of steel, vol. 62, p. 9, St. Louis, Mo., September 3, 1887.

Contains an article on the manganese deposits of Polk County, together with analyses and a general description of the region.

Weeks, J. D., Manganese: U. S. Geol. Survey Mineral Resources, 1886–1892.

Short notices of the manganese ores of southwestern Arkansas, with several analyses.

Comstock, T. B., Report upon the geology of western-central Arkansas, with especial reference to gold and silver: Arkansas Geol. Survey Ann. Rept. for 1888, vol. 1, 1888.

Some manganese deposits are described and a number of analyses are given, but the principal purpose of the report was to present the results of an investigation of reported occurrences of gold and silver that had just caused considerable excitement in western Arkansas.

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

Describes every known manganese region in North America. The report was prepared upon the general plan of discussing the uses of manganese, together with the history and statistics of the manganese industry, the ores of manganese, and the nature of the manganese deposits. The deposits of west-central Arkansas are described at length.

Griswold, L. S., Whetstones and the novaculites of Arkansas: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 3, 1892.

The economic value, character, and origin of the novaculite are fully and ably treated; and the topography and geology of the novaculite area are described in detail and are represented on two colored maps. Although the manganese deposits are not described, the distribution and structure of the novaculite are shown on the two maps and are treated in the text. There are, however, three brief references to the manganese deposits, including a summary after Penrose.

Gurley, R. R., Geological age of the graptolite shales of Arkansas: Arkansas Geol. Survey Ann Rept. for 1890, vol. 3, pp. 401–423, 1892.

The first fossils found in the novaculite area are described and their age indications are discussed.

Ashley, G. H., Geology of the Paleozoic area of Arkansas south of the novaculite region: Am. Philos. Soc. Proc., vol. 36, p. 309, 1897.

Mentions small quantities of manganese ore in region described.

Purdue, A. H., The slates of Arkansas, Arkansas Geol. Survey, 1909.

The chapter on the geology of the slate area, which is partly in the Caddo Gap and De Queen quadrangles, describes for the first time the different rock formations to which names are applied. The distribution and structure of these formations in the mountainous portion of the Caddo Gap quadrangle are shown on a carefully prepared map. No mention is made of the manganese deposits, but the map especially is of value to prospectors, for it shows the structure and distribution of the Arkansas novaculite, in which the deposits are found.

Harder, E. C., Manganese deposits of the United States, with sections on foreign deposits, chemistry, and uses: U. S. Geol. Survey Bull. 427, pp. 119–122, 1910.

This report contains a good brief description of the manganese deposits of west-central Arkansas. The description given is a summary after Penrose.

Hewett, D. F., Manganese and manganiferous ores: U. S. Geol. Survey Mineral Resources, 1912, pt. 1, p. 219, 1913.

A number of manganese deposits in southeastern Oklahoma, adjoining the Arkansas region, are briefly described.

Joslin, G. A., Manganese in west-central Arkansas: Min. and Sci. Press, vol. 113, pp. 947–948, Dec. 30, 1916.

Describes briefly the manganese ores, methods of prospecting, and mining conditions.

No detailed report as a result of an examination of the manganese deposits of west-central Arkansas has appeared since the publication of Penrose's report in 1891. In the last quarter of a century knowledge of the geology of the region has been greatly increased, many new openings have been made, and some of the old ones have been reopened.

Practically all of the recently developed deposits were examined by the writer in the spring and summer of 1916, during the course of the field work for the De Queen-Caddo Gap folio, now being prepared by A. H. Purdue and him. No attempt was made to examine the undeveloped deposits. The region was visited at a favorable time, for the deposits were being prospected then and all the workings could be entered. The results of explorations that have been carried on since then will probably not materially affect the conclusions presented in this report. Penrose's report has been freely drawn upon for the description of such deposits as were not examined by the writer. The location of the deposits described by Penrose, as well as of those visited during the field work for this report, is shown on Plate III.

The information dealing with the general geology is the result of detailed field studies in the Caddo Gap, De Queen, and Hot Springs and vicinity quadrangles by A. H. Purdue, assisted by the writer and R. D. Mesler, in 1907; by Mr. Purdue, assisted by the writer, during the years 1908 to 1911; by the writer, assisted by Mr. Mesler, in 1912; and by the writer in 1913, 1914, and 1916. The field work in 1907 was done in cooperation with the Geological Survey of Arkansas.

The writer is under obligations to the people living within the area herein described and to the officials of the different mining companies for their uniformly courteous treatment. Among those to whom special acknowledgments are due for information are Messrs. S. A. Hanna and D. M. Nicholson, of Caddo Gap; Will Whisenhunt, of Shady; R. Lowery, W. E. Rainwater, and S. W. Sherrod, of Albert; H. L. Watkins and W. R. Sossamon, of Glenwood; Chester Stevens, of Hot Springs; C. L. French, consulting engineer for Edgar & Co.; N. H. Ohnsorg, manager of mines of the Mississippi Valley Iron Co.; G. A. Joslin, mining engineer for Dierks Lumber & Coal Co.; George Hammond, of Wickes; Robert Porter and W. R. Porter, of Fancy Hill; and Dallas Hollifield and M. A. Janes, of Hopper.

HISTORY.

The manganese deposits in west-central Arkansas have been worked only in a very small way, and up to the time of the completion of the present examination (Aug. 13, 1916) have yielded less than 200 tons of marketed ore. Most of the work has been done during two periods of activity, one beginning about 1885 and ending in 1889, and the other beginning in 1915 and still in progress. The earlier period occurred in the midst of the excitement over gold and silver that raged for a few years in west-central Arkansas, especially in Garland and Montgomery counties. The history of the exploitation of the manganese deposits at that time is summarized as follows by Penrose:[1]

> A great many places have been prospected, but the only considerable amount of work that has been done is on the land of the Arkansas Development Co. in Polk County, on the Brushy Creek branch of the Cossatot River. This company worked during the year 1888 and continued until April, 1889, when operations were suspended. A shaft was sunk to a depth of 142 feet, and a tunnel about 500 feet long was run in the side of a mountain. Many prospect openings were also made in the surrounding country from the headwaters of the Cossatot to those of the Saline River. About 20 tons of ore are said to have been taken out of the shaft on Brushy Creek, and this represented practically all the manganese that was mined by this company.
>
> About the same time the Capitol Land & Mining Co. carried on operations in Pulaski County, 12 miles west of Little Rock, in what is called the Fletcher Range. A few small prospect pits and tunnels were made, but no ore was shipped, and work has been discontinued.
>
> The only shipments of manganese ore known to have been made from the whole region were a few tons of the ore mined by the Arkansas Development Co., and 4 tons from a small pit on the Burns claim on North Mountain near

[1] Penrose, R. A. F., jr., op. cit., p. 305.

the headwaters of the Little Missouri River. A sample of 500 pounds was also shipped by Mr. Webb Thornton from his claim on Leader Mountain, some 5 miles south of North Mountain.

Besides the above-mentioned localities, many small prospect pits have been made throughout the mountains wherever manganese crops out, but no ore has been shipped from them. Most of them have been made by the Arkansas Development Co. and by Mr. Burns.

The present mining operations are confined almost entirely to the mountainous districts in the northern parts of the Caddo Gap and De Queen quadrangles. The first work was done in August, 1915, by Chester Stevens, who mined and shipped 58 long tons of ore carrying 48.5 per cent of manganese from the Nelson mine, an open cut on Nelson Mountain 5 miles north of Glenwood, and 25 tons of ore from Pigeon Roost Mountain, 1½ miles from McKinley Crossing on the Memphis, Dallas & Gulf Railroad. Pigeon Roost Mountain is just east of the Caddo Gap quadrangle. Very little other work was done during 1915.

In March and April, 1916, F. P. Fay and Mr. Stevens prospected 14 lode-mining claims lying end to end along the crest of Leader Mountain, in the southeast corner of Polk County and the southwest corner of Montgomery County. These claims were later transferred to the firm known as Edgar & Co., of which Messrs. Fay and Stevens became members.

In May, 1916, Edgar & Co. established a mining camp on Little Missouri River in sec. 16, T. 4 S., R. 27 W., in Montgomery County and began prospecting in the vicinity. At the time of the writer's examination (July and August, 1916) the company had completed or partly completed five tunnels, and had made a number of shallow pits and cuts near the camp. It was also doing work in Pike County and was beginning work a few miles east of Caddo Gap, in Montgomery County.

In the spring of 1916 the Dierks Lumber & Coal Co. did a little work on a manganese deposit near the camp of Edgar & Co., but no ore was shipped.

In May, 1916, the Mississippi Valley Iron Co. began work on He Mountain and Coon Creek, in the southeast corner of Polk County. It has also done some work on Risner, Hogpen, and Redland mountains, near Langley, in the northwest corner of Pike County. The Still mine, on the southwest slope of Hogpen Mountain, had yielded 37 long tons of manganese ore at the time it was visited. This ore was hauled by wagons 20 miles to Glenwood, and thence shipped to the company's furnaces at St. Louis for testing. This company has also done some prospecting on Bear and Brushy mountains, 9 miles west of Glenwood. A letter from the company dated December 6, 1916, states that it had ceased operations at least temporarily.

The activity of these individuals and companies has aroused much interest among the farmers and other people of this region, and many of them had prospected and were still prospecting their land and numerous mining claims in August, 1916.

GEOGRAPHY.

The manganese-bearing region under discussion embraces parts of Montgomery, Polk, Pike, and Howard counties in west-central Arkansas and a narrow strip of McCurtain County in southeastern Oklahoma. (See Pl. III.) It consists of two parts, in each of which the manganese deposits are confined to mountainous districts. The larger of the two parts is a belt 4 to 9 miles wide, extending westward across the northern part of the Caddo Gap quadrangle and into the northeast corner of the De Queen quadrangle. It includes much of the manganese-bearing belt described by Penrose. The other part, which is much smaller, is a belt 1 to 7 miles wide, extending from the west side of the De Queen quadrangle eastward halfway across the quadrangle. It is the east end of a mountainous area in the north-central part of McCurtain County, Okla., that contains manganese deposits, some of which are described in a forthcoming report by D. F. Hewett.

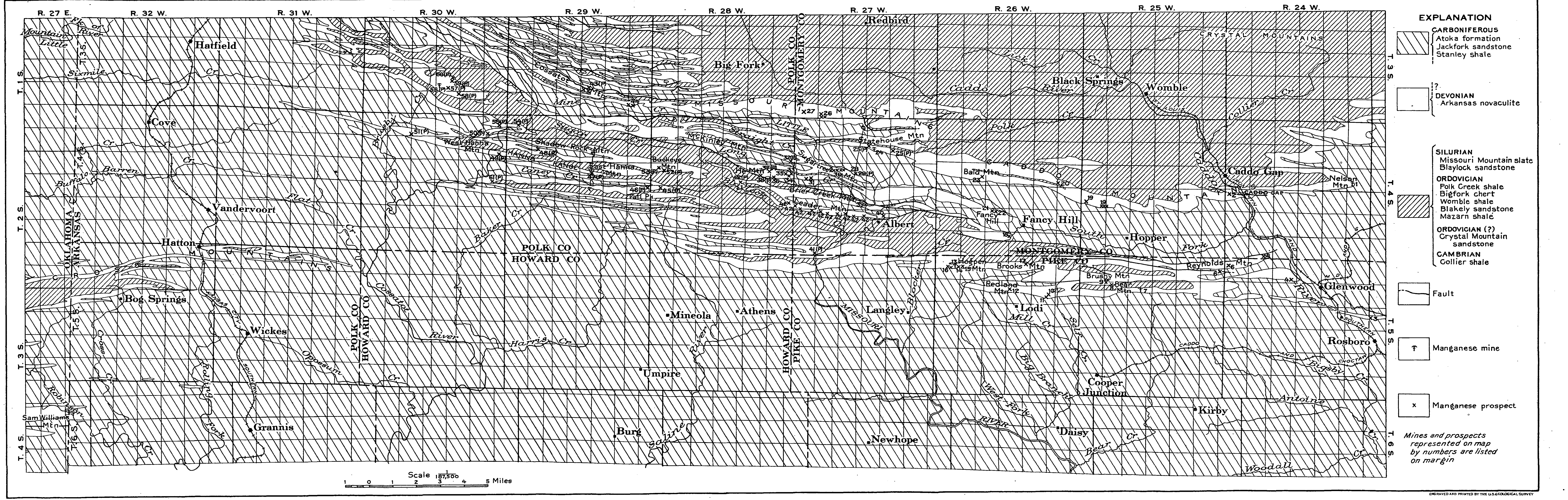
These mountainous districts are a part of the extensive system of ridges known as the Ouachita Mountains. In the area under discussion they are composed of groups of high ridges separated on the south from the Coastal Plain by a dissected piedmont plateau, highest at the north, which stands 750 to 1,100 feet above sea level. The ridges are high, narrow, and nearly parallel and trend in general east and south of east. They are separated by valleys of similar magnitude, which in most places extend parallel with the ridges but in others cut through them in gorgelike water gaps. The ridges have steep, rugged slopes and sharp, even crests, a few hundred feet above which rise a great many peaks, and they commonly range from 500 to 1,000 feet above the adjoining valleys and the piedmont plateau. Most of the ridges range from 1,500 to 2,000 feet above sea level, but several are higher. Raspberry Peak, the highest point, rises to an altitude of 2,360 feet. Other prominent peaks are Tall Peak, East Hanna Mountain, West Hanna Mountain, Eagle Mountain, High Point, and Whisky Peak, in the De Queen quadrangle; and Brushheap, Hogpen, Hightop, Tweedle, Wilson, and Strawn mountains, in the Caddo Gap quadrangle.

The mountains are very rough, the slopes are steep, and rock ledges are numerous. There are, however, no large surfaces of bare rock except along the crests of some of the higher ridges and in the water gaps, and cliffs are not very numerous. The slopes, where

MANGANESE MINES AND PROSPECTS.

Numbers indicate locations on map. Numbers followed by (P) indicate prospects and mines that were not visited by the writer but were described by Penrose. Their location is taken from his descriptions.

1. Nelson.
2. S. A. Hanna.
3. Frank Brunson.
4. Watkins-White.
5. Fields.
6. Reynolds Mountain.
7. Fagan.
8. Bear Mountain.
9. Brushy Mountain.
10. W. T. White.
11. N. F. White.
12. Rattlesnake.
13. Still.
14. Prospect No. 3.
15. Prospect No. 2.
16. Risner Mountain.
17. R. M. Cogburn
18. Bud Hill.
19. Janes.
20. Caddo Mountain.
21. Robert Porter.
22. Cady.
23. W. R. Porter.
24. North Mountain.
25. (P) Crooked Creek.
26. Slatington Mountain.
27. Missouri Mountain.
28. Dierks Lumber & Coal Co.
29. (P) Morrell.
30. Sugartree Mountain.
31. Rainwater.
32. (P) McKinley Mountain.
33. Tellus Davis No. 1.
34. Tellus Davis No. 2.
35. W. A. Davis No. 1.
36. W. A. Davis No. 2.
37. (P) He Mountain.
38. (P) Coon Creek.
39. Eureka.
40. Bluff Mountain.
41. (P) Little Musgrove Mountain.
42. Leader Mountain.
43. (P) Cossatot Mountain.
44. Grant.
45. (P) Pointed Rock.
46. (P) Tall Peak Mountain.
47. (P) East Hanna Mountain; High Peak.
48. (P) East Hanna Mountain; William Allen claim.
49. (P) East Hanna Mountain; west end.
50. (P) West Hanna Mountain; William Allen claim.
51. (P) West Hanna Mountain; Bowen claim.
52. (P) Manganese Mountain.
53. (P) Walston.
54. (P) C. C. Avant (manganese).
55. (P) C. C. Avant (iron).
56. (P) Arkansas Development Co.
57. (P) Jumbo pit.
58. (P) Tunnel No. 2.
59. (P) Shaft No. 3.
60. (P) Shaft No. 4.
61. (P) Little Manganese Mountain.



Base map from the Caddo Gap and DeQueen topographic maps of the U. S. Geological Survey.

GEOLOGIC MAP OF THE NORTHERN PARTS OF THE CADDO GAP AND DE QUEEN QUADRANGLES, ARKANSAS AND OKLAHOMA

Geology by A. H. Purdue and H. D. Miser, assisted by R. D. Mesler

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

not occupied by bare ledges, are covered by talus, much of which is boulders.

The principal streams are Caddo, Little Missouri, Saline, and Cossatot rivers, all of which rise in the mountains in the area under discussion and flow southward or southeastward beyond its borders, the first two entering Ouachita River and the last two Little River.

Except for small tracts that have been cleared and put under cultivation, the region is densely forested, and much of it is included in the Arkansas National Forest. Public and secondary roads reach all parts of the area, but only a few of them are maintained in good condition. They keep to the valleys in the mountainous districts and cross the mountains only through water gaps and saddles. Some of the roughest portions of the area are reached by means of trails, many of which have been constructed by the Forest Service.

The Kansas City Southern Railway traverses the west end of the region herein described from north to south, and a branch of the St. Louis, Iron Mountain & Southern Railway penetrates its east end, passing through Rosboro, Glenwood, and Caddo Gap and terminating at Womble. The Caddo & Choctaw Railroad extends from Rosboro westward to Cooper Junction, a distance of 14 miles. From Cooper Junction a logging spur of the Caddo River Lumber Co. penetrates as far as a point on Little Missouri River 2 or 3 miles south of Langley, and an extension of this spur to a point within 1¼ miles of the Still mine was being planned at the time of the writer's examination. The Memphis, Dallas & Gulf Railroad passes through Glenwood, but from that place southeastward as far as Shawmut its trains run over the track of the St. Louis, Iron Mountain & Southern Railway. Some of the mines and prospects, whose location is also shown on Plate III, are near railroads, but many are as far as 25 to 30 miles away.

GEOLOGY.

STRATIGRAPHY.

GENERAL FEATURES.

The geologic formations in the region here described are Paleozoic, ranging from Cambrian to Carboniferous. The Arkansas novaculite contains the manganese deposits and is the most conspicuous formation in the region. It is thus the only formation whose detailed description need be given in this report.

The succession of formations, together with the principal features of their lithology, is outlined in the following table:

Generalized section of the Paleozoic rocks of the Caddo Gap and De Queen quadrangles, Arkansas and Oklahoma.

System.	Formation.	Thickness (feet).	Character.
Carboniferous.	Atoka formation.	6,000+	Hard micaceous ripple-marked light-gray to greenish-gray sandstone interbedded with equal amount of sandy micaceous black clay shale.
	Jackfork sandstone.	5,000-6,600	Massive compact fine-grained to coarse-grained light-gray sandstone with some millstone grit, especially in the basal part. Indeterminable invertebrate fossils found in millstone grit at base. Green fissile clay shale constitutes a very small part of formation. Exposed in low pine-clad ridges.
	Stanley shale.	6,000	Bluish-black and black fissile clay shale and fine-grained compact greenish-gray or bluish-gray sandstone. Beds of novaculite conglomerate at and near base. Beds of graywacke near base in western part of De Queen quadrangle. Some shale at base has in places been altered to slate, to which the name "Fork Mountain slate" has been earlier applied. Upper part of formation has yielded a single collection of plants, including some ferns. Quartz veins contain lead, zinc, and antimony minerals in De Queen quadrangle.
	—Unconformity—		
Devonian (?). Devonian.	Arkansas novaculite.	250-950	Consists of three lithologic divisions—a lower one, made up almost entirely of massive white novaculite, at whose top is one of the two manganese horizons; a middle one, consisting mainly of thin layers of dense dark-colored novaculite interbedded with shale and having a conglomerate of local distribution at the base; and an upper one, consisting chiefly of massive, highly calcareous novaculite, which also yields manganese. The lower division is of lower Oriskany (Lower Devonian) age, and the middle and upper divisions are tentatively assigned to the Upper Devonian. These correlations are more fully discussed on pages 70-71.
Silurian.	Missouri Mountain slate.	50-300	Red and green clay slate. No fossils have been found, and the assignment to the Silurian system is therefore based on its lithologic character and stratigraphic relations.
	—Unconformity?—		
	Blaylock sandstone.	0-1,500	Fine-grained light-gray to dark-gray or green compact hard sandstone and buff to dark shale. A collection containing seven species of graptolites was obtained at the south base of Blaylock Mountain. These species, as pointed out by E. O. Ulrich, are not comparable to any described from America but have all been described from the Birkhill shales of Scotland, which are in Britain considered the base of the Silurian system. He thus assigns the Blaylock to the Silurian system.
	—Unconformity?—		

Generalized section of the Paleozoic rocks of the Caddo Gap and De Queen quadrangles, Arkansas and Oklahoma—Continued.

System.	Formation.	Thickness (feet).	Character.
Ordovician.	Polk Creek shale.	0-175	Black graphitic shale; in parts siliceous and in others clay shale. Graptolites are abundant.
	Bigfork chert.	700	Thin-bedded gray to black much shattered chert interbedded with thin layers of black shale. Fossils consist mainly of graptolites.
	Womble shale.	1,000	The Womble shale receives its name from the town of Womble, part of which is on the base of this shale. Much of the shale to which this name is now applied was in 1909 regarded by Purdue[a] as a part of his "Ouachita shale," which as defined comprised the rocks between the Crystal Mountain sandstone below and the so-called Stringtown shale above. A sandstone, now called the Blakely sandstone, that was in 1909[a] regarded as the upper part of the Crystal Mountain sandstone, has since been determined by Purdue and the writer to occur in the middle of the "Ouachita shale." The use of the name Stringtown has been discontinued in this area because the beds to which it was applied do not form a mappable unit distinct from the rest of the shale above the Blakely sandstone; because the graptolites supposed to be characteristic of it have apparently been found well down in the underlying shale; and because, according to E. O. Ulrich, the limits and character of the Stringtown shale at the type locality in Oklahoma are in doubt. With the recognition of the Blakely sandstone as a distinct formation and the failure to separate the Stringtown it became necessary to give a new name (Womble shale) to the whole interval between the Blakely sandstone and the Bigfork chert. The name "Ouachita shale" is abandoned because its limits are not the same as those of any one of the units now mapped, and because Ouachita has the same pronunciation as Washita, the well-established name of the upper group of the Comanche series. The formation consists of black graphitic shale with thin beds of sandstone near the base and beds of limestone near the top. The shale near the base is composed of black and green layers that split at an angle with the bedding and thus show ribboned cleavage surfaces. Graptolites of Lower Ordovician age are numerous.
	Blakely sandstone.	0-400	The Blakely sandstone takes its name from Blakely Mountain, in Garland County, Ark., from which it is continuously exposed as far west as Womble, where it thins out, thus permitting the Womble and Mazarn shales to come together west of that town. It consists of shale in alternating black and green layers and hard gray sandstone. The shale constitutes 75 per cent of the whole, but the sandstone, which produces ridges, is the prominent feature. Graptolites of Lower Ordovician age found only in Blakely Mountain.

[a] Purdue, A. H., The slates of Arkansas, pp. 30, 33-35: Arkansas Geol. Survey, 1909; (abstract) U. S. Geol. Survey Bull. 430, pp. 321-325, 1910; (abstract) U. S. Geol. Survey Prof. Paper 71, pp. 160-162, 1912.

Generalized section of the Paleozoic rocks of the Caddo Gap and De Queen quadrangles, Arkansas and Oklahoma—Continued.

System.	Formation.	Thickness (feet).	Character.
Ordovician—Con.	Mazarn shale.	1,000	The Mazarn shale takes its name from Mazarn Creek, whose headwaters are in the northeast corner of the Caddo Gap quadrangle. The name is applied to the part of the "Ouachita shale" lying below the Blakely sandstone. The formation consists of shale and of small amounts of limestone and sandstone. The shale is ribboned, consisting of alternating black and green layers that split at an angle with the bedding. Graptolites of Lower Ordovician age have been found.
Ordovician (?).	Crystal Mountain sandstone.	850	Coarse-grained massive gray to brown sandstone, calcareous in places. A conglomerate at the base contains limestone and chert pebbles derived from the Collier shale. The formation has not yielded any fossils. Owing to its stratigraphic relations and lithologic character, it is tentatively assigned to the Ordovician system. Clusters of quartz crystals are found in fissures at numerous places, and many are sold at Hot Springs, Ark., to museums and for use as ornaments.
	Unconformity		
Cambrian.	Collier shale.	200+	Bluish-black soft graphitic, intensely crumpled clay shale, some limestone, and a few thin layers of dark chert. Has yielded no fossils. Assigned to the Cambrian because it unconformably underlies the Crystal Mountain sandstone, which in turn underlies the Mazarn shale, of Lower Ordovician age.

ARKANSAS NOVACULITE.

The Arkansas novaculite in the Caddo Gap and De Queen quadrangles, as in other parts of the Ouachita Mountains, is exposed in more or less parallel and nearly eastward-trending belts, whose narrowness is due to the steep dips of the beds. Owing to the narrowness of these belts and to the greater resistance of the novaculite to weathering than the adjacent strata above and below, its outcrops stand up as sharp ridges, whereas both the older and the younger rocks form intervening valleys. The mountainous districts of the quadrangles thus present a corrugated surface when viewed from a high point.

Because of the brittleness of the novaculite and of its numerous joints, it breaks down into angular blocks of large and small size and forms a surficial material that covers the ridges in most places; but in others, particularly along the crests and in the water gaps, the edges of the beds project in rough, bare ledges through the débris. Some of these ledges stand up in walls several feet high along the crests.

The Arkansas novaculite is thickest in its southernmost outcrops, where the thickness at many if not at most places is about 900 feet.

The greatest known thickness, 950 feet, was measured 1 mile west of West Hanna Mountain. At Caddo Gap the formation is about 890 feet thick. It thins toward the north and along the northern border of the area is about 250 to 300 feet thick. This thinning finds expression in the lower elevation of the ridges toward the north. In the Cross Mountains, on the west side of the De Queen quadrangle, the formation is 540 feet thick.

In the Caddo Gap and De Queen quadrangles and many other parts of the Ouachita Mountains the formation consists of three lithologic divisions—a lower one, made up almost entirely of massive white novaculite; a middle one, consisting mainly of thin layers of dense dark-colored novaculite interbedded with shale; and an upper one consisting chiefly of massive, highly calcareous novaculite. The manganese is found at the top of the lower division and in the upper division. These divisions vary in thickness and character from place to place.

The lower division is commonly from 150 to 300 feet thick, though at some places the thickness is greater; the maximum of 410 feet is at Caddo Gap, and the minimum of 25 feet is in the extreme northeast corner of the De Queen quadrangle. This division is made up almost wholly of typical novaculite, whose white color and massiveness make it the most conspicuous part of the formation. In fact, it is this part that usually occupies the crests of the ridges. The beds are from 2 to 10 feet thick and are commonly even bedded, though in places some of the novaculite occurs in thin lenses and nodules. Some of the exposed bedding planes show large uneven ripple marks. At a number of places beds of red, buff, and, less commonly, black and green shale, reaching 15 feet in thickness, are interbedded with the basal layers of this division of the formation.

The massive novaculite is usually dense, gritty, fine grained, homogeneous, highly siliceous, translucent on thin edges, and white with a bluish tint, but where unweathered it is bluish gray. It has an uneven to conchoidal fracture and a waxy luster like that of chalcedony. Though the bulk of the rock is white, much of it varies in shades of red, gray, green, yellow, and brown, and in many places it is black. These shades are produced by iron and manganese oxides and possibly in some places by carbonaceous matter. The darker colors are prevalent in the lower 50 to 75 feet. In parts, especially near the base, the rock shows a fine parallel lamination, and much of it contains a few cavities that are oval in cross section and half an inch in their longest dimension, besides others of less size and of irregular shape. The rock contains a little calcite, but exposures of the calcareous stone are not common and have been found only in stream beds. Joints are numerous and run in all directions, but the most prominent joints are normal to the bedding. Many of them are filled by white quartz veins which are usually so thin as to be inconspicuous. Slickensides along both joints and bedding planes are common.

The middle part of the formation consists chiefly of interbedded novaculite and shale. The novaculite is similar to that in the lower massive part of the formation, except that the common color is dark gray to black and that the beds are much thinner, usually between 1 inch and 6 inches thick. Moreover, some thin layers are argillaceous and have a fairly good cleavage, resembling in these respects a highly siliceous shale. The whole division is cut by many joints, some of whose faces are so smooth they look as if they had been polished. A conglomerate at the base of this division was observed at a number of places. It consists of small rounded and subangular pebbles of novaculite in a sandy and dense flinty matrix. The shale ordinarily observed is black, weathering to a buff or brown color, but some of it is red. It is in beds from a fraction of an inch to 70 feet thick. As a rule, it is fissile argillaceous shale, but at some places it has been hardened to slate. Much of it strongly resembles the lower part of the Stanley shale.

The upper part of the formation ranges from about 20 to 125 feet in thickness and is thickest along the southernmost exposures. It consists chiefly of massive, highly calcareous light-gray to bluish-black novaculite which is so resistant that at some places where it and the accompanying beds of the formation are not overturned it produces low ridges or knobs on the slopes of the higher ridges. Some thin beds of ordinary dense chalcedonic novaculite like that so characteristic of the middle and lower parts of the formation are also included. Fine lamination parallel with the bedding is common. On weathering, the more calcareous rock loses its calcium carbonate, becomes white or cream-colored and porous and soft enough to receive impressions from the hammer without breaking, and shows a great many oval and irregular-shaped cavities like those in the basal division of the formation. Some of these cavities are due simply to the removal of calcium carbonate through solution, but others appear to have a different origin and may be casts of poorly preserved shells. Although some dense, hard novaculite is present at most if not all places where this division of the formation is exposed, it becomes less calcareous and more siliceous toward the north, and at some localities it consists entirely of novaculite like that in the basal division of the formation.

The only remains of animals thus far found in the formation consist of numerous conodonts in a minutely pebbled novaculite conglomerate and of conodonts and small linguloids and sporangites in associated shale, which have been obtained from the middle division of the formation at Caddo Gap. Upon them E. O. Ulrich bases the opinion that the middle and upper divisions of the formation are to be correlated with the Woodford chert in the Arbuckle Mountains in southern Oklahoma and with the Chattanooga shale. He assigns these two formations to the Mississippian series of the Carboniferous and accordingly regards the middle and upper divisions of the Arkansas novaculite as belonging to that series, but the United States Geological Survey tentatively places these two divisions of the novaculite in the Upper Devonian. The lower division is separated from the middle one by an unconformity of at least local extent and, by its lithologic character and stratigraphic relations, is correlated with the Camden chert of western Tennessee, which is known by its fossils to be of lower Oriskany (Lower Devonian) age.

STRUCTURE.

The beds of the Arkansas novaculite are rarely horizontal but are inclined at various angles so that their edges appear at the surface. When they are crossed from north to south they are found to lie in a series of anticlines (arches) and synclines (troughs), and in a few places they have suffered displacement by faults.

The Caddo Gap and De Queen quadrangles contain two areas where the oldest rocks have been uplifted through folding and now stand as high as the youngest. One of these areas includes the mountainous portion of the Caddo Gap quadrangle and the northeast corner of the De Queen quadrangle. This is a part of the west end of the Ouachita anticline, which is the prominent fold of the Ouachita region in Arkansas. The other area includes the Cross Mountains, in the western part of the De Queen quadrangle. It is the east end of the Choctaw anticline, which is the most prominent fold of the Ouachita region in Oklahoma.

These large folds are composite and are thus essentially anticlinoria. Some of their larger subdivisions can be followed for long distances; but the single folds, some of which are represented in figures 3 and 4, are narrow, overlap one another lengthwise, and can be traced only a few miles along their axes. They all have the same general direction as that of the ridges and thus bear a close relation to the topography, for outcropping edges of the hard strata upturned on the folds have formed the ridges and the softer intervening strata underlie the valleys. Their general trend does not greatly depart from west, but it is north of west in the Ouachita anticline, west in the Choctaw anticline, and south of west in the piedmont plateau. Many adjacent folds are of nearly the same height, and the same beds are repeated many times at the surface. The dip gradually changes in amount from place to place along the strike, and on some of the folds it even changes in direction within a mile. These changes may take place where a single fold breaks up into two or a symmetrical fold is closely compressed so that the strata are parallel. Two structure sections of the same mountain or valley only a mile apart might therefore be very different. Scarcely any two ridges are alike in structure, and some of them, especially many high peaks, are composed of two or three lesser anticlines with their intervening synclines. The sides of most of the folds have been compressed until they are parallel, the rocks on one side having been turned through an angle exceeding 90°, so that the beds on the two sides of the fold dip in the same direction. The dips of the overturned rocks are in places as low as 40°. This means that the rocks in such places have been turned through an angle of 140°. In some parts of the area the pressure that produced such overturning was exerted from the north; in other parts from the south. As a rule the folds are smallest, most numerous, and most closely squeezed in the shales and thin-bedded sandstones and chert. Joints in several sets and slickensides are common in all the rocks but are most numerous in those just named.

Faults are common, though less so than might be expected in strata that have been so closely compressed as these. This is due to the great predominance of thin-bedded strata over massive, rigid beds like the Crystal Mountain sandstone, Arkansas novaculite, and Jackfork sandstone, in consequence of which the beds as a whole bent rather than broke under stress. About thirty faults have been mapped in the two quadrangles, and others, which doubtless exist, may be detected in future work. The faults were produced by the breaking and overthrusting of strata in closely compressed anticlines. So far as observed, all the faults are thrust faults, with the exception of one small normal fault in the SW. ¼ sec. 31, T. 3 S., R. 26 W. The direction of the faults, therefore, is in the main east or parallel with the ridges. The length of the longest ones does not exceed 12 miles, and most of them are much shorter. The dip of all the fault planes is high; some of them dip south and some north. The dislocation ranges, even along a single fault, from a few feet to several hundred or a few thousand feet or more, but only a minimum measure is obtainable anywhere.

As may be seen by reference to Plate III, a large number of the faults occur near the north border of a group of mountains extending westward from the vicinity of Glenwood. This is, in fact, the principal zone of faulting in the area. It extends south of east from the valley of Sugar Creek, in the De Queen quadrangle, passing south of Fancy Hill, in the Caddo Gap quadrangle, and eastward along the valley of South Fork, apparently terminating near Caddo River.

Many structural details are mentioned in the descriptions of the mines and prospects, beginning on page 85.

ORE DEPOSITS.

CHARACTER OF ORES.

The manganese ores of the Caddo Gap and De Queen quadrangles consist of oxides, four of which, psilomelane, pyrolusite, manganite, and wad, have been identified; if others are present, they probably occur in minute quantities. Although these minerals may be found separately, as a rule two or more are intimately mixed in the same deposit, and in some places they are associated with iron ores and manganiferous iron ores. Psilomelane, pyrolusite, and manganite form the larger part of the manganese ore in this region. A material consisting of rock fragments and clay cemented together by soft manganese oxide is present at a number of places; locally it is known as "bog ore." Descriptions of these minerals follow.

Psilomelane is a black or steel-blue mineral that breaks with a conchoidal fracture, shows in places botryoidal surfaces, and occurs in the amorphous form and with a massive, concentric, or stalactitic structure. It has a specific gravity of 3.7 to 4.7 and a hardness of 5 to 6, which means that a knife blade scratches it with difficulty, if at all. The chemical composition of psilomelane is not definite; potash, baryta, and water occur in it in varying amounts and are supposed by some mineralogists to be mechanically admixed. An analysis of psilomelane is given below.

Pyrolusite is a grayish-black to black mineral with a crystalline or granular structure and a black or bluish-black streak. It has a hardness of 2 to 2.5, being much softer than psilomelane and a specific gravity of 4.8. Pure pyrolusite contains 63.2 per cent of metallic manganese, but the mineral is usually impure, as is shown in the accompanying analysis. This mineral was identified by Penrose as occurring in the area under discussion but was not detected by the present writer, though it is possible that a small quantity of the manganite described herein is pyrolusite.

Analyses of psilomelane and pyrolusite from the Caddo Gap and De Queen quadrangles.[a]

[R. N. Brackett, analyst.]

	Psilomelane.[b]	Pyrolusite.[c]
MnO	73.17	76.90
O	15.11	16.66
Fe_2O_3	.26	1.06
Al_2O_3	6.53	.79
CoO	Tr.	Strong tr.
CaO	1.58	.52
BaO	.05	2.83
MgO	....	.14
K_2O	2.12	.26
Na_2O	2.35	.20
P_2O_5	Tr.	....
SiO_2	.15	[d] 1.52
	101.31	99.88

[a] Penrose, R. A. F., jr., Manganese—its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, pp. 314-315, 1891.
[b] North Mountain in southwestern Montgomery County.
[c] Cossatot Mountain, in southeastern Polk County.
[d] Includes insoluble matter.

Manganite is a black brittle massive or crystalline mineral with a reddish-brown or nearly black streak. It has a specific gravity of 4.2 to 4.4, a hardness of 4, and a theoretical content of 62.4 per cent metallic manganese and 10 per cent water. It occurs generally with psilomelane in alternating layers in botryoidal masses. In such masses it consists of numerous needles that radiate from the walls toward the middle of the vein. Locally crystals of manganite are scattered through masses of psilomelane or occupy the centers of stalactite-like rods of psilomelane, the association being such as to lead to the conclusion that manganite is an alteration product of psilomelane.

Wad, an impure mixture of manganese oxides, is a soft dark-brown or black earthy mineral occurring with psilomelane and manganite or by itself. At a few places it occurs in alternating layers with psilomelane in botryoidal masses. Dendrites, branching moss-like growths of wad, are common along joints in the novaculite.

The iron ores comprise various hydrous sesquioxides, of which limonite is probably the most abundant. The mineralogic species of the iron oxides found in each deposit in the area have not, however, been determined, and the materials are called simply brown or red iron oxides. By some people these are mistaken for manganese oxides. Iron pyrites in veinlets and minute scattered crystals is common in the unweathered portions of the novaculite. One of the places where it was noted is the lower tunnel at the North Mountain mine, in sec. 10, T. 4 S., R 27 W.

The most abundant material with which the iron and manganese ores are associated is clay, some of which has been brought in by ground water and some of which is residual and probably in place. Minute quantities of dufrenite, a green mineral composed of phosphorus pentoxide, iron sesquioxide, and water, and usually occurring in globular aggregates with a radial structure, occur in a few of the prospects. Thin layers of opal are associated with weathered dufrenite at the Missouri Mountain prospect and the Tellus Davis prospect No. 2. Films of chalcedony in which are small particles of native copper were found in the lower tunnel at the North Mountain mine. This chalcedony is stained bluish green by a minute quantity of chrysocolla, a copper silicate combined with some water. Films of similar chalcedony were found on claim No. 7 on Leader Mountain.

OCCURRENCE OF ORES.

The manganese ores occur as nodules, pockets, and short irregular veins from a fraction of an inch to 4 feet thick. Thicknesses of 4 feet, however, are rare, and those of a foot are not common. The ore bodies are scattered through the hard novaculite, and can doubtless be found on every mountain where the Arkansas novaculite is exposed. The ores occupy bedding planes or joint cracks or form a cement in a novaculite breccia, in which the rock fragments range from a fraction of an inch to over a foot in diameter. The iron and manganese ores may be intimately mixed in the same pocket or vein, they may occur separately in different parts of the same vein, or they may occur in separate masses. Most of the ore is confined to two stratigraphic horizons in the Arkansas novaculite. One of these is in the upper division of the formation and the other is near the top of the lower division. Some deposits, however, such as those at the North Mountain mine, the Fagan mine, and the Eureka, Rattlesnake, S. A. Hanna, and R. M. Cogburn prospects, are found in other parts of the lower division, and the geologic position of some others was not determined.

The Arkansas novaculite and other formations have been thrown into a series of folds whose trend is parallel with the ridges. This formation is very resistant; the upturned edges stand up as ridges on which rock ledges or their débris abound. The beds at the two ore horizons, which show ore at the surface in many places, may thus be followed for long distances along the slopes, and their outcrops, owing to the numerous folds, are repeated on the slopes or crests of the many parallel ridges, or even on a single ridge. The outcrops of these ore-bearing beds are sometimes called "lodes" or "leads."

The accompanying section (fig. 3) through Leader, Brier Creek, Sugartree, and Statehouse mountains, on or near which extensive

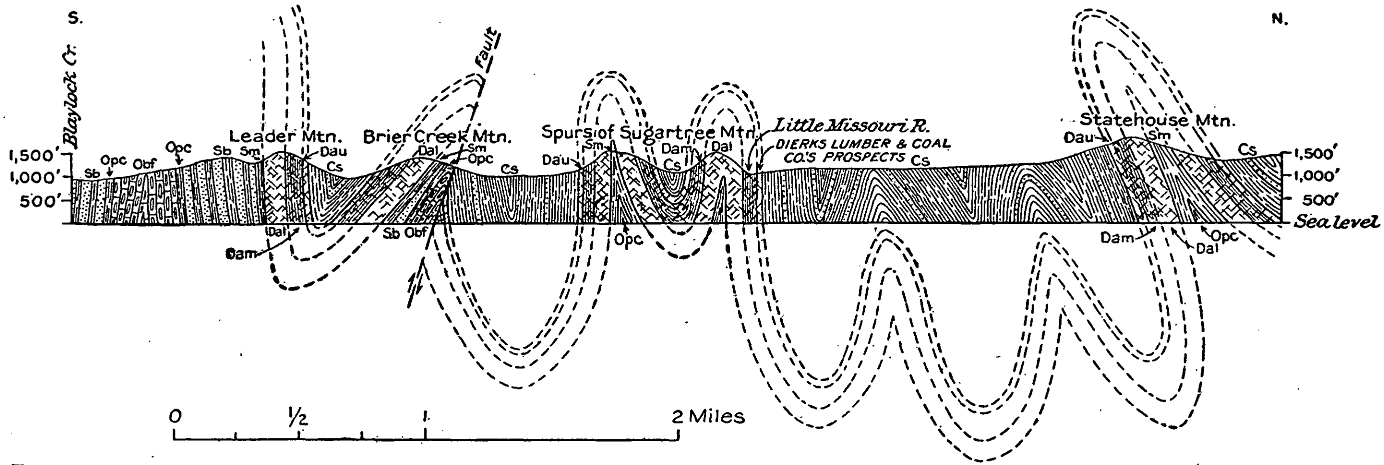


Figure 3.—Section along line C–D on Plate III, through the east ends of Leader, Brier Creek, and Sugartree mountains and the west end of Statehouse Mountain, Montgomery County, Ark., showing the folding of the Arkansas novaculite. Cs, Stanley shale; Dau, upper division of Arkansas novaculite, upper manganese horizon; Dam, middle division of Arkansas novaculite; Dal, lower division of Arkansas novaculite (lower manganese horizon is at the top of this division); Sm, Missouri Mountain slate; Sb, Blaylock sandstone; Opc, Polk Creek shale; Obf, Bigfork chert. The probable underground structure of the Arkansas novaculite below sea level is represented by the broken lines in the lower part of the figure, and the probable structure of the novaculite before it was eroded down to the present level is represented by the broken lines in the upper part.

prospecting for manganese is going on, illustrates the way in which the beds of the two manganese horizons are repeated on different ridges. Many other ridges are similar in structure to those shown in the section; but others, as well as different parts of the same ridge, are different. The structure of some is complicated; for example, that of East Hanna Mountain, a high peak in sec. 34, T. 4 S., R. 29 W., 3 miles east of Cossatot River. (See fig. 4.)

These sections represent the structure as it is inferred from the position of the beds observed at the surface and are on too small a scale to show all the minute structural details.

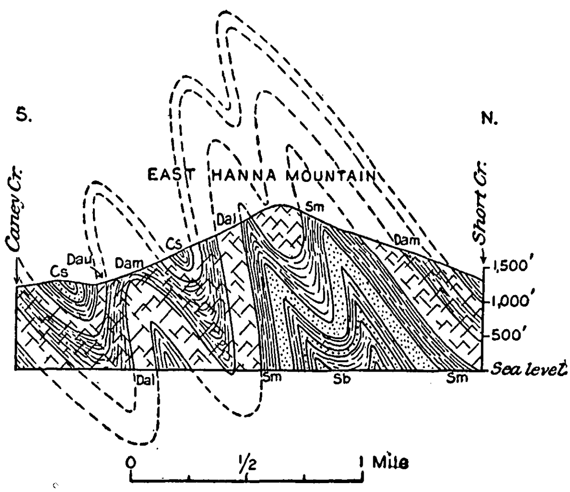


FIGURE 4.—Section along line A–B on Plate III, through East Hanna Mountain, Polk County, Ark., showing the folding of the Arkansas novaculite. Cs, Stanley shale; Dau, upper division of Arkansas novaculite; Dam, middle division of Arkansas novaculite; Dal, lower division of Arkansas novaculite; Sm, Missouri Mountain slate; Sb, Blaylock sandstone.

The beds at the two manganese horizons, as shown in figure 3, occur on Leader Mountain, those at the lower horizon on the crest and those at the upper horizon on the north slope. The prospected manganese deposits on this mountain are in the beds at the lower horizon.

The two horizons are represented on the south slope of Brier Creek Mountain, the upper beds being lower on the slope than the lower beds, but neither horizon is represented on the north slope, owing to the presence of a fault that has been produced by the breaking of the strata in a closely compressed anticline. No prospecting has been done on this mountain. Penrose,[1] however, states that "A stain of iron and manganese and occasionally small masses of the ores occur in the gray novaculite on the part of the mountain lying in Polk County, and probably these same occurrences extend into Montgomery County; but no important quantity of either ore was seen."

Both horizons are represented at two places on or near each of the two eastward spurs of Sugartree Mountain, as the structure of the spurs is anticlinal. A manganese deposit at the upper horizon has

[1] Penrose, R. A. F., jr., Manganese—its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, p. 357, 1891.

been revealed in the Dierks Lumber & Coal Co.'s prospect near the north base of the north spur, and others at both horizons have been found in the Rainwater prospects and the Sugartree Mountain prospects, farther west on Sugartree Mountain.

Both horizons are also twice represented on the part of Statehouse Mountain through which the section is made. A manganese deposit that is being explored by Edgar & Co., about half a mile east of the line of the section, is at neither horizon but is near the base of the formation. The structure at that place (fig. 9, p. 100) is different from that shown in figure 3. Other deposits on this mountain not visited by the writer are described by Penrose (pp. 102–103). Their stratigraphic position in the Arkansas novaculite is not known.

The structure of East Hanna Mountain, shown in figure 4, is more complicated than that of any of the mountains just described; it comprises three anticlines and the two intervening synclines.

The above-described sections and that of Penrose,[1] illustrating the occurrence of the manganese ores and reproduced by Griswold[2] and in part by Harder,[3] agree in their essential features, but Penrose's section is incorrect in its detail and shows manganese-bearing beds at only one horizon, concerning which he says:[4]

> The rock carrying the manganese represents an interbedded stratum in the upper part of the gray novaculite, usually occurring at or near the contact of that bed with the overlying gray and black siliceous shale. Similar ores probably sometimes occur in small quantities in the lower part of the novaculite, but they are of no importance.

The section by Penrose was made across two parallel ridges 1 mile east of Cossatot River, separated by Short Creek. The southern ridge he called "East Hannah Mountain" and the northern one "Shadow Rock Mountain." On the topographic map of the De Queen quadrangle no name is given to "Shadow Rock Mountain," the name "East Hanna Mountain" is applied to a peak 3 miles east of Cossatot River, and the name "Hanna Range" is applied to the "East Hannah Mountain" of Penrose. The Hanna Range, 1 mile east of Cossatot River, is made up of three anticlines and the two intervening synclines, and the structure of the unnamed ridge ("Shadow Rock Mountain" of Penrose) is monoclinal, with the oldest rocks exposed on the north slope.

Deposits that bear certain definite relations to the structure of the Arkansas novaculite occur at the following places. The deposits at

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[1] Penrose, R. A. F., jr., op. cit., p. 322.

[2] Griswold, L. S., Whetstones and the novaculites of Arkansas: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 3, p. 261, 1892.

[3] Harder, E. C., Manganese deposits of the United States, with sections on foreign deposits, chemistry, and uses: U. S. Geol. Survey Bull. 427, p. 120, 1910. The horizontal scale of the figure given by Harder is incorrect; the number of miles should be read as tenths instead of whole numbers.

[4] Penrose, R. A. F., jr., op. cit., p. 321.

the Nelson mine, Fields prospect, Watkins-White prospects, Janes prospects, Brushy Mountain prospects, and North Mountain mine are on or near the noses of plunging anticlines; the deposit at the Bear Mountain prospect is exactly on the axis of an anticline; that at the S. A. Hanna prospect is along a fault; and that at the Eureka prospect is near a fault.

The depth to which the ore extends is not known. An 8-foot vein of solid manganese ore is, however, reported to have been found in the lower tunnel at the North Mountain mine at a distance of about 615 feet from the portal. This tunnel is 250 feet above the road along the south base of North Mountain; it is 530 feet below the crest of the mountain and is 216 feet below the upper tunnel, which penetrates the exposed ore body near its main outcrops. At other places ore is found only in the present shallow workings. These workings and the outcrops of ore occur at all altitudes on the high ridges, from the level of the streams that cut through them up to their crests, which are even and probably represent a Cretaceous peneplain. The deposits examined by the writer range from 900 to 1,800 feet above sea level, but the greatest difference in altitude in any single locality is about 800 feet. This range does not necessarily mean that a shaft sunk from the crest of a mountain would find ore at a depth of 800 feet or that a tunnel driven into the base of a mountain 800 feet below its crest would find ore, for the lower limit of the ore, which may not extend much below water level, may be higher in the mountains than in the valleys, just as the water level is higher in the mountains than in the valleys. It appears probable, however, that the ore extends downward some distance—say 200 or 300 feet—below the water level. In Virginia and Maryland, as pointed out by Hewett,[1] manganese ore is mined to a depth of 220 feet below the water level.

ORIGIN.

The occurrence of the manganese ores in the Arkansas novaculite suggests that their origin and that of the novaculite are intimately associated. Penrose [2] has expressed the opinion that they were deposited at the same time as the novaculite, a rock which is regarded by the present writer and some others as having been deposited through chemical or organic processes, or both, and thus belonging to the class of cherts.

That manganese, as finely disseminated particles, was deposited with the silica that formed the novaculite at the two main ore hori-

[1] Hewett, D. F., Some manganese mines in Virginia and Maryland: U. S. Geol. Survey Bull. 640, pp. 63–64, 1916.

[2] Penrose, R. A. F., jr., op. cit., p. 325.

zons is indicated by partial analyses made by George Steiger, of the United States Geological Survey. A specimen of unweathered calcareous novaculite from the top of the basal division of the formation on Little Missouri River, near the east line of sec. 16, T. 4 S., R. 27 W., contains 0.084 per cent of manganous oxide (MnO), and a specimen of similar novaculite taken from the upper division in the old Sugartree tunnel, at the north base of Sugartree Mountain, contains 0.022 per cent. At both these localities a black oxide of manganese penetrates and partly replaces the novaculite along cracks, but the material analyzed was free from veins and stains of such oxide. It seems probable that much of the manganese ore of the deposits herein described was derived from this finely disseminated manganese by processes of solution, segregation, and redeposition during the erosion of the mountains down to their present level. Whether or not the manganese originally deposited with the novaculite was less abundant in other parts of the formation is not known, but the occurrence of most of the deposits at the two horizons mentioned suggests that a greater quantity of manganese was originally deposited there than elsewhere in the formation, or that these two parts of the formation have later offered the most favorable places for the deposition of manganese from outside sources.

Some of the manganese ores here described may have been derived from other parts of the Arkansas novaculite, from the underlying Missouri Mountain slate, or from the overlying Stanley shale, the last two of which contain minute quantities of manganese.[1] Had the bulk of the ores been concentrated from the rocks just mentioned, however, manganese deposits would have been formed in the Arkansas novaculite at any place structurally favorable for deposition. It is believed by the writer that the two manganese horizons of the Arkansas novaculite, except as regards supply of material, offer no more favorable places for the deposition of ore than other parts of the formation. The middle division, however, which contains much shale, is relatively impervious, and thus would not permit the free circulation of ore-bearing solutions.

The concentration of the ores has been effected by ground water, which has carried down their constituents from the vast mass of rock that has been eroded from the region. The local concentration of the ores into deposits large enough to be of value appears to have been dependent upon the amount of open space in the Arkansas novaculite, which is hard and compact and usually has no visible openings between the layers or along the joints. The places where

[1] Purdue, A. H., The slates of Arkansas, pp. 62–65, Arkansas Geol. Survey, 1909.

fissures are largest and most numerous would be most favorable for the circulation of underground water, and consequently for the deposition of the ore, little of which replaces the novaculite. The fissures were formed during the folding, faulting, and fracturing of the novaculite late in the Carboniferous period. The ores would be expected in those places where the novaculite has undergone much fracturing and close folding, as on and near faults and at the noses or ends of plunging anticlines. A number of such places where deposits occur are mentioned on pages 78–79. It is noteworthy that many cold springs and even the hot springs at Hot Springs, Ark., issue on the noses of plunging anticlines, showing that such places are especially favorable for the circulation of ground water.

Hewett[1] has pointed out that some manganese deposits of Virginia and Maryland occur at or a few hundred feet below the Harrisburg (early Tertiary) peneplain, and he concludes that they were "formed during some stage of early Tertiary erosion." The deposits herein described occur at or several hundred feet below what are probably remnants of a Cretaceous peneplain, preserved in the even crests of the mountain ridges. They thus bear much the same relation to the Cretaceous peneplain of the region under discussion as the deposits described by Hewett bear to the early Tertiary peneplain of the Appalachian region. This similarity suggests that the ores here described were deposited about the beginning of the Cretaceous period, when the region had been reduced to a peneplain. Were this true, however, it would mean that they were deposited within a comparatively short time, but there is no evidence at hand to show that the deposition of the ores of the Caddo Gap and De Queen quadrangles could not have extended over a long period.

ANALYSES.

Analyses of psilomelane from North Mountain, in Montgomery County, and pyrolusite from Cossatot Mountain, in Polk County, are given on page 74. The following are analyses of manganese ores and manganiferous iron ores from the Caddo Gap and De Queen quadrangles:

[1] Hewett, D. F., Some manganese mines in Virginia and Maryland: U. S. Geol. Survey Bull. 640, pp. 63–64, 1916.

Analyses of manganese and manganiferous iron ores from the Caddo Gap and De Queen quadrangles, Ark.

	1	2	3	4	5	6	7	8	9
Manganese (Mn)	60.28	58.36	55.80	51.54	48.65	48.34	40.51	27.68	26.20
Iron (Fe)	....	....	.50	....	2.03	....	25.53	35.39	16.83
Silica (SiO_2)	....	9.02	3.72	....	11.86	....	.80	1.88	29.00
Phosphorus (P)	.413	....	.038	.167	.308	.449	.767	.230	.343

	10	11	12	13	14	15	16	17
Manganese (Mn)	22.84	11.93	2.06	30.93	48.02	56.66	49.24	52.16
Iron (Fe)	....	22.26	50.38	9.21	5.55	.18	2.04	4.00
Silica (SiO_2)	.42	44.40	....	5.86	.52	.15	2.98	.24
Phosphorus (P)	.047	.576	1.450	.320	.310	Trace.	.380	.390
Manganese dioxide (MnO_2)	....	....	....	42.09	71.73	82.10	71.41	77.60

	18	19	20	21	22	23	24	25
Manganese (Mn)	42.75	59.55	25.99	30.95	16.45	23.96	60.54	43.52
Iron (Fe)	2.72	.74	10.75	12.80	5.11	7.45	....	6.72
Silica (SiO_2)	10.46	.52	5.21	6.20	17.16	25.00	8.30	[a] 5.17
Phosphorus (P)	.450	None.	.387	.461	.181	.264	.22	.35
Manganese dioxide (MnO_2)	62.75	90.52	....	....	....	....	....	([b])
Alumina (Al_2O_3)	....	....	8.44	10.04	8.62	12.55	....	4.80
Lime (CaO)	....	....	.04	.05	.04	.06	....	1.42
Magnesia (MgO)	....	....	.04	.05	.04	.06	....	Trace.
Sulphur (S)	....	....	.024	.029	.028	.041	....	.02
Moisture	....	....	16.04	....	31.35	....	....	....

[a] Silica and insoluble in HCl. [b] Oxidizing power equal to 64.60 per cent MnO_2.

Analyses 1 to 12 from Age of Steel, vol. 62, p. 9, Sept. 3, 1887; 13 to 19 from Penrose, R. A. F., jr., op. cit., p. 319; 20 to 23 furnished by Mississippi Valley Iron Co.; 24 furnished by Dierks Lumber & Coal Co. Analysts: 1, 4, 6, 12, Regis Chauvenet & Bro.; 2, 3, 5, 7–77, St. Louis Sampling & Testing Works; 13–19, R. N. Brackett; 24, Kansas City Testing Laboratory; 25, George Steiger.

1–12. Polk County, locality unspecified.

13. Line Mountain, Pike County.

14. Fancy Hill Mountain [W. R. Porter prospect], Montgomery County.

15. North Mountain [mine], Montgomery County.

16. McKinley Mountain, Polk County.

17. Tall Peak Mountain, Polk County.

18. Manganese Mountain, Polk County.

19. Cossatot Mountain, Polk County.

20–23. Still mine, Pike County. 20, One car, natural; 21, same, dry; 22, another car, natural; 23, same, dry.

24. Dierks Lumber & Coal Co.'s prospect, Montgomery County.

25. Composite sample from 39 localities in Pike, Polk, and Montgomery counties.

Analyses 1 to 12, inclusive, represent the composition of manganese and manganiferous iron ores from the land of the Arkansas Development Co. Analyses 15 and 19 were made on picked specimens and represent a better grade of ore than the average of the deposits from which they were taken.[1] Analyses 13, 14, 16, 17, and 18 were made on samples that were selected to represent as nearly as possible the average of the deposit.[2] Samples 20 to 23 were taken from two cars of ore containing 37 long tons, shipped by

[1] Penrose, R. A. F., jr., op. cit., p. 318.

[2] Idem, pp. 318–320.

the Mississippi Valley Iron Co. from the Still Mine to its furnaces in St. Louis, Mo. Analysis 24 represents solid psilomelane collected by G. A. Joslin[1] from the smallest opening shown on figure 10 at the Dierks Lumber & Coal Co.'s prospect. Analysis 25 was made on a composite sample of specimens of manganese minerals collected by the writer from 39 localities, 20 grams of mineral from each locality being mixed to make the sample. The specimens consisted of wad, psilomelane, manganite, and bog manganese; they were selected from the parts of the deposit most free from iron oxide, clay, and fragments of novaculite. The localities from which specimens for the composite sample were collected are as follows:

Nelson mine.
S. A. Hanna prospect.
Watkins-White prospects (pit farthest west).
Fagan mine.
Bear Mountain prospect.
Brushy Mountain prospects (first cut described).
Rattlesnake prospect.
Still mine.
Prospect No. 2.
Prospect No. 3.
Risner Mountain prospects (cut farthest west).
Janes prospects:
- Pit No. 1.
- Pit No. 3.
- Pit No. 4.
- Prospect No. 5.
- Pit No. 6.
- Pit No. 8.
- Pit farthest west.

Bud Hill prospect.
R. M. Cogburn prospect.
Robert Porter prospect.
Cady prospect.
W. R. Porter prospect.
North Mountain mine (Burns pit).
North Mountain mine (upper tunnel).
North Mountain mine (middle tunnel).
Slatington Mountain prospects (cut farthest east).
Dierks Lumber & Coal Co.'s prospect (three sets of specimens obtained from the two middle cuts).
Sugartree Mountain prospects (cut farthest northwest).
Tellus Davis prospect No. 1.
W. A. Davis prospect No. 1.
Eureka prospect.
Bluff Mountain prospect.

[1] Personal communication.

Leader Mountain prospects:
- Claim No. 12.
- Ore picked up on surface on crest.
- North end of cut on claim No. 14.
- South end of cut on claim No. 14.
- Claim No. 5.

Grant prospect.

ECONOMIC POSSIBILITIES.

The possibilities of manganese mining in west-central Arkansas are ably discussed by Penrose,[1] from whom the following is quoted:

> The aggregate amount of manganese in the region is undoubtedly large, but it is distributed over an extensive area, and in almost all places it is hopelessly scattered through the rock in small nests and seams. If these nests and seams were in sufficient quantities the rock might be crushed and the ore concentrated by washing, but the pockets containing them are too small to permit the expense of machinery. It is a popular idea that the ore will increase in quantity at a depth, but there is absolutely no reason to expect this, as such deposits are just as likely and sometimes even more likely to become poorer at a depth than they are to improve.
>
> From the nature of the deposit it is to be expected that the ore at a depth is, at the very best, no more plentiful than in the surface outcrops of the so-called "lodes"—that is, that it exists as a series of pockets separated by greater or less distances of barren rock. With very few exceptions the pockets of ore seen on the surface can not be worked at a profit, and in the rare cases, where a small profit might be made, the amount would not be enough to pay for sinking through the barren rock that separates the pockets from each other. The intervening thickness of barren rock is much greater than the depth of any one pocket.

The quantity of manganese ore that can be mined at a profit from any one deposit is therefore small, which means that under normal conditions manganese mining will never become one of the chief industries in this region.

Ores from a number of manganese deposits, as shown by the chemical analyses on page 82, contain a sufficiently high percentage of manganese (40 per cent or more) and a sufficiently small percentage of silica (8 per cent or less) for the manufacture of ferromanganese, but most of the ores of which analyses are available exceed the phosphorus limit (0.20 per cent) for this purpose. The prices paid for medium-grade ores used in the metallurgic industries are relatively stable and generally range between $8 and $13.50 a ton,[2] being governed by the content of manganese, phosphorus, and silica. The price has, however, steadily increased since the outbreak of the war in Europe. Manganese ores sold in 1915 for $14.40 to $22.05 a ton,[3] and

[1] Penrose, R. A. F., jr., Manganese—its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, p. 306, 1891.

[2] Harder, E. C., Manganese ores of Russia, India, Brazil, and Chile: Am. Inst. Min. Eng. Bull. 113, pp. 763–764, May, 1916.

[3] Hewett, D. F., U. S. Geol. Survey Mineral Resources, 1915, pt. 1, p. 39, 1916.

in 1916 the maximum price was $32.50.[1] This increase in price has accordingly increased the possibility of the economical recovery of the manganese ores of the area herein described, but some deposits that might now be worked at a profit will not pay to work after the price of ore again becomes normal, which will probably be within a year after the conclusion of peace.

The wad and other low-grade oxides could be used for giving bricks a chocolate color. The pyrolusite, manganite, and psilomelane could be used to produce the spots of some varieties of speckled bricks and mixed with red-burning clay for brown bricks, and with buff-burning clay for gray bricks.

Some of the purer psilomelane and especially the manganite and pyrolusite could be used in chemical industries, in the manufacture of electric batteries, and for other purposes. Psilomelane is hard, however, and is less easily treated than manganite and pyrolusite. Ores required in the manufacture of dry batteries should contain less than 1 per cent of iron, less than 0.05 per cent of copper, nickel, and cobalt, and at least 80 per cent of manganese peroxide,[2] which is the form of the larger part of the manganese in pyrolusite, manganite, and psilomelane. The prices of ores suited for the above-mentioned purposes fluctuate greatly, ranging from $20 to $100 a ton.[3]

MINES AND PROSPECTS.

NELSON MINE.

The Nelson mine is on the northeast slope of a low crescent-shaped ridge that skirts the east end of Nelson Mountain, about 5 miles north-northeast of Glenwood. It was worked from August to December, 1915, by Chester Stevens and yielded 58 long tons of manganese ore, which was hauled in wagons to Glenwood and shipped to Birmingham, Ala., for use in the manufacture of ferromanganese. The workings consist of a northwestward-trending cut 25 feet wide, 50 feet long, 10 to 15 feet deep, and 100 feet above the wagon road at the base of the ridge and two northeastward-trending trenches on the slope above the cut. The strata exposed in the workings and on the crest of the low ridge are massive hard jointed white, somewhat porous novaculite, and belong to the upper division of the Arkansas novaculite, whose structure in this vicinity is that of an eastward-pitching anticline. The mine is on the east end or nose of this anticline. Although the beds in the workings are slightly wrinkled, their general dip is about 40° N. 40° E., and at

[1] Hewett, D. F., U. S. Geol. Survey Press Bulletin 306, January, 1917.
[2] Hewett, D. F., U. S. Geol. Survey Mineral Resources, 1915, pt. 1, p. 32, 1916.
[3] Harder, E. C., op. cit., p. 763.

the southeast end of the cut they are broken by a northeastward-trending fault by which the beds on the southeast side have been dropped a few feet.

The manganese ore consists of hard psilomelane, much of which shows botryoidal and stalactitic structure, and a meager quantity of crystalline manganite, some of which fills the centers of the psilomelane stalactites. It occurs as thin disconnected veins and pockets along joints and bedding planes. A 2-inch vein near the fault is the thickest one observed, but on the dumps there are pieces of ore that indicate the presence of veins at least several inches thick. In fact, veins a foot or so wide are said to have been found in the bottom of the cut, but they were obscured by débris at the time of the examination (April, 1916). Dendrites are common along the numerous cracks in the novaculite and are to be found on most pieces of rock from the cut.

The marketed ore was hand picked and is said to have carried 48.5 per cent of manganese and 1.75 per cent of iron. Ore in some of the discarded rock could be recovered by crushing and jigging, but the quantity is too small to make the installation of machinery for this purpose worth while.

The trenches above the cut are 2 feet wide and 1½ feet deep. The lower one is 40 feet long and shows no manganese oxide. The higher one, which is in line with the lower and is 90 feet long, shows brown iron oxide here and there but no manganese oxide. A few hundred pounds of the iron oxide has been thrown out, and some single pieces weigh about 100 pounds. The novaculite beds in the southwest end of the upper trench are near the base of the upper division of the Arkansas novaculite.

S. A. HANNA PROSPECT.

The prospect on the land belonging to S. A. Hanna is 1 mile south of the village of Caddo Gap, in a narrow gorge half a mile west of the hot springs that issue in the bed and edge of Caddo River. It consists of a northward-trending cut made in 1909 or 1910 on the south side of the gorge 300 feet above Caddo River. The cut is a few feet wide and 20 feet long, and at its south end is about 18 feet deep. The rock blasted out is hard white massive novaculite from a bed near the top of the lower division of the Arkansas novaculite, which here dips 50° N. 45° E. Thin veins of psilomelane and of a much smaller amount of brown iron oxide, both of which may occur in separate veins or together in the same vein or even in a small hand specimen, occupy some of the joints and bedding planes in the novaculite. The thickest vein, which is at the south end of the cut, is from 4 to 15 inches wide and dips 70° S. 50° E. Angular pieces of novaculite make up about one-fourth of this vein, and slickensides show on the hanging wall. Probably 1 ton of psilomelane has been removed from the cut, but no shipments have been made.

FRANK BRUNSON PROSPECT.

The prospect on land belonging to Frank Brunson is on the crest of a low ridge, near the west line of sec. 18, T. 5 S., R. 23 W., about 1 mile north of Rosboro. A little blasting has been done here in the uppermost division of the Arkansas novaculite. The small pit so formed shows irregular nodules and seams of brown iron oxide occurring along joints and bedding planes. A very small amount of manganese oxide is mixed with the iron oxide.

WATKINS-WHITE PROSPECTS.

Three openings were made in May, 1916, by H. L. Watkins and J. B. White on a low ridge 1 mile west of Glenwood. The one farthest east is a cut 8 feet wide, 15 feet long, and 8 feet deep, on the northeast slope of the ridge, about 200 feet above Caddo River. It is in the base of the upper division and the top of the middle division of the Arkansas novaculite, which here dip to the south at angles ranging from 30° to 40°. Seams of wad averaging less than an inch in width were found along bedding planes and joints through a 3-foot thickness of novaculite, but at one place a pocket of wad 3 feet long and 12 inches wide at the widest place was found. The wad is associated with psilomelane and manganite, and most of it is mixed with clay. Thin clay seams in the northeastern part of the cut contain brown iron oxide and a minute quantity of manganese oxide. Dendrites in lacelike forms are common.

A pit 12 feet long east and west, 6 feet deep, and 6 feet wide, is about 700 feet west of the cut just described, on the north slope of the ridge a few feet below its crest. It is in hard yellow massive novaculite in the upper division of the Arkansas novaculite. Oxides of manganese and iron were found in a few seams a fraction of an inch thick and in a pocket 4 feet long with a maximum thickness of 16 inches. Of these oxides massive steel-blue psilomelane, several hundred pounds of which has been placed on the dump, occurs in greatest amount. Some of it has botryoidal surfaces, and some occurs as small stalactite-like rods. Dendrites are abundant.

The third opening is a very small cut on the south slope of the ridge about 100 feet below its crest, southeast of the pit just described. It is in the upper division of the Arkansas novaculite, which is here a soft, porous buff-colored stone. Veins of psilomelane, usually less than an inch wide, ramify through the novaculite but are most numerous in a zone a foot wide striking across the bedding and dipping 90°. In some places brown iron oxide is associated with the psilomelane.

Commercial quantities of manganese ore have not been exposed in any of these three openings.

FIELDS PROSPECT.

The Fields prospect is a pit 6 feet wide, 8 feet long, and 3 to 4 feet deep, on the southwest slope of a low northwestward-trending ridge at the east end of Reynolds Mountain, in the SW. ¼ SE. ¼ sec. 32, T. 4 S., R. 24 W. It was made in June, 1916, by Messrs. Wright & Horn on land owned by R. C. Fields. The upper division of the Arkansas novaculite is exposed in the pit and forms the ridge at this locality. Pockets of brown iron oxide, some of which are several inches thick, were found along fissures in the broken novaculite, and in places they contain a small percentage of manganese.

REYNOLDS MOUNTAIN PROSPECTS.

A very small pit that in August, 1916, was being worked by Babbit & Co. is on the crest of Reynolds Mountain, in the SW. ¼ SW. ¼ sec. 6, T. 5 S., R. 24 W. Veins of psilomelane, manganite, and brown iron oxide attaining a thickness of several inches show in the massive novaculite in the pit and for a distance of 100 to 125 feet west of it. The iron oxide is the most abundant. Numerous needle-like stalactites of it, some 4 inches long, were found in a vug 2 feet wide, 8 inches high, and 3 or 4 feet long. The novaculite at this locality is in the basal division of the Arkansas novaculite and dips 40° or 50° S.

Some prospectors have recently broken off pieces of brown iron oxide from the face of a bluff, 50 feet high on the south side of a small stream at the south base of Reynolds Mountain, in the eastern part of sec. 1, T. 5 S., R. 25 W. This oxide occurs as veins and pockets in the upper division of the Arkansas novaculite. One pocket is 4 feet long and 3 or 4 feet thick. No manganese oxide was seen here by the writer.

FAGAN MINE.

The Fagan mine is on the head of Cowlick Branch, in sec. 9, T. 5 S., R. 25 W. The workings, which are near the level of the branch where it flows through a water gap, consist of a north-south, badly caved cut 60 feet long on the west side of the branch and a pit a few feet east of the branch. The cut was made several years ago. Some work was done in the pit in 1916 by Will Fagan and some was done later in the same year by Edgar & Co., but work by this company was discontinued on the day of the writer's examination (Aug. 8, 1916).

The cut is in vertical beds near the base of the Arkansas novaculite, but it has caved so much that no ore is visible. The pit is 12 feet square and 14 feet deep, and the bottom is 4 or 5 feet below the bed of the branch. The novaculite into which it has been sunk is only about 20 feet south of the contact of the Arkansas novaculite with the Missouri Mountain slate, which is exposed in the branch to the north, and the rock is so open from shattering that frequent vigorous bailing was necessary to keep the water out. A northeastward-trending zone of this shattered novaculite 10 feet wide and containing in places thin veins of crystalline manganite has been uncovered for 30 feet in the northwest half of the pit and in a trench leading from it. Associated with the manganite is a small quantity of stalactitic and botryoidal brown iron oxide. The manganite makes up only a small percentage of the rock mass, and to recover it would require crushing and jigging, which probably would not be profitable.

BEAR MOUNTAIN PROSPECT.

A cut made on the Rose placer-mining claim in May, 1916, by the Mississippi Valley Iron Co., is on the west end of Bear Mountain, 9 miles in a straight line west of Glenwood, and is 25 feet above Self Creek, which here flows southward through a gap at the west end of the mountain. The cut is 14 feet square and on the east side shows a 10-foot vertical face of massive shattered novaculite that has been bent into an anticline whose axis trends eastward. Slickensides were observed in places. Three lenses of manganese oxide, the largest 6 inches wide, lie along bedding planes (fig. 5), and at two places manganese and iron oxides occur in thin films ramifying through the novaculite and penetrate the novaculite away from the films. A few hundred pounds of manganese oxide consisting of psilomelane banded with a very small amount of manganite has been piled on the dump.

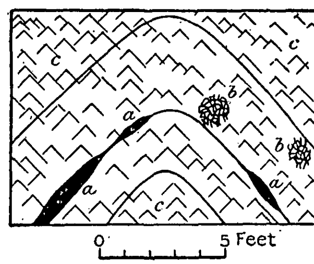

FIGURE 5.—Section of east face of Bear Mountain prospect, Pike County, Ark., showing veins (*a*) of manganese ore along the bedding planes and a network of films (*b*) of iron and manganese oxides at the crest of an anticline in the novaculite (*c*).

BRUSHY MOUNTAIN PROSPECTS.

Four cuts on Brushy Mountain, in the S. ½ SW. ¼ SW. ¼ sec. 5, T. 5 S., R. 25 W., were made in May, 1916, by the Mississippi Valley Iron Co. The principal one is 45 feet long, from 7 to 14 feet wide, and 8 feet deep at the deepest place and is on the south slope of the mountain 40 feet above Self Creek. It is in massive novaculite dipping 25° or 30° S., on the south side of a small westward-plunging anticline. A bed of conglomerate overlying the massive lower division of the Arkansas novaculite is exposed at the north end of the cut. A zone of novaculite breccia, from 1 foot to 3½ feet thick is exposed on the west side of the cut and on part of the east side. The novaculite fragments are cemented together by a much less quantity of hard steel-blue psilomelane, which in places occurs in stalactite-like rods and in places has botryoidal surfaces. Some pockets of psilomelane are found in this zone, but the largest ones are only a few inches wide, and few exceed a foot in length. Below this zone there are coatings of psilomelane along some of the bedding planes and stains of it along some cracks in the novaculite. Dendrites are common. Several hundred pounds of psilomelane free of rock has been placed on the dump.

A second cut 18 feet long from east to west, 2 to 3 feet deep, and 2 to 4 feet wide is on the north bank of Self Creek 75 feet southwest of the cut just described. It is in massive crushed novaculite dipping to the southwest and west, on the southwest slope of the small anticline mentioned in the preceding paragraph. A small quantity of psilomelane cements together fragments of novaculite or occurs as veins an inch or less thick.

A third cut, 10 feet wide, 15 feet long, and 5 feet deep on the upper side is 150 west of the first one described and at about the same height above Self Creek as that cut. The highest bed exposed in the cut is a flat-lying conglomerate 3 feet thick, which is the same bed as the one exposed at the north end of the first-described cut. Brown iron oxide is found as veins along joints in this conglomerate and as cementing material in a bed of breccia 2 to 3 feet thick below the conglomerate. A minute quantity of manganese oxide is mixed with the iron oxide, and some dendrites are present. The prospect is on the nose or west end of the small westward-plunging anticline.

The fourth cut is 20 feet long from north to south, 6 feet wide, and 1 to 2 feet deep and is 50 or 60 feet northwest of the third one. It is northwest of the westward-plunging anticline in this vicinity and merely lays bare the upper surface of the above-mentioned conglomerate, which dips the same as the slope—that is, 25° S. No manganese oxide was found here.

It is obvious from the above descriptions of the four openings that manganese oxide occurs only in small quantity at this locality and will probably not be found to increase in quantity with increasing depth.

W. T. WHITE PROSPECT.

A pit was made in June, 1916, by W. T. White well up on the south slope of Warm Spring Mountain, in the eastern part of sec. 11, T. 5 S., R. 26 W. It is L shaped, with each arm 8 feet long, and is 8 feet deep in the deepest part. The novaculite exposed near by dips 55° N. 10° W. and is near the top of the lower division of the Arkansas novaculite. A mixture of brown and red oxides of iron and of novaculite fragments embedded in clay is exposed in the pit and for 10 feet west of it. At only one place in the pit do these oxides look as if they might contain a small percentage of manganese, and at another place they contain a minute quantity of brown altered dufrenite. Although a few hundred pounds of iron oxide has been removed from the pit, it does not occur in sufficient quantity to be mined with profit.

N. F. WHITE PROSPECT.

Three very small openings on the mountain side 400 or 500 feet southwest of the W. T. White pit were made in June, 1916, by N. F. White, in the massive novaculite in the upper division of the Arkansas novaculite, whose beds here dip 90°. A few seams of psilomelane and manganite an inch or less thick occur along bedding planes and joints, and some manganese oxide penetrates the novaculite for a fraction of an inch.

RATTLESNAKE PROSPECT.

The Rattlesnake prospect is on Redland Mountain, on the west side of sec. 9, T. 5 S., R. 26 W. It consists of a cut 85 feet long, from 2 to 6 feet deep, and extending from north to south across the crest. Massive novaculite dipping 60° S. and belonging in the lower division of the Arkansas novaculite is exposed in the south end of the cut for a distance of 35 feet. A few widely separated veins of steel-blue psilomelane and brown iron oxide, which occur together, even in the same part of a vein, were found in the novaculite. These minerals penetrate the novaculite to a depth of a fraction of an inch. The largest vein, which is from 2 to 9 inches wide, occupies a joint dipping to the north and contains some pieces of novaculite.

Green shale and thin-bedded flint were penetrated for a distance of 30 feet just north of the massive novaculite, from which they are separated by a foot of manganiferous and ferruginous slate. The rest of the cut is in massive novaculite that shows no ore.

The work at this locality was done in May, 1916, by the Mississippi Valley Iron Co.

STILL MINE.

The Still mine is on the southwest slope of Hogpen Mountain, a peak in the northwest corner of T. 5 S., R. 26 W. It receives its name from the ruins of a "moonshine" still on Hogpen Branch, which flows southward along the west base of the mountain. Work was being done here at the time of the examination (Aug. 6, 1916) by the Mississippi Valley Iron Co. The workings consist of a tunnel and a T-shaped cut 75 feet above Hogpen Branch. (See fig. 6.)

The north-south part of the cut is in thin-bedded vertical novaculite, between whose layers are seams of clay. These beds are at the base of the middle division of the Arkansas novaculite and contain a very small quantity of brown iron oxide and a short vein of ferruginous manganese. The east-west part of the cut, about 25 feet deep, and the tunnel are in massive beds of hard, shattered novaculite, striking east and dipping almost 90°. These beds are at the top of the lower division of the Arkansas novaculite and show irregular veins and pockets of ore mixed with clay. Some of the veins and pockets are as much as 6 inches thick and a few 18 inches, but they make up only a small portion of the rock mass. Most of the ore is wad and is free of rock, but some is psilomelane and a little is manganite, which is usually disseminated through the psilomelane. Dendrites are common along cracks in the novaculite.

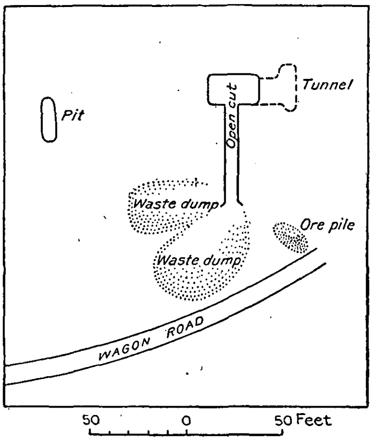

FIGURE 6.—Plan of Still mine on Hogpen Mountain, Pike County, Ark.

A pit to the west is 50 feet above Hogpen Branch and was partly filled with water at the time of visit. The south end is in thin-bedded novaculite, and the north end in massive novaculite, which belong to the middle and lower divisions of the Arkansas novaculite, respectively. The beds in the two divisions strike east, dip 90°, and are separated by a 3-foot bed of conglomerate composed of round and subangular pebbles of novaculite in a sandy and dense flinty matrix. Films of iron and manganese oxides occur through the novaculite, but no veins are visible.

About 37 long tons of ore as taken from the mine without washing or other preparation was hauled to Glenwood, 20 miles away, and then shipped to the company's iron furnaces in St. Louis, where it was used to raise the manganese in pig iron above 1 per cent. A fews tons of ore, consisting mainly of wad mixed with much clay, still remains on the ore pile. Better transportation over a proposed logging spur to be built within 1¼ miles of the mine was expected within a few months after the writer's visit, but mining at this place has since been discontinued, the reason given being that the results were disappointing both as to the quality and quantity of the ore.[1] Analyses of the ore shipped, given on page 82, show that the phosphorus content is too high and the manganese content too low for use in the manufacture of ferromanganese.

PROSPECT NO. 3.

Prospect No. 3 of the Mississippi Valley Iron Co. is on the south slope of Hogpen Mountain, about 750 feet east of the Still mine and 200 feet higher on the mountain. Work was begun here August 1, 1916, and at the time of examination, five days later, a cut 15 feet long, 3 to 4 feet deep, and 5 to 6 feet wide had been made. Most of the cut was in red clay, but the north end showed some massive novaculite that was penetrated by thin films of manganese oxide. This novaculite, like the massive novaculite in the Still mine, is at the top of the lower division of the Arkansas novaculite. Psilomelane associated with a minor amount of wad and some brown iron oxide was found in red clay for a north-south distance of 7 feet. One boulder, weighing 300 or 400 pounds and said to have been exposed on the surface, thus furnishing a reason for making the cut here, was rolled down the mountain and shipped with the ore from the Still mine. If further work should prove that this manganese-bearing clay maintains a width of 7 feet at depth and for some distance on the surface, this would be a promising prospect.

PROSPECT NO. 2.

Prospect No. 2 of the Mississippi Valley Iron Co. consists of a cut on the south slope of Hogpen Mountain about 120 feet east of prospect No. 3. The work was done in June, 1916. The cut extends 60 feet N. 20° W. into the mountain, and is 25 feet deep at its north end. Its south end is in the middle part of the Arkansas novaculite, and the north end in the lower part, both of which dip 80° or 85° S. The middle part of the formation consists of novaculite, usually in thin layers interbedded with clay. The lower part, which is exposed for 24 feet at the north end and which is separated from the middle part by a conglomerate, consists of nodules, layers, and lenses of jointed novaculite interbedded with much clay. Small pockets and veins of wad mixed with clay ramify through

[1] Letter dated Dec. 6, 1916, from the Mississippi Valley Iron Co.

the whole bed, but they constitute a very small percentage of the bulk of the rock, and none of them exceed a few inches in thickness. A few hundred pounds of wad has been placed on the dump.

RISNER MOUNTAIN PROSPECTS.

Risner Mountain is a short ridge west of Hogpen Mountain, from which it is separated by the gorge through which Hogpen Branch flows. Two north-south cuts were made on it in July, 1916, by the Mississippi Valley Iron Co. One of these, 34 feet long and 4 feet deep, is on the southeast slope about 300 feet above Hogpen Branch, a quarter of a mile southwest of the Still mine. The south end has been blasted in massive novaculite at the top of the Arkansas novaculite, and the north end in thin-bedded novaculite interbedded with clay. Iron oxide in thin films is the only mineral observed in the cut, but several pounds of brown iron oxide and a few pieces of novaculite, to which a little psilomelane adheres, were seen on the dump. The iron and manganese oxides penetrate the novaculite to a depth of half an inch along some of the cracks.

The other cut, known as prospect No. 4, is on the south slope of the mountain, northwest of the one just described and about 100 feet higher. It is 42 feet long and at its north end is 20 or 25 feet deep. Its south end is in conglomerate and thin-bedded novaculite. This conglomerate is the same bed as that found in the pit near the Still mine and in prospect No. 2, on Hogpen Mountain. The rest of the cut is in massive jointed novaculite dipping 65° S., some of which occurs as nodules and lenses. A few veins of wad, brown iron oxide, and ferruginous manganese oxide mixed with much clay were found near the south end of the cut north of the conglomerate. They are thickest through a north-south distance of 7 feet, but even there they are only a few inches thick and constitute only a small part of the rock mass. Farther north are thinner veins of manganese oxide associated with red and yellow clay along bedding planes and joints. Dendrites are abundant along cracks in the novaculite. Only a small quantity of manganese oxide was found in the cut, and all was thrown away with the waste except 100 or 200 pounds that was placed in a pile. In this pile are pieces of iron oxide and psilomelane containing manganite. The manganese minerals in this cut are at the same horizon as in the Still mine and in prospects Nos. 2 and 3, namely, at the top of the massive novaculite that makes up the lower division of the Arkansas novaculite.

R. M. COGBURN PROSPECT.

The prospect of R. M. Cogburn is on the crest of Brooks Mountain, in the eastern part of sec. 3, T. 5 S., R. 26 W. The only work done here has been the overturning of a few boulders of novaculite by means of crowbars. Veins and pockets of psilomelane a few inches thick show on these boulders.

A little prospecting is said to have been done at other places on Brooks Mountain, but the writer did not examine the openings.

BUD HILL PROSPECT.

An exposure of "bog ore" in which a little digging has been done is on Bud Hill's land, in the north-south wagon road half a mile southwest of Fancy Hill post office. The deposit crops out for about 150 feet along the road and overlies thin-bedded novaculite in the middle division of the Arkansas novaculite, some pieces of which are embedded in it. The deposit probably does not exceed a few feet in thickness. Iron oxide is being deposited by two small springs that issue from the "bog ore," which is itself probably a spring deposit.

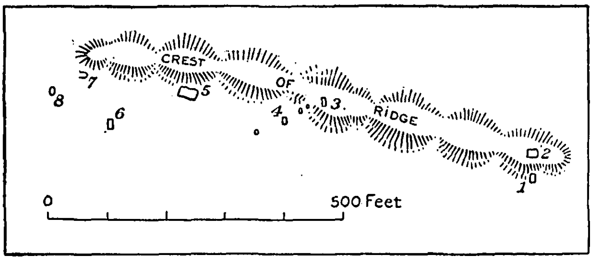

FIGURE 7.—Sketch map showing the location of most of the Janes prospects, Montgomery County, Ark. Numbers refer to openings described in the text.

JANES PROSPECTS.

A number of openings were made from February to June, 1916, by M. A. Janes on a low ridge in the eastern part of sec. 19, T. 5 S., R. 25 W. (See fig. 7.) The upper division of the Arkansas novaculite, here about 50 feet thick, forms the crest of the ridge. It consists of massive jointed novaculite, which strikes parallel with the direction of the ridge and dips at angles exceeding 65°. The openings are described and numbered in the order in which they were examined, beginning at the east.

A 5½-foot bed of novaculite in the north end of pit No. 1, which is 16 feet long, 9 to 10 feet wide, and 2 to 6 feet deep, contains irregular veins of manganese oxide that in places reach a maximum thickness of 12 inches, but if they were all put together their average aggregate thickness across the pit would not exceed 10 inches. Two thin veins, one of which is 3 inches thick, occur farther south. Dendrites and other manganese stains along joints are common. The other manganese minerals are wad, manganite, and psilomelane, the last two predominating.

Pit No. 2, 12 feet wide, 13 feet long, and 2 to 3 feet deep, reveals two veins of mixed manganese and iron oxides parallel with the bedding. The northern vein is from 12 to 18 inches wide; the southern one is thinner. About 2 tons of these oxides has been removed from the pit and placed on the dump.

Pit No. 3, 10 feet long, 3 to 4 feet wide, and 2 to 3½ feet deep, shows a small quantity of psilomelane which on the east side occurs in a 19-inch vein of clay between layers of novaculite and which on the west side occurs as two veins, each 2 inches wide, and as fragments in surface clay. The psilomelane is comparatively free of iron oxide. About half a ton of it has been removed from the pit.

Pit No. 4, 6 feet long, 4 feet wide, and 3 feet deep, shows veins and pockets of psilomelane 1 foot in maximum width, in which there are pieces of novaculite. The psilomelane placed on the dump weighs about 500 pounds. One piece alone weighs about 150 pounds. A very small pit 50 feet southwest of pit No. 4 has yielded 100 pounds of psilomelane and manganite, and two small ones about midway between pits Nos. 3 and 4 have yielded 25 or 30 pounds of psilomelane.

A group of adjoining pits and cuts (prospect No. 5), all within an area 30 feet long from east to west and 14 feet wide, reveals three manganese veins. One of these is from 3 to 6 inches wide; another, which is exposed for a distance of 6 feet, attains a maximum width of 15 inches; and the third, which is exposed for a distance of 16 feet, is 20 to 22 inches wide and at the east end of the exposure contains some fragments of novaculite. The three veins are composed almost entirely of psilomelane; the rest is brown iron oxide and manganite. Probably 3 tons of these oxides lie on the dump.

The largest visible vein of manganese in pit No. 6, which is 12 feet long, 6 feet wide, and 2 to 5 feet deep, is 2 inches wide, but several hundred pounds of psilomelane lying on the dump is said to have been removed from surface clay. A pocket of manganese oxide 8 inches wide is exposed 12 to 15 feet northeast of pit No. 6, and a 14-inch vein of brown iron oxide is exposed about 20 feet west of pit No. 5.

A few blasts at prospect No. 7 have been made on an outcrop of brown iron oxide mixed with some psilomelane. These minerals occur in a vein that ranges from 3 inches to over 3 feet in width and is exposed for an east-west distance of 10 feet.

Pit No. 8, 6 feet long, 2½ feet wide, and 1 to 3 feet deep, shows a 20-inch vein of soft and hard manganese oxides containing some red clay and a few fragments of novaculite. A boulder of solid psilomelane that protruded above the surface 20 feet west of this pit has been dug up. It weighs about 175 pounds.

Parts of the deposit just described might possibly be worked on a small scale.

Another pit made in July, 1916, by Mr. Janes is well up the south slope of Caddo Mountain, near the west line of sec. 19, T. 5 S., R.

25 W. It is 8 feet long, 2 to 3 feet wide, and at the north end 3 feet deep. It is in massive novaculite at the very top of the lower division of the Arkansas novaculite, which here dips 85° N. Small pieces of psilomelane were found in surface clay, and outcrops of this mineral were observed on protruding ledges of novaculite for a distance of fully 200 feet west of the pit.

CADDO MOUNTAIN PROSPECT.

A cut 15 feet long, 4 feet wide, and 1 to 3 feet deep was made a number of years ago about 450 feet east of the forest ranger's tower that is on the highest point of Caddo Mountain, northeast of Fancy Hill post office. It is just south of the trail leading east along the crest of the mountain. Some of the novaculite boulders that were thrown out of the cut are brecciated and the fragments are cemented together with narrow veins of psilomelane.

A number of openings are said to have been made along the crest west of the ranger's tower, but they were not visited.

ROBERT PORTER PROSPECT.

The Robert Porter prospect is on the north slope near the crest of a hill at the north base of Fancy Hill Mountain, in the northern part of sec. 28, T. 4 S., R. 26 W., and is about 200 feet above South Fork. The workings consist of two cuts made in the spring and summer of 1916. The lower cut is 9 feet long from north to south, 3 to 4 feet wide, and 1 to 1½ feet deep, and the other, which is on the slope just above it, is 20 feet long, 3 to 7 feet wide, and 1 to 4 feet deep. The massive beds of the upper division of the Arkansas novaculite form the crest of this hill and dip 60° N.

The manganese deposit revealed in the cuts and in exposures on either side consists largely of boulders of iron and manganese oxides lying on the surface. These boulders appear to have been once a part of a surficial layer from a few inches to 18 inches thick which was probably deposited from an extinct spring that issued at this locality. They are found within a north-south distance of 30 feet, and some were seen along the slope for a distance of 100 feet west of the cuts, but their size decreases toward the west.

A 4-foot vein of ore occurs in the novaculite at one place in the upper cut, and much thinner veins were seen in near-by outcrops of the novaculite.

The deposit is well described, as follows, by Penrose:[1]

> The manganese ore is a hard, black variety, and the iron is in the form of a bright vitreous brown ore, often having a honeycombed structure. The two are intimately mixed together, the iron being much the more plentiful;

[1] Penrose, R. A. F., jr., op. cit., pp. 349–350.

and sometimes nodules of manganese, from a fraction of an inch to 1 inch in diameter, are cemented in a matrix of iron ore. Sometimes the ores are comparatively free from any admixture of rock, and at other times they form the cement of a novaculite breccia. * * *

The deposit represents a pocket of ore much larger than is usually seen in the gray novaculite, but, as shown by the accompanying analysis, it is of poor quality for use in the manufacture of spiegeleisen and ferromanganese on account of its high percentage of phosphorus; and its association with iron renders it undesirable for many chemical purposes. Its high percentage of peroxide of manganese, however, would for some purposes counterbalance the latter disadvantage.

Analysis of manganese ore from Fancy Hill Mountain, Montgomery County.

[R. N. Brackett, analyst.]

Manganese	48.02
Iron	5.55
Silica	.52
Phosphorus	.31

Manganese peroxide, 71.73.

CADY PROSPECT.

The Cady prospect is about 150 feet above South Fork, on the north slope of a low hill, about a quarter of a mile east of the Robert Porter prospect. It consists of two cuts made in the spring and summer of 1916. The hill is formed by the massive beds of the upper division of the Arkansas novaculite, which here dips 60° N. The larger cut, 11 feet long, 8 feet wide, and 5 feet deep on the south side, contains a pocket of clay that, although partly removed, appears to be 5 feet long, 3½ feet wide, and 3 feet thick. Botryoidal and stalactitic psilomelane and a smaller quantity of manganite are embedded in the clay. Probably half a ton of these manganese minerals has been taken out and placed on the dump.

A smaller cut, 3 feet long, 2½ feet wide, and 1½ feet deep, is 25 feet west of the one just described. It is in surface clay and rock débris and has yielded 500 pounds or more of psilomelane, one piece of which weighs nearly 150 pounds.

W. R. PORTER PROSPECT.

The prospect of W. R. Porter is on the south slope of Bald Mountain, about 400 feet above its base, in sec. 17, T. 4 S., R. 26 W. It consists of a small cut made in June, 1916, in the top of the lower division of the Arkansas novaculite, which here dips 50° S. Stains, thin veins, and pockets of manganese and iron oxides were found in the novaculite and in clay, and a few veins show on large boulders of novaculite, of which some are near their parent ledge, but others have rolled down the mountain side. A vein of hard, compact psilomelane is exposed on a ledge of novaculite 125 feet west of the cut. The vein in the lower part of the exposure, where it passes beneath surface material, is 16 inches thick, but 4 feet away in the upper part of the exposure it is only a fraction of an inch thick.

NORTH MOUNTAIN MINE.

North Mountain is a local name given to a broken novaculite ridge in the northern part of T. 4 S., R. 27 W., near the headwaters of Little Missouri River. It is a part of Statehouse Mountain, shown on the Caddo Gap topographic map.

A manganese deposit on the south slope of North Mountain is being extensively explored by Edgar & Co., who have erected an air-compressing plant at the mouth of the lower tunnel and a sawmill at the base of the mountain, and have been working here since early in May, 1916. (See fig. 8.) The first opening at this locality consisted of a pit blasted out almost 30 years ago by a Mr. Burns, who shipped 4 tons of ore.

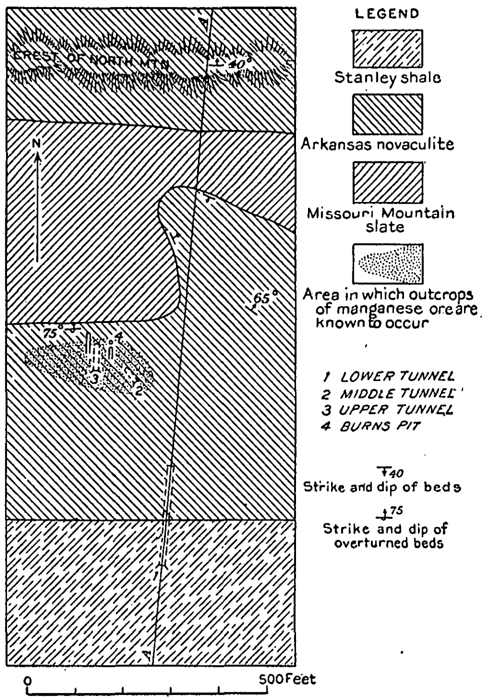

FIGURE 8.—Sketch geologic map showing workings on south slope of North Mountain, Montgomery County, Ark.

The deposit occurs in the lower division of the Arkansas novaculite, and although it is on the south side of a closely compressed easterly anticline, the structure is complicated by a minor anticline just northeast of the deposit. (See figs. 8 and 9.) The crest of the mountain north of the workings is 780 feet above the wagon road at the south base of the mountain. The lower tunnel, which is 10 feet wide and 7 feet high, is 250 feet above this road and was about 200 feet long at the time of the writer's examination (Aug. 4, 1916). It passes through the base of the Stanley shale and the upper division of the Arkansas novaculite and at a distance of 200 feet back into the mountain is in the middle division of the formation, which consists of hard layers of novaculite and black shale. This tunnel is being driven into the mountain to determine the downward extent of the exposed manganese deposit. The only manganese found before the examination consists of thin films in the upper division of the novaculite, but a recent communication[1] states that an 8-foot vein of solid manganese was found about 615 feet from the mouth of the tunnel. Native copper is also reported to have been found at places in this tunnel. Specimens sent to the writer by R. Lowery, of Albert, Ark., consist of broken pieces of novaculite and quartz cemented together by films of chalcedony in which are small particles of native copper. The chalcedony is stained bluish green by a minute quantity of chrysocolla, a copper silicate combined with some water.

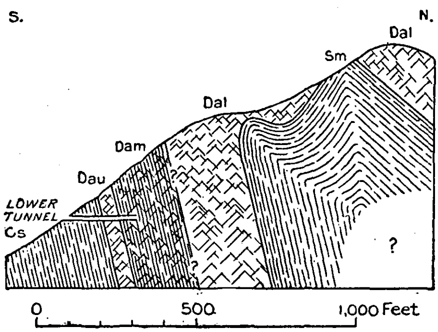

FIGURE 9.—Section along line A–A, figure 8, on south slope of North Mountain, Montgomery County, Ark. Cs, Stanley shale; Dau, upper division of Arkansas novaculite; Dam, middle division of Arkansas novaculite; Dal, lower division of Arkansas novaculite; Sm. Missouri Mountain slate.

The middle tunnel is 166 feet above the lower, or 416 feet above the base of the mountain, and at the time of visit was 35 feet long. The novaculite penetrated by it is massive and very hard, is much shattered, shows some slickensides, and belongs to the lower division of the formation. A vein of manganese oxide 2 to 6 inches wide shows in a joint on the northeast side of the tunnel and about halfway back. Another vein 4 to 15 inches wide is revealed on the southwest side near the portal but does not appear on the northeast side. Besides these two veins some thin films and veins an inch or so thick were observed.

The upper tunnel is 50 feet above the middle tunnel, or 466 feet above the base of the mountain and was 50 feet long at the time of visit. It penetrates massive shattered, very hard novaculite like that in the middle tunnel. Manganese ore mixed with some clay occupies narrow fissures and spaces between fragments of novaculite through a distance of 14 feet at the face of the tunnel. Practically all the ore on the dump contains fragments of novaculite, but pieces of solid ore weighing several pounds were seen.

A cut that is 45 feet long and 10 feet west of the upper tunnel reveals a zone of breccia ore which is apparently the same as that found in the back of this tunnel. The zone in the vertical exposure of 5 feet on the west side of the cut is $2\frac{1}{2}$ feet wide at the top and $3\frac{3}{4}$ feet wide at the bottom; it is also present on the east side, but the

[1] Letter dated Dec. 6, 1916, from Chester Stevens, formerly of Edgar & Co.

dimensions are different. A lens of breccia ore 10 feet long and 8 inches thick was found at another place. The manganese ore in this cut cements novaculite fragments together, but it does not fill the entire space between the fragments. The north end of this cut is 20 feet south of the contact of the Arkansas novaculite with the Missouri Mountain slate, and the ore farthest north in the cut is 35 feet south of this contact.

A shallow cut 2 to 5 feet deep and a small pit at its north end are 20 feet east of the upper tunnel and show manganese ore for a north-south distance of 30 feet. The deposit is an eastward continuation of the same zone as that found in the upper tunnel and in the cut to the west. The pit is the one that was blasted out almost 30 years ago by Mr. Burns. It was visited by Penrose,[1] who describes the ore as follows:

> The ore is a hard glossy black variety and usually forms the cement of a breccia of angular novaculite fragments from a fraction of an inch to 4 or 5 feet in diameter. The ore forms from an eighth to less than a quarter of the mass. In spots, however, there are comparatively pure bodies of it, and a horizontal pocket of such ore about 2 feet wide runs across the face of the pit. It contains no rock, but a small lenticular layer of clay a few inches thick is included in it. Such masses of pure ore are rare and of limited extent. Figure 10 represents the face of the opening and illustrates the occurrence of the ore.
>
> The mass of novaculite in the center is surrounded by smaller pieces cemented by manganese ore and represents simply an exceptionally large component fragment of the breccia. It is noticeable that the angles of almost any two adjacent fragments of novaculite would fit into each other if the separating layer of manganese was removed, showing that the breccia has been formed by the breaking of the rock in place and not by an indiscriminate mixing of rock fragments.

The ore-bearing breccia is largely obscured by loose material, but it was not found in rock exposures east of the pit and cut east of the upper tunnel or west of the cut west of this tunnel. However, seams of manganese oxide a few inches thick were observed in outcrops of massive novaculite as far as 50 feet southwest and 150 feet west of the mouth of the upper tunnel and 20 feet east of the mouth of the middle tunnel.

The ore consists of hard steel-blue psilomelane showing in places a banded structure and in places a botryoidal surface. It is associated with a small quantity of wad, and some of it contains minute quantities of manganite. Some of the psilomelane occurs in layers alternating with wad. Analyses of psilomelane from this locality are given on pages 74 and 82.

The deposit just described represents a local accumulation of manganese in the ordinarily compact novaculite, after open spaces had

[1] Penrose, R. A. F., jr., op. cit., p. 352.

been formed in it by the processes of brecciation and folding. The proximity of the deposit to the nose of the small anticline near by suggests that the brecciation was caused by crushing forces accompanying the formation of the anticline. The reported discovery of an 8-foot vein of solid manganese ore in the lower tunnel 216 feet below the upper tunnel, which penetrates the exposed ore body, may mean that the exposed ore body continues down to the lower tunnel, but the discovery does not necessarily prove this to be so. The 8-foot vein may in fact turn out to be merely a pocket separated from the exposed ore body by an intervening mass of novaculite.

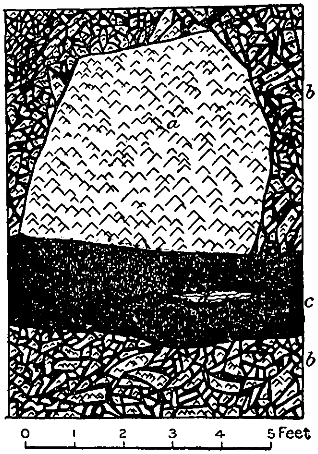

FIGURE 10.—Section in a pit on North Mountain, Montgomery County, Ark., showing a manganiferous breccia in the Arkansas novaculite. (After Penrose.) *a*, Novaculite fragment; *b*, breccia of novaculite fragments in a cement of manganese ore; *c*, pocket of manganese ore; *d*, clay.

The writer agrees with the following statement made by Penrose:[1] "The deposit is limited. Some manganese could doubtless be taken out at a profit, but the deposit would soon run into ore in quantities too small to work."

The ore at this locality is so intimately mixed with fragments of novaculite and adheres so tightly to the novaculite that only a small proportion of the mined ore could be hand picked; the rest would require treatment in a concentrating plant.

CROOKED CREEK.

Penrose[2] describes as follows some pits near Crooked Creek:

Crooked Creek runs west through the northern tier of sections of 4 S., 27 W., and then turns abruptly to the southeast, flowing thence into the Little Missouri River in the same township. It forms one of the main forks of the Little Missouri River in this region of the headwaters of that stream, and its valley is bordered by novaculite ridges. Several small pits have been sunk on the ridges on the outcrop of the manganese and iron bearing stratum.

On the top of the more southerly of the two novaculite ridges immediately south of the creek, probably in sec. 10, a small pit has been sunk on the gray novaculite, showing a hard black manganese ore, in seams rarely over a quarter of an inch in thickness and generally thinner, penetrating the rock in all directions. The ore is frequently stained with iron, and often small masses of manganese ore inclose kernels of brown hematite.

About a mile east of this exposure, on the south slope of the same mountain, in the gray novaculite and near its contact with the shale, a small prospect pit has been sunk on iron ore. The ore is found in the rock in small seams and

[1] Penrose, R. A. F., jr., op. cit., p. 353.
[2] Idem, p. 351.

pockets from 1 to 4 inches in thickness. It is frequently fibrous, porous, or stalactitic and very often has a brilliantly iridescent surface showing glossy green, blue, and pink colors. It decomposes on a weathered surface into a brown earthy ore. The ore on Crooked Creek has nowhere been seen in workable quantities.

SLATINGTON MOUNTAIN PROSPECTS.

Some manganese deposits on the south slope of Slatington Mountain, in the northwestern part of T. 4 S., R. 27 W., were prospected in June, 1916, by Edgar & Co. This mountain is one of the group known as the Missouri Mountains, and the prospecting was done about a mile north of Round Mountain.

A north-south cut 2 to 3 feet deep, several feet wide, and 45 feet long, was made along the bed and side of a southward-flowing branch to explore a deposit of ferruginous bog manganese which cements together fragments of novaculite and shale. Where the deposit is revealed in the cut—for about 25 feet along the east side of the branch—it is 6 feet wide, and at one place where the cut went through the deposit it is 20 inches thick and underlain by interbedded shale and novaculite. How far the deposit extends west of the stream is not known, but it was seen at places for a distance of 150 feet downstream and about the same distance upstream. The branch water running over this "bog ore" is now depositing iron oxide.

On the south slope of the mountain, about 250 feet north of the cut just described, is a pit 6 feet wide, 7 feet long, and 3 feet deep. A surficial deposit of iron oxide containing a small quantity of manganese is exposed in the pit and for several feet on each side, and one outcrop of the deposit was seen 85 feet east of the pit. The deposit is 3 feet thick at the pit and overlies shale and thin-bedded novaculite.

A second cut in this vicinity is about 300 feet east of the one in the branch, on a slope about 100 feet above the branch. It is 5 to 8 feet wide and 3 to 6 feet deep, and extends 25 feet parallel with the strike of the novaculite, N. 70° E. The novaculite, which has been blasted out to make the cut, is massive, light colored, and hard, is in the upper division of the formation, and dips 35° S. 20° E. Two parallel veins of iron and manganese oxides 2 feet apart were found here between the beds of novaculite. The upper vein ranges from a fraction of an inch to 4½ inches in thickness and consists of brown iron oxide, ferruginous manganese oxide, manganese oxide, and fragments of novaculite. The lower vein is from a feather edge to 12 inches thick and branches upward into two veins, each of which is an inch or two thick. It is composed mainly of brown iron oxide, with which a little manganese oxide is mixed. The manganese minerals in this cut are hard steel-blue massive psilomelane and manganite, the latter in small quantity.

MISSOURI MOUNTAIN PROSPECT.

A shallow north-south cut 13 feet long and 3 to 5 feet wide was blasted out on the north slope near the summit of Missouri Mountain, in sec. 31, T. 3 S., R. 27 W., in the spring of 1916, by J. T. Smith, who has since sold his claim to Edgar & Co. The rock blasted out is hard, massive, crushed novaculite belonging to the lower division of the Arkansas novaculite. It contains some irregular veins and pockets of brown iron oxide and a little psilomelane along joints; the largest vein is 3½ inches wide. These two minerals occur in separate veins, in the same part of a single vein, or in different parts of the same vein, and they are mixed with a small quantity of dufrenite and thin films of colorless opal. In places iron oxide has penetrated the novaculite to a depth of 1 inch away from the joints.

DIERKS LUMBER & COAL CO.'S PROSPECT.

A manganese deposit in sec. 16, T. 4 S., R. 27 W., just east of the mining camp of Edgar & Co., was prospected in the spring of 1916 by the Dierks Lumber & Coal Co., which owns the entire section. The workings consist of four cuts on a low terrace at the edge of a stream flat that stands 10 feet above Little Missouri River. (See fig. 11.) They penetrate a bed of terrace gravel ranging from a few inches to 8 feet in thickness; three of them penetrate also both the Stanley shale and the Arkansas novaculite, and the fourth only the novaculite.

The novaculite penetrated by the workings is mostly massive, light colored, soft, and much jointed, but some of it is hard. It strikes S. 80° E. and in some places dips 80° N. and in others 80° S. The massive bed is 50 feet thick and is the upper division of the Arkansas novaculite. The middle and lower divisions of the formation are exposed farther south in Little Missouri River and on Sugartree Mountain. (See fig. 3, p. 76.)

The cut farthest west is from 5 to 6 feet wide, 3 to 8 feet deep, and 43 feet long. The manganese oxide found here consists of a few short veins less than 1 inch wide in the novaculite.

The next cut to the east is 3 to 15 feet deep and 50 feet long. A pocket of wad 2 feet wide and 4 to 5 feet long shows on the west side of the north end of the cut. Farther south on the west side there is a seam of wad 6 inches wide along the bedding, a pocket of ore 6 inches wide and 18 inches long, and a vein 6 to 10 inches wide that follows the bedding and shows on both sides of the cut. All these deposits are in the novaculite, and there are also numerous films and much thinner veins of wad in the novaculite and the adjacent layers of the Stanley shale. The wad is mixed with some red clay, from which it would be separated with difficulty.

The third cut to the east contains at its south end a pit 7 feet wide, 11 feet long, and 12 feet deep. A vein of ore from 8 to 24 inches wide is exposed in the northeast corner of the pit, several seams and pockets ranging from a fraction of an inch to 14 inches in thickness show on the east side, and one in the southeast corner is 2 feet thick. A vein of ore from 12 to 17 inches wide and three or four small pockets from 2 to 4 feet long and at most 12 inches thick have been found on the west side of the pit. All these pockets and veins occur along bedding planes and joints in the novaculite. The ore consists of hard psilomelane, showing in places banded, botryoidal, and stalactitic structure, but intimately mixed or banded with it is a small percentage of manganite. Several tons of ore free from rock have been taken from the pit and piled near by. Analyses of three samples of ore from this pit have been supplied by the Dierks Lumber & Coal Co. and showed 60.54, 55.36, and 45 per cent of manganese. The ore yielding the largest percentage of manganese was solid psilomelane, a more complete analysis of which is given on page 82.

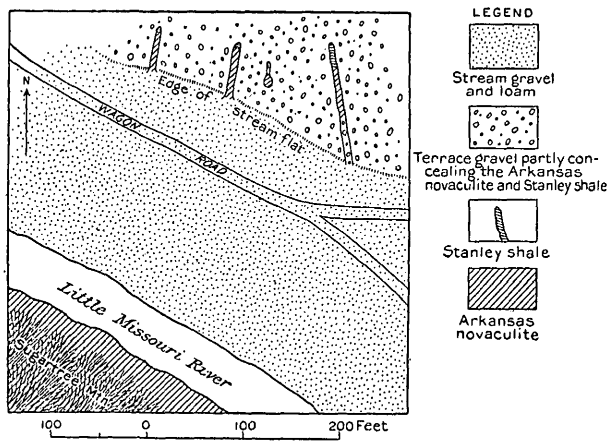

FIGURE 11.—Sketch map of workings on land of Dierks Lumber & Coal Co., Montgomery County, Ark.

The cut farthest east had badly caved at the time of the examination (Aug. 1, 1916). The only manganese visible is a pocket of manganiferous clay 4 feet long and 2 feet wide, and none of it has been placed on the dump.

The deposits exposed in these openings are small and some ore might be mined here at a profit, especially when manganese ores command high prices, as at present.

MORRELL CLAIM.

Penrose[1] describes a manganese deposit on the Morrell claim, in sec. 16, T. 4 S., R. 27 W., "on the east side of the Little Missouri

[1] Penrose, R. A. F., jr., op. cit., p. 353.

River, at a point where that stream cuts through a novaculite ridge." This location accords very closely with that of the workings of the Dierks Lumber & Coal Co. just described, and the pit which he describes as follows may have been at the same place, but if so it has been enlarged or was not seen by the writer.

A small pit sunk near the water level shows a hard, massive steel-blue manganese ore, often in stalactitic form. The ore is associated with black or brown glossy iron ore, and together they form a pocket from 1 to 3 feet in width in the novaculite. The ore frequently contains pockets of red clay.

SUGARTREE MOUNTAIN PROSPECTS.

On the north slope of Sugartree Mountain, a broken ridge bearing north of west, in sec. 17, T. 4 S., R. 27 W., a number of openings were made in the spring and summer of 1916 by Edgar & Co. Two tunnels have been driven into the base of the mountain. One of these, known as the Old Sugartree tunnel, extends west 50 feet into the mountain from the bottom of a ravine and penetrates the upper division of the Arkansas novaculite, which here dips 50° N. A very small amount of iron oxide shows on the surface rocks, and only stains of iron and manganese oxides were found in the tunnel. An air-compressing plant has been built 100 feet north of the mouth of the tunnel.

The second tunnel, known as the New Sugartree tunnel, is 2,000 feet west of the Old Sugartree tunnel and extends south 30 feet into the mountain. It was not visited. No manganese ore is said to have been found in the shale that was penetrated. Compressed air for drilling was piped from the plant at the other tunnel.

A north-south cut, known as Sugartree prospect, is 500 feet east of the Old Sugartree tunnel and 75 feet above the base of the mountain. It is 75 feet long and 15 feet deep in the deepest part and is in massive novaculite dipping 50° N. 40° E. and belonging to the upper division of the formation. Two veins of manganiferous iron oxide lie along the bedding. One of these is from 10 to 24 inches thick and is said to contain 10 per cent of manganese; the other is from 6 to 24 inches thick. Both are cut off at the north by what appears to be a fault. There is also a pocket of such oxide 3 feet long and 16 inches wide. This pocket and the two veins contain much clay, a little quartz, and a few pieces of novaculite.

A north-south cut 30 feet long and 2 to 3 feet deep has been made on the south side of the crest of a spur of Sugartree Mountain, 1,000 feet west of the Old Sugartree tunnel and about 250 feet above Little Missouri River. The massive novaculite that has been blasted out to form the cut contains a pocket of brown iron oxide 2½ feet long and 1½ feet wide and also a few veins of this mineral, all less than 1 inch thick. No manganese was found here.

A second north-south cut, which is 25 feet long, 8 to 10 feet wide, and 10 or 12 feet deep at the south end, is on the north slope of Sugartree Mountain, 1,600 feet west of the Old Sugartree tunnel and about 400 feet above Little Missouri River. Massive novaculite is revealed in the cut, but owing to the numerous joints its dip could not be determined. Veins and pockets of psilomelane associated with some wad and manganite were found in the novaculite through a north-south distance of 20 feet. Few of them are more than 6 inches thick, though one pocket containing a vug partly filled with clay is 3 feet long and 2 feet wide. The psilomelane is steel blue, shows botryoidal surfaces, and in places occurs in alternating layers with manganite whose radiating needle-like crystals are perpendicular to the surfaces of the curved layers. Some of the psilomelane also occurs in alternating layers with wad. These minerals occur in small quantity and probably can not be mined with profit. About a ton of them has been placed on the dump.

A third cut, 1,900 feet west of the Old Sugartree tunnel and about 450 feet above Little Missouri River, extends from north to south across the crest of a spur of Sugartree Mountain. It is 125 feet long, though 10 feet of rock at the crest has not been removed. The northern two-thirds of it—the part lying north of this unremoved portion—ranges from 4 to 10 feet in depth and is in massive novaculite dipping 55° N. 25° E. Only two very narrow veins of manganese oxide mixed with clay were found here. The south third of the cut is 10 feet deep at the deepest place and is in novaculite and decomposed shale separated by a band of hard brown ferruginous clay. A few hundred pounds of brown iron oxide was obtained from pockets in the novaculite.

RAINWATER PROSPECTS.

Nine small pits were made in June, 1916, by W. E. Rainwater, on the south slope of Sugartree Mountain, in sec. 18, T. 4 S., R. 27 W. Four of these are in a deep ravine at an elevation of about 150 feet above Long Creek. Two of the four are in the upper division of the Arkansas novaculite, which here stands nearly vertical, and they reveal thin, widely separated veins of hard and soft oxides of manganese mixed with some iron oxide. Only a very small quantity of these oxides has been taken out. The largest pieces on the dump weigh only a few pounds. The other two pits are in débris which includes some boulders of manganese oxide that weigh over 100 pounds and contain some fragments of novaculite. The character of the novaculite in these boulders indicates that they came from the same beds of novaculite that were penetrated by two of the pits.

The other five pits are in a ravine a quarter of a mile northeast of the pits just described and are all in massive novaculite, which here dips 90°. The pit farthest west shows no manganese oxide; one of the others reveals a pocket of manganese oxide a foot long and 3 or 4 inches wide; and the rest contain some float pieces of this oxide but none in place.

McKINLEY MOUNTAIN.

A manganese deposit on McKinley Mountain has been described as follows by Penrose:[1]

> Almost on the line of Polk and Montgomery counties it [McKinley Mountain] is cut through by Straight Creek, a tributary of Long Creek, the latter a branch of the Little Missouri River. Straight Creek passes through the mountain in a deep gulch, on either side of which the novaculite forms steep bluffs.
>
> A small pit has been sunk in the novaculite on the western side of this pass, in 4 S., 28 W., a few hundred yards west of the Montgomery County line. The pit shows manganese ore scattered irregularly and in limited quantities through a breadth of about 6 feet of the rock, and in some places the ore-bearing part of the rock is possibly still wider. The ore is a hard, compact steel-blue variety, frequently stained yellow or red by iron. It occurs throughout the rock in small seams and pockets, from a fraction of an inch to 4 inches in thickness. In some places the ore blends into the novaculite, turning it a deep black; in other places the line of separation is sharp and well defined. The following analysis shows the composition of this ore:

Analysis of manganese ore from McKinley Mountain, Polk County.

[R. N. Brackett, analyst.]

Manganese	49.24
Iron	2.04
Silica	2.98
Phosphorus	.38

Manganese peroxide, 71.41.

TELLUS DAVIS PROSPECT NO. 1.

The Tellus Davis prospect No. 1 is on the steep slope on the east end of He Mountain, about 300 feet above Long Creek, which flows through a gorgelike water gap separating He Mountain from Sugartree Mountain, near the east edge of Polk County, less than a quarter of a mile from the line. It is on a claim located by Tellus Davis, but in August, 1916, being prospected by the Mississippi Valley Iron Co.

The prospect is an east-west cut 25 feet long and 10 to 20 feet wide and when visited (July 31, 1916) showed a face of 10 feet at the west end. It is in massive beds of hard white fractured novaculite in the basal division of the Arkansas novaculite, which here dips 55° N. Small pockets and veins of psilomelane, the largest observed by the writer being 3 inches wide and the largest one reported in the

[1] Penrose, R. A. F., jr., op. cit., pp. 353–356.

removed rock being 6 inches wide, were found here and there along the joints and bedding planes throughout the width of the cut, and in places some manganese oxide penetrates the novaculite.

The psilomelane is hard and steel-blue and in places shows a concretionary structure and botryoidal surfaces. It is associated with a less amount of crystalline manganite, much of which shows radiating needles, together with iron oxide and clay. A narrow vein of low-grade siliceous brown iron oxide mixed with a small quantity of dufrenite and manganese oxide lies along the bedding of the novaculite on the south side of the cut.

TELLUS DAVIS PROSPECT NO. 2.

The Tellus Davis prospect No. 2 is on the south slope of He Mountain about 500 feet south of west from the prospect just described, on the same claim. It consists of a cut which at the time of visit (July 31, 1916) was 40 feet long, 8 to 10 feet wide, and 10 to 12 feet deep at the north end. It was then being worked by the Mississippi Valley Iron Co. Beds of massive shattered novaculite dipping 85° S. and belonging to the basal division of the Arkansas novaculite were encountered in making the cut. A number of veins of brown iron oxide, which if put together would make a continuous vertical vein not over a foot wide, were found along bedding planes. A lenticular vein 6 inches thick contains ferruginous manganese. Vugs and cracks in two or three of the veins contain a small quantity of dufrenite. In their weathered parts the dufrenite has changed its color from green to brown, and the iron oxide shows coatings of colorless opal.

W. A. DAVIS PROSPECT NO. 1.

The W. A. Davis prospect No. 1 consists of a north-south cut 38 feet long, a few feet wide, and 18 feet deep, near the east end of He Mountain, high on the south slope, less than half a mile from the east boundary of Polk County, and a quarter of a mile west of the Tellus Davis prospect No. 1. It is on a mineral claim located by W. A. Davis and was worked in the summer of 1916 by the Mississippi Valley Iron Co.

Massive novaculite, probably near the top of the lower division of the Arkansas novaculite, dipping 85° S., was blasted out to make the cut. Manganese veins ramify through a vertical zone of broken novaculite 4 feet wide on the east side of the cut and 6 feet wide on the west side and constitute less than half the bulk of the zone, but most of the ore that is free from novaculite fragments is confined to an irregular vein which on the east side is 12½ inches wide at a height of 6 feet above the bottom of the cut, 32 inches wide 3 feet above the bottom, and 7 inches wide at the bottom.

The ore consists of psilomelane and manganite, except that there is a little brown iron oxide south of the zone just described and on the west side of the cut. The psilomelane makes up the greater part of the deposit. It is massive, hard, and steel-blue, much of it has a banded structure and a botryoidal surface, and some is stalactitic. The manganite is in places intimately mixed with the psilomelane, but the two may be found together in a single narrow vein, occurring in alternating layers in which the psilomelane is the massive hard steel-blue variety and the manganite consists of plumose crystal growths whose fibers diverge toward the center of the vein. Some of the stalactites of psilomelane contain cores of manganite consisting of radiating fibers that diverge outward. Dendrites are common along the joints in the novaculite, and some of them are very delicate.

Some pieces of the psilomelane and manganite that are on the dump or that have rolled down the mountain slope contain angular fragments of novaculite and would require crushing and jigging to recover the ore, but 3 or 4 tons of these minerals are free of rock fragments. Four pieces of solid ore seen by the writer weigh about 250 pounds each.

It is possible that a small quantity of ore might be profitably mined at this locality, especially while the prices paid for manganese ores are high.

W. A. DAVIS PROSPECT NO. 2.

The W. A. Davis prospect No. 2 is a cut that was made in the summer of 1916 by the Mississippi Valley Iron Co. on a claim located by W. A. Davis, half to three-quarters of a mile southwest of the W. A. Davis prospect No. 1, near the base of a hill slope on the south side of Coon Creek, which here flows east along the south side of He Mountain. The cut extends 60 feet S. 30° W. into the hill and at its southwest end is 18 to 20 feet deep. The novaculite here belongs to the upper division of the formation and is in beds that dip 40° S. 30° W. and are cut by numerous joints. Thin veins of wad, in places mixed with brown and red oxides of iron, occur along some of these joints. They are usually less than half an inch thick, but one partly exposed pocket containing some red iron oxide and ferruginous manganese is 2 feet or more wide. Several feet of débris overlying the novaculite was penetrated in the cut, and embedded in it are boulders of psilomelane containing angular fragments of novaculite. The boulders have obviously rolled down the hillside from the parent pocket or vein.

Just west of the mouth of the cut is an exposure of a 2-foot vein containing manganese oxide, brown iron oxide, and specular hematite, but half of the vein is novaculite. Another exposure of novaculite showing two veins of hard massive psilomelane, one 1 to 6 inches wide and the other 12 inches wide, is 60 feet southeast of the mouth of the cut. From these veins many veinlets of psilomelane half an inch or less in width extend into the novaculite on each side and form a perfect network. This manganese-bearing zone may be the same as the 2-foot vein just described, and if so passes near the north end of the cut, in which it was not found.

HE MOUNTAIN.

A manganese deposit "on the summit of He Mountain, in Polk County, a little over a mile west of the Montgomery County line" is described by Penrose[1] as follows:

A small pit 3 feet deep has been sunk on the ore, which is in small seams and pockets, rarely over 2 or 3 inches in thickness. The exact width of this ore-bearing part of the novaculite can not be seen, but the pit exposes a breadth of about 6 feet, and it is probably considerably wider. The ore is scattered through the rock in limited quantities. It is a hard, massive steel-blue variety, frequently having a concretionary structure and a mammillary surface, and is generally associated with more or less massive brown iron ore. The latter often incloses nodules of manganese or forms the outside layer of pockets of that ore. There are often small cavities in the novaculite, from 1 to 6 inches in diameter, lined with layers of iron and manganese ores. In some places both ores are sharply separated from the novaculite; in others they blend into it, staining it brown or black.

COON CREEK.

Penrose[2] furnishes the following description of a manganese and iron deposit on Coon Creek, a tributary of Long Creek that flows along the south side of He Mountain:

In a novaculite hill bordering this creek on the south, half a mile southwest of the He Mountain locality just described, and in Polk County, 4 S., 28 W., another small pit has been opened on a deposit of manganese and iron. Both ores are in about equal quantities, and both are very much like those described on He Mountain. They either form the cement of a brecciated novaculite or occur as thin layers, nests, or pockets throughout the rock. The largest mass of ore seen came from one of these pockets and was 2 feet in diameter. Such masses, however, are rare.

EUREKA PROSPECT.

The Eureka prospect is at the east end of Brier Creek Mountain, in T. 4 S., R. 27 W., and is at the same level as the flat of Long

[1] Penrose, R. A. F., jr., op. cit., pp. 356–357.
[2] Idem, p. 357.

Creek, 6 feet above the stream. Contorted ledges of massive white novaculite dipping at a high angle and striking east have been laid bare of débris through a distance of 20 feet from north to south, and a little solid rock has been removed. The work was done in 1916 by S. W. Sherrod. The débris on the slope just above the cut is a few inches thick and consists of fragments of novaculite. Manganite in small quantity cements some of this débris and occurs as veins between the ledges. It has apparently been deposited from the spring water that issues in a strong stream from the cut and higher on the mountain. Most of the veins are less than 2 inches thick, but one is 6 inches thick. A few hundred pounds of manganite could be obtained by careful hand picking of the material in sight.

BLUFF MOUNTAIN PROSPECT.

On the crest of Bluff Mountain, just north of Albert post office, in the southwest corner of Montgomery County, a pit 10 feet long from east to west, 6 to 7 feet deep, and 5 feet wide was made in May or June, 1916, by Walter Lyon and Foster Hays. It is in massive shattered novaculite in the lower part of the Arkansas novaculite, which here strikes east and stands vertical. A vein composed of psilomelane and manganite found at the east end of the pit is 18 inches wide at the bottom, where one-third to one-half its bulk consists of angular fragments of novaculite. Higher in the pit the vein widens to 3 feet and novaculite makes up the greater part of it. It continues to the west end of the pit, where it is only a few inches wide. Two pockets of ore a few inches wide were found within 18 inches north of this vein. They and the vein just described contain some red clay that has been brought in by ground water.

The deposit consists mainly of hard steel-blue psilomelane showing in places a botryoidal surface. A small quantity of manganite is in minute crystals intimately mixed with the psilomelane. The quantity of these minerals placed on the dump probably amounts to a ton.

LITTLE MUSGROVE MOUNTAIN.

Penrose[1] describes as follows a manganese deposit on the Webb Thornton claim, on Little Musgrove Mountain:

> Little Musgrove Mountain runs east and west in the extreme southwestern part of 4 S., 27 W., and is intersected by the Little Missouri River just above where that stream, issuing from the rocky gorge that it has cut through the novaculite ridges, flows into the less rugged country to the south. The mountain is composed mostly of gray novaculite dipping almost vertically and forming prominent bluffs on both sides of the river.

[1] Penrose, R. A. F., jr., op. cit., pp. 353–354.

The Webb Thornton claim is in sec. 31, on a steep bluff in the south face of Little Musgrove. A soft black manganese ore (pyrolusite) occurs here in an equally soft white novaculite, easily crushed in the fingers. The largest exposure of ore is an oblong pocket 4 inches in its thickest part.

LEADER MOUNTAIN PROSPECTS.

Leader Mountain runs a little north of west in T. 4 S., Rs. 27 and 28 W., partly in Polk County and partly in Montgomery County. It lies between Brier and Blaylock creeks, and Little Missouri River passes through a gap at its east end. Manganese deposits have been found here and there along its crest and were explored during March and April, 1916, by F. P. Fay and Chester Stevens, who located 14 lode claims lying end to end from Little Missouri River westward about 4 miles into Polk County, and numbered consecutively 1, 2, 3, etc., from the east to the west. The claims have since been transferred to Edgar & Co.

The lower massive division of the Arkansas novaculite, which dips about 90°, occupies the crest of the mountain throughout most of the 4-mile stretch that has been explored, but in some places the middle division, cropping out farther north, occupies the crest. The two are separated by a breccia-like conglomerate which in places is 3 feet thick. The structure of the mountain is shown in figure 3 (p. 76). The manganese deposits are in the top of the lower division of the Arkansas novaculite.

A cut on the crest of the mountain extends diagonally across the boundary line between claims Nos. 3 and 4. It was blasted 2 to 3 feet deep for a distance of 40 feet in massive novaculite and reveals no ore. Two pits farther east on the mountain were not visited by the writer but are said to show no manganese ore.

A north-south cut 25 feet long is in massive novaculite just north of the crest of the mountain on claim No. 5. It reaches a depth of 6 feet at the deepest place and shows two veins of psilomelane, one of which is 4 inches wide and the other 2 inches wide. Some of the psilomelane contains angular fragments of novaculite.

Another north-south cut 30 feet long on the crest of the mountain, on claim No. 6, is in both the massive novaculite and the thin-bedded novaculite. It shows a vein of manganese oxide 4 inches wide and some stains of this mineral along cracks in the massive novaculite.

The north-south cut on claim No. 7 is 25 feet long and 5 to 8 feet deep and is on the crest of the mountain. The south end, which is in the massive novaculite, shows a little brown iron oxide in thin irregular veins along bedding and joint planes, and the north end is a thin-bedded novaculite. Thin films of chalcedony stained a bluish-green color with chrysocolla, a copper silicate combined with water, were found at one place in the cut.

Claim No. 8 has been prospected by means of a north-south cut 52 feet long and 7 feet deep on the crest of the mountain. The south end is in massive novaculite, but most of the cut is in thin-bedded novaculite. A stain of iron oxide was found in some of the cracks in the novaculite, but no manganese was found.

A north-south cut 50 to 60 feet long and 2 to 4 feet deep on the crest of the mountain, in claim No. 9, is mostly in massive novaculite dipping 65°–70° N., but the north end is in thin-bedded novaculite. A very small amount of brown iron oxide, some of which exhibits rainbow colors, was found here. No manganese oxide was found.

A cut 24 feet long and 4 to 6 feet deep just north of the crest, on claim No. 10, revealed no ore. A shallow pit on the same claim about 300 feet east of the cut shows a very small quantity of brown iron oxide.

Claim No. 12 has been prospected by means of a north-south cut 30 feet long and 3 to 6 feet deep. The north 10 feet of the cut is in contorted thin-bedded novaculite; the rest is in shattered massive novaculite, which is cut here and there by veins and pockets of manganese oxide, generally less than one-eighth of an inch thick. The largest pocket is 5 inches wide, and a foot of its length is exposed.

Two shallow north-south cuts on claim No. 13 show a very small amount of brown iron oxide but no manganese ore.

A north-south cut 72 feet long and 6 to 10 feet deep on claim No. 14, is in the massive novaculite on the north slope, high up near the divide in the saddle of Leader Mountain. An old pit in the north end was blasted out some 20 years or more ago, but it has been enlarged during the making of the cut. A zone of broken novaculite 6 feet wide and dipping 50°–60° N., parallel with the bedding, is near the north end of the cut and contains lenses of manganese oxides lying mostly along the bedding planes. The largest is 8 inches wide at the widest part. Some veins have been found along joints and reach a thickness of 3 inches. In places these oxides cement novaculite fragments. Farther south they were found in pockets and veins through a distance of 12 feet, but they constitute only a small percentage of the bulk of the rock. The manganese oxides are wad, manganite, and psilomelane mixed with much brown and red iron oxides.

In addition to the above-described localities, where manganese ore was found, the writer saw at several places along the crest thin veins in novaculite outcrops and pieces of manganese oxide scattered over the surface.

Penrose describes two manganese deposits on Leader Mountain. One of these is the Webb Thornton claim,[1] on the eastern part of the

[1] Penrose, R. A. F., jr., op. cit., p. 358.

mountain in T. 4 S., R. 27 W., in Montgomery County, and is probably on one of the 14 recently located claims just described, but to judge from Penrose's description, given below, it was not visited by the present writer.

A pit 3 feet deep has been sunk on a deposit of manganese in the gray novaculite, and 500 pounds of ore are said to have been shipped. The manganese is a fine-grained soft crystalline ore often appearing in plumose forms. It occurs as the cement of a brecciated novaculite and forms from a tenth to as much as two-thirds of the whole mass. Occasionally the manganese is stained with a little iron, but much of it is comparatively free from that impurity.

The pit shows a width of about 5 feet of this breccia, and though the same ore is seen on either side, it is in very much smaller quantities. The deposit runs along the top of the mountain but thins out in a short distance in both directions and is represented either by simply a stain or by thin layers of ore in the novaculite.

A deposit on the J. Guy Lewis claim, on Leader Mountain, not visited by the present writer, is described by Penrose[1] as follows:

The J. Guy Lewis claim is on Leader Mountain, about 4 miles west of the Thornton claim and 2½ miles west of the line between Polk and Montgomery counties. A small cut has been made on a deposit of hard, brittle, brown hematite, of a shaly structure. It occurs as pockets and lenticular beds in the novaculite, the largest seen being a pocket 2 feet thick. Such deposits are scattered irregularly through the rock on the summit of the mountain over a breadth of about 20 feet. The ore is traceable in intermittent outcrops for half a mile east and west from the cut, and also occasionally beyond these limits.

Sometimes a few small masses of hard steel-blue manganese ore occur in the iron ore, especially at its contact with the country rock.

It is obvious from the above descriptions of the manganese deposits on Leader Mountain that at no place has ore been found in workable quantity.

COSSATOT MOUNTAIN PROSPECTS.

Cossatot Mountain is north of Mine Creek, a tributary of Cossatot River, and is a westward continuation of the Missouri Mountains. A number of old openings are on the mountain in the southeastern part of T. 3 S., R. 29 W., 2½ miles east of Cossatot River, where this stream passes Spring Valley School. They are described by Penrose[2] as follows:

Several small pits have been sunk for manganese on the summit of the mountain, and a tunnel 40 feet long has been run into the north side about 20 feet below the summit. The gray novaculite forms the crest of the ridge, and the siliceous shale comprises the slopes. The tunnel has reached the novaculite through the shale. The manganese is in the form of a crystalline pyrolusite, mixed with a hard, massive ore, and occurs in irregular nests from a quarter of an inch to 3 inches in diameter and in thin seams from a sixteenth to a

[1] Penrose, R. A. F., jr., op. cit., p. 358.
[2] Idem, pp. 370–371.

quarter inch in thickness. Such bodies of ore are scattered irregularly through a breadth of about 40 feet of novaculite. The manganese forms but a small portion of the ore-bearing stratum, and, except in the richest places, the aggregate amount of the scattered bodies of ore would form a very small percentage of the mass.

GRANT PROSPECT.

The Grant prospect consists of a cut about a quarter of a mile east of Three Oak Gap, on the south slope of Cossatot Mountain. The cut is 10 feet long, 5 to 6 feet wide, and 4 to 6 feet deep, and was blasted 20 years or more ago in projecting ledges of the upper division of the Arkansas novaculite. Pockets and veins of manganese and iron oxides reaching a width of 9 inches were found along cracks in the massive novaculite, which has been minutely fractured and somewhat faulted, as shown by the presence of slickensides. Some of these oxides cement many of the fractured pieces. The manganese oxide is more abundant than the iron and consists of hard steel-blue psilomelane, some of which contains small crystals of manganite. The iron oxide is represented by both brown and red oxides.

About a ton of manganese ore that has been removed from the cut and since scattered around it on the surface could be separated from the novaculite by hand picking. It is said that several hundred pounds of this material has been carried away as specimens.

A shallow pit from which a little manganese oxide, a larger amount of brown iron oxide, and some red iron oxide have been removed is about 50 feet northeast of the cut just described, on the same ledges of novaculite.

A pit revealing massive brown iron oxide along bedding and joint planes has been dug about a quarter of a mile west of the above-described locality, on the same bed of novaculite. Very little manganese was seen here.

BIG FORK.

A number of small openings on manganese deposits a few miles southwest of Big Fork, in Polk County, have recently been made by farmers. None of the localities were visited by the writer.

OTHER DEPOSITS IN POLK COUNTY.

Some manganese deposits in Polk County that were not visited by the writer are described by Penrose,[1] as follows:

Pointed Rock Tunnel.—Pointed Rock Tunnel is in 4 S., 28 W., sec. 19, and is the property of the Arkansas Development Co. A deposit of hard laminated brown hematite occurs here, interbedded in gray and black siliceous shale. The rocks stand vertically or dip at angles of 70°–80° N. and form part of a

[1] Penrose, R. A. F., jr., op. cit., pp. 358–371.

low hill. A tunnel has been run in at the foot of the hill, just above the level of a small creek, and follows the iron ore in the direction of the strike of the rock for about 100 feet. The ore occurs in a series of parallel strata from 1 to 12 inches in thickness, separated by similar strata of shale, or of clay which has resulted from the decomposition of the shale. The northern part of the hill is composed of the gray novaculite, and the ore occurs near the contact of the shale with that rock. The rocks strike across the hill, and the ore can be traced a distance of a quarter of a mile over the summit and down to a creek on the other side. The alternating strata of iron ore and shale occupy together a belt varying from 20 to 50 feet in width. Sometimes the ore in a given stratum runs out and is represented by rock for a few feet, but it usually appears again beyond. In places the combined thickness of all the ore strata, if brought together, would amount probably to over 5 or 6 feet; in others it would not be a quarter of that thickness.

Tall Peak Mountain.—Tall Peak Mountain forms part of a long novaculite ridge known as Raspberry Mountain, which runs in a general direction a little north of west across the headwaters of the Saline River and the Harris Creek fork of the Cossatot River. On the lower part of the northern slope of Tall Peak Mountain, on a claim controlled by the Arkansas Development Co., in 4 S., 29 W., sec. 24, the gray novaculite is impregnated with manganese for a width of about 20 feet. The ore-bearing part of the novaculite is at the contact of that rock with the shale and protrudes in a low ledge above the surrounding surface. Its relation to the different rocks is shown in the accompanying figure [fig. 12], which represents a north-south section across a part of the claim.

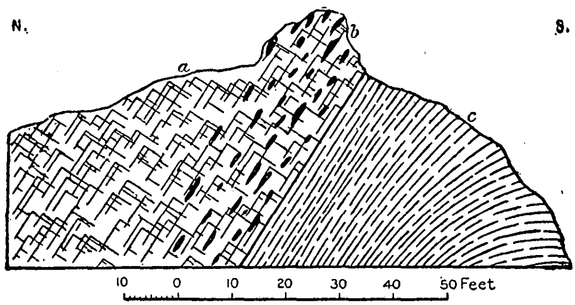

FIGURE 12.—Section on the north slope of Tall Peak Mountain, Polk County, Ark., showing the occurrence of manganese ore in the gray novaculite. (After Penrose.) *a*, Gray novaculite; *b*, manganese-bearing part of the novaculite (black parts represent ore); *c*, siliceous shale.

The ore is in pockets and lenticular layers scattered through the rock, the largest seen being 2 feet long by from 3 to 6 inches in thickness. It occurs both in the form of a hard massive steel-blue ore and as a finely crystalline variety, the crystals frequently being grouped in a plumose form and having a brown streak. Occasionally the manganese contains small quantities of iron, but it is generally comparatively free from that impurity.

On the west the ore-bearing stratum disappears under the gravel of a small creek; on the east it rapidly thins out on the slope of the mountain and is replaced by the pure gray novaculite.

The usual strata of brown hematite, from 1 to 12 inches in thickness, occur in the siliceous shale shown in the figure to the south of the manganese. A tunnel was run into this rock with the intention of reaching the manganese but was not continued far enough to do so. At the mouth of the tunnel the shale is almost horizontal, but to the north it rapidly curves around, and when it reaches the novaculite it is dipping at the same steep angle as that rock. The shale has in many places been decomposed into a fine gray clay containing layers of the unaltered rock. The following analysis shows the composition of the manganese ore on this property:

Analysis of manganese ore from Tall Peak Mountain, Polk County.

Manganese	52.16
Iron	4.00
Silica	.24
Phosphorus	.39

Manganese peroxide, 77.60.

East Hannah Mountain; the High Peak.—The High Peak of Hannah is a part of the Hannah Ridge, about 3 miles east of the Cossatot River. On the south slope of the mountain, and probably about 300 feet from the summit, is a deposit of brown iron ore in the gray novaculite. The deposit is 3 feet in the widest part, and about two-thirds of it is composed of ore. It follows along the slope of the mountain for about 10 feet and beyond these limits becomes thin and is often represented only by a stain.

East Hannah Mountain; the William Allen claim.—The William Allen claim is on the north side of East Hannah Mountain, near its base, about a mile and a half east of the Cossatot River. It is on what is known as the Condor "lode," which contains manganese ore in seams and pockets from a fraction of an inch to 8 or 10 inches in thickness, scattered through the novaculite. The latter size, however, is exceptional, and the largest mass seen measured 3 by 6 by 10 inches. The ore is of both the crystalline and massive varieties, the former often showing a plumose structure. The massive variety is hard and often in stalactitic and mammillary forms. The manganese is associated with a glossy black iron ore.

East Hannah Mountain; the west end.—On the western end of East Hannah Mountain, in the neighborhood of the Cossatot River, both manganese and iron are scattered in small quantities through a belt of novaculite varying from 5 to 20 feet in width. In some places the ore is iron and in others manganese; in still others both ores are mixed together in varying proportions. They occur in thin seams along lines of bedding or joint cracks, or as the cement of a brecciated novaculite; in places also they are in small nodules and often form only a stain in the rock. The rocks dip uniformly to the north at angles of from 60° to 80°.

West Hannah Mountain; the William Allen claim.—This one of the William Allen claims on West Hannah Mountain is a quarter of a mile west of the Cossatot River, on the north slope of the mountain, and on what is known as the Fawn "lode." The manganese is in the gray novaculite, near its contact with the shale. The ore impregnates the rock for a width of 10 feet in small seams and pockets from a quarter of an inch to 3 inches in thickness and is both massive and crystalline. The manganese is associated with small quantities of brown iron ore.

West Hannah Mountain; the Bowen claim.—The Bowen claim is on the summit of West Hannah Mountain, at its extreme west end, 4 miles west of the Cossatot River, and overlooks the valley of Brushy Fork. Manganese is found here in the crystalline form with smaller quantities of a hard massive ore. It occurs in thin discontinuous seams occupying cracks and joints in the novaculite and sometimes forming the cement of a breccia. The largest mass of solid ore visible is 3 inches in thickness and 3 feet in length, thinning out at both ends.

Buckeye and Shadow Rock mountains.—Buckeye and Shadow Rock are names given to different parts of a novaculite ridge which runs parallel to and immediately north of East Hannah Mountain in 4 S., 28 and 29 W. In its eastern part it is known as Buckeye Mountain until within about 4 or 5 miles of the Cossatot River, and from that on to the river it is known as Shadow Rock Mountain. The ridge rises from 500 to 800 feet above the Cossatot, its average height being much lower than that of East Hannah to the south. It is separated from the latter ridge by a deep ravine which marks the course of Short Creek, a tributary of the Cossatot.

A large number of claims have been taken on exposures of manganese and iron on both ends of the mountain, and the principal ones are here described:

1. Manganese Mountain: Manganese Mountain is a small spur of Buckeye Mountain, running out from the south side of the ridge about 5 miles east of the Cossatot River. Manganese is found here in the gray novaculite in the form of a hard massive steel-blue ore, blending at times into a semicrystalline ore. It is generally in the form of flat, botryoidal, or concretionary masses, often having hollow interiors. It tends to follow lines of bedding, but it also runs off in joint cracks. The bedded layers are the larger, and one of them measured from 3 to 6 inches in thickness and 4 feet in length. The seams in the joint cracks rarely measure over a quarter of an inch in thickness, though they are often so numerous as to honeycomb the rock in all directions.

The accompanying figure [fig. 13] shows the character of the bedded deposits in the side of a small opening on the summit of the spur. It will be observed in the figure that the lenticular layers of ore lie intermittently along different planes of stratification, and that they are separated along the same planes by barren areas, which, however, are generally stained with iron ore or manganese. Sometimes the layers of ore are simply flat concretions. The following analysis shows the composition of the ore from this locality:

Analysis of manganese ore from Manganese Mountain, Polk County.

Manganese	42.75
Iron	2.72
Silica	10.46
Phosphorus	.45

Manganese peroxide, 62.75.

2. The Walston claim: The Walston claim is on the same hill as the last-named locality and a quarter of a mile northwest of it. Layers from 2 to 6 inches in thickness of glossy black or dark-brown iron ore are interbedded in the gray novaculite. The ore also runs across the stratification in fractures in the rock. The deposit occurs at the crest of a small, local anticline, and the layers of ore dip off in both sides of the pit. No manganese was seen at this opening.

Another one of the Walston claims is near the last and at the point where Manganese Mountain joins the main Buckeye Mountain. Iron ore similar to that just mentioned has been found here in a small pit now mostly filled up. It is said to have been in larger quantities than at the last place.

C. C. Avant claims.—Mr. Avant owns several claims in the vicinity of the upper waters of the Cossatot River, and two of them are here described:

1. Manganese: This claim is in 4 S., 29 W., sec. 6, on a novaculite ridge running parallel to and north of West Hannah Mountain. The ore-bearing stratum is known here as the Eldridge "lode," and the Avant claim is near its eastern end, a few hundred yards west of where the ridge slopes off to the valley of the Cossatot River. Manganese ore is found in the gray novaculite on and near the summit of the mountain and is of a hard steel-blue variety, often in stalactitic and mammillary forms. The ore-bearing part of the rock varies from 1 to 5 feet in thickness and contains the ore in thin seams, from a

fraction of an inch to 8 inches in thickness, following the stratification or occupying joints and cracks. The ore-bearing deposit dips to the north with the inclosing rock, at angles from 70° to 90°, and is traceable for several hundred yards along the mountain, when it thins out, widening again to the west.

2. Iron: This claim is in 4 S., 30 W., sec. 1, about a mile west of the last locality (claim 1), on the south slope of the same mountain, and about a quarter of the way from the summit. Here the ore-bearing stratum is represented mostly by iron ore, though small quantities of a black massive manganese ore sometimes occur. The iron ore is in the form of a brown hematite and forms the cement of a brecciated novaculite, in which the rock masses vary from a fraction of an inch to 6 inches in diameter and are sometimes stained throughout by iron. This mixture of rock and ore has a width of about 30 feet on the slope of the mountain, but only a small part of it is composed of ore.

The Arkansas Development Co.'s mine.—The Arkansas Development Co.'s mine is in 3 S., 30 W., sec. 27, and is locally known as the Ward manganese mine, from the name of the former superintendent. It is near the headwaters of the Brushy Fork branch of the Cossatot River, on a novaculite ridge which rises over 400 feet above the creek. It is the property of the Arkansas Development Co., and was worked during the year 1888 and until April, 1889, when operations were stopped. During this time a shaft 142 feet deep was sunk on the north slope of the ridge, and a tunnel about 500 feet long was run into the northern side near the level of Brushy Fork. About 20 tons of ore are said to have been taken from the shaft; none was found in the tunnel.

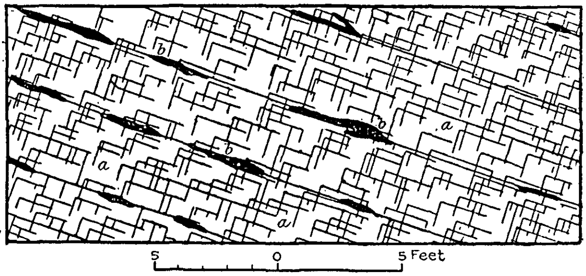

FIGURE 13.—Section in a pit on Manganese Mountain, Polk County, Ark., showing the occurrence of manganese ore in the gray novaculite. (After Penrose.) *a*, Gray novaculite; *b*, manganese ore.

The summit and upper slopes of the ridge are composed of gray novaculite, while on the north side, where the tunnel has been run, the lower slopes are composed of black siliceous shale. The manganese occurs in the novaculite in the form of crystalline pyrolusite, associated with a hard iron-gray massive ore, the former often coating the latter as an incrustation, and both occurring in kidney-shaped or stalactitic forms. Sometimes small quantities of a black iron ore (limonite) showing a glossy, brilliantly iridescent surface, are associated with the manganese, but a large part of the latter is free from such impurity.

The manganese-bearing deposit varies from 1 to 2 feet in thickness and dips almost vertically. The ore, however, composes only a small part of this and usually occurs as thin seams and pockets from a fraction of an inch to over 2 inches in thickness, scattered irregularly through the rock. Occasionally, however, the ore widens out locally into pockets of somewhat larger size. Sometimes the ore disappears altogether or is represented only by a stain in the rock, but widens out again at irregular intervals.

Other openings made by the Arkansas Development Co. on Brushy Fork.[1]—Several other smaller openings have been made by the Arkansas Development

[1] Several properties owned by this company elsewhere in Polk County have already been described (pp. 116–118).

Co., on both manganese and iron, in the same neighborhood as the Ward mine. The most important are given below:

1. The Jumbo pit: The Jumbo pit is 500 yards east of the Ward mine, on the north slope of the same ridge. Manganese ore impregnates the novaculite in the same way as at that place. A pit 15 feet deep and 8 feet square has been sunk, and on all sides of it are seen thin, irregular, and discontinuous "stringers" of ore, from 1 to 5 inches in thickness, either in lines of bedding or in joint cracks. The novaculite is generally stained a buff or a brown color and is soft, often disintegrating into a powder.

2. Tunnel No. 2: Tunnel No. 2 is little over half a mile east-northeast of the Ward mine. It is 20 feet long and was run into a gray siliceous shale, on a deposit of brown iron ore. The ore is a brown hematite, interbedded in the rock in irregular pockets, from a few inches to a foot or more in thickness. The ore is laminated and has much the same structure as the inclosing shale, into which it blends both laterally and vertically. The quantity of ore is very limited.

Two hundred yards northeast of this tunnel is a small pit on a similar ore in a similar rock. The ore frequently forms the cement of a breccia of fragments of the inclosing rock and is irregularly scattered through a stratum 3 feet thick. The shale in contact with the ore is often much decomposed and exists in the form of a fine siliceous powder.

3. Shaft No. 3: Shaft No. 3 is over a half mile northeast from the Ward mine and is a pit 8 feet square and 20 feet deep, sunk for manganese in the gray novaculite. The ore occurs in small nests and thin discontinuous seams, from 1 to 6 inches in thickness. Sometimes they follow joints, but the largest seams are in the bedding planes of the rock, which pitches to the southwest with an undulating dip of about 30°. The deposits in the joint cracks frequently cross those in the lines of bedding, showing that the ore in the bedding planes was deposited previously to that in the joints.

4. Shaft No. 4: Shaft No. 4 is near shaft No. 3, is about the same size, and has been sunk in the novaculite for manganese. The ore is a hard, massive variety in a mammillary form and occurs as in shaft No. 3, in lines of bedding and in joint cracks. The largest seam measured was 4 inches thick and 4 feet long, representing a lenticular layer.

Little Manganese Mountain.—Little Manganese Mountain is the name given to the western end of the novaculite ridge running parallel to and a mile south of East Hannah Mountain. Iron and manganese are found on it a mile east of the Cossatot River, where the mountain begins to slope down to the valley of that stream. The claim is owned by Mr. William Allen and is known as the Cave "lode." The ridge here is composed mostly of gray novaculite, dipping at angles of from 45° to 60° N. and overlain on the northern slope by the siliceous shale. In the novaculite near the contact with the shale are discontinuous strata of brown hematite, associated with smaller quantities of manganese and varying from a fraction of an inch to 4 inches in thickness. They run sometimes continuously in the direction of the ridge for 50 or 60 feet and then thin out, appearing again beyond. The manganese is in much smaller quantities than the iron ore and occurs in nodules and thin seams. As a rule the iron ore seems to be largely confined to the contact of the novaculite and shale, while the manganese is found not only there, but also in the novaculite, farther from the contact line.

HATTON.

Prospecting was done during the summer of 1916 on a number of manganese deposits on the novaculite ridges in the vicinity of

Hatton. The following information on that locality has been supplied by George Hammond, of Wickes, Ark.[1]

A tract of land owned by Jacob Hoblitzel in secs. 13 and 14, T. 5 S., R. 32 W., has been prospected and several hundred pounds of manganese ore obtained here was shipped to a chemist in Fort Smith, Ark., for experimental work.

Land owned by M. H. Doty in the SW. ¼ sec. 18, T. 5 S., R. 32 W., has been prospected, but only samples of manganese ore have been shipped.

Considerable prospecting has been done in sec. 10, T. 5 S., R. 32 W., on land owned by E. L. Henson and leased by O. W. Thompson.

Prospecting had been temporarily discontinued when the writer was at Hatton (July 23, 1916), and he did not visit the workings.

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[1] Letter dated Dec. 9, 1916.