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

GEOLOGICAL SURVEY
W. E. Wrather, Director

Bulletin 940-H

MANGANESE DEPOSITS OF THE FLAT TOP AND ROUND MOUNTAIN DISTRICTS BLAND AND GILES COUNTIES, VIRGINIA

BY

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Strategic Minerals Investigations, 1943

(Pages 219–245)

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1944

For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.
Price 75 cents

CONTENTS

ILLUSTRATIONS

MANGANESE DEPOSITS OF THE FLAT TOP AND ROUND MOUNTAIN DISTRICTS, BLAND AND GILES COUNTIES, VIRGINIA

By Harry S. Ladd and Frank W. Stead

ABSTRACT

The manganese deposits in the Flat Top and Round Mountain districts, in Bland and Giles Counties, Va., occur in three geological formations. In the Flat Top Mountain district the largest deposit is in the Devonian Becraft sandstone, where the beds have been fractured on the nose of a plunging anticline. In the Round Mountain district the largest deposit is in a residual clay derived from the Silurian Tonoloway limestone, which underlies the Becraft, in a structural and topographic saddle between the Round Mountain and Burkes Garden structural domes. In both districts there are smaller deposits, of lower grade, in the sandy clays of the still older sandstone of the Clinton formation, which is of Silurian age. The commonest manganese mineral in all the deposits appears to be psilomelane, but the larger deposits also contain appreciable quantities of pyrolusite.

Up to June 30, 1942, the two districts together had produced more than 30,000 tons of high-grade manganese concentrates. In 1942, three mines were operating in the Flat Top Mountain district and two in the Round Mountain district. It is estimated that the two districts together can still produce about 20,000 tons of concentrates containing 40 percent or more of manganese, and 1,000 tons of lower-grade concentrates.

INTRODUCTION

As shown in figure 21, the Flat Top and Round Mountain districts lie in southwestern Virginia near the West Virginia border. Both produced manganese ore during World War I, and they have continued to produce intermittently during the ensuing years. The total production of the two districts before June 30, 1941, had been more than 25,000 tons of high-grade manganese concentrates. In consequence of recent activity, including the reopening of old mines and the opening of one new property, about 5,000 tons of high-grade concentrates was shipped during the year ending June 30, 1942. In both areas manganese ore is being produced from the Becraft sandstone, but in the Round Mountain district most of the production is from the

underlying residual clay derived from Tonoloway limestone. In both areas a little ore has been found at a still lower horizon, in the Clinton formation, but very little of this ore has been shipped.

A branch line of the Norfolk & Western Railroad, starting at Narrows, Va., passes between the two districts, ending at Bastian, 7½ miles from the Round Mountain deposits. The Flat Top deposits lie 10 miles, by a good but unpaved road, from the railroad at South Gap.

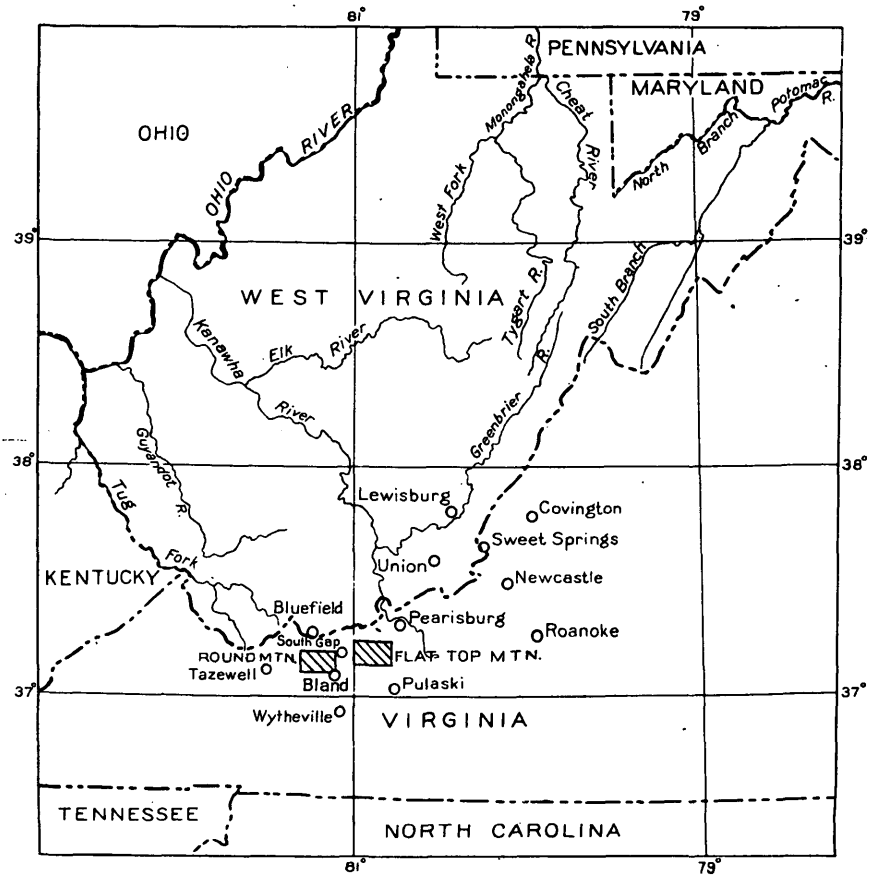

Figure 21.—Index map showing location of Flat Top Mountain and Round Mountain districts, Virginia.

The important deposits of both districts were studied by Stose and Miser during World War I.1/ The study whose results are given in the present report has involved the preparing of detailed geologic maps, the examination of all known deposits, and the obtaining of information that would aid in estimating

1/ Stose, G. W., and Miser, H. D., Manganese deposits of western Virginia: Virginia Geol. Survey Bull. 23, 1922. This report contains references to earlier reports, and has been freely used during the present study.

reserves and planning additional prospecting. Field work on Flat Top Mountain occupied Ladd for three months during the fall of 1940, and he spent an equal period of time in mapping on Round Mountain in the following spring. Plane-table maps of parts of both areas were made by David Gallagher, and additions to Gallagher's map of Round Mountain were made by Stead, assisted by Almon F. Robertson of the Bureau of Mines.

Early in 1940 a Bureau of Mines party, in charge of L. B. Moon, carried out a program of drilling and trenching on Flat Top Mountain. Cuttings obtained from the drill holes were examined by Watson H. Monroe of the Geological Survey. During 1942 a program of exploration was carried out on Round Mountain by Mitchell Kline, Harold B. Ewoldt, Almon F. Robertson, and Frank J. McIntosh, of the Bureau of Mines. Frank Stead worked with this party, examining trenches, pits, and drill cuttings, and suggested the sites for all the excavations. Valuable assistance and cooperation were given by Mr. and Mrs. Ottomar Stange, Mr. Ray Arms, Mr. R. F. Biggam, Mr. E. R. Boyd, Mr. H. B. Greever, and others in the area who are interested in the development of various manganese properties. Copies of the engineering plans used in the construction of the new road from Hunting Camp Creek to Burkes Garden were furnished by the Civilian Conservation Corps through Mr. Fred Pederson, State Forester of Virginia. The present study was made under the direction of H. D. Miser, and the writers are indebted to him and to G. W. Stose, Josiah Bridge, and Charles Butts for much helpful advice.

GEOLOGY

In the Flat Top and Round Mountain districts a thick sequence of sedimentary rocks ranging in age from Cambrian to Devonian is exposed. The units mapped during the present investigation are briefly described in the table on the following page, in which the manganese-bearing horizons are indicated.

FLAT TOP MOUNTAIN DISTRICT

Structure

Flat Top Mountain is carved from a broad anticline that plunges to the southwest. Several formations are exposed along its crest, the largest areas of outcrop being those of the Clinton formation and Becraft sandstone (pl. 37). Between the two lies the comparatively thin Tonoloway limestone, but at the highest altitudes this formation is altered to clay, and outcrops of it near the mountain crest are exceedingly rare. Above the Becraft, on the flanks of the mountain, lie 50 feet of chert and sandstone of Onondaga age. All of these formations dip beneath a wide belt of younger Devonian shales which borders the plunging southwest nose of the anticline. The anticline is adjoined on the north by folded Clinton sandstones, and on the southeast by the basin of Dismal Creek, where the beds lie nearly flat. Still farther to the southeast the beds are sharply folded into an overturned canoe-shaped syncline, whose axis parallels the main anticline. Along the crest of Brushy Mountain the Clinch sandstone is thrust against the syncline (see sec. A-A', pl. 37).

Sedimentary rocks of the Flat Top and Round Mountain districts

Age	Mapped unit	Thickness (feet)	Character
Devonian	Shales.....	2,700±	Black, gray, and green shales, shaly sandstones; some conglomerate near top.
	Onondaga formation.	50	Bedded chert and sandstone with green glauconitic sands near top and bottom.
	Becraft sandstone..	100	Upper part coarse-grained or conglomeratic porous ferruginous sandstone, which locally carries manganese oxides; lowest 40 feet mottled silt and sandy clay.
Silurian	Tonoloway limestone	65	Laminated impure limestone; where weathered to clay carries manganese oxides in places.
	Clinton formation[1/]	330	Light-colored well-bedded or ripple-marked sandstones, greenish shales and shaly sandstones; some sandstones highly ferruginous; white quartzite near top of formation. Upper part carries manganese oxides in places.
	Clinch sandstone...	110	White sandstone and quartzite.
Ordovician	Juniata formation..	200-375	Red sandstones and shaly sandstones.
	Martinsburg shale..	1,400	.....
	Moccasin limestone.	300	Red and gray earthy limestones.
Cambrian and Ordovician	Cambrian and Ordovician limestones and dolomites.	Not determined.	Gray fine-grained to coarsely crystalline limestone, with some black chert, underlain by gray cherty dolomite.

1/ In the saddle between Round Mountain and possibly in other parts of the area beds of sandstone carrying fossils of Wills Creek age occur between the Clinton formation and the overlying clay derived from the Tonoloway limestone. These beds were mapped with the Clinton.

The Flat Top Mountain anticline is broken by five small faults. Three of these are parallel to the axis of the fold; the other two, which are tear faults, cross the regional strike. These minor faults, together with still smaller breaks that were formed when the beds were folded, have fractured the sandstones and have thus facilitated the circulation of manganese-bearing waters. Major thrust faults, such as the one

paralleling Brushy Mountain, have not, so far as known, had any important effect on mineralization.

Manganese deposits

Concentrations of manganese oxides in workable quantities are found in the Flat Top Mountain district at two horizons. The older ore-bearing layer, which is in the top of the Clinton formation, consists chiefly of nodular masses of psilomelane in clays and sandy clays. The younger is in the porous, fractured sandstones of the Becraft. The beds in the Becraft contain better ore on the average than those in the Clinton formation. The manganese deposits at both horizons lie close to the surface and are being worked at the present time, and now as in the past the Becraft horizon is the more productive.

In the several pits of the Dismal Creek mine on the southeast side of Flat Top Mountain the sandstone beds of the upper part of the Clinton formation are impregnated with manganese oxides, and the sandy clay contains low-grade nodular ore. Similar occurrences in the Clinton formation have been explored on Silver Creek, on the northwest side of Flat Top Mountain. Small quantities of manganese oxide in rocks believed to be Clinton were seen in the long-abandoned Johnson prospect, which is near the crest of Flat Top Mountain, and in Jenny Cabin Hollow, south of Big Horse Gap. The Johnson prospect lies near a fault, but at the other places there is no clear evidence that structural or topographic features affected the manganese occurrences.

At several places in the district the porous sandstones of the Becraft are impregnated with manganese oxides. At the western end of the plunging Flat Top Mountain anticline, where these beds have been fractured by folding and broken by small faults, a sizable ore body has been uncovered in the Stange and Arms mines. The deposit extends west-southwest along the crest of the anticline for a distance of nearly 1,000 feet. The mineralized zone has a maximum width of 300 feet, and ore has been mined from the surface downward through 60 feet of sandstone.

The manganese oxides are chiefly psilomelane and pyrolusite. They occur along bedding planes, in joint cracks and in irregular fractures. In some places the oxides fill pore space; in others they fill molds left by the removal of calcareous fossils; and in many places they cement angular fragments of sandstone to form a breccia. Some of the sandstone fragments included in bodies of manganese oxides are rounded, suggesting that the oxides have replaced parts of the sandstone.

The original source of the manganese now found in the Becraft sandstone is not known. Watson 2/ suggested that it might have been derived from the thick Devonian shales which have been eroded from the areas where the manganese now occurs. This remains a possibility, though it gains no support from the single analysis that has been made of the black shale.3/

2/ Watson, T. L., Mineral Resources of Virginia: Virginia Jamestown Exposition Commission, pp. 408-410, 1907.

3/ Stose, G. W., and Miser, H. D., op. cit., pp. 53-54.

Recognizing that manganese oxide often occurs in fairly close association with glauconite, G. W. Stose has suggested to the writers that the glauconitic sandstone zones in the overlying Onondaga formation might be considered as potential source beds. Samples of glauconitic sandstones were accordingly collected at Holly Brook, near the foot of Flat Top Mountain, and were analyzed in the laboratory of the Geological Survey. The results, however, were negative; the two analyses that were made showed only 0.015 and 0.011 percent of MnO.

There is a third possible source of the manganese now contained in the Becraft sandstone. This sandstone is now coarse, porous, and friable, but the occurrence of numerous molds of fossils at certain horizons suggests that the rock once contained much carbonate of lime. If it also contained manganese carbonate, as the underlying Tonoloway limestone does at Holly Brook (see p. 235), manganese oxides could have been formed by weathering and redeposited in favorable places.

Whatever their source may have been, the deposits of the Flat Top Mountain district appear to be surficial, and to have been deposited by cold solutions in the zone of weathering. They probably were formed at a time when drainage was at a higher level than now, for, like most of the large manganese deposits in the Appalachians, they lie hundreds of feet above present drainage. Smaller deposits are found at much lower levels, their vertical range on Flat Top Mountain being as much as 750 feet.

Reserves

The probable reserves of the combined Stange and Arms mines on Flat Top Mountain in April 1941 were estimated at 4,000 tons of recoverable concentrates containing 40 percent or more of manganese. Sufficient work has not been done on other deposits in the district to serve as a basis for accurate estimates, but another 1,000 tons of ore averaging 35 to 40 percent manganese may well be available, and additional work on some of the little-known properties might increase this figure considerably.

Mines and prospects

Stange and Arms mines

The ore body from which the Stange and Arms mines have obtained their production is the largest known in the area. It has yielded a total of more than 20,000 tons of concentrates, and apparently much of the better-grade ore has been removed. The deposit lies near the southwest end of the crest of Flat Top Mountain, at an altitude of 3,000 feet. As shown in plate 37, the mines are in Bland County, close to the Giles County line.

The deposit at the Stange mine was first worked by Johnson Brothers & Co. during the summer of 1917. In the fall of that year the mineral rights were purchased by E. S. Suffern, who operated the mine until the summer of 1918, when he sold the property to Ottomar Stange.4/ The Stange interests built a

4/ These facts and additional information concerning early operations are given by Stose and Miser, op. cit., pp. 134-142.

washing and jigging plant on Ding Branch, at the foot of the mountain, and operated it occasionally until 1940. In November 1940, the mine was purchased by D. E. Conley of Rocky Gap, Va., but the treatment plant on Ding Branch was not included in the sale. In 1941 Conley leased the mine to the Biggam Manganese Co., Inc., which resumed production. This company at first leased the Ding Branch plant from Stange, but in 1942 it constructed a washing plant of its own on Dismal Creek.

The Arms mine is in the southeastern part of the mineral-bearing tract on Flat Top Mountain. Mineral rights to about 77 acres in this vicinity are owned by the heirs of the Byrnes estate (pl. 39), and for many years this tract has been worked independently of the Stange mine. Prior to 1941, J. Lee Marcum operated the mine under a lease from the Byrnes Heirs, treating the crude ore in a washing plant at Holly Brook, 2 miles southwest of the mine. In the summer of 1941, Mr. Marcum assigned his lease to Ray Arms, who rebuilt the washing plant and in 1942 was operating it together with the mine.

Concentrates from the Stange, Arms, and Biggam washers are trucked over good but unpaved roads to South Gap, from which they are shipped by rail on a branch of the Norfolk & Western Railroad. The trucking distance from the Stange washer is 9 miles; from the Arms washer it is about 11 miles, and from the Biggam washer it is about 14 miles.

Geology and manganese deposits.--On the nose of the Flat Top Mountain anticline, where the Stange and Arms mines are located, the ore-bearing Becraft sandstone is greatly fractured. Most of the fractures probably were formed at the time the beds were folded, and on most of them there was little if any displacement.

Some of the larger fractures may be traced in the field for considerable distances (pl. 38), but drilling records indicate that even on these there was no appreciable vertical displacement. Several faults of greater magnitude cut the margins of the plunging anticline and visibly offset the outcrops of the Becraft and adjoining formations (pl. 37). The Stange and Arms mines lie between two such faults. These faults are believed to be normal, and to have been formed after the folding that produced the anticline; their throw is probably nowhere more than 100 feet.

In the Stange and Arms mines the Becraft sandstone is 100 feet thick and contains three recognizable lithologic units: (1) a basal zone of yellowish and reddish silt and sandy clay, (2) a zone of slabby sandstone that in some places is cross-bedded, and (3) an upper zone of coarse sandstone with pebble beds and molds of fossils, which are especially numerous near the top. The two upper zones, which have a total thickness of about 70 feet, contain most of the known manganese deposits.

The Becraft is underlain by a thick mass of residual clay derived from the Tonoloway limestone. This clay is exposed on an old road near the reservoir and in several trenches, and it was penetrated by a number of drill holes. It is about 60 feet thick, but its lower limit is gradational, its lower part becoming calcareous before passing into unaltered limestone (pl. 38). On Flat Top Mountain this clay shows only traces of manganese oxide, but on Round Mountain it contains the main ore deposit.

In 1920 a plane-table map of the area as it then appeared was made by H. D. Miser.5/ The area was remapped in 1940 by David Gallagher (pl. 38). Using Gallagher's maps as base, Lowell B. Moon of the Bureau of Mines drew up a general plan of the workings (pl. 39). What is called the Main pit of the Stange mine, from which most of the production has been obtained, is now nearly worked out. Ore was still being mined, however, in 1942 from an opening known as the North pit. This is an irregular excavation, shared by the Biggam Manganese Co. and Ray Arms, operator of the Byrnes Heirs' property. A rather large opening called the Arms pit is also being actively worked.

At the Stange mine, very little manganese ore can now be seen in the Main pit, but good ore is still exposed in parts of the North pit. Some of the ore occurs on normal bedding planes in the sandstone, but some of it is concentrated along planes of cross-bedding, which are abundantly developed in the upper part of the formation. At some places, veins of manganese oxides follow well-developed joint cracks roughly perpendicular to the normal bedding (fig. 22). Elsewhere the rock is cut by irregular veins, which may follow fractures caused by folding or may have been formed by irregular replacement of the rock (fig. 23). The ore-bearing parts of the Becraft sandstone were made exceedingly porous by removal of the carbonate that they originally contained, thus making it possible for mineral-bearing solutions to circulate freely.

Many of the veins of manganese oxides in the sandstone show a core of pure oxides bordered on each side by a zone of oxides containing scattered grains of sand; these zones in turn are bordered by sandstone merely stained with manganese oxides, and outside of this darkened sandstone there is light-colored unstained sandstone, the boundary between the two being fairly sharp. This sequence suggests replacement rather than cavity filling. In some veins, however, pure oxides lie close to unstained sandstone, and the central parts of such veins contain open cavities. Some openings in the ore-bearing sandstone are filled with a red clay, which probably was washed in by ground water after the manganese oxides were deposited (fig. 23).

Early in 1941, the Bureau of Mines began exploratory work at the Stange and Arms (Byrnes Heirs) mines, with a view to determining how much recoverable ore remained in the vicinity of the workings. In the course of three months, 35 churn-drill holes were put down, and 17 trenches, totaling more than 4,500 feet in length and having a maximum depth of 17 feet, were opened with a bulldozer.

Of the 35 drill holes, five reached depths of 100 feet or more; the greatest depth was 153 feet, the average 50 feet. All of the holes were started in the Becraft sandstone; 22 of them passed into the underlying Tonoloway limestone or its residual clay, but none passed entirely through the limestone (pl. 38). A number of the holes revealed ore in the Becraft, but only traces were noted in the clay. Three of the holes that entered the clay (Nos. 7, 26, 28) ended in hard, unweathered limestone. The altitude of the top of the unweathered limestone is about 2,900 feet in drill holes 7 and 28 and 2,965-2,970 feet in drill hole 26. The highest observed outcrop of hard limestone in the Flat Top Mountain district is on the Ramsey farm, a mile northeast of the mines, at an altitude of 2,880 feet; no other outcrop was found above 2,620 feet.

5/ Stose, G. W., and Miser, H. D., op. cit., p. 134.

Most of the trenches opened with the bulldozer showed only Becraft sandstone, which in a few of the trenches contained a little ore. Seven of the trenches on the south side of the prospected area exposed chert of Onondaga age. In these trenches and in the Main pit of the Arms (Byrnes Heirs) mine the upper layers of the chert are blanketed with a talus of a red sandy clay, which carries numerous fragments of high-grade manganese oxides with fragments of sandstone and chert. The clay is residual material derived mainly from the Becraft sandstone, which has been deeply eroded on the crest of the mountain. It is unconsolidated and is easily handled with a shovel and in the washer. Its thickness varies considerably.

Production.--Johnson Brothers & Co., the earliest operators in the area, shipped 5 cars of manganese ore in 1917. E. S. Suffern, who was the next person to mine in the area, shipped 900 tons in the following year. In the years 1918 to 1940 the Stange mine shipped about 16,000 tons of concentrates containing more than 35 percent manganese, and about 3,000 tons that was of lower grade.

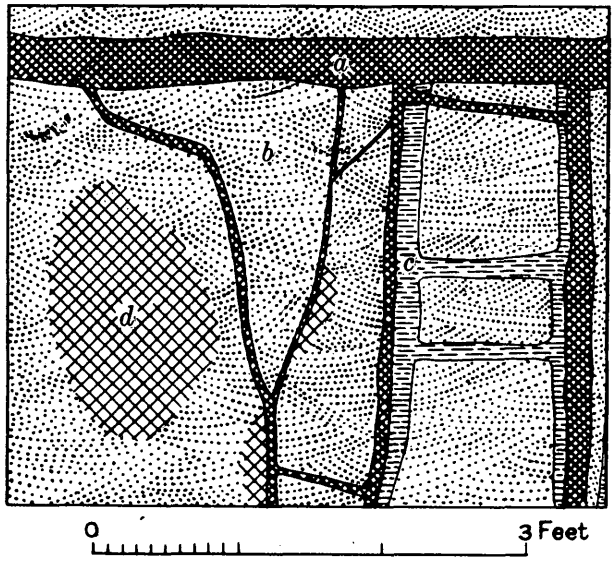

Figure 22.--Manganese oxides and red clay along bedding planes and joint cracks in Becraft sandstone at Arms mine. a, Manganese oxides; b, cross-bedded Becraft sandstone; c, red clay; d, manganese oxides on joint face.

Analyses of 38 carload shipments made from 1917 to 1919 were quoted by Stose and Miser.6/ Analyses of 68 carload shipments, amounting to about 3,000 tons, made from 1934 to 1942 are given in the table on the following pages. The silica content is higher in these later shipments than in those recorded by Stose and Miser.7/

6/ Stose, G. W., and Miser, H. D., op. cit., p. 141.

7/ A 7-ton sample of ore from the Stange-Arms mine area, collected by L. B. Moon, was tested by the Metallurgical Division of the Bureau of Mines. Results of several methods of ore-dressing were published in U. S. Bur. Mines Rept. Inv. 3633, pp. 1-14, 1942.

Partial record of carload shipments from Stange, Arms, and Biggam mines 1/

Date	Tons	Mn (percent)	SiO_2 (percent)	Fe (percent)	Al_2O_3 (percent)	P (percent)	BaO (percent)	Producer
1934								
June	*45	46.73	11.58	1.60	....	0.23	....	Ottomar Stange
Do	*45	51.29	5.08	.70	....	.24	....	Do.
Do	48.16	48.30	6.50	1.80	....	.24	....	Do.
Do	47.71	47.48	8.08	1.50	....	.25	....	Do.
July	44.28	46.83	11.78	1.35	....	.24	....	Do.
Do	*45	46.65	10.46	1.10	....	.23	....	Do.
Do	*45	45.45	12.00	1.25	....	.22	....	Do.
1938								
May	50.80	41.42	14.64	3.20	....	.....	....	Do.
Do	45.62	42.47	15.64	2.50	....	.....	....	Do.
June	51.65	38.89	22.00	2.60	....	.....	....	Do.
Do	44.73	39.93	24.76	1.00	....	.....	....	Do.
July	52.45	44.85	10.14	1.50	....	.....	....	Do.
Do	52.14	45.30	10.32	1.40	....	.....	....	Do.
August	54.15	43.36	14.00	3.50	....	.....	....	Do.
Do	46.69	42.17	15.92	1.60	....	.....	....	Do.
Do	35.00	44.25	10.92	3.40	....	.....	....	Do.
1940								
August-October	*405	48.60	9.80	3.75	....	?	....	J. Lee Marcum
November	*22.50	49.26	.....	.50	1.90	.226	....	Ottomar Stange
Do	*22.50	47.03	.....	.48	1.81	.216	....	Do.
Do	*22.50	48.54	.....	1.05	2.65	.234	7.51	Do.
Do	*22.50	45.89	.....	.99	2.51	.221	7.10	Do.
Do	*22.50	48.97	.....	.50	1.52	.228	7.35	Do.
Do	*22.50	47.45	.....	.48	1.47	.220	7.12	Do.
Do	*22.50	46.34	.....	.95	1.68	.203	....	Do.
Do	*22.50	44.29	.....	.91	1.61	.194	....	Do.
1941								
August	*20	46.79	7.90	2.90	.59	.27	....	R. F. Biggam
October	30.5	39.81	14.64	5.80	.49	.258	....	Do.
Do	37.2	42.03	15.04	4.00	.82	.275	....	Do.
Do	35.4	43.36	16.40	1.00	....	.201	....	Do.

1941								
November..........	38.7	43.95	15.18	1.70	.66	.259	....	Do.
Do..............	40.3	44.55	13.50	2.30	.49	.274	....	Do.
Do..............	47.0	42.03	18.86	2.70	.42	.238	....	Do.
December..........	32.7	43.96	11.50	3.30	.72	.279	....	Do.
Do..............	37.5	44.25	8.38	4.80	.82	.294	....	Do.
Do..............	34.3	42.33	17.16	3.20	.16	.277	....	Do.
Do..............	41.5	44.55	12.78	2.50	.33	.302	....	Do.
October 1941 to	39.42	46.71	11.10	1.55	....	.200	....	R. W. Arms
about March	39.86	49.04	9.10	1.13	....	.196	....	Do.
1942.	27.63	48.74	8.04	1.65	....	.208	....	Do.
	44.24	45.43	14.08	1.82	....	.195	....	Do.
	42.81	45.43	14.88	1.82	....	.235	....	Do.
	42.37	42.38	16.88	1.62	....	.266	....	Do.
	43.04	40.13	19.81	1.72	....	.251	....	Do.
	40.44	38.32	26.18	1.42	....	.224	....	Do.
	39.96	41.22	21.26	1.52	....	.218	....	Do.
	43.44	40.50	21.04	2.13	....	.206	....	Do.
	43.97	41.22	20.18	1.62	....	.196	....	Do.
	46.32	41.12	20.22	2.04	....	.200	....	Do.
	48.53	45.72	12.72	2.13	....	.178	....	Do.
	47.36	43.40	15.24	2.33	....	.190	....	Do.
	47.14	47.32	9.22	2.03	....	.182	....	Do.
	42.76	45.58	11.22	2.53	....	.179	....	Do.
	47.99	47.75	8.40	2.33	....	.186	....	Do.
	44.73	46.74	6.46	4.05	....	.189	....	Do.
	50.00	47.75	9.32	2.03	....	.189	....	Do.
	42.81	43.69	14.86	2.43	....	.170	....	Do.
	38.87	44.12	15.56	2.53	....	.199	....	Do.
	40.15	43.51	14.42	2.43	....	.189	....	Do.
	42.62	46.27	10.12	2.33	....	.174	....	Do.
April............	29.2	40.70	15.50	5.10	.79	.278	7.34	R. F. Biggam
Do..............	22.2	38.70	19.82	2.40	.33	.212	6.84	Do.
May..............	24.5	41.29	18.26	2.50	.23	.228	7.03	Do.
Do..............	27.8	40.90	19.62	1.80	.20	.204	6.89	Do.
June.............	34.4	40.10	21.36	2.00	.12	.194	6.81	Do.
Do..............	26.6	40.40	21.96	1.60	.58	.192	7.11	Do.

Partial record of carload shipments from Stange, Arms, and Biggam mines 1/--Continued

Date	Tons	Mn (percent)	SiO_2 (percent)	Fe (percent)	Al_2O_3 (percent)	P (percent)	BaO (percent)	Producer
1942								
June............	28.8	39.74	23.64	1.50	.27	.198	7.03	R. F. Biggam
Do..............	38.1	41.29	18.20	2.70	1.00	.270	8.68	Do.
Do..............	26.7	40.90	29.39	....	....	.260	....	Do.
Total.........	2,978.24							

1/ Records furnished by producers. * Tonnage approximate.

Dismal Creek mine

The Dismal Creek mine lies in Dismal Basin, between Flat Top and Brushy Mountains; it is about 2¼ miles southeast of the Stange-Arms mines. Shallow excavations were made some 20 years ago 8/ about 1,000 feet south of the Falls of Dismal, near the crest of a ridge, at an altitude of 2,300 feet. They were examined in the fall of 1940, at which time no evidence of recent work was noted. Geologic mapping, and examination of the material in and near the pits, showed that the manganese oxides occur in the upper part of the Clinton formation.

In the spring of 1942 the Biggam Manganese Co., which had leased the property from D. E. Conley, the owner, opened a series of pits in the area previously prospected, and also discovered some deposits at the same geologic horizon across Dismal Creek to the east-southeast. Prospecting by Mr. Biggam likewise revealed considerable float ore in Pearis Thompson Hollow, north of the Falls of Dismal. The Biggam Manganese Co. constructed a washing plant on Dismal Creek between the prospected areas and began mining operations. According to Mr. Biggam the concentrates are so low in manganese and so high in silica that they cannot be shipped profitably unless mixed with concentrates from the Stange mine. One carload of 23.4 tons, containing only Dismal Creek concentrates, was shipped in April 1942. It assayed Mn, 37.44; SiO_2, 15.66; Fe, 8.30; Al_2O_3, 1.55; P, 0.232; BaO, 5.96.

Silver Creek mine

The Silver Creek mine, recently operated by the Silver Creek Manganese Mining Co., is on the northwest side of Flat Top Mountain, 2 miles north-northwest of the Stange mine. The openings on the property comprise three pits, which lie on the southeast side of Silver Creek (formerly called No Business Creek); about 300 feet above the stream.

The property was described as the "No Business Creek prospect" by Stose and Miser, whose description shows that only shallow excavations were made prior to

8/ Stose, G. W., and Miser, H. D., op. cit., pp. 142-143.

their visit in August 1920.9/ At that time the property was owned by Ottomar Stange, who later sold it to Joseph Taylor. Mr. Taylor leased the property to Messrs. Dunn, Stickley, and Stafford, who shipped 19 cars of concentrates in the years 1926-29. At least 12 additional cars, said to be all of 40-ton capacity, were shipped by Taylor in 1929-34.

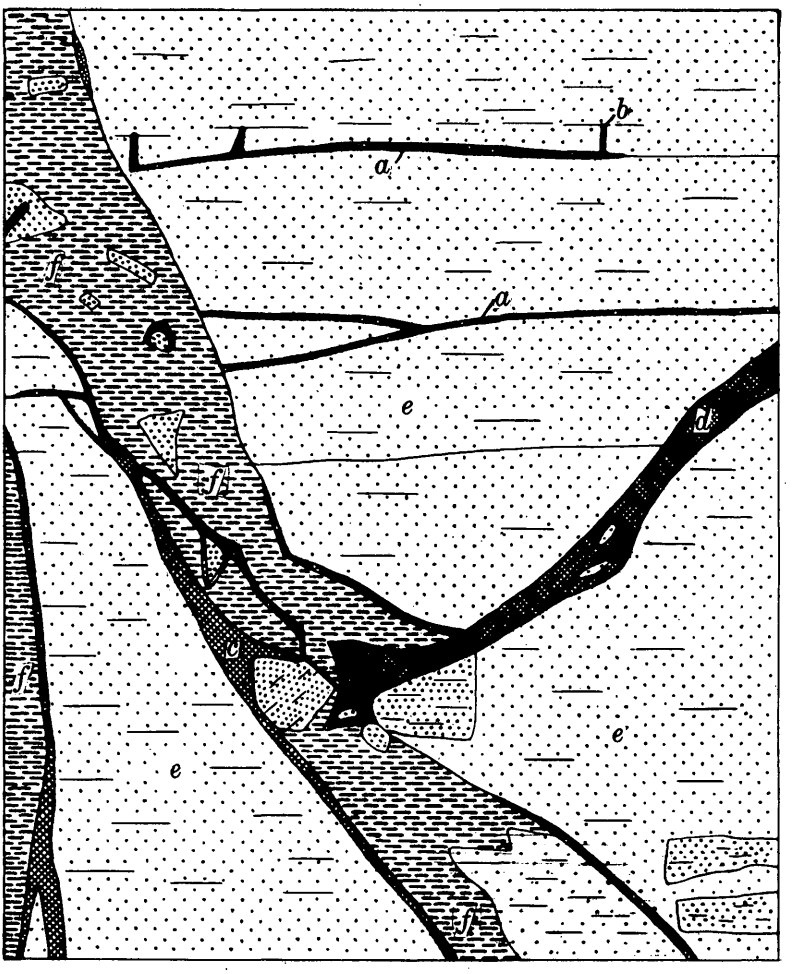

Figure 23.--Manganese oxides in Becraft sandstone at Arms mine. a, Oxides along bedding plane; b, oxides in joint crack; c, oxide in crevice with red clay; d, oxides apparently replacing sandstone; e, sandstone; f, red clay.

In 1940 the property was purchased by the present owners, the Crismond family, who opened a series of test pits and constructed a small washing plant on Silver Creek below the prospected area. In 1941 a gas shovel was brought in and three large pits were opened. Two cars of concentrates, said to carry 38 to 40 percent manganese, were shipped during the first

9/ Stose, G. W., Miser, H. D., op. cit., pp. 131-132.

half of the year, but mining operations were abandoned in September 1941. In January 1942 R. F. Biggam leased the property, but since then he has dismantled the washing plant and moved it to the Dismal Creek mine.

The pits are in the fossiliferous sands and clays of the upper part of the Clinton formation. When last examined, in September 1941, the largest pit measured 200 feet by 50 feet and had a maximum depth of 12 feet. Talus up to 6 feet in thickness was exposed in the walls. Some of the largest pieces of manganese-bearing material are irregularly distributed in the lower part of this blanket of overburden, on the up-hill side of the pit. Some of the ore in the talus is siliceous, consisting of medium-grained sandstone impregnated with manganese oxides, but most of it consists of fragments of nodular masses, which appear to have been derived from ferruginous clays and shales. Most specimens are dull black and are light in weight; others are heavier and show shrinkage cracks filled with bright hard psilomelane.

Immediately above the large pit there are two smaller, subcircular pits. The lower one, measuring 25 feet in diameter and 5 to 8 feet in depth, shows good exposures of the sandstone and mottled clays of the Clinton formation. The beds strike about N. 5° E. and dip 28° W. In the northeast wall there is a 4-foot section of bedrock. The clays, which vary in color through shades of yellow, pink, and green, contain ferruginous nodules of light-weight manganese oxides, but these nodules, though numerous, do not cover more than 5 percent of the surface. The higher of the two subcircular pits is the larger, but it gives only poor exposures of the manganese-bearing clay.

Morris prospect

The Morris prospect is in the valley of Silver Creek, at the foot of Flat Top Mountain, three-tenths of a mile east-northeast of Silver Creek School. It lies about 25 feet above the level of the creek.

The first prospecting at this site was done by the owner, C. C. Morris, in 1937. A few tons of concentrates were produced and shipped before excessive water seepage halted the work. In 1941 arrangements were made with Messrs. D. C. Yates and Joseph D. Hebert for additional work, employing a steam shovel rented from Ottomar Stange. Pits were excavated as described below, and about 15 tons of concentrates were washed in the Stange mill and shipped to the E. J. Lavino Co., in Lynchburg, Va. No work was being done on the prospect in 1942.

As shown in plate 37, the prospect lies on a small exposure of sandstone of the Clinton formation in the valley of Silver Creek. Large blocks of the overlying Tonoloway limestone are found at the site, but no ledges of it are revealed at the surface. Across the creek to the north, younger beds of Becraft sandstone and chert of the Onondaga formation are exposed. In general the strata in this vicinity dip to the north, but at the prospect the Clinton formation strikes N. 60° W. and dips 8° SW.

A steam-shovel pit, measuring 100 feet by 25 feet and having a maximum depth of 10 feet, was opened by Messrs. Yates and Hebert about 100 yards southeast of the Morris house. This pit exposes the sandstones and green clays that are characteristic of the upper part of the Clinton. Two other pits, comparable

in size to the first but more irregular in outline, were opened a short distance to the northeast. Both were partly filled with water at the time of examination.

Very little manganese ore was visible in the pits when they were visited. Most of the ore appeared to lie in the overburden. Two types of manganese oxide could be distinguished, a hard psilomelane of good grade and nodular material distinctly lighter in weight. The nodular ore has a dull luster but carries thin veinlets of bright steel-blue manganese oxide. An analysis of a sample submitted to E. J. Lavino Co. by Mr. Yates showed: Mn, 41.74; SiO_2, 16.14; Fe, 3.90; P, 0.072.

Wyrick prospect

The Wyrick prospect is a quarter of a mile south of Silver Creek School and 1 3/4 miles northwest of the Stange mine (pl. 37). It lies on a left tributary to Silver Creek, and the bottom of the pit is 50 feet above the main stream. The altitude above sea level is 2,290 feet—700 feet lower than the bottom of the Main pit of the Stange mine.

The occurrence is on land owned by the Wyrick family. It was discovered by Henry Wyrick in 1926, and was worked intermittently on a small scale until 1937. Some ore has been shipped from it.

The lowest 10 feet of the walls of the main pit are covered with talus, above which there is a bed of green clay several inches thick, containing flattened nodules of low-grade manganese oxide. The clay is overlain by 10 feet of porous, ferruginous, cross-bedded blocky sandstone. Fresh pieces of the clay are slightly glauconitic, and weathering of the glauconite is probably responsible for much of the ferruginous stain. No fossils other than poorly preserved molds were found in the clay. The sandstone probably is Becraft, but it may belong in the younger Onondaga. The numerous joint faces of the sandstone are coated with crystalline pyrolusite in dendritic plumose forms. Manganese oxide locally impregnates the sandstone and fills narrow fractures. The beds strike N. 77° E. and dip 20° NW., which is the general attitude of the northwest flank of the Flat Top Mountain anticline. The prospect lies close to a small dip fault, and fractures in the beds may have stimulated ground-water circulation and aided the localization of the manganese oxides.

Johnson prospect

The Johnson prospect is 1.3 miles northeast of the Stange mine and three-tenths of a mile northwest of the road that follows the crest of Flat Top Mountain, on a short secondary ridge that parallels the main crest. The main pit lies 100 feet above a tributary to Ding Branch, at an altitude of 2,940 feet. The deposit was discovered in 1917 and worked during a part of the following year, when some 15 tons of float ore was shipped from South Gap.10/ No work has been done on it since then.

The manganese oxides appear to be in the Clinton formation. They impregnate and cement gray, fine-grained sandstone and

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10/ Stose, G. W., and Miser, H. D., op. cit., p. 133.

brecciated quartzite. Nodules of ferruginous manganese oxides also occur, and although they were not found in place they presumably have weathered out of the yellow and brown clay reported by Stose and Miser. No high-grade material was found. The brecciation in the quartzite may be due to the proximity of a fault (pl. 37).

Other occurrences

The location of a series of old prospect pits near the crest of Flat Top Mountain is indicated on plate 37, on a spur that extends southeastward from the summit road at a point half a mile southwest of Little Horse Gap. These pits lie at an altitude of 3,450 feet, about 70 feet below the road. They are excavated in Becraft sandstone, which in this area is very ferruginous and contains a little manganese oxide. Six-tenths of a mile southwest of the abandoned pits, vertical beds of Becraft sandstone impregnated with iron oxide and a little manganese oxide are exposed immediately south of the road.

In Jenney Cabin Hollow, a mile southeast of Little Horse Gap, sandstones believed to be Clinton are impregnated with manganese oxide and a smaller quantity of iron oxide. These beds strike N. 50° E. and dip 10° SE.; they are exposed in a small pool in the bed of the creek, at an altitude of about 2,665 feet.

Southeast of the road in Big Horse Gap much of the Clinton sandstone float is impregnated with oxides of iron and manganese, but no outcrops of this rock were found.

ROUND MOUNTAIN DISTRICT

Structure

Round Mountain is carved from a broad anticline comparable in size to that of Flat Top Mountain, and is capped by the same geological formations. The Round Mountain anticline, however, shows higher dips than the Flat Top Mountain anticline, and it is not faulted. The axis of the Round Mountain anticline trends northeast. The fold is unsymmetrical, the northwest flank having the steeper dip. Toward the northeast the older formations disappear beneath younger shales. Southwest of the Round Mountain anticline, and separated from it by a structural and topographic saddle, lies the much larger Burkes Garden anticline. Both these folds are well-formed elongate domes, but the Burkes Garden anticline has been excavated by erosion to form a basin, whereas Round Mountain is a dome topographically as well as structurally. In the saddle between the two domes there are two outcrops of the Tonoloway and Becraft formations, which contain most of the manganese in the area.

Manganese deposits

Concentrations of manganese oxides in workable quantities are found, in the Round Mountain district, at three stratigraphic horizons. The lowest of these is in the upper part of the Clinton formation, the middle one in residual clay derived from the overlying Tonoloway limestone, and the highest in the

Becraft sandstone; the three lie within a stratigraphic interval of less than 200 feet. Small quantities of low-grade ore have been produced from the Clinton and Becraft horizons, but up to the present time the bulk of the best ore in the Round Mountain district has come from the residual clay of the Tonoloway limestone, which has yielded no ore in the nearby Flat Top Mountain district. As at Flat Top Mountain, the largest deposits at Round Mountain occur high above present drainage levels.

The sandstones and sandy clays of the upper part of the Clinton formation carry manganese oxides in at least three localities in the Round Mountain district. At the Suiter West mine, a small proportion of Clinton ore is mixed, after its recovery, with float ore derived from the Becraft sandstone to give a satisfactory product. At the Donahue prospect, the manganese oxide in the Clinton formation is intimately associated with iron oxide, so that the one small lot of ore that has been shipped from this prospect had to be carefully hand-picked. Iron oxide is also closely associated with the float ore from the Clinton formation at the Fire Tower prospect on Round Mountain.

The Tonoloway limestone is known to contain a small percentage of manganese. Some of the manganese is in the form of oxides. On Silver Creek at the base of Flat Top Mountain, for example, outcrops of this limestone show small cavities that are partly filled with calcite and hydrous manganese oxides. Small quantities of manganese oxides can be seen, also, in the limestone of the quarry at Holly Brook, but some of the manganese in this limestone occurs as carbonate. Two analyses of the fresh limestone showed a total manganese content of 0.36 and 0.23, most of it in the form of manganese carbonate, of which the rocks contained, respectively, 0.61 and 0.47 percent.11/ This quantity of manganese carbonate, though small, is appreciably larger than that ordinarily found in limestone. If the samples tested are representative of the Tonoloway in this area, the limestone would serve as an adequate source of the manganese in the deposits now found in the clay derived from it and in the top of the underlying Clinton formation.

In the high saddle between Round Mountain and Burkes Garden the Tonoloway limestone has weathered to a clay. During this process the manganese carbonate was changed to oxides and the rock was leached of all calcium carbonate, and parts of the leached material were left notably porous. In much of the clay, however, the laminations that are so characteristic of the unaltered limestone are still preserved. Considerable silica was introduced, as indicated by the abundant occurrence of silicified fossils in the clay.

A detailed view of an occurrence of ore is shown in figure 24. The cavity now filled with angular fragments of laminated clay probably represents a part of the limestone that was dissolved out before the alteration to clay took place.

The belt of outcrop of the Becraft, which in places contains manganese oxides, encircles Round Mountain almost completely, and in the west-central part of the district it extends westward along the flank of Garden Mountain. The trace of the belt makes a zig-zag pattern (pl. 40), as the sandstone

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11/ The determinations were made in the laboratory of the Geological Survey. The samples were treated with 1:4 nitric acid to dissolve the manganese carbonate. The manganese oxides, which were unaffected by this treatment, were determined separately in the residue.

and the more resistant chert of the Onondaga formation which overlies it dip away from the center of the dome, forming a series of flatironlike spurs. On many of these spurs the porous Becraft sandstone is locally impregnated with manganese oxides or contains veinlike deposits of fairly pure oxides. These relations are shown in the Bastian prospect, near the tip of one of the hills and about 700 feet above Hunting Camp Creek, where bluish-black psilomelane occurs in cracks and fissures in the sandstone. The veins are relatively free from sand, and they contain a little cobalt. At the Shott prospect, which is on Garden Mountain at a level 450 feet above Wolf Creek, there are nodular masses of manganese oxides, presumably from a layer of clay. Parts of the deposit in this prospect

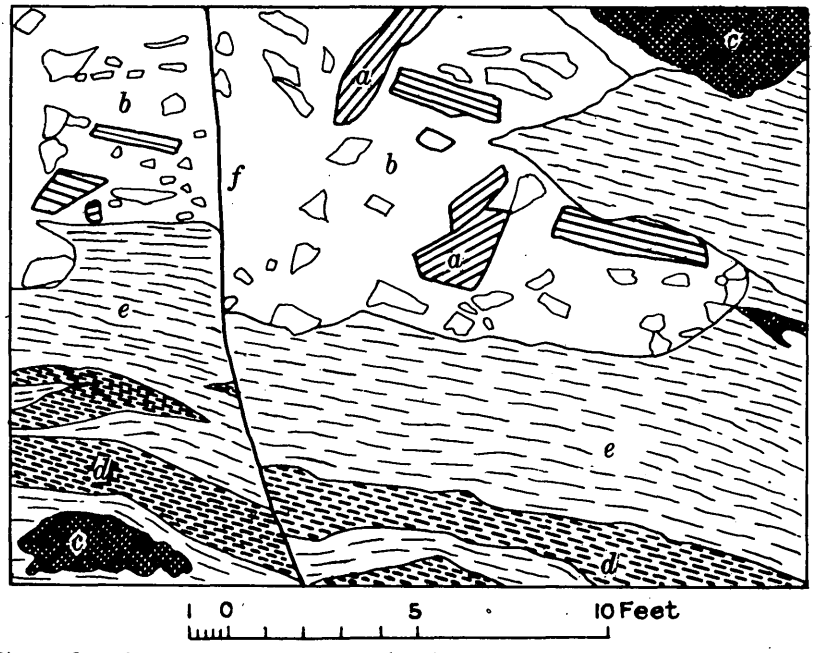

Figure 24.—Manganese oxides in residual clay of Tonoloway limestone in the Hall pit of the Round Mountain mine. a, Angular fragment of laminated clay enclosed by b, dark, nonlaminated clay; c, irregular mass of manganese oxides; d, band of clay stained purplish black by manganese; e, laminated residual clay; f, small fault. From a color photograph taken by David Gallagher.

contain a high percentage of iron. In the saddle between Round Mountain and Burkes Garden, much of the Becraft float is impregnated with manganese oxides and some of it is almost completely replaced by them. Similar material of this type from the Suiter West mine area has been shipped.

Reserves

Probable ore.--The extensive program of churn-drilling, shaft-sinking, and trench-cutting carried out by the Bureau of Mines in the Suiter East mine and Round Mountain mine areas revealed the presence of considerable new ore east of the Suiter ore body, which yielded 6,000 tons of concentrates during the World War I. The ore is irregularly distributed in

the residual clay and sandy clay derived from the Tonoloway limestone. Using data obtained by the Bureau of Mines, the junior author blocked out eight ore-bearing zones and estimated the quantity and grade of the ore contained in each. In making these estimates it was assumed that all metallic manganese shown by assay was 100 percent recoverable in the form of 40 percent manganese concentrates. Such assumptions, however, as Stead pointed out, give the maximum amounts obtainable under ideal conditions. A recovery far below 100 percent was obtained in a test run of the Virginia Hardwood Lumber Co.'s mill. Furthermore, mill tests by the Bureau of Mines at Rolla, Mo., suggested that a 40-percent concentrate is the maximum, rather than the mean, to which the ore can be beneficiated.

The reserves of the entire district, including the deposits indicated by the Bureau of Mines data, probably do not exceed 16,000 tons of concentrates containing about 40 percent of manganese. Not enough work has been done at other prospects and mines in the district to make accurate estimates possible. There may be undiscovered ore pockets on Round Mountain, in the area of clay (derived from the Tonoloway limestone) lying east-northeast of the area tested by the Bureau of Mines.

Mines and prospects

Suiter mines

The Suiter mines, covering two separate areas of operation, are located in the topographic and structural saddle that separates Burkes Garden from Round Mountain, their exact location being shown on a map made from a plane-table survey by Miser in 1920.12/ The mines lie about 1,000 feet above the present-day drainage in the valleys to the southeast and northwest.

An account of the discovery in 1917 and of operations in both areas to the end of 1918 is given in Bulletin 23 of the Virginia Geological Survey.13/ Since 1938 both properties have been controlled by the Miller Manganese Co., of Bluefield, W. Va. This company now owns 127 acres of the mountain, essentially the same acreage as that originally owned by R. B. Miller, who discovered and developed the property. Of this total two areas aggregating about 20 acres contain most of the known manganese deposits.

Most of the production from the East mine has been obtained from the residual clay of the Tonoloway limestone. One large and exceptionally rich pocket yielded most of the 6,000 tons of ore produced in 1917-18. In this pocket large masses of ore were scattered irregularly through the clay.

Small quantities of manganese oxides are still to be seen in exposed banks of clay. The Bureau of Mines put down one drill hole (DH 37) and two pits (Nos. 51 and 52) in the East mine area (pl. 41). The drill hole passed through 48 feet of yellow clay showing only a trace of manganese oxides, all in the lowest 10 feet. Both pits were carried through the clay to the underlying Clinton formation, which was reached at a depth of 16 feet in pit 51 and at a depth of 33 feet in pit 52. Only slight traces of manganese were found in the pits and in the

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12/ Stose, G. W., and Miser, H. D., op. cit., pl. 28.
13/ Idem, p. 159.

drill hole, and it therefore seems unlikely that any ore body of considerable size will be found in the Suiter East mine area or adjacent to it.

At the West mine shallow excavations are scattered over a wide area, but few of them penetrate bedrock. Where bedrock is exposed it consists of sandstone and sandy clay. It is mapped as Clinton, though some of the highest beds contain fossils that appear to be slightly younger—of Wills Creek age. The beds dip to the northeast at low angles. None of the laminated clay derived from the Tonoloway was found, but boulders of Becraft sandstone are scattered over the surface and many of them are impregnated with manganese oxides. Small quantities of nodular ore are found in the exposed bedrock, but apparently much of the ore produced at the mine has been float derived from boulders of Becraft sandstone.

During the period of the World War I only three or four carloads were shipped from the West mine. The present owners, who have confined their activities largely to this area, report shipments as follows:

Partial analyses of recent carload 1/ lot shipments from Suiter West mine

Date	Mn (percent)	SiO_2 (percent)	Fe (percent)	Moisture (percent)	Buyer
1938					
June.....	46.64	.....	....	....	E. J. Lavino Co.
July.....	47.23	.....	....	....	Do.
August.....	46.19	13.68	....	....	Do.
November...	47.40	.....	....	....	National Paint & Manganese.
1939					
March.....	45.74	12.97	1.7	....	Do.
May.....	46.36	9.88	1.0	4.0	Do.
July.....	46.63	8.92	2.0	....	Do.
September..	49.32	6.48	1.0	....	Do.
October....	45.15	13.16	2.1	1.0	Do.
1940					
June.....	40.85	10.22	*3.1	....	Do.
August.....	43.07	17.76	1.6	....	Do.
December...	46.19	.....	....	....	E. J. Lavino Co.
1941					
April.....	37.89	.....	....	....	Do.
July.....	37.87	18.76	*5.9	11.0	Do.

1/ Carloads of approximately 35 long tons.
* High iron is due to admixture of ore from East mine.

Round Mountain mine

The name Round Mountain mine, as used here, is applied to a group of openings lying east of the Suiter mines, from which manganese ore has been mined by the Virginia Hardwood Lumber Co. (pl. 41). The geologic occurrence of the ore in the mine is the same as at the Suiter East mine.

The occurrence of siliceous manganese-bearing float in this area, near the crest and on the southeast slope of Round Mountain, was noted more than 20 years ago, and shallow pits were

then excavated; but as most of these pits proved barren the area was considered unpromising.14/ In 1940 Mr. E. R. Boyd, General Manager of the Virginia Hardwood Lumber Co., used a bulldozer to open three trenches across the crest of the mountain. The first of these was 360 feet long and had a maximum depth of about 12 feet. It exposed laminated residual clays, in part sandy, derived from the Tonoloway limestone. Most of the very small amount of manganese ore that was found was in float material derived from the Becraft sandstone, but some occurred in a 3-inch layer in the upper part of the residual clay.

Mr. Boyd also opened a dozen other trenches across three spurs lying east of Suiter area, still without finding more than traces of manganese. Three additional trenches were opened above and below a manganese-stained cut in the CCC road, nearly three-quarters of a mile southeast of the Suiter East mine. These trenches revealed showings of manganese oxides in the talus and in erratic masses of Becraft sandstone. Mr. Boyd then moved a gas shovel into the area immediately east of the Suiter East mine, and there he struck a rich pocket, which was mined in what became known as the Hall pit. This pocket yielded 30 carloads of ore during the last half of 1941.

In 1942 the mine was being actively worked. Ore from the mine is trucked over a dirt road for a distance of 3½ miles to a washing and jigging plant located on Hunting Camp Creek at the foot of the mountain. Concentrates were formerly loaded into railway cars at the mill, but in 1942 the Norfolk & Western removed the spur from Bastian to Suiter, so that concentrates are now carried to Bastian by truck, over a dirt road 4 miles long.

Geology and manganese deposits.--The geological relations at the Round Mountain mine are shown in plate 41 and in figures 25 and 26. The beds lie nearly flat, and most of the ore is contained in clay derived from the Tonoloway limestone. Becraft sandstone showing traces of manganese caps the higher hills, and in several places residual chert from the Onondaga formation is fairly abundant.

In the Hall pit a section 30 feet thick was exposed in a vertical face. Laminated residual clays near the base of the section showed no manganese oxides, but at higher levels manganese oxides were found to be concentrated in certain layers of the clay, which alternated with sandy beds. Still higher was a cone containing pockets of a soft, purplish-black, crystalline manganese mineral showing columnar structure and having a low specific gravity; near these pockets were others containing abundant silicified fossils of a type common in the hard, unweathered limestone of the lowlands.

In the Hall pit, and also in a number of excavations made later by the Bureau of Mines, some unusual deposits of gray sand and silt carrying plant remains were uncovered. The Hall pit occurrence was in the east wall at an altitude of 3,360 feet. It carried a little manganese and overlay the residual clay of the Tonoloway limestone. These deposits are probably Recent in age; they apparently were laid down in a swamp that

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14/ Stose, G. W., and Miser, H. D., op. cit., pp. 157-158.

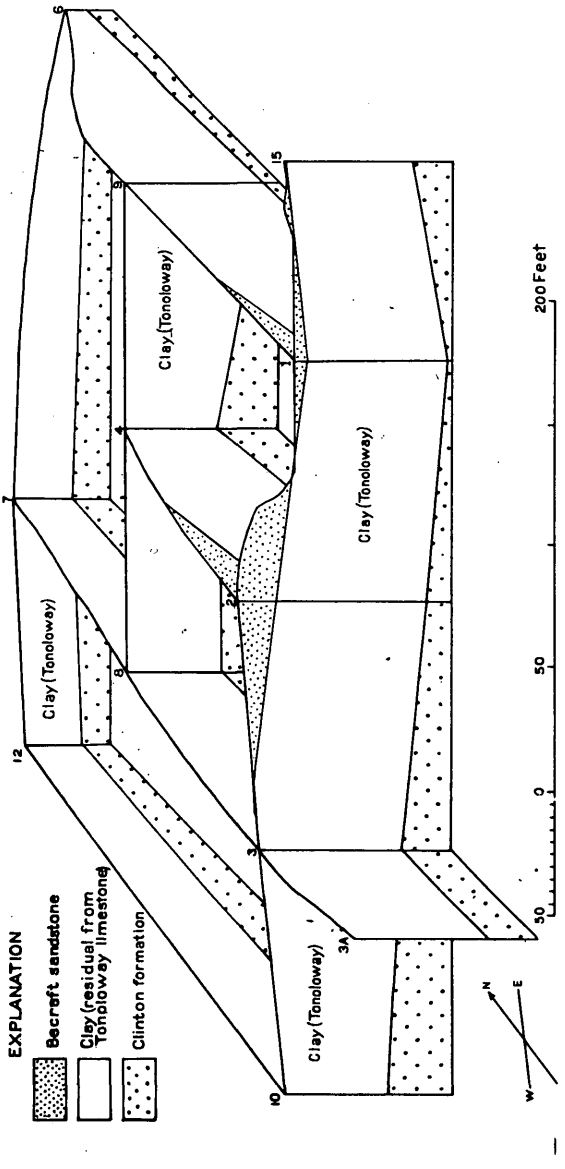

Figure 25.--Fence diagram showing geologic relations in the saddle northwest of the Hall pit, Round Mountain mine. Base of fence at 3,320 feet; numbers refer to holes drilled by Bureau of Mines. Drawn by Frank W. Stead.

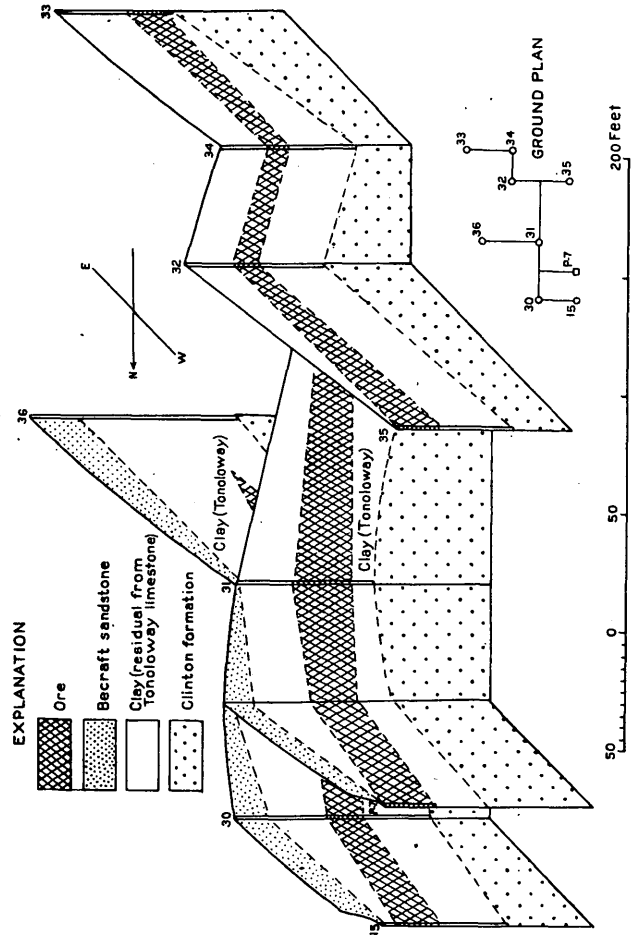

Figure 26.--Fence diagram showing distribution of ore to the east of the Hall pit, Round Mountain mine. Base of fence at 3,300 feet. Based on drill holes and one pit put down by Bureau of Mines. Drawn by Frank W. Stead.

temporarily occupied the lower part of the broad saddle between Round Mountain and Burkes Garden.15/

During a period of about six months in 1942, the Bureau of Mines carried on an extensive program of exploration. About 75 churn drill holes were put down, their depths totaling more than 5,000 feet. About 50 pits and shafts also were dug, with an aggregate depth of more than 700 feet, and 11 trenches were made with a bulldozer. The locations of all of these openings are shown in plate 41. About two-thirds of the drill cores contained traces of manganese, and there was ore in 20 of the holes. At least a trace of manganese oxide was found in about half of the pits, and in 13 of them there was ore. Fifty-eight of the drill holes and 27 of the pits went down to the Clinton formation. Several trenches revealed appreciable quantities of ore, but most of them showed only traces. Some of the ore is deeply buried, and only a part of it has the regular distribution shown in figure 26. The soft ore is lost in the washing process, and much of the hard ore is so fine-grained that a good deal of it is lost in milling.

Some individual pockets, such as the one in the Hall pit, are exceedingly rich, and the manganese oxides in these appear to have extensively replaced the clay. The theory of replacement finds support in the fact that masses of ore include sand grains and irregular masses of sandy clay.

Production.--Available production figures and analyses of carload shipments are given in the table below.

Partial record of carload lot shipments from Round Mountain mine 1/

Date	Tons 2/	Mn (percent)	SiO_2 (percent)	Fe (percent)	Al_2O_3 (percent)	P (percent)
1941						
May	28.69	35.08	14.24	11.40	....	0.204
Do	36.35	34.04	18.36	9.60	2.42	.190
June 3/	43.07	41.22	19.82	1.34	2.79	.216
July	43.12	46.79	5.50	6.70	....	.....
August	36.00	44.25	6.66	8.00	....	.....
Do	31.88	44.40	6.42	7.70	....	.....
Do	42.00	45.45	5.92	6.50	....	.....
Do	40.08	46.36	4.88	6.00	....	.....
September	38.19	47.21	6.36	4.50	....	.....
Do	34.11	46.18	7.42	4.80	....	.....
Do	32.40	45.58	6.44	6.20	....	.....
Do	36.95	45.58	6.34	5.60	....	.....
Do	39.54	45.88	6.70	5.40	....	.....
Do	40.63	44.99	8.00	5.70	....	.....
Do	45.85	44.09	8.40	4.01	....	.146
October	37.36	43.69	7.42	5.67	....	.142
Do	40.99	44.86	6.28	5.27	....	.144
Do	40.79	44.05	7.64	5.47	....	.140
Do	38.67	45.44	5.16	5.10	1.24	.129
Do	41.75	40.85	8.40	8.90	1.99	.170

1/ Records furnished by the Virginia Hardwood Lumber Co.
2/ Dry long tons. 3/ BaO, 5.16 percent.

15/ R. W. Brown of the Geological Survey, who examined plant remains collected in this material, identified several types of wood. Except for one species, which at present appears to be restricted to somewhat lower levels on Round Mountain, the flora appears similar to that living today. Some of the wood, however, is in an advanced state of lignitization, suggesting an age of possibly a thousand years or more.

Partial record of carload lot shipments from Round Mountain mine 1/--Continued

Date	Tons 2/	Mn (percent)	SiO_2 (percent)	Fe (percent)	Al_2O_3 (percent)	P (percent)
1941						
October	38.26	43.66	7.88	7.00	....	.....
Do	42.33	43.33	7.70	6.80	....	.....
Do	40.89	44.84	7.46	8.30	1.42	.168
Do	40.04	44.40	8.70	6.30	1.22	.....
Do	43.00	41.29	9.52	7.80	....	.....
Do	47.38	38.77	12.22	9.00	1.97	.162
November	44.97	40.40	10.88	9.00	.85	.168
Do	42.96	38.32	16.66	7.60	2.03	.158
Do	43.87	38.92	12.32	8.50	....	.....
Do	41.50	42.33	8.88	6.10	1.58	.138
Do	44.70	43.96	8.64	5.00	1.10	.133
December	45.25	44.99	9.02	4.80	1.01	.140
Do	44.27	44.55	8.46	5.10	.88	.134
1942						
April	44.63	41.29	8.44	8.60	....	.179
Do	41.38	36.26	10.08	11.80	....	.204
Do	40.74	38.92	7.86	10.40	....	.157
Do	37.13	37.44	11.70	8.60	....	.157
Do	41.21	37.44	11.84	10.30	....	.180
Do	41.11	34.34	17.84	10.50	....	.150
Do	43.17	38.78	10.28	9.10	....	.178
Do	43.43	36.85	11.94	11.10	....	.174
Do	43.66	35.82	13.14	11.60	....	.183
Do	43.57	38.48	10.32	9.60	....	.184
May	42.10	38.92	9.60	10.50	....	.189
Do	42.14	41.00	7.36	9.00	....	.188
Do	42.13	41.29	9.36	7.30	....	.163
Do	44.28	35.67	14.64	10.70	....	.190
Do	45.24	33.60	17.98	11.60	....	.190
Do	40.96	36.11	11.64	11.50	....	.198
Do	41.41	32.56	17.28	11.90	....	.194
Do	42.28	32.71	18.40	11.70	....	.190
Do	43.52	35.22	13.36	10.90	....	.203
June	46.42	37.74	15.62	7.20	....	.158
Do	41.69	39.96	11.14	7.70	....	.163
Do	37.84	41.00	9.38	7.80	....	.158
Do	41.59	34.34	12.86	12.90	....	.204
Do	41.16	38.04	9.04	10.50	....	.169
Do	43.02	36.85	9.80	11.80	....	.205
Do	.....	37.74	8.96	10.20	....	.192
Do	.....	35.22	10.80	13.00	....	.207
Total	2,383.65					

1/ Records furnished by the Virginia Hardwood Lumber Co.
2/ Dry long tons.

Fire Tower prospect

On the crest of Round Mountain, at a point three-quarters of a mile southwest of the fire tower, a shallow trench excavated in surface materials a number of years ago revealed blocks of sandstone impregnated with manganese oxides. No rock in place is now exposed in the trench, but flat-lying sandstone of the Clinton formation, which forms the crest of the mountain in this vicinity, crops out 200 feet southeast of the trench. The sandstone on the dump contains oxides of iron as well as of

manganese. Along its bedding planes and in joint cracks there are thin veins of hard psilomelane, but no large pieces of high-grade material were found.

Across the road and 400 feet to the northwest of the above-mentioned trench, there is a series of old prospect pits opened about 25 years ago in a search for iron ore. Some iron oxide, mixed with a little manganese oxide, was found. Just north of these pits is an area, several acres in extent, that is littered with small fragments of manganiferous sandstone. According to Mr. E. R. Boyd, of the Virginia Hardwood Lumber Co., an analysis of one specimen gave the following results: Mn, 49.21; SiO_2, 7.06; Fe, 7.06. Early in 1942 five pits were excavated in this area, all of which reached barren sandstone in the Clinton formation within 6 feet of the surface. The float ore in this area is probably residual from the uppermost layers of the Clinton formation, which have largely been eroded from the crest of the mountain.

Bastian prospect

Shallow excavations have been opened by the Virginia Hardwood Lumber Co. on the southeast side of Round Mountain, northwest of Bastian and about 700 feet above Hunting Camp Creek. The excavations lie only 25 feet below the crest of a flatiron-like spur of Becraft sandstone. They have exposed layers of Becraft sandstones containing manganese oxides for a distance of 70 feet along the side of the hill. The chief manganese mineral appears to be a bluish-black psilomelane, which, according to William G. Pierce of the Geological Survey, carries some cobalt. The mineral is deposited in cracks and cavities in the rock, and most of the material seen was practically free from sand.

Shott prospect

No manganese prospects have been located on the northwest side of Round Mountain itself, but manganese oxides are known to occur at several places in the headwaters of Wolf Creek, northwest of the mountain. One of these, at the Shott prospect, is on the north side of Garden Mountain, a mile southwest of Grapefield Post Office and nearly 2 miles west-northwest of the Suiter mines. The manganese oxides are found in the Becraft sandstone, near the tip of a flatiron on Garden Mountain, 450 feet above Wolf Creek. They impregnate the sandstone and form botryoidal masses in cavities. Much iron oxide is associated with the manganese oxides. Early work on this prospect has been described by Stose and Miser.16/ According to Mr. Herbert Kidd, the present owner of the property, a little work was done in 1939 by W. W. McNeil and John Stamper, of Bluefield, W. Va., who had a lease on the property. No additional work was done at the original prospect pit, but a new pit was dug to a depth of 20 feet at a point north of the original prospect and 80 feet lower. Becraft sandstone containing some manganese was encountered, but the pit is now badly caved. Some of the veins of ore, according to Mr. Kidd, were several inches thick. The material now found on the dump is practically free from iron. It includes coarse sandstone impregnated with manganese oxides, and concretions of manganese oxides that

16/ Stose, G. W., and Miser, H. D., op. cit., pp. 167-168.

appear to have come from a layer of clay. No ore has ever been shipped from either pit.

Donahue prospect

Manganese oxides are known to occur in Clinton sandstones exposed on the south slope of Rich Mountain at a point 1½ miles northwest of Grapefield in the Donahue prospect, described by Stose and Miser.17/ The deposit lies on the upper tip of a flatiron of sandstone, at a level nearly 600 feet above Wolf Creek. The manganese oxides are intimately associated with iron oxides. Hand-picked concentrates totaling less than one carload have been shipped from the prospect, but no work has been done there in recent years. Since 1927 the property has been owned by the Virginia Hardwood Lumber Co.

Nye Cove prospects

Manganese oxides are known to occur at several places in Nye Cove, on property owned by the H. Bowen estate, a part of which is included in the area mapped. Reference to early prospecting in this vicinity is given by Stose and Miser.18/ No work has been done on the property in recent years. All the specimens from it that were shown to the writer were high in iron or silica or both.

17/ Stose, G. W., and Miser, H. D., op. cit., pp. 169-171.
18/ Idem, pp. 175-177.