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MANGANESE DEPOSITS OF THE LYNDHURST-VESUVIUS DISTRICT AUGUSTA AND ROCKBRIDGE COUNTIES VIRGINIA

BY

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MANGANESE DEPOSITS OF THE LYNDHURST-VESUVIUS DISTRICT, AUGUSTA AND ROCKBRIDGE COUNTIES, VIRGINIA

By Maxwell M. Knechtel

ABSTRACT

Deposits of manganese ore and manganiferous iron ore occur in the Lyndhurst-Vesuvius district, Augusta and Rockbridge Counties, Va., at scattered localities in a belt extending from Lyndhurst southwest through Vesuvius, along the northwest foot of the Blue Ridge Mountains. The principal mines that have produced manganese are the Lyndhurst, Mount Torry, Kennedy, Red Mountain, Mine Bank, and Vesuvius mines. The manganese oxide minerals psilomelane, pyrolusite, and wad are intermixed in several of the deposits with variable proportions of limonite, from which at present they cannot be separated economically. More than 36,000 long tons of manganiferous iron ore concentrates, averaging approximately 20 percent in metallic manganese, has been marketed for use in manufacturing high-manganese pig iron, and probably at least 50,000 long tons of concentrates of this grade remains in reserve. The recorded production of manganese ore that contained 35 percent or more of metallic manganese, thus being suitable for use in making ferro-manganese, is less than 10,000 long tons, and the proved reserves of such material probably amount to less than 2,000 long tons.

The ore deposits are for the most part irregular bodies in residual clay of the Tomstown dolomite—formerly called the Shady dolomite—of Lower Cambrian age. Most of the deposits occur in synclines and on monoclinal flexures, where the iron and manganese oxides have been concentrated through weathering of dolomite, limestone, and shale beneath the valley-floor peneplain. The most productive deposit, however, that at the Lyndhurst mine, occurs along a thrust fault, and a few small vein deposits fill fractures in older quartzites of Lower Cambrian age. Manganese carbonate, supposed to have been the source of the manganese, may have been disseminated through many formations, but it must have been particularly abundant in certain layers of the Tomstown dolomite. The manganese probably was dissolved as bicarbonate by surface and underground water and transported in this form to the localities at which it was deposited as oxide.

INTRODUCTION

Most of the manganese deposits of the Lyndhurst-Vesuvius district, in Augusta and Rockbridge Counties (fig. 15), occur in a narrow belt extending along the northwest foot of the

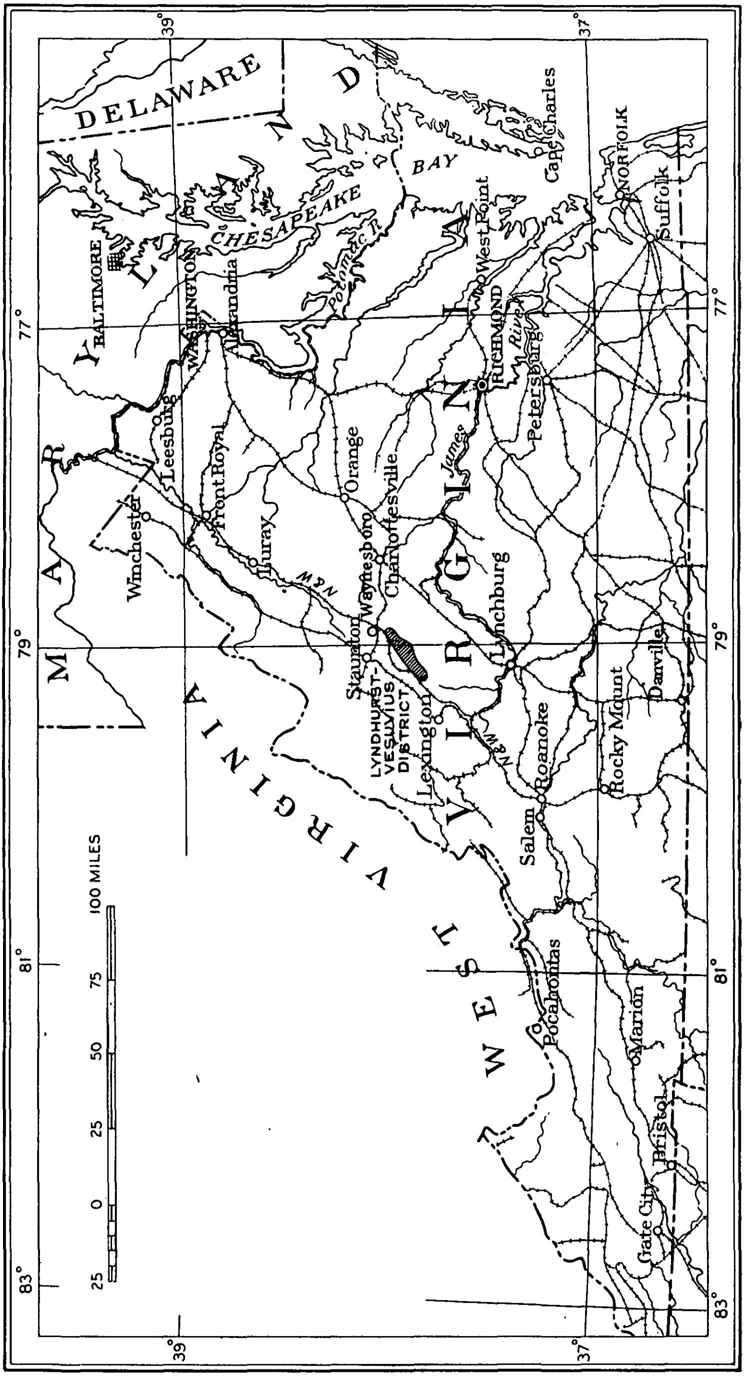

Figure 15.--Index map of Virginia, showing location of Lyndhurst-Vesuvius district.

Blue Ridge Mountains, though a few lie within the mountains. Mining and prospecting for manganese ore have been carried on in the district for more than 80 years.

The Norfolk & Western Railway extends along the northwest side of the district, and roads branching from U. S. Highways 12 and 11 at Waynesboro, Stuart's Draft, Steele's Tavern, and many intermediate points make most parts of the district accessible by automobile. Much of the district is wooded and brushy, and the greater part of it lies within the Pedlar Ranger district of the George Washington National Forest. Permission to prospect and mine in the National Forest is granted at the discretion of the Supervisor at Harrisonburg, Va.

The writer began his investigation of the manganese deposits in 1940. The field work, which was directed by D. F. Hewett, G. W. Stose, and H. D. Miser, was carried on intermittently in the autumn of that year and the spring and autumn of 1941. The writer spent altogether about six months in the field, and he was assisted for brief periods by W. R. Wagner, M. R. Ellis, and T. D. Lance. He is greatly indebted to Edmund Newton, J. W. Wheatley, George B. Tullidge, and many other residents of the district for information regarding the manganese deposits.

GEOLOGY

Surface features

Most of the manganese deposits of this district lie on benches at or near the western base of the Blue Ridge. These benches are the remnants of an ancient plain, of early Tertiary age, known as the "valley-floor peneplain." Today extensive remnants of this plain form a gravel-covered pediment sloping gently away from the Blue Ridge. The pediment is dotted with sink holes, many of which are several hundred feet in diameter, making a karst topography caused by weathering of the underlying bedrock, which is chiefly shale, dolomite, and limestone. North of the divide between the Shenandoah and

James River basins, which passes south of Lofton, the plain is little dissected, but south of the divide much of it has been removed by erosion, leaving fragmentary remnants. A gravel-covered terrace, underlain by both manganese ore and manganiferous iron ore, that lies near the head of St. Mary's River at an altitude of 2,250 feet, may be a remnant of an intermontane alluvial plain contemporaneous in origin with the valley floor peneplain.

The manganese deposits at the Lyndhurst mine underlie a gravel-covered plain. This plain is half a mile wide, extends along Back Creek from Sherando to Lyndhurst and stands 30 to 40 feet below the local level of the valley-floor peneplain. A similar and possibly equivalent low gravel-covered terrace extends along both sides of South River from Vesuvius to Pkin station and continues as far as the old Cotopaxi furnace on St. Mary's River, and a plain 50 feet lower extends along the St. Mary's and South Rivers. The manganese deposits in this vicinity, however, appear to be associated exclusively with the valley-floor peneplain, which here is represented by the third terrace above these rivers.

Exposed rocks

The bedrock exposed in this district consists chiefly of Cambrian sedimentary strata, but in a narrow belt along the Blue Ridge Mountains, at the southeast margin of the district (pl. 29), it also includes pre-Cambrian igneous, metamorphic, and sedimentary rocks. The Cambrian strata exposed in the mountains are chiefly quartzite, sandstone, and shale, and the younger rocks of Cambrian age along the margin of the Appalachian Valley are chiefly shale, dolomite, and limestone. The general character, succession, and thicknesses of the exposed rock formations are given in the table on pages 168-169.

The Tomstown dolomite and the Waynesboro formation have been deeply weathered in a belt a few hundred feet to 3 miles wide adjacent to the Blue Ridge Mountains. Scattered exposures in this belt show gray, yellow, and red clay containing residual lenses and nodules of silica, a few weathered sandy beds, and local deposits of iron and manganese ore. The character of the unweathered bedrock of this belt is known (1) from fresh rock found at various depths in scattered wells, shafts, and drill holes; (2) from exposed thin beds of weathered sandstone and of clay carrying nodules and lenses of chert, which consists in part of silica that has replaced calcareous oolite, and (3) from the character of unweathered rocks at about the same horizons, as exposed outside the belt.

The original bedding is well preserved in most of the clay derived from shale, but it has been completely destroyed in much of the clay derived from limestone and dolomite, from which large amounts of lime and magnesia have been carried away in solution. The depth to unweathered rock varies greatly. At the Lyndhurst mine fresh dolomite lies about 100 feet from the surface. A hole at the lower workings of the Mount Torry tract was recently bored by the Bureau of Mines through approximately 150 feet of weathered rock, mostly clay, which rests on unweathered dolomite. About 1,000 feet to the southwest, large dolomite fragments coming from a depth of less than 20 feet are strewn on the surface near an old shaft close to Orebank Creek.

The residual clay and the associated gravel that floors the terrace remnants show considerable minor faulting, wrinkling, and local tilting, but these features are probably a result of settling. Several deposits of white clay of commercial grade, including that exposed in the Cold Spring clay pit (pl. 29), which contains chert pebbles and a little bauxite, evidently consist of transported material deposited in large

Generalized section of rocks exposed in the Lyndhurst-Vesuvius district

Age	Formation	Thickness (feet)	Character
Quaternary.......	Alluvium............	....	....
Tertiary.........	Gravel and clay.....	....	....
Middle and Upper Cambrian.	Elbrook dolomite....	1,800	Mainly dark gray argillaceous dolomite and limestone in rather thick beds, with a few thin layers of dark gray shale and lenses of sandstone.
Lower Cambrian...	Waynesboro formation (Watauga shale*).	2,000	Exposed as unweathered rock only at northeast and southwest ends of Lyndhurst-Vesuvius district, where the bedrock is mostly limestone, dolomite, and shale with a few intercalated beds of sandstone and chert. Limestone and dolomite mostly dark and impure. Shale gray, greenish gray, and maroon; has a slaty cleavage that commonly cuts across the beds.
	Tomstown dolomite (Shady*).	400+	Not exposed as unweathered rock in district but found in shafts, wells, and bore holes as finely crystalline dolomite. Its residual clay contains lenses of oolite, a few sandy beds in its basal part, and most of the manganese deposits of the district.
	Antietam quartzite (Erwin*).	725	Quartzite and sandstone, buff to nearly white, in massive cross-bedded layers, many of which carry abundant tubes of *Scolithus linearis*. Basal part includes about 65 feet of dark beds resembling dark beds of Harpers shale. A few veins of manganese oxide occur along fractures in quartzite.
	Harpers shale (Hampton*).	1,000	Shale, fine-grained arkose, and quartzite. Shale and arkose dark gray, thin-bedded. Quartzite forms three thick members in middle of formation, resembling Antietam but carrying *Scolithus* tubes in less abundance. Vein of manganese oxide at Hogpen Hollow along fracture in uppermost quartzite member.

	Weverton quartzite..	900-2,000	Comprises three members. (1) Lowest member, 250 feet of quartzite, sandstone, conglomerate, and a little shale. Quartzite and conglomerate form conspicuous layers, mostly light gray to nearly white. Pebbles are chiefly angular fragments of quartz. (2) Middle member, 500 feet of dark gray shale, weathering greenish gray and pink at some localities. (3) Top member, 150 feet of quartzite resembling Antietam but apparently containing no Scolithus tubes. Shows a little red iron coloration at some localities.
			Unconformity
Pre-Cambrian.....	Catoctin metabasalt, basalt, and sedimentary rocks.	0-500+	Greenstone schist, amygdaloidal basalt, tuff, shale, arkose, and conglomerate.
			Unconformity?
	Crystalline rocks...	....	Granodiorite.

* Name used in Bulletin 17 of Virginia Geological Survey.

solution cavities during or after the early Tertiary peneplanation.

Structure

The geologic structure of the Lyndhurst-Vesuvius district is essentially that of a monocline dipping northwestward toward the valley. The oldest rocks, along the southeast side, are overlain successively by younger and younger rocks to the northwest. Near the center of the district, where the mountain front bulges northwestward, the monocline is interrupted by northeast-trending anticlines, synclines, and faults (see cross sections on pl. 29). As a rule the axes of the folds plunge northeastward but a segment of one fold plunges southwestward from the head of St. Mary's River, forming a structural basin, the bottom of which is occupied by the manganese-bearing residual clay exposed at the Mine Bank and Red Mountain mines. At most places on the southeast limbs of the anticlines the strata dip gently, but they are in general more steeply inclined, and in places overturned, on the northwest limbs.

On a thrust fault extending north along Back Creek east of the CCC camp, steeply inclined, overturned pre-Cambrian rocks, exposed east of the creek, are in contact with gently dipping Antietam quartzite exposed west of the creek. The stratigraphic displacement on this fault is at least 2,000 feet near Lake Sherando, but decreases toward the north. The fault is obscure near Sherando, but it probably continues north along the low ridge followed by the State Highway at the Lyndhurst mine. The relations along this fault, and especially the overturning on its east side, suggest that it is a break in the northwest or lower limb of a large northeast-plunging recumbent anticline (sec. E-E', pl. 29). Brecciation of the Antietam quartzite near this fault is well displayed under the bridge at Sherando and in a cut bank on the west side of Back Creek about 1,000 feet south of the Lyndhurst mine. Some of the manganese ore of this mine is a partial replacement of brecciated Antietam quartzite, which is overlain by several feet of terrace gravel.

A thrust fault of less displacement may follow Mills Creek, continuing northeast along the north side of Mount Torry and passing through or near the Mount Torry mine. Another thrust fault may extend along St. Mary's River west of the Mine Bank mine, but the evidence for such a fault is not considered strong enough to warrant placing it on the map or on section B-B'. A fault of small displacement about a quarter of a mile south of the Vesuvius mine appears to be either a normal fault or an underthrust from the southeast.

ORE DEPOSITS

The manganese deposits of the Lyndhurst-Vesuvius district, all of which are associated with rocks of Lower Cambrian age, are of types that prevail along the outcrop of these rocks in Virginia, Tennessee, Georgia, and Alabama. Several reports 1/ published by the Virginia and Federal Geological Surveys and by the Bureau of Mines are of interest in connection with them. Newton 2/ describes the methods commonly employed in this region in the mining of manganese ores and in their preparation for the market. Rogers 3/ briefly outlines the problems arising in war time from the utilization of manganese in the manufacture of steel.

Ore minerals

The manganese in the ores of the Lyndhurst-Vesuvius district is wholly in the form of oxides. The ore minerals are chiefly, if not exclusively, pyrolusite and psilomelane, mixed with more or less limonite and associated in places with considerable wad, which is not recovered in mining.

Apparently psilomelane and pyrolusite tend to occur in this district in separate "pockets", the psilomelane forming veins and streaks in which pyrolusite is absent or is only a minor constituent of the ore, and the pyrolusite occurring in aggregates that contain little or no psilomelane.

The pyrolusite (MnO_2, generally with a little H_2O) all gives a jet-black streak, but otherwise it varies greatly in its physical characteristics—from heavy to light, from soft

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1/ Weeks, J. D., Mineral Resources U. S., 1885, p. 317, 1886.
Harder, E. C., Manganese deposits of the United States: U. S. Geol. Survey Bull. 380, pp. 261-263, 1909.
Watson, T. L., Mineral resources of Virginia: The Virginia Jamestown Exposition Commission, pp. 249-250, Lynchburg, 1907.
Hewett, D. F., Stose, G. W., Katz, F. J., and Miser, H. D., Possibilities for manganese ore on certain undeveloped tracts in Shenandoah Valley, Va.: U. S. Geol. Survey Bull. 660, pp. 271-304, 1918; Stose, G. W., Miser, H. D., Katz, F. J., and Hewett, D. F., Manganese deposits of the west foot of the Blue Ridge, Va.: Virginia Geol. Survey Bull. 17, pp. 99-112, 1919.

2/ Newton, Edmund, Mining and beneficiation of Appalachian manganese ores: U. S. Bur. Mines Inf. Circ. 7145, 1941.

3/ Rogers, B. A., Utilization of manganese in the steel industry: U. S. Bur. Mines Inf. Circ. 7162, 1941.

to rather hard, from dense to granular, from dull to lustrous, and from gray to grayish black. It occurs ordinarily in irregular lumps, many of which are nodules, locally called "kidneys," with botryoidal surfaces. In some of the lumps thin concentric layers of a fine-grained variety of the mineral alternate with layers of a fibrous or granular variety. The mineral also forms minute seams in limonite. All the known bodies of pyrolusite in this district are in clay and sandy clay, and most of them contain considerable limonite, which, at the present price of manganese ore, cannot be profitably separated from the pyrolusite by any known process.

The psilomelane (H_4MnO_5, generally containing some potassium, barium, and cobalt) is a hard, heavy, dense, bluish-black mineral giving a brownish-black streak and occurring characteristically as lumps with botryoidal surfaces. Some specimens contain aggregates resembling oolites, made up of tiny spherical grains of the mineral. At the west end of the main pit of the Mine Bank mine a barium-free variety of psilomelane, recently named cryptomelane,[4/] forms nodules in residual clay, but in at least a part of the Lyndhurst mine and at three other localities at which ordinary psilomelane has been found it fills fissures and the openings in brecciated zones in sandstone and quartzite.

The wad, which contains from 30 to 42 percent of manganese, is a soft dark brown to black earthy material of low specific gravity.

The limonite ($2Fe_2O_3.3H_2O$) is easily distinguished from psilomelane and pyrolusite by its yellowish-brown streak.

4/ Richmond, W. E., and Fleischer, Michael, Cryptomelane, a new name for the commonest of the "psilomelane" minerals: Am. Mineralogist, vol. 27, No. 9, pp. 607-610, September 1942.

Manner of occurrence

The manganese ore deposits of this district occur mainly in the mantle of residual clay that rests on the Tomstown dolomite, formerly designated Shady dolomite in some reports; a few deposits consist of veins filling fractures in the Antietam quartzite, sometimes called Erwin quartzite; and at least one small vein deposit occurs in a quartzite member of the Harpers shale, sometimes called Hampton shale. The residual clay in which most of the ore bodies occur has resulted from weathering of dolomite, limestone, and shale beneath the surficial gravel of the valley-floor peneplain, and in places this gravel contains pebbles of manganese oxides washed from the subjacent clays. In stratigraphic and physiographic environment, therefore, these manganese deposits resemble many others, previously described,5/ that are scattered along the west foot of the Blue Ridge from Tennessee to northern Virginia. The deposits occur in association with synclines, monoclines, and faults.

Several synclines—the St. Mary's River syncline, the syncline northwest of Torry Ridge (locally called Mount Torry), and the synclines along Kennedy Creek and along Mills Creek northwest of Turkey Ridge—have long been regarded as of special interest in connection with the search for manganese deposits in the Lyndhurst-Vesuvius district. Within each of these synclines there is at least one tract in which the stratigraphic, physiographic, and structural conditions generally considered most favorable for the occurrence of manganese oxides at the west foot of the Blue Ridge are fulfilled in

5/ Stose, G. W., Miser, H. D., Katz, F. J., and Hewett, D. F., Manganese deposits of the west foot of the Blue Ridge, Va.: Virginia Geol. Survey Bull. 17, pp. 49-54, 1919.

Analyses of ores from Lyndhurst-Vesuvius district

	1	2	2A	2B	3	3A	5	5A	7	9	
Mn	44.19	51.99	58.80	54.83	39.33	50.54	54.66	42.24	41.19	47.27	Manganese ores
Fe	2.80	3.82	Trace	2.08	6.47	.25	.24	4.42	5.30	.13	
Al_2O_3	......	......	.91	2.81	......	.78	1.08	......	3.93	......	
SiO_2	......	......	.18	3.98	11.36	.22	.22	.24	16.36	......	
P	.446	.332	......	......	.052	.275	.253	.056	.094	.043	
Ba	5.70	2.10	2.51	.28	......	11.53	None	......	......	8.51	
Ni	None	None	......	......	......	None	.14	......	......	......	
Co	.86	.36	......	......	......	.28	.95	......	......	.40	
Cu	.07	None	......	......	......	.008	None	......	......	.07	
K_2O	......	......	......	......	......	......	*	......	......	......	
CaO	......	......	2.81	Trace	......	......	......	......	......	......	
MoO_3	......	......	......	......	......	.01	None	......	......	......	
H_2O	......	......	2.75	2.93	......	......	......	......	......	......	
Insoluble	4.56	2.38	......	......	......	......	......	......	......	.19	

	3B	4	4A	5B	6	8	
Mn	......	33.53	......	8.22	......	......	Manganiferous iron ores
Fe	45.34	3.88	52.50	41.13	38.95	48.50	
P	.206	.227	.229	.26	.10	......	
S	......	.083	......	......	......	......	
Ba	......	6.93	......	......	......	......	
SiO_2, H_2O, etc	......	17.69	......	......	......	......	
Insoluble	......	......	......	14.83	28.29	14.46	

* Strong qualitative reaction.

1. Robinson Hollow prospect. Specimen obtained by M. M. Knechtel. Analysis by J. G. Fairchild and F. S. Grimaldi, Geological Survey.

2. Lyndhurst mine. Specimen obtained by M. M. Knechtel. Analysis by J. G. Fairchild and F. S. Grimaldi, Geological Survey.

2A. Lyndhurst mine. Analysis by J. Blodgett Britton, taken from Weeks.1/

2B. Lyndhurst mine. Analysis by J. Blodgett Britton, taken from Weeks.

3. Mount Torry tract, lower workings. Carload lot analysis by Levine, Philadelphia.

3A. Mount Torry tract, Kidney cut. Specimen obtained by M. M. Knechtel. Analysis by V. North, Geological Survey.

3B. Mount Torry tract. Analysis by F. A. Gooch, taken from Benton.2/
4. Kennedy mine. Analysis by F. P. Dunnington, taken from Weeks.1/
4A. Kennedy mine. Analysis by F. A. Gooch, taken from Benton.2/
5. Mine Bank. Specimen obtained by M. M. Knechtel. Analysis by Michael Fleischer, Geological Survey.
5A. Mine Bank. Carload lot analysis by Union Carbide Co., Alloy, W. Va.
5B. Mine Bank. Analysis by A. S. McCreath, taken from Weeks.1/
6. Black Rock mine. Analysis by A. S. McCreath, taken from Weeks.1/
7. Vesuvius mine. Sample analysis by E. J. Lavino & Co., Reussens, Va.
8. Old Dixie mine. Analysis by A. S. McCreath, taken from Watson.3/
9. Hogpen Hollow prospect. Specimen obtained by M. M. Knechtel. Analysis by J. G. Fairchild and F. S. Grimaldi, Geological Survey.

1/ Weeks, J. D., Mineral Resources U. S., 1885, pp. 317-319, 1886.
2/ Benton, E. R., Iron-ore mines of Virginia: 10th Census, Vol. 15, Mining industries, p. 286, 1886.
3/ Watson, T. L., Mineral resources of Virginia: The Virginia Jamestown Exposition Commission, pp. 249-250, 1907.
Note: Mn, Fe, Ba, Ni, Co, Cu, and P were recalculated where they appeared in several of the original analyses as MnO, MnO_2, Fe_2O_3, BaO, NiO, CoO, CuO, and P_2O_5.

some degree. Each of them is occupied by an ancient valley whose walls are formed by the upper part of the Antietam quartzite on the flanks of a syncline. Along a part of each syncline the valley floor is underlain by the next younger formation, the Tomstown dolomite, deeply weathered to clay beneath a thin cover of ancient terrace gravel, and in three of these four synclines some manganese ore has been mined from this clay. The Mills Creek syncline, the only one of the four in which no ore has so far been discovered, has never been prospected, although it was recommended for prospecting in a publication 6/ based on an earlier study.

The productive deposits of manganese ore are extremely variable in size, form, attitude, and spacing, as well as in the quality and grade of the ore. Some of the ore bodies have yielded hundreds of tons of

6/ Hewett, D. F., Stose, G. W., Katz, F. J., and Miser, H. D., Possibilities for manganese ore on certain undeveloped tracts in Shenandoah Valley, Va.: U. S. Geol. Survey Bull. 660, pp. 287-288, 1918.

concentrates, others only a few tons. Some are irregular pockets, some are lenticular masses, and some consist of stringers in various attitudes. Their distribution appears to bear little relation to the bedding of the residual material. Some areas of several acres have been rather thoroughly explored for manganese ore and have been found to be underlain by barren, or nearly barren, residual clay; other nearby areas of comparable size contain several bodies of ore. In some places the ore follows zones of brecciated chert and clay along planes of slipping in the residual material; elsewhere it occurs as nodules studded in nearly homogeneous clay showing little or no evidence of slipping.

The proportion of concentrates to waste obtained in mining some particularly rich pockets is as high as 1 to 3, but usually it is much less. The amount of phosphorus is generally negligible, but iron is high in most of the ore. Much of the ore, especially in the brecciated zones, contains inclusions of chert, sandstone, and clay, which are separable by crushing and jigging. The ore is mined in open pits and in underground workings, and most of it is made ready for marketing by treatment in log washers followed by hand picking.

Origin

The manganese may originally have been disseminated, as carbonates and possibly also as silicates, through a great thickness of rock strata; it is believed, however, to have been present in the Tomstown dolomite in more than average quantities. Possibly it is for this reason, and because circulation of ground water was especially active in the lower part of the Tomstown, that most of the manganese deposits of this district occur in the residual clay of that formation; some deposits, however, consist of swarms of pellets in Tertiary gravel, or of veins and breccia-filling in brecciated rock along fractures and shatter zones in the Antietam quartzite and a quartzite member of the Harpers shale.

The manganese is believed to have been dissolved as bicarbonate and transported by water flowing in surface and underground channels. The manganese of the solutions moved through beds of relatively porous rock, such as shale, sandstone, and impure sandy limestone, as well as in fracture zones and limestone caverns; and it was deposited as oxides (1) replacing residual clay and sandstone, (2) cementing and replacing shattered and brecciated chert and quartzite, and (3) replacing clay and gravel that had been deposited in old caverns. Some bodies of manganese oxide may have been formed by the deposition of manganese from solutions flowing into limestone sinks and thence into channels in the bedrock, including brecciated cherty zones along fractures caused by settling due to the decay of the Tomstown dolomite. Some manganese may have been deposited locally through algal action in ancient surface streams,[7] later to be redissolved and deposited elsewhere.

Ore deposition was possibly influenced more by topographic features, and particularly by the valley-floor peneplain, than by structural features. The structure, however, determines the areal distribution of the outcropping rocks into which manganese in solution can be most easily introduced from the land surface and deposited as oxides.

Production

he district has produced more than 46,000 long tons of ore concentrates containing from 7 percent to more than 45 percent of metallic manganese, nearly all of which came from the Lyndhurst, Mount Torry, Kennedy, Red Mountain, Mine Bank, and Vesuvius mines. About four-fifths of the marketed ore was

7/ Howe, M. A., The geologic importance of the lime-secreting algae, with a description of a new travertine-forming organism: U. S. Geol. Survey Prof. Paper 170, pp. 57-65, 1932.

manganiferous iron ore suitable only for use in the manufacture of spiegeleisen and manganiferous pig iron; only about one-fifth contained more than 35 percent of metallic manganese. Production figures for the district are given in the following table:

Production, in long tons, of manganese and manganiferous iron ores from the Lyndhurst-Vesuvius district, 1906-1940
[Data taken from records of Bureau of Mines, United States Department of the Interior]

Year	Concentrates containing 35 to 46 percent of manganese. (Weighted average of manganese content of all shipments is approximately 37 percent)	Low-grade concentrates containing less than 35 percent of manganese. (Weighted average of manganese content of all shipments is approximately 20 percent)
1906	60	......
1907	2,200	1,044
1908	5,200	......
1917	1,236	10,303
1918	638	7,724
1919	.....	9,786
1921	36	......
1928	185	......
1930	.....	160
1933	21	......
1938	.....	592
1939	.....	3,839
1940	.....	3,189
Totals	9,576	36,637
Total tonnage of manganese and manganiferous iron ores..46,213		

The total production, as given above, does not include the earliest output from some of the mines, nor the shipments in 1941 from the Mine Bank, Vesuvius, and Mount Torry mines.

Most of the high-grade concentrates have come from the Lyndhurst mine, though some shipments have been made from the Kennedy mine and small amounts have been produced at the Vesuvius, Red Mountain, Mount Torry, and Mine Bank mines. Virtually all of the marketed ore from the Lyndhurst mine and most of that from the Kennedy and Vesuvius mines was high-grade manganese ore, but most of the ore produced at the Red Mountain, Mine Bank, and Mount Torry mines, which were worked originally for iron ore to supply charcoal furnaces, has been manganiferous iron ore. Prospecting has revealed the presence of either manganese ore or manganiferous iron ore, or both, at several localities, and some highly siliceous ore has been found that might be used advantageously in making silicomanganese.

Reserves and future possibilities

It is estimated that between 1,000 and 2,000 long tons of concentrates could be obtained from high-grade manganese prospects and mine workings in the Lyndhurst-Vesuvius district, mainly at the Vesuvius and Mine Bank mines. The available manganiferous iron ore, chiefly at the Mine Bank mine, would probably yield more than 50,000 long tons of concentrates.

During the period of 16 months over which the writer's investigation extended, less than 10 carloads of high-grade manganese concentrates was shipped from the few widely separated localities at which mining was in progress. The small amount of high-grade ore then in sight suggested that no large increase in production was to be expected in the near future, though two rich but small pockets, each capable of producing several carloads of concentrates, were being worked at the Mine Bank mine. A body of manganiferous iron ore, possibly capable of yielding as much as 50,000 long tons of marketable concentrates averaging nearly 17 percent of metallic manganese, remained to be taken out at the Mine Bank mine, and it is the hope of the mining company that in mining ore of this type they may discover additional pockets of high-grade manganese ore.

The known occurrences of manganese ore in this district are virtually all at places where the manganese oxides crop out naturally or were discovered in mining iron. During the present investigation the possibilities of the areas underlain by residual clay from the Tomstown dolomite, and particularly the parts of those areas beneath which the rocks have a synclinal structure, received special attention. The residual clay, however, is largely concealed under a thin cover of ancient stream gravel, in nearly flat areas devoid of any visible feature—other than actual cropping of the ore—that might aid the prospector in restricting his search to promising localities; and at some localities in which relatively large quantities of manganese oxides have already been found, much of the manganese has little value because of its association with large percentages of iron. Bodies of good manganese ore may, however, lie concealed under the large areas of gravel, and prospecting for them by geophysical methods might be worth trying. Such methods might also afford a means of estimating the full extent of manganese deposits that so far have not been adequately explored, such as those at the Black Shaft, at the Shields prospect, and on the terrace west of Kelly Bank. Heiland 8/ states that deposits in such places may be explored by the magnetic method with fairly good chances of success. Other methods that might be tried are the electrical resistivity, inductive electrical, and gravimetric methods.

MINES AND PROSPECTS

Robinson Hollow prospect

On the hillside south of Robinson Hollow (pl. 29), a small quantity of manganese ore was mined shortly after the Civil War from an inclined shaft about 85 feet long in a layer of the Antietam quartzite. The ore extended to the bottom of the shaft, where it ended abruptly against barren quartzite. In 1941 five shallow pits were dug along a line extending about 400 feet S. 25° E. up the hill from its base to a point about 65 feet higher. Pits at the base of the hill and 65 feet

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8/ Heiland, C. A., Geophysics in war: Colorado School of Mines Quarterly, vol. 37, No. 1, p. 75, 1942.

higher are barren of ore, but three intermediate pits, at heights of 37, 50, and 56 feet, show a vein of manganese oxide ranging in thickness from 2 inches to 1 foot, honeycombed with small cells filled with red clay. The hanging wall, striking N. 20° E. and dipping 60° E., is shattered quartzite containing numerous thin seams of manganese oxide. The foot wall is a breccia of quartzite fragments cemented and partly replaced by psilomelane, in sandy red clay.

Crooks Run prospect

In the bed of Crooks Run (pl. 29) about 6 feet of manganese-bearing clay was struck at 60 feet in two holes drilled about 150 feet apart, shortly after the Civil War. A caved shaft 35 feet deep, midway between the holes, is barren. Mottled yellow and pink residual clay beneath 6 feet of coarse gravel is exposed about 50 feet downstream from the workings.

Lyndhurst mine

The Lyndhurst mine (pl. 29) was first opened in 1859, and ore was mined in 1885 and 1886 over a horizontal distance of 300 feet from a 20-foot zone at a depth of 65 feet.[9] In 1907 and 1908 the shipments of manganese concentrates totaled 7,400 long tons, valued at $69,000. Most of this production came through a shaft 110 feet deep, west of an old mill race (fig. 16), where an ore body was stoped upward from the 40-foot level. Some ore was taken from the 100-foot level on the south side of this shaft, and a little was taken from the 40-foot level through a shaft about 300 feet farther north and through two shafts east of Back Creek. Ore was found beneath several feet of terrace gravel in a few shallow pits, dug in 1940, southeast of the main workings west of Back Creek. The

9/ Weeks, J. D., Mineral Resources U. S., 1885, p. 317, 1886.

underground workings at the Lyndhurst mine have been inaccessible for more than 30 years.

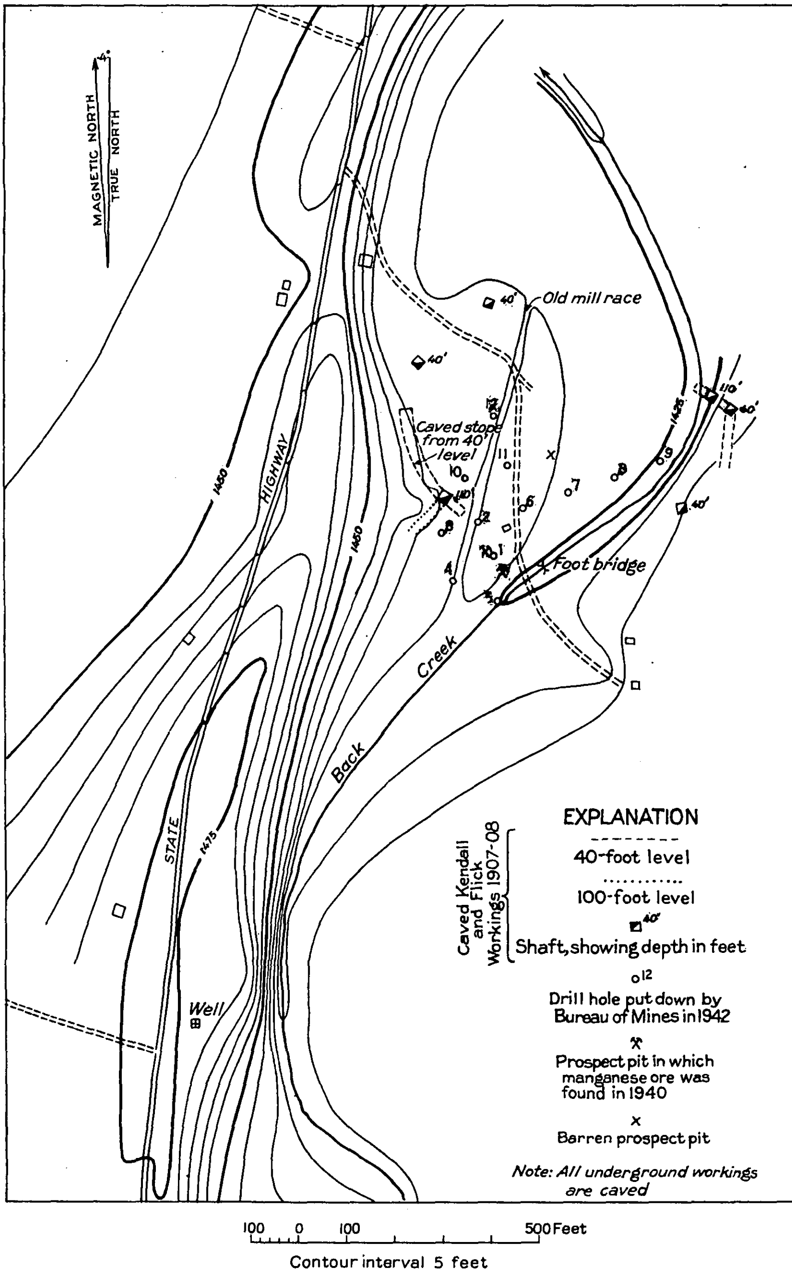


Figure 16.--Map of Lyndhurst mine and vicinity, Augusta County, Va.

Harder 10/ says of the occurrence of the ore in these workings:

10/ Harder, E. C., Manganese deposits of the United States: U. S. Geol. Survey Bull. 380, p. 261, 1909.

This deposit consists of scattered kidneys and irregular masses in clay. The former occur in small, irregular nodules averaging an inch or two in diameter, but in places reaching 5 or 6 inches. They are scattered through horizontal layers or lenses of red, brown, and variegated clays at intervals of a few inches to a foot or more. Mingled with the light-colored clays are layers and lenses of dark manganiferous clays which contain the ore of the second type. This varies from seams to irregular masses of different sizes and is either hard or soft. The ore is scattered at irregular intervals in a pocket which has been tested to a depth of about 60 feet and for a horizontal extent of about 300 yards. On account of the scattered location of the ore masses, much dirt has to be washed to get a small quantity of ore.

Chert noted in the old dumps consists in part of silicified oolite, which resembles that commonly present as lenses in the residual clay at manganese workings in the Tomstown dolomite elsewhere in the Lyndhurst-Vesuvius district. Although most of the manganese ore occurs in clay, some of it, as may be noted from material in the dumps, occurs in brecciated Antietam quartzite. The geologic structure in the vicinity of the mine is not known in detail, but this breccia, as well as similar breccia exposed nearby along Back Creek, is evidently in a zone of thrust faulting that has been traced 12 miles southwestward from the mine (pl. 29, secs. C-C', D-D').

In the early months of 1942 the Bureau of Mines, United States Department of the Interior, sank 12 churn drill holes (fig. 16), the deepest of which, No. 10, ended in shale at a depth of 167 feet. The holes were drilled largely in clay, through which fragments of quartzite were more or less abundantly scattered, but partly in solid quartzite breccia. Fresh dolomite was reported in the bottom of hole No. 3, which is 146 feet deep, and fresh shale was reached in the lower parts of most of the holes. Holes 6, 7, 8, 9, 10, 11, and 12 were barren, but holes 1, 2, 3, 4, and 5, which are close to the old Kendall & Flick workings, showed a little manganese in clay and breccia at various depths. At a depth of 25 feet, hole No. 2 entered 3 feet of high-grade ore, underlain by 2 feet of dark brown clay of the same color as the clay occurring at 28 to 30 feet in hole No. 1 and at 25 to 30 feet in hole No. 3. In holes 1 and 3 this brown clay lies beneath material containing only a little manganese.

Mount Torry tract

The Mount Torry tract (pl. 29) lies in a valley extending along a syncline, in which the Antietam quartzite plunges northeastward beneath a wash-covered basin floored by the Tomstown dolomite and its residual clay. The dolomite is nowhere exposed in this valley, but an old shaft, less than 15 feet deep, near the center of the valley, has its bottom in fresh gray dolomite. Boring tests made in this tract prior to 1919 failed to show any large body of high-grade manganese ore, and a number of additional holes, records of which are not available, were drilled in the vicinity of the lower workings in 1927.

A program of prospecting was carried out by the Bureau of Mines in the winter of 1941-1942, when a number of prospect pits were dug and eight holes ranging in depth from 30 to 150 feet, were bored. The placing, in plate 30, of the boundary between the brecciated rock and the residual clay of the Tomstown dolomite southwest of the lower workings is largely based on information supplied by these pits and drill holes, since both formations are mostly covered with gravel. The weathered bedrock south of the line is tentatively regarded as belonging to the Antietam quartzite, because it contains much brecciated sandstone and quartzite, embedded in a clay matrix which appears to contain none of the cherty material that is so abundant in the typical residual clay from the Tomstown dolomite. Two holes (Nos. 1 and 2) bored south of the line went through a thin capping of surficial gravel into breccia composed of sandstone fragments in reddish clay, and they continued in this material until solid quartzite was reached at depths of 130 feet and 30 feet. In the other drill holes the fresh bedrock, which is dolomite in Nos. 3, 4, and 5 and quartzite in Nos. 6, 7, and 8, was reached after drilling 50 feet or more through residual clay containing a few sandy layers. A little manganiferous iron ore was found in holes 3, 4, and 6. The scattered test pits likewise show residual clay north of the line and brecciated sandstone with a clay matrix south of it. In many of the pits south of the line the angular sandstone fragments are closely packed in the breccia, with little or no intermingled clay. A few pits, however, are chiefly in clay but show a little brecciated sandstone, some of which is well slickensided. Quartzite breccia, cemented and partly replaced by manganese oxide, is exposed in an old prospect pit west of Orebank Creek, 600 feet above the mouth of Turkeypen Branch, and float of similar breccia occurs at several other places in the Mount Torry tract.

The available data do not permit a satisfactory interpretation of the breccias south of the line of contact, and, though the abundance of such material suggests faulting, the evidence is not considered strong enough to justify placing a fault on the maps and cross sections illustrating the structure of this locality.

Manganese ore has been mined in the Mount Torry tract at three widely separated localities, known as the lower workings, the Kidney cut, and the Turkeypen cut.

Lower workings.--The lower workings are described by Stose and others 11/ as follows:

> The older workings consist of a number of pits scattered over an area about one-fourth mile square and a shaft from which iron ore was first taken out and smelted in the company's furnace on Back Creek. The ore contained too much manganese to be satisfactory for iron manufacture at that time and was abandoned, but later it was extensively prospected and worked to a small extent for manganese ore.

11/ Stose, G. W., and others, op. cit., p. 101.

Three shafts near Orebank Creek, a few hundred feet south of the reservoir, were put down more than 50 years ago. The dump at the shaft nearest the creek shows a number of large chunks of fresh gray dolomite reported to have come from a depth of less than 15 feet. The shaft about 100 feet east, which is 40 feet deep, was put down to explore manganese ore that had been brought up by a churn drill from a depth of 60 feet. When a level had been driven about 8 feet eastward from the bottom of this shaft, water entered and filled the shaft within an hour. The third shaft, about 150 feet farther south, was put down to a depth of 19 feet after a diamond drill had struck hard rock at 60 feet. No information is at hand regarding the history of a shaft about 400 feet still farther south, near a large clearing, where many fragments of quartzite breccia, partly replaced by manganese oxide, occur in the dump material.

Early in 1941 a new cut southwest of the washing plant was started near some old underground workings. Several small "pockets" of manganese oxides, chiefly pyrolusite, were uncovered but were soon worked out. Some streaks several feet thick of soft, wadlike manganese oxide of low specific gravity were uncovered but were not mined. The oxides in this cut occur in lumps and nodules in yellow and red clay containing a few thin beds of sand and fairly abundant nodules and lenses of chert, some of which is oolitic. The clay is cut by many minor slips, mostly dipping at low angles, with considerable slickensiding and brecciation of included chert. The manganese oxides tend to follow these slips, many of which, however, are barren or nearly so. In some specimens the manganese oxides have partly replaced the chert.

Kidney cut.--Kidney cut is described by Stose and others 12/ as follows:

12/ Stose, G. W., and others, op. cit., p. 101.

In an open cut in altered buff sandstone on the side of Torry Mountain, * * * nodular ore occurs in clay and as an impregnation of the adjacent sandstone. The manganese oxide penetrated along joints and bedding planes and replaced sandstone blocks to various degrees, some having only a core of unchanged sandstone.

An old shaft which is reported to have yielded "kidney ore" from clay at a depth of 40 feet or less has been cleaned out recently to a depth of 20 feet without revealing any ore. Sandstone exposed at the surface within a few feet of the shaft shows many fractures containing veinlets of psilomelane partly replacing the sandstone.

Turkeypen cut.--This small open cut near the head of Turkeypen Branch was started about 15 years ago, and two carloads of manganese ore was shipped at that time. It was extended in the early months of 1940, when a vein of manganese oxide averaging about 1 foot in thickness, striking due east, and dipping 20° to 45° N., was mined. The oxide occurs as small veins, lumps, and nodules in undifferentiated yellow and red clay close to its contact with the Antietam quartzite at the foot of Turkeypen ridge. About 4 feet of barren terrace gravel rests on the clay.

Kennedy mine

The Kennedy mine (pl. 29) has not been worked since 1917-1918, when several carloads of ore was shipped that averaged more than 40 percent in manganese. The mine is described by Stose and others 13/ as follows:

The workings at the Kennedy mine comprise an old open cut and short tunnel and a new deep wide trench, about 250 feet long and 30 feet wide, which crosses the trend of the deposit. At its deepest part, about 45 feet depth, the section shows at the top about 15 feet of gravel, sand, red mottled clay, and wash which contain red nodular iron ore and a little manganese; then about 15 feet of yellow to red clay containing scattered rounded rotted quartzite boulders and pebbles, decomposed white chert, and masses of manganese ore; below this is brown clay, apparently free from boulders, containing richer pockets and masses of manganese ore and wad. The deposit is said to have been thoroughly tested by bore holes

13/ Stose, G. W., and others, op. cit., pp. 103-107.

which show this lower clay to be about 15 to 30 feet thick beneath which a layer of coarse porous sandstone is struck, then more clay, and finally the top hard layer of the Erwin [Antietam] quartzite. This porous sandstone composed of large round grains loosely held together has been observed at many places, especially farther south, where it lies about 50 feet above the top quartzite beds of the Erwin; and in the interval between are soft purple, red, yellow, and in some places chert-bearing yellow clay evidently derived from limestone. These transition beds are regarded as the basal beds of the Shady [Tomstown] dolomite. The test holes are reported to have determined an ore body which runs northeasterly, suggesting that the stream which deposited it had this course. In an old open cut adjacent to the new trench laminated clay containing chert fragments, unquestionably derived from the decomposition of limestone in place, is exposed, overlain by red and white mottled clay, evidently transported only a short distance by creep on the mountain slope, and this overlain by gravel and wash. The basal part of the gravel is jointed and manganese is deposited on the joint planes and in crevices. The few boulders in it are rotted and the chert fragments are soft and porous, indicating that at least the lower part of the gravel deposit is old.

A sketch accompanying the above description shows most of the ore-bearing material as boulder-bearing clay. This material is here interpreted as representing a deposit beneath the terrace gravel, and may have been formed in an old solution cavity. The terrace gravel on the north side of the open pit has dropped, possibly from uneven settling over a buried solution-channeled mass of Tomstown dolomite, about 15 feet on the east side of a nearly vertical slip, against white, yellow, and pink clay.

Black shaft mine

The Black shaft (pl. 29), which is now inaccessible, is described by Stose and others [14] as follows:

At a depth of 20 feet, chiefly in wash, a drift was run into laminated clay with cavernous cherty breccia which dipped about 10° SE. Cavities in the chert were lined with secondary drusy quartz and the breccia was impregnated with manganese oxide. Quartzite was reported to have been struck in bore holes about 20 to 30 feet below the brecciated chert. The dip of the beds indicates an anticlinal axis northwest of the shaft which does not seem to bring the quartzite quite to the surface but which makes a structural basin of the area between the shaft and the mountain. Bore hole records are said to bear this out. If this proves to be a fact, a narrow area parallel to the mountain front and close to the foot of the steep slope should have favorable structure for the accumula-

[14] Stose, G. W., and others, op. cit., pp. 107-108.

tion of ore. A short distance southwest of the shaft, up a small stream from the mountain, an open cut exposes wavy banded residual clay and chert which are impregnated with manganese. The bedding dips 5° to 10° NE., indicating that the exposure is near the bottom of a syncline. The quartzite of the mountain dips 15° NW., representing the dip on the other side of the syncline.

The dump at the mouth of the shaft shows yellow clay, with a few small pieces of manganese ore and fragments of silicified oolite and chert. A small amount of ore from this working was beneficiated and shipped with the product from the Kennedy mine.

Shields mine

One carload of manganese ore was shipped from the Shields mine (pl. 29) in 1910 or 1911. The discovery of the ore at the surface led to the excavation of a small open pit; later a 40 or 50 foot shaft was sunk, from which two short levels, both in ore, were run toward the mountain, one 20 feet below the surface and the other at the bottom of the shaft. A hole was drilled at a point a hundred yards or more southeast of the shaft, but neither its depth nor the materials penetrated are known. The dump and the pit show yellow clay, probably residual from the Tomstown dolomite, with a few fragments of chert and some breccia of Antietam quartzite cemented and partly replaced by manganese oxide.

Blue Bank mine

The Blue Bank mine (pl. 29) was abandoned several years before 1919 [15] and has not been reopened in recent years. Harder [16] describes it as a "series of open cuts and tunnels some distance apart," and describes the ore mined as "dark brown to blue, highly manganiferous iron ore" apparently occurring in large masses.

15/ Stose, G. W., and others, op. cit., p. 111.
16/ Harder, E. C., Manganese deposits of the United States: U. S. Geol. Survey Bull. 427, p. 64, 1910.

St. Mary's River tract

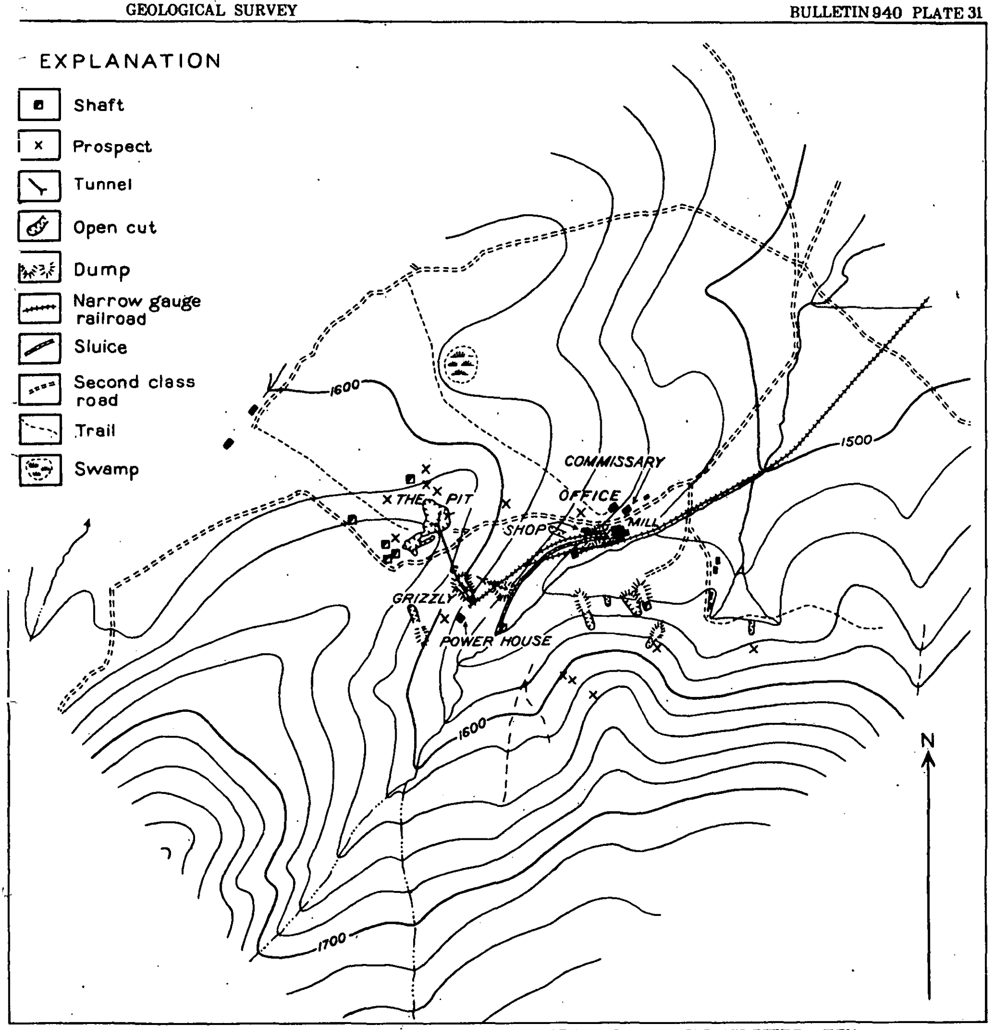
The St. Mary's River tract (pl. 29) is an isolated intermontane area about 2 miles long, extending east-northeast, with an average width of about one-fifth mile. It is underlain by clay residual from the Tomstown dolomite, resting on Antietam quartzite in the bottom of a syncline, the axis of which plunges at low angles from both ends of the tract toward its middle. A thin covering of terrace gravel rests on the clay in the higher parts of the tract, but it has been removed by erosion along several small streams. The geologic structure and physiography of the St. Mary's River tract appear to favor natural concentration of manganese, and mining carried on over several decades has shown that a considerable amount of manganese oxide was actually deposited here; most of this oxide, however, is mingled with iron ore, and the mixture is marketed as manganiferous iron ore. Mining has been carried on at three localities: Mine Bank, at the extreme western end of the tract; Manganese Hollow, near the middle; and Red Mountain, near the eastern end.

Mine Bank (Pulaski) mine.--The Mine Bank mine is an enlargement of the eastern open pits of the old Pulaski mine, described by Stose and others 17/ as follows:

> The pits expose yellow clay which contains iron ore and a little manganese oxide, overlain by a bed of coarse rusty sandstone which is capped by a hard crust of iron ore. The near-by rocks lie nearly horizontal, dipping gently into the shallow syncline. The sandstone bed associated with the iron crust is probably the coarse bed near the base of the Shady [Tomstown], and the clay in which the mine is located is probably the residuum of calcareous beds beneath the sandstone bed at the base of the Shady. * * * There is very little manganese in the ore that is being mined but more manganese is reported in prospect pits east of the mine where higher beds apparently are inclosed. The Pulaski mine is operated by a subsidiary of the Pulaski Iron Co., and the ore is shipped to Pulaski, Va. The product is all iron ore with the content of manganese not over 5 percent.

From 1939 to 1941 the Great Valley Manganese Corporation of New York shipped more than 250 carloads of manganiferous

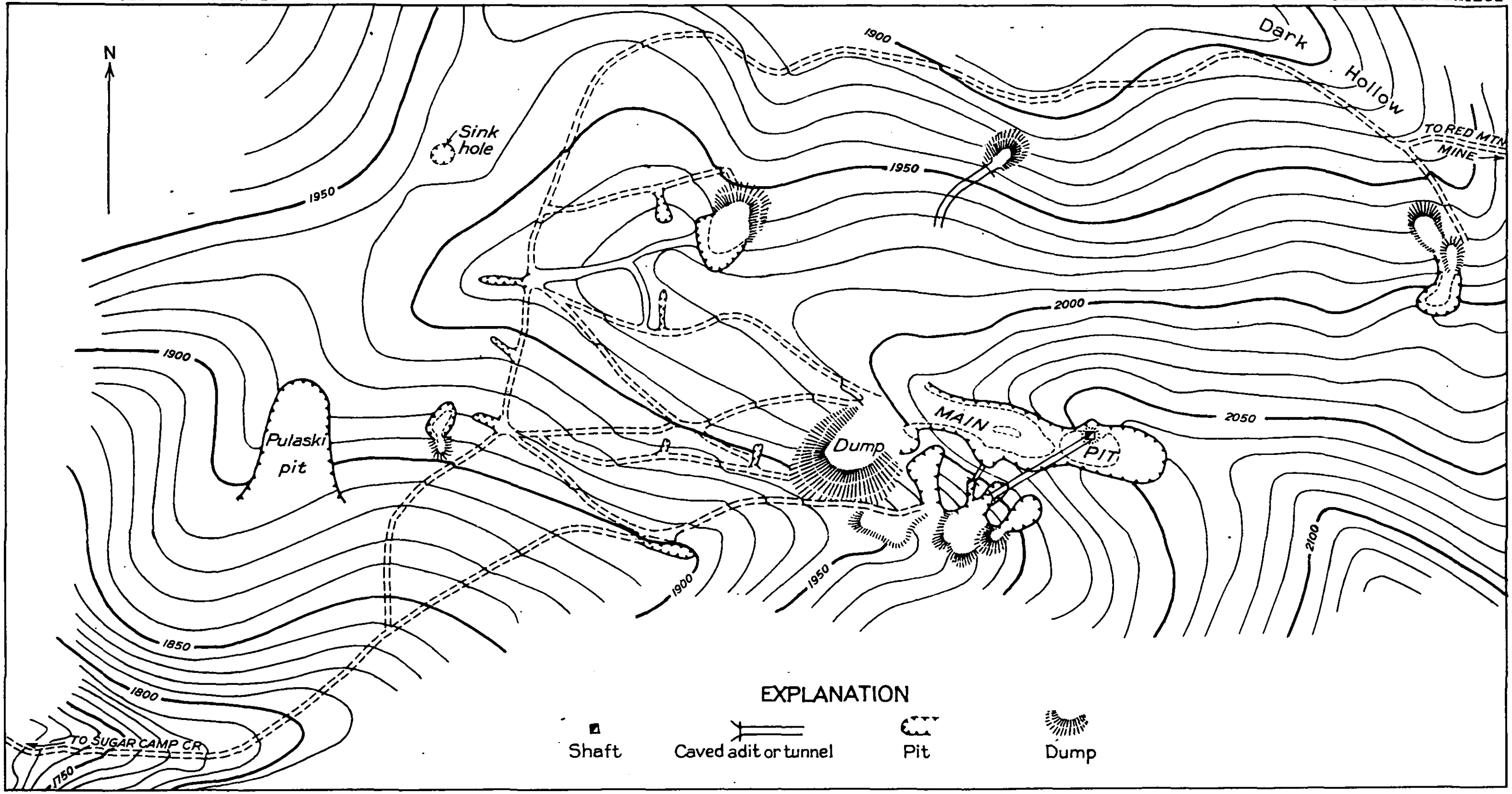
17/ Stose, G. W., and others, op. cit., pp. 109-110.



MAP OF KENNEDY MINE, AUGUSTA COUNTY, VA.

1000 0 1000 2000 Feet

Contour interval 20 feet



MAP OF MINE BANK WORKINGS, AUGUSTA COUNTY, VA.

300 0 300 600 Feet

Contour interval 10 feet

Datum assumed, elevations of contours are therefore subject to considerable correction

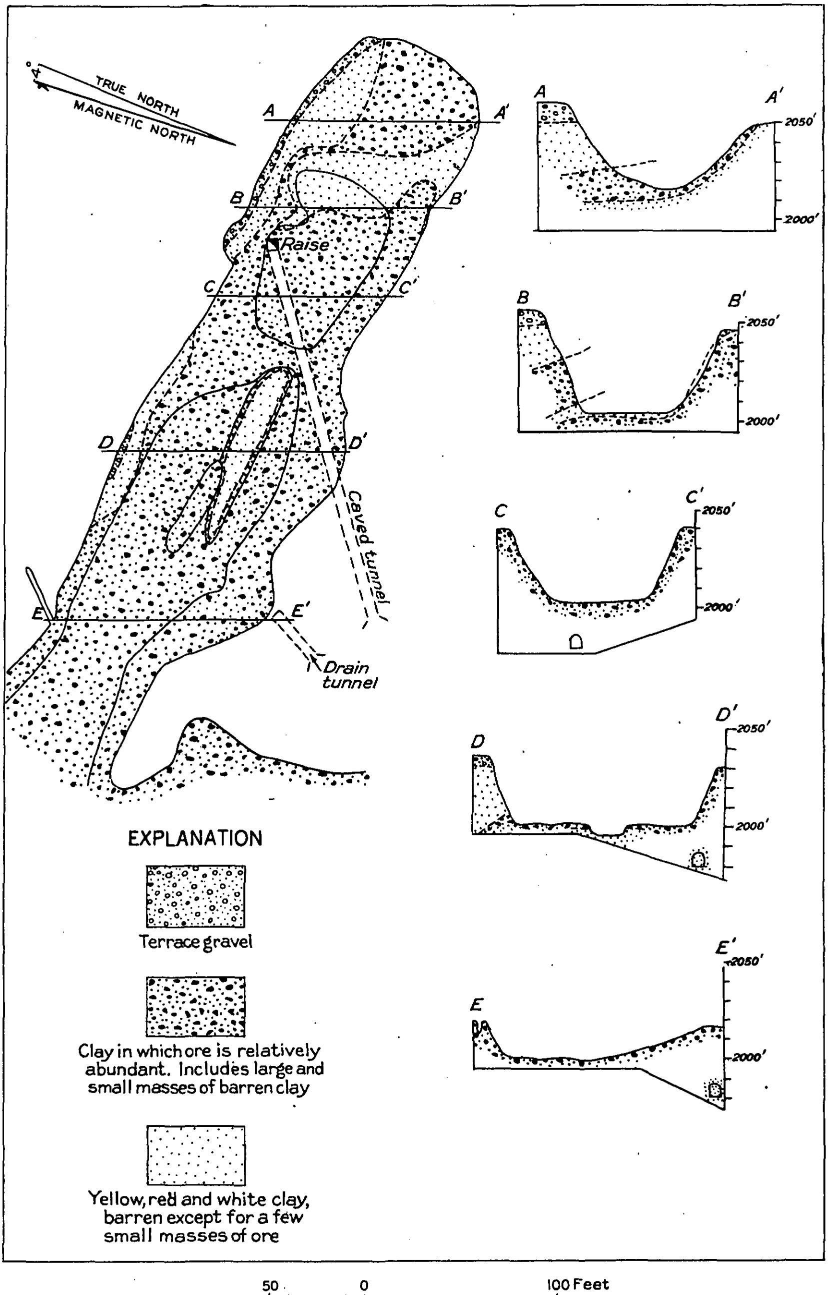


Figure 17.--Map and cross sections of main open pit of Mine Bank mine, Augusta County, Va.

iron ore, mainly from this mine, and the property is now being worked, both for manganese ore and manganiferous iron ore, by the General Development Co. of New York. The several open pits and abandoned tunnels have together yielded more than 25,000 long tons of manganiferous iron ore and a few hundred long tons of manganese ore. The total metallic content in carload samples is fairly constant at about 42 percent, but the proportion of iron to manganese is extremely variable. Much of the manganiferous iron ore has been sold to the Alan Wood Steel Co., Swedeland, Pa., for mixing with iron ore that is deficient in manganese, to produce high-manganese pig iron.

The main open pit, which extends about S. 70° E. along the crest of a long spur, is more than 300 feet long, has an average width of approximately 85 feet, and is 50 feet deep near the eastern end. The walls of the pit show lumps and nodules of manganese and iron oxides imbedded in red, yellow, and white clay. The iron content is generally high. but some of the ore is manganese oxide of good grade. The clay also encloses lenses of oolitic chert and nodules of chalcedonic silica containing small cavities lined with drusy quartz. Beneath the ore body (fig. 17, sec. B-B') is a body of nearly barren clay comprising an upper yellow layer and a lower red layer. Ore is said to have been taken from a room about 15 feet wide beneath this part of the pit, at the bottom of an old raise and at the inner end of a caved tunnel (sec. C-C'). Nearly barren clay on the north side of the pit at section D-D' probably represents an extension of the upper barren clay of sections A-A' and B-B', which has been removed by erosion in the vicinity of section C-C'. The depth of the nearly barren clay in the bottom of the pit (sec. D-D') is not known. The "drain tunnel" was run in barren clay. On the north side of the pit coarse gravel, containing well-rounded crumbly fragments of Antietam quartzite, rests on nearly barren white to yellow clay containing small concretionary lumps of silica. At the east end of the main open pit, nearly barren clay rests on yellow, red, and white clay containing abundant large lumps of iron ore of variable manganese content, with some nodules of hard manganese oxide and considerable wad. The prevailingly dark color of the ore-bearing clay contrasts strongly with the generally bright hues of the clay masses above and below. Kidney-shaped growths of manganese oxide an inch and more in diameter protrude from many of the large ferruginous lumps. This zone contains many angular fragments of oolitic chert, in which some of the oolites contain cavities having the rhombic cross section of calcite crystals. The clay also is brecciated, small angular clay fragments of one or several colors being enclosed, at many places, in clay of a different color. A little manganiferous iron ore has been taken from a small pit 700 feet west of the main pit.

Analyses of manganiferous iron ore from 84 carloads shipped since November 1940 show an average manganese content close to 16½ percent and a total metallic content, almost wholly iron and manganese, close to 42 percent. Phosphorus averages 0.066 percent and silica fluctuates between 9 and 17 percent.

Two pockets of ore consisting of nodules of manganese oxide imbedded in clay were discovered in 1941. The ore averaged 40 percent manganese and yielded about 1 ton of concentrates to 4 tons of material mined. Several carloads of the concentrates from one of these pockets, at the east end of the main pit, has been shipped to E. J. Lavino & Co. at Reussens, Va., and at least two carloads from the other pocket, 300 feet to the north, to the Union Carbide Co. at Alloy, W. Va. Quantities estimated at several carloads remained in each of these two pockets in the spring of 1942.

Manganese Hollow workings.--The Manganese Hollow workings are largely inaccessible, and little trustworthy information on their history is available. They include a small open pit and a caved inclined shaft, as well as a number of borings made with cyclone drills between 1926 and 1930. Only a few carloads of ore of unknown quality has been produced from this locality.

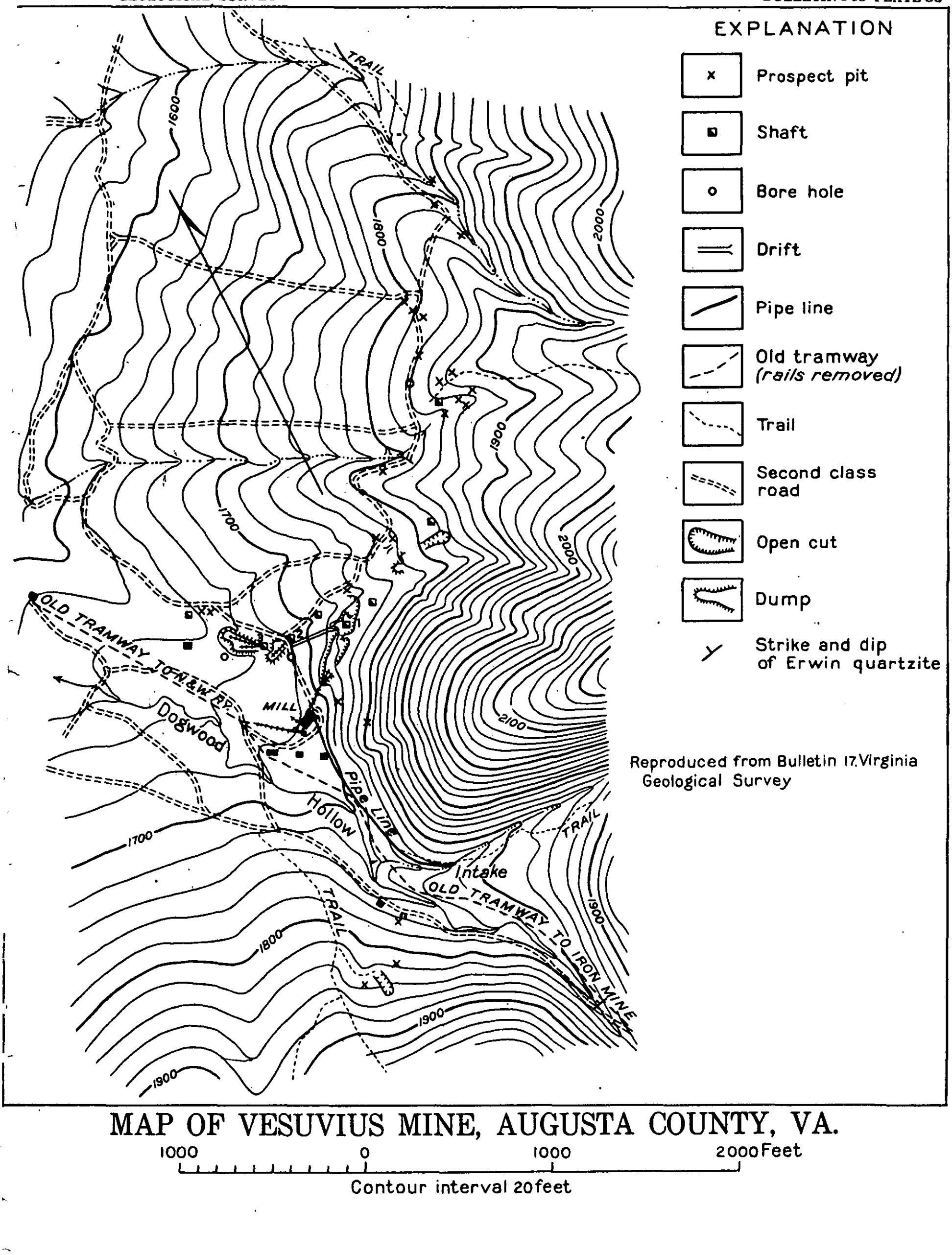
Red Mountain mine.--From 1917 to 1940 this mine produced more than 14,000 long tons of manganiferous iron ore and a few hundred tons of manganese ore. The mine is similar to Mine Bank in the character of the ore produced and the geologic relations of the ore bodies. The following description is quoted from Stose and others:[18]

> The workings at the Red Mountain mine consist of several open cuts and deep trenches. They are located at the southwest end of a low hill in the bottom of the basin composed of the residual clay from the limestone and capped by wash from the adjacent mountains. When visited in 1917 two open cuts at the southwest end of the hill were being operated by steam shovel. A third large open cut had been worked from the stream level at the southeast and another large trench had been opened on the top of the hill to the northeast. The intervening ground was reported to have been fairly well prospected by drill holes and trenches, and ore was reported at shallow depth over most of the hilltop. The open cuts are 30 feet deep and expose wavy laminated yellow clay showing the bedding of the limestone to have been about horizontal in the bottom of the syncline. The clay is covered by a thin layer of quartzite wash. Large masses of crumbly white sandstone are mixed with the upper layers of the clay and a few seem to occur deeper in the clay, possibly in solution channels. The clay contains pockets and seams of wad in which there is considerable psilomelane and iron ore. The ore, however, seems to be restricted to the upper 10 to 15 feet of the clay, the deeper parts of the trenches seeming to be barren of ore. The two deep open cuts have therefore been abandoned and shallower workings at the top of the hill are being extended.

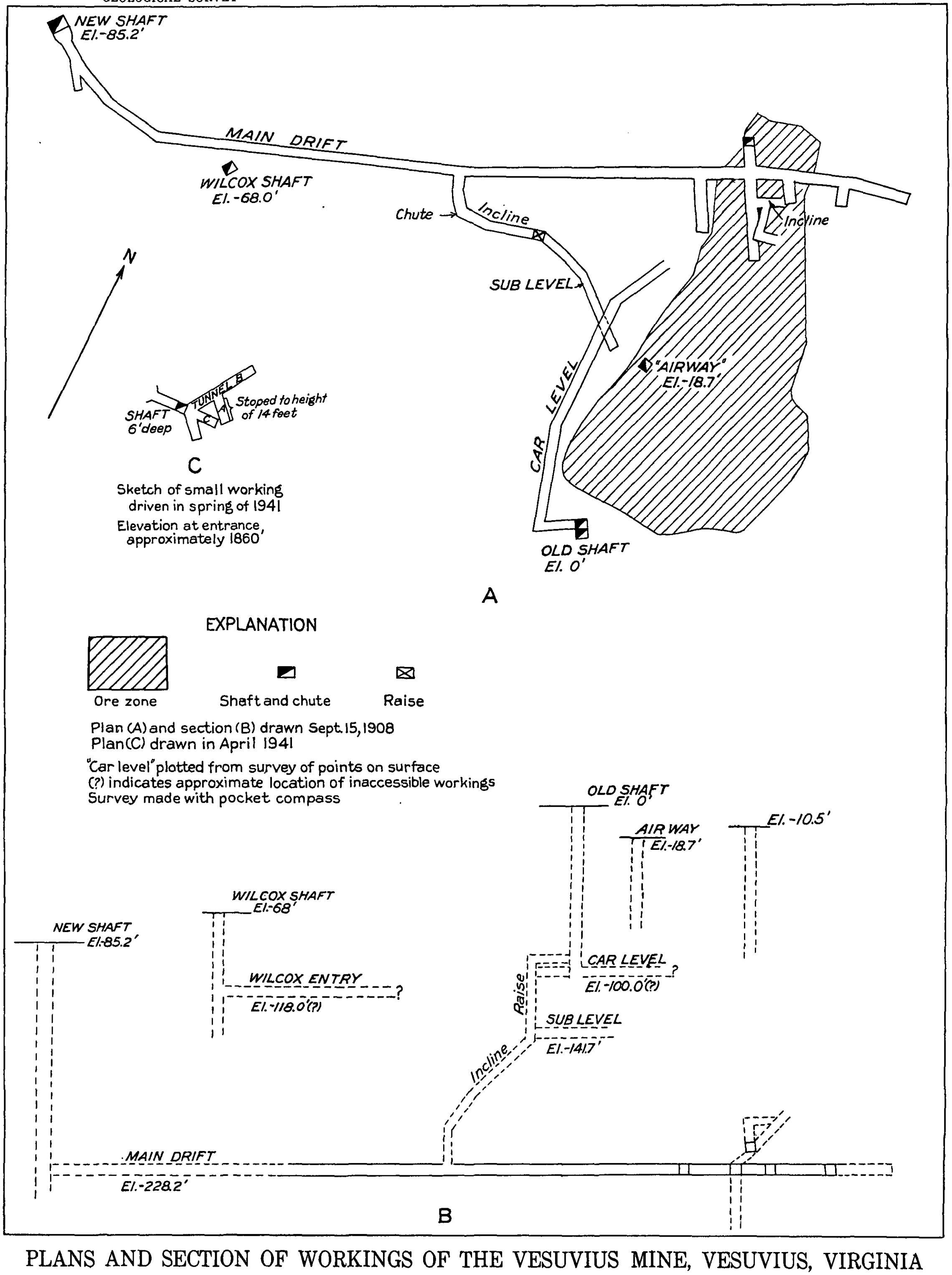
Vesuvius mine

A plan of the principal workings of the Vesuvius mine (pl. 29), dated 1908, is reproduced in plate 34. These workings, which are now inaccessible, were somewhat enlarged during 1919, when 16 carloads of manganese ore was shipped. Water had to be pumped regularly during the operation. J. T. Austin of Vesuvius, who was superintendent of the mine, estimates that approximately 16 carloads of available manganese concentrates of good grade remains. This mine is described as

18/ Stose, G. W., and otners, op. cit., p. 109.



MAP OF VESUVIUS MINE, AUGUSTA COUNTY, VA.



PLANS AND SECTION OF WORKINGS OF THE VESUVIUS MINE, VESUVIUS, VIRGINIA follows by Stose and others:19/

The workings consist of several old pits and a shaft with drifts, formerly operated under the name of the Fauber mine, and two more recent shafts, operated by the Manganese Corporation of Virginia. The old shaft (1) is higher on the slope, 1,750 feet in elevation, and is reported to be 80 feet deep. The newer shafts are 1,690 (2) and 1,660 (3) feet in elevation and are reported to be 50 feet and 160 feet deep respectively. A drift is said to run from the bottom of the deeper shaft (3) 300 feet toward the mountain. There are yellow clay and fresh chert fragments on the dump of the lower shaft and the associated ore was chiefly manganiferous iron. From the upper shaft good nodular manganese ore was obtained, a considerable quantity of which was still at the mill below. It is mostly stalactitic and kidney psilomelane, 2 to 3 inches in diameter, with some crystalline manganite in cavities. Psilomelane also coats and cements white chert and fine sandstone fragments into a breccia and to some extent replaces them. This material came from the upper layers in the open cut and represents deposition in the surficial wash. Soft wad occurs in streaks and patches in the clay and follows the original bedding of the clay which is the residual product of decomposed Shady dolomite.

In 1940 a small log washer and three jigs were installed near the mine by the Virginia Manganese Corporation of Richmond, Va. A carload of ore from No. 2 shaft was treated and shipped early in 1941, and another carload was ready in April of that year but had not been shipped in the spring of 1942. Some of the material rejected in concentrating the first carload is a breccia of angular fragments of silicified calcareous oolite, mostly less than half an inch in diameter, firmly cemented with manganese oxide, which has partly replaced the silica.

A small tunnel (pl. 34) was driven into the hillside in the spring of 1941 at a point higher than any of the other workings. Manganese ore, some of which is brilliant, coarsely crystalline, high-grade pyrolusite occurring in lumps a foot or more in diameter, is irregularly distributed in clay at many places in the bottom of this drift and in a 6-foot shaft near the entrance. An auger hole 4 feet deep in the bottom of the shaft continued through ore-bearing clay. In tunnel A, a stope was extended for 14 feet up from the floor and 14 feet

19/ Stose, G. W., and others, op. cit., p. 110.

back from the face, following a vein of manganese ore that strikes N. 45° E. and dips 30° SE. The vein is about 2½ feet thick both at the face and at the northwest end of the stope. The ore contains much brecciated silica, and the vein evidently occupies a zone of slipping in the residual clay.

Kelly Bank mine

Ore occurring in three small open pits at Kelly Bank, half a mile southwest of the Vesuvius mine, was originally mined for iron, but a few carloads of manganiferous iron ore was shipped about 1941. The ore consists of irregular lumps of oxides in yellow residual clay, which also contains lenses of silicified calcareous oolite and nodules of non-oolitic chert, in such abundance that the proportion of silica in the ore is regarded as objectionably high. On the south side of the pit are abundant tiny white rounded radiating aggregates of the fibrous mineral weinschenkite, a phosphate of yttrium and erbium, heretofore known to occur only in Bavaria. Whether or not this mineral adds an objectionable amount of phosphorus to the ore is not known.

Prospects west of Kelly Bank

On the terrace west of Kelly Bank, on the land of Mrs. E. Avery, are a few small prospect pits. Here, in 1941, there was found a chunk, about a foot in diameter, of brecciated quartzite cemented and partly replaced by manganese oxide. A pit that was not found is reported to have yielded "nuggets" of manganese ore.

Hogpen Hollow prospect

On the north side of Hogpen Hollow (pl. 29) an old tunnel at an altitude of 2,050 feet extends due south about 25 feet into the hillside, following a body of manganese oxide which is plainly visible as a vein in the west side of the roof and face of the tunnel and in a cliff above the entrance. The walls of the vein consist of light-buff vitreous quartzite of the Harpers shale, in massive beds striking N. 70° E. and dipping 45° N. The vein is about 4 feet wide at the tunnel entrance, 1½ feet wide at the face, and 7 feet wide at the top of the cliff, about 25 feet above the floor of the tunnel.

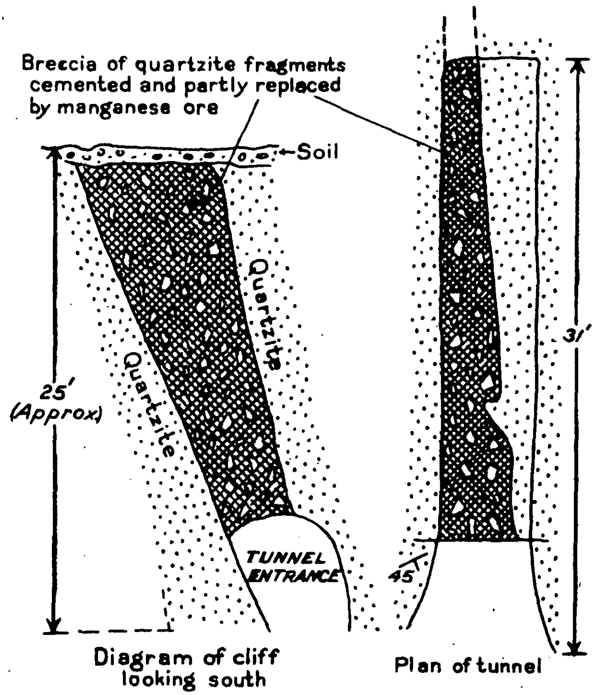


Figure 18.--Sketches of Hogpen Hollow prospect, Rockbridge County, Va.

The footwall, a nearly even surface striking due north and dipping 65° E., shows slickensides pitching S. 60° E. The hanging wall is somewhat irregular. The vein is largely a breccia of angular quartzite fragments, up to 1 foot in diameter, cemented and partly replaced by psilomelane of good grade. A few thin seams of psilomelane occur in the quartzite on top of the ridge above the tunnel; some ore can be seen, also, in the talus on the hillside, and some in the bed of the creek, about 130 feet below the tunnel. The tunnel was driven about 35 years ago by the Virginia Coal & Coke Co. in prospecting for iron ore, but was discontinued when the ore proved to be manganese oxide. The form of this ore body and its relation to structure and stratigraphy suggest that it is related in origin to the nearly parallel steeply dipping vein of limonite ore at the abandoned Old Dixie (Coal Shear) mine 20/ in Bear Hollow, about 750 feet to the east.

Mary Creek mine

The Mary Creek mine (pl. 29) was originally worked for iron to supply a charcoal furnace. It was abandoned between 1914 and 1919, and when it was visited in 1914 "blue psilomelane and soft ore in yellow clay, probably residual from calcareous shale," were seen "on the dump and in small open cuts." 21/ A little manganiferous iron ore was mined here in 1939 or 1940, and a little ore of this type was visible in the residual clay in 1941.

20/ Harder, E. C., The iron ores of the Applachian region in Virginia: U. S. Geol. Survey Bull. 380, pp. 238-239, 1919.
21/ Stose, G. W., and others, op. cit., p. 112.

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