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MANGANIFEROUS AND FERRUGINOUS CHERT IN PERRY AND LEWIS COUNTIES TENNESSEE

BY

ERNEST F. BURCHARD

WITH A STATEMENT ON

CONCENTRATION TESTS ON MANGANESE FROM PERRY COUNTY

By H. S. RANKIN

Prepared in cooperation with the
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MANGANIFEROUS AND FERRUGINOUS CHERT IN PERRY AND LEWIS COUNTIES, TENNESSEE

By Ernest F. Burchard

ABSTRACT

Perry and Lewis Counties, east of the Tennessee River, in west-middle Tennessee, are underlain by nearly flat-lying rocks of Paleozoic age, with Mississippian cherty limestones forming the greater part of the surface of the western Highland Rim Plateau ridges. Near the summits of the ridges there is a fairly definite horizon in the chert that contains manganese and iron oxides in varying degrees of concentration. Weathering of the mineralized chert has produced widespread float on the hill slopes and in the beds of small spring branches, and the presence of this float, some of it rich enough for metallurgical manganese ore, has encouraged a search for promising deposits in place. In the present study 52 localities where the mineralized beds crop out or have been prospected were examined.

The ore-bearing zone, generally at the top of the steep ridge slopes and about 195 feet above the Hardin sandstone member of the Chattanooga shale, is marked by a hard bed of chert 1 to 3 or 4 feet thick, which locally has been more or less replaced by brown iron oxide and manganese oxide, and below this bed there are beds of softer chert varying in thickness from 1 to 5 feet in which the proportion of manganese oxide is usually greater than in the upper bed.

The iron minerals are hydrated oxides typical of "brown iron ore," or limonite." They are generally of a chocolate-brown color and consist of amorphous material that has replaced chert to varying degrees. There is also an appreciable showing of glossy black iron oxide in the form of stalactites and as linings of open cavities, which locally has been mistaken for manganese oxide. Some dark-brown goethite also occurs in stalactitic form. No iron pyrites, siderite, or hematite were noted. Considered as a whole, the recoverable iron ore appears to be extremely siliceous and to contain little or no lime carbonate.

The manganese minerals are oxides, predominantly impure psilomelane, but more or less fibrous pyrolusite occurs in thin streaks. The manganese oxides occur much as do the iron oxides, along fractures in the chert and replacing it in seams that reach thicknesses of 2 to 3 inches in places. They occur also in kidney-shaped lumps, as small stalactites, and as isolated dark bluish-gray streaks, spots, and patches in brown iron oxide. Some of the purest-looking manganese oxide when analyzed shows surprisingly high percentages of silica and iron. In a few areas the iron and manganese oxides are contained in residual chert and clay rather than in chert ledges in place.

Prospecting has been shallow and superficial and has failed to disclose the extent of the deposits. No tunnels or trenches have been dug entirely through

or across a narrow ridge following the mineralized zone, nor has test pitting on the slopes of a ridge been sufficiently continuous or closely spaced enough to demonstrate the continuity of the deposits for more than a few yards. Only by deeper, wider, and more thorough digging of prospect pits and tunnels and by drilling on the level areas will the necessary information be acquired. However, in view of what is now known of the geological conditions, it may seriously be questioned whether the expenditure of further funds would be warranted. Certainly the results of the work thus far have been discouraging, and further work should be undertaken with the realization that it is more or less of a venture.

No actual mining has been done; consequently there are no data that might indicate the probable proportions of ore and waste. These appear to vary greatly from place to place, but nowhere were the observed proportions, even of brown iron ore, comparable with those of successfully mined deposits in west-middle Tennessee. Some of the chert is finely fractured and brittle, a condition suggesting that the cementing iron and manganese oxides might be freed from the chert by crushing and heavy-liquid separation. The Tennessee Valley Authority cooperated in the collection of samples and the making of laboratory tests, which included heavy-liquid separation, table tests, agglomeration tabling, and chemical analyses. The conclusions reached by Tennessee Valley Authority engineers did not favor carrying the study further.

More than 50 analyses of manganiferous, ferruginous, cherty material have been tabulated. These analyses are not all comparable, but in most of them manganese and the insolubles were determined. In more than half of them the silica or silica plus alumina exceeds 35 percent and may exceed the percentage of either iron or manganese, or even the total of these metals; in the same proportion of analyses the iron and manganese were each less than 15 percent. A few samples contained more than 35 percent of iron or of manganese, but these were chiefly hand-picked specimens. It is difficult to determine from these analyses just what types of ore are represented or whether the material can be considered as ore at all. Most of it falls below the standards of present-day commercial grades of ore. However, the presence of manganese oxide intimately associated with the iron may enhance its value for special uses, or in the event of a national emergency through which imports of manganese ores are restricted or cut off the predominantly manganiferous material might become of interest.

INTRODUCTION AND ACKNOWLEDGMENTS

For several years rumors have been in circulation to the effect that a large acreage in Perry and adjacent counties, Tennessee, is underlain by manganese ore. The evidence upon which these rumors were based was the presence of lumps of float iron and manganese oxides and chert partly replaced by these minerals in the bottoms of hollows and small spring branches and in the rock debris on the hill slopes. Specimens of manganese oxide submitted to the State geologist, Capt. Walter F. Pond, proved in many instances to contain sufficiently high percentages of manganese to fulfill the requirements of metallurgical ore. A brief reconnaissance by Captain Pond and the writer in July 1936, under the guidance of local citizens who had done considerable prospecting for manganese ore, disclosed that the manganiferous deposits were widespread in Perry County and were represented in Lewis and other counties in the vicinity. It was, therefore, deemed advisable to undertake more detailed geologic examinations of the deposits. The following year a cooperative agreement was effected between the Tennessee State Division of Geology and the Geological Survey, United States Department of the Interior, under which the writer was designated to carry on the field work. Fortunately the field work was not begun until autumn 1937, which permitted further prospecting to be accomplished and some trial shipments of ore to be made. The field work by the writer required 7 days in November 1937 and 12 days in April and 1 day in June 1938. During a few days in April 1938, Mr. H. S. Rankin, chief of the Minerals Research Division of the Tennessee Valley Authority, collaborated with the writer in the collection of samples of manganese ore for concentration tests. The results of the tests made on these samples at the Minerals Testing Laboratory at Norris, Tenn., are given in the appendix.

The helpful cooperation in the field of the following persons is gratefully acknowledged: Rev. W. M. Wood, Messrs. W. P. Grover, C. F. Pennington, and A. C. Hargrove of Hohenwald; John Sweeney of Paris; John Daniels of Blue Sky; W. H. French of Linden; Capt. W. F. Pond, State geologist of Nashville; H. S. Rankin, and N. A. Rose of the Tennessee Valley Authority; and Charles Morgan and George De Vaney of the Geological Survey.

Thanks are due to Thomas G. Andrews of the University of Alabama and to James S. Williams of the Geological Survey, both of whom visited the field with the author. Dr. Andrews made a petrographic study of the rocks and ores typical of these deposits and Dr. Williams made collections of fossils from Devonian and Mississippian rocks in the area.

REPORTS AND MAPS ON THE AREA

REPORTS

Miser, H. D., Mineral resources of the Waynesboro quadrangle, Tenn.: Tennessee Geol. Survey Bull. 26, 171 pp., 1921. Includes geologic map.

Wade, Bruce, The geology of Perry County and vicinity: Resources of Tennessee, Tennessee Geol. Survey, Oct. 1914, pp. 150–181.

Burchard, E. F., The Brown iron ores of the western Highland Rim, Tennessee: Tennessee Dept. Education, Div. Geol., Bull. 39, 227 pp., 1934.

Spain, E. L., Jr., Tripoli deposits of the western Tennessee Valley: Am. Inst. Min. Met. Eng. Tech. Pub. 700, 16 pp., 1936.

MAPS

Quadrangles of the areas in which the deposits examined are situated are listed below in order from north to south. These planimetric maps were compiled by the Federal Geological Survey from aerial photographs of the Tennessee Valley area. The maps are approximately 18½ by 23 inches and represent the surface on a scale of 1:24,000 (1 inch=2,000 feet). They show the culture (roads, railroads, towns, churches, schools, and houses) and forested areas but do not show surface relief by means of topographic contours. They may be purchased from the Director of the Geological Survey, Washington, D. C., and from the State geologist, Nashville, Tenn., at 10 cents a copy.

	Latitude	*Longitude*
Daniels Landing	35°45′-35°52′30″	87°52′30″-88°
Lobelville	35°45′-35°52′30″	87°45′-87°52′30″
Pine View	35°37′30″-35°45′	87°52′30″-88°
Chestnut Grove	35°37′30″-35°45′	87°45′-87°52′30″
Pope	35°30′-35°37′30″	87°52′30″-88°
Linden	35°30′-35°37′30″	87°45′-87°52′30″
Graves Spring	35°30′-35°37′30″	87°37′30″-87°45′
Kimmins	35°30′-35°37′30″	87°30′-87°37′30″
Leatherwood	35°22′30″-35°30′	87°45′-87°52′30″

A topographic map of the Waynesboro quadrangle on a scale of 1:125,000 (1 inch=nearly 2 miles), with 50-foot contour intervals, is for sale by the Geological Survey, Washington, D. C., at 10 cents a copy. A geologic map on this topographic base showing the structure by means of structure contour lines with 50-foot intervals is included in Tennessee Geological Survey Bulletin 26, listed under reports.

The geologic map of Tennessee, 4th edition, published by the Tennessee Geological Survey in 1933 on a scale of 1:500,000 (1 inch=nearly 8 miles) shows the general distribution of the rock formations in the area.

GEOGRAPHIC RELATIONS

Location of deposits.—The manganiferous deposits described herein are in west-middle Tennessee. (See fig. 33.) They have been prospected mainly along State Highway No. 20, which follows a ridge from Hohenwald in Lewis County to Linden in Perry County, but there are also some deposits on ridges south of Highway No. 20, and in places west, northeast, and southwest of Hohenwald and northwest of Linden. In the southern part of the area described there is a showing of manganiferous chert about eight-tenths of a mile east of Flat Woods.

Topography.—The manganiferous deposits that are in place, or embedded in undisturbed rock, lie for the most part near the summits of the ridges that make up the western Highland Rim Plateau. The ridges within the area here described are long, narrow, and crooked. They extend out in long salients between the streams and reach alti-

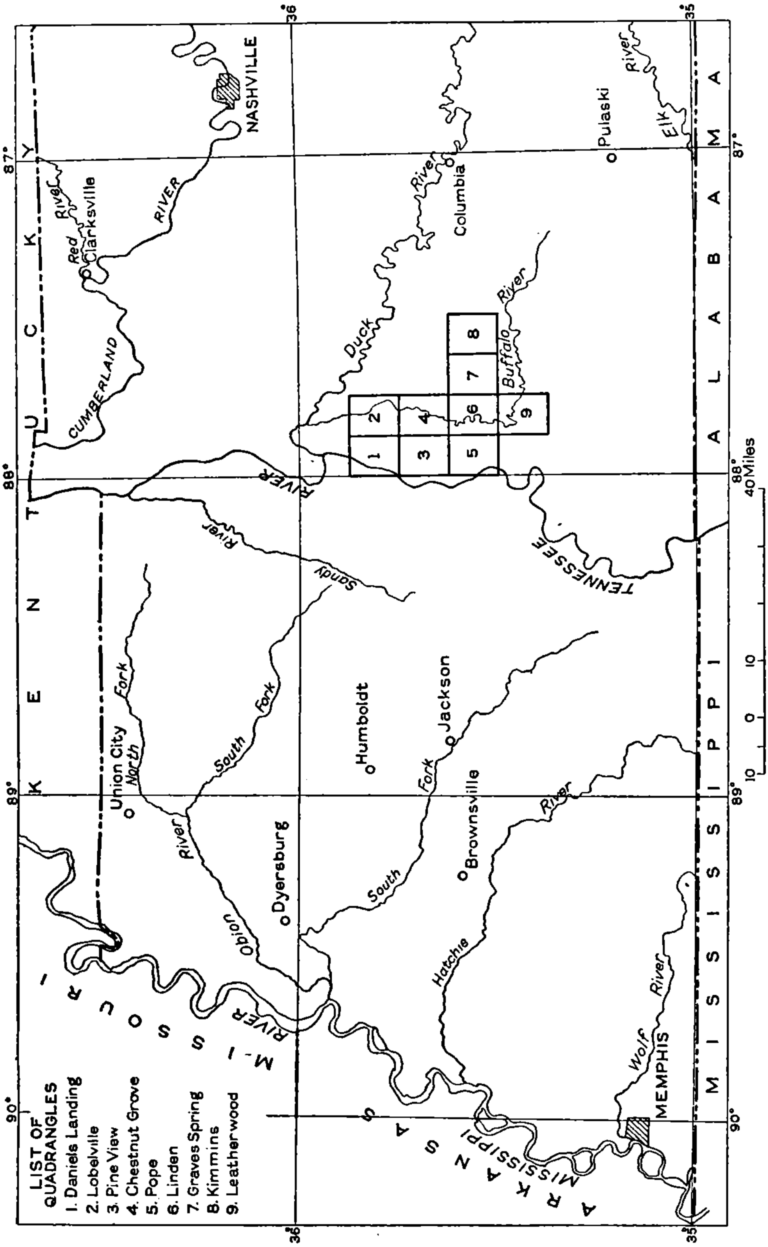

FIGURE 33.—Index map showing quadrangles in Tennessee in which manganiferous iron ores occur.

tudes of 700 to nearly 1,000 feet above sea level. The Tennessee River, the master stream of the area, has cut its channel down to an altitude of about 365 feet, and its eastern tributaries in this vicinity have developed an intricate system of dendritic drainage, a good example of which is shown on the contour map of the Waynesboro quadrangle, which comprises the extreme southern part of this area.

GEOLOGIC RELATIONS

ROCKS EXPOSED

The manganese-bearing area is in the western part of the western Highland Rim of the Nashville uplift and is underlain by sedimentary rocks, which lie nearly flat or in places dip gently westward toward the Tennessee River. The rocks comprise formations of Ordovician, Silurian, Devonian, Carboniferous (Mississippian), and Cretaceous ages the oldest of which are exposed along the Tennessee and Buffalo Rivers. Mississippian limestone and chert form the surface of the western Highland Rim and the escarpments overlooking the major streams and their tributaries. The rocks are only slightly disturbed and are not notably faulted in the area under consideration but are more or less fractured in places, owing to weathering and to settling in the vicinity of underground channels and caves. A detailed geologic map would probably show many gentle folds in the strata similar to those shown on the geologic map of the Waynesboro quadrangle,[1] which adjoins Perry and Lewis Counties on the south.

The following generalized section comprises certain of the rocks cropping out in the Waynesboro area, which are also represented in Perry and Lewis Counties.

Rocks underlying Perry and Lewis Counties, Tenn.

	Thickness (feet)
Quaternary system: Terrace deposits and alluvium.	
Cretaceous system:	
Upper Cretaceous series: Tuscaloosa gravel	0–50
Carboniferous system:	
Mississippian series:	
St. Louis and Warsaw limestone and chert	50–100
Fort Payne chert	100–200
Ridgetop shale	25–75
Devonian or Carboniferous system:	
Chattanooga shale: Hardin sandstone member at base	0–30
Devonian system: Pegram limestone and Linden group	0–40
Silurian system:	
Decatur limestone	0–60
Brownsport formation	0–200
Wayne formation	0–125
Brassfield limestone	0–25

On Highway 20, from the Buffalo River, three-fourths of a mile south of Linden, to bench mark 788, plate 18, the following sequence

[1] Miser, H. D., Mineral resources of the Waynesboro quadrangle, Tennessee: Tennessee Geol. Survey Bull. 26, pl. 1, 1921.

of beds is exposed, beginning with the mineralized beds at the top that are exposed at localities 1, 2, and 3 and extending westward down the hill toward Linden:

Section on Highway 20, ¾ to 3 miles southeast of Linden

	Altitude (feet)	Thickness (feet)
Mississippian:		
Warsaw (?) and Fort Payne:		
Chert, ferruginous and manganiferous, exposed in cut on Highway 20; no determinable fossils present	820	
Chert, mostly disintegrated to small fragments on surface exposed, with slight dip to east on north side of highway at bench mark	788	
Chert, horizontally bedded, nonfossiliferous, similar to above; exposed all along north side of Highway 20, with small quarry formerly worked for road metal at	745	
Chert, similar to above; exposed at intervals down to a quarry face 30 to 35 feet high, where finely disintegrated and sandy chert is obtained for road surfacing; base of quarry at	710	
Chert, exposed down along north side of highway in horizontal beds, becoming thicker than above; no fossils observed.		
Cherty limestone, dark where fresh, but weathering gray; top at	685	150
Ridgetop:		
Noncherty, argillaceous limestone in horizontal beds, dark and apparently bituminous where fresh, but weathering gray and shaly; top at	665	32
Mississippian or Devonian:		
Chattanooga:		
Shale, black, fissile, weathers gray; top at approximately	633	2¾–3
Sandstone (Hardin member), massive bedded; top at	630	1$^{10}/_{12}$–2$^{1}/_{12}$
Devonian:		
Linden group:		
Limestone, gray, fine to coarse crystalline, weathers into rough, thin to medium thick noncherty beds; contains crinoid and brachiopod remains; top at	628	
Lowest part exposed	620	8
Cherty and noncherty limestones exposed at intervals down the slope and in cliff of Buffalo River at Highway 20 bridge south of Linden at bench mark	488	132

The sequence of the beds above the Chattanooga shale and the character of the chert beds support the belief that the chert is of Fort Payne age. Other sections of the beds from the Hardin sandstone up to the mineralized chert may be seen on the local roads that extend southward from Highway 20 at bench mark 788 (see pl. 18) to Hurricane Creek, and from Highway 20 at station T Tr 25 FR to Hurricane Creek at station T Tr 57 SS, as shown on plate 23.

ORE-BEARING ROCK

The ore-bearing rock is bedded chert of Mississippian age, which probably belongs either to the Fort Payne or to the Warsaw formation. It may represent the horizon of an unconformity between the two formations. The chert in general contains few determinable fossils, although brachiopods and bryozoans are occasionally found that may be characteristic of both Fort Payne and Warsaw cherts. The scarcity of fossils applies particularly to the lack of crinoid remains, which are abundant in the Fort Payne chert in some other places.

The beds of chert are generally a few inches to 3 feet or more thick, and masses as much as 4 feet thick are found embedded in soil on the slopes of ridges and are probably not in place. The lower part of the formation contains lime carbonate, but this has been dissolved out near the tops of the ridges, leaving the rock cavernous and in places friable. This rock corresponds very closely to the Fort Payne chert, as described by Wade.[2] Loose pieces of gray, porous chert composed mostly of small fragments of fossils, including some Warsaw forms, are found in places on the surfaces of high ridges. Such residual chert has evidently been let down during the removal of higher beds. In the beds of streams near Blue Sky, in the Daniels Landing quadrangle, blocks of chert containing the fossil *Lithostrotion*, characteristic of the St. Louis limestone, have been noted. The Warsaw and St. Louis formations are both higher in the Mississippian series than the Fort Payne chert, and whatever is found of them in this mineralized area appears to be residual material that has been derived from beds that once were present above the ore-bearing chert. That the ore-bearing beds are the Fort Payne chert is indicated by the fact that the series merges below into the calcareous shaly beds recognized as the Ridgetop. E. L. Spain, Jr.,[3] of the Tennessee Valley Authority geologic staff, finds that the Fort Payne chert is not highly fossiliferous, but that the chert from the Warsaw is almost always filled with fossil remains and sometimes is entirely composed

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[2] Wade, Bruce, The geology of Perry County and vicinity: Resources of Tennessee, Tennessee Geol. Survey, Oct. 1914, p. 171.

[3] Spain, E. L., Jr., Tripoli deposits of the western Tennessee Valley: Am. Inst. Min. Met. Eng. Tech. Pub. 700, pp. 6, 7, 8, 1936.

of matted Bryozoa. Furthermore, he finds that the tripoli deposits of the Warsaw are of finer and more even-grained material and are freer from the undecomposed chert that marks the Fort Payne deposits. This corresponds with the observations of the writer to the effect that partly disintegrated chert associated with the ferruginous manganiferous deposits is wholly inferior to commercial grades of tripoli.

The beds of ore-bearing chert lie nearly horizontal but have very low regional dips toward the west and southwest. Mississippian limestone and chert form the surface of the western Highland Rim and the escarpments overlooking the major streams and their tributaries. The ores consist of oxides of iron and manganese, which locally have replaced beds of chert. At localities 1, 2, and 3, plate 18, the ore-bearing beds lie about 195 feet above the Hardin sandstone member of the Chattanooga shale.

The ore-bearing zone, generally at the top of the steep ridge slopes, is marked by a very hard bed of chert 1 to 3 feet thick, which has been locally replaced by brown iron oxide and a little manganese oxide, and below this bed there are beds of softer chert ranging in thickness from 1 to 5 feet, in which the proportion of manganese oxide is usually greater than in the upper bed, although iron oxide seems slightly to predominate in the whole deposit. In places, especially on Sassafras Stand Ridge (see pl. 18), the chert below the hard, upper "marker" bed has decomposed to friable white sand, locally called "tripoli," but contains too much grit for commercial tripoli. The chert is more or less fractured, and "mineralization," or replacement by iron and manganese oxides, has proceeded along the fracture planes, making a checkered pattern of ore and unreplaced chert. In some places, there are small open vugs lined with botryoidal black goethite, which has been mistaken locally for manganese oxide. Manganese oxide, however, may immediately underlie the thin lining of hydrous iron oxide in the open spaces. In places a thin film of red iron hydroxide covers the black goethite.

CHARACTER OF THE MINERAL DEPOSITS

Iron minerals.—The iron minerals in the chert ledges are hydrated iron oxides typical of "brown iron ore" or "limonite" ($2Fe_2O_3.3H_2O$). They are generally of a chocolate-brown color and consist of amorphous material that has replaced chert to varying degrees. There is also an appreciable showing of glossy black iron oxide in the form of stalactites and as a lining of open cavities, where it forms the surface of a thin layer having radial fibrous, or "needle," structure, and there are some films of red iron hydroxide resembling turgite and hematite. A little dark-brown goethite was observed in stalactitic form. At two places in the area an assemblage of hydrated iron phosphate minerals, resembling cacoxenite, beraunite, and strengite was observed, and possibly other phosphates are present in the mineralized chert. These places were in Highway 20 cut, east of bench mark 788, plate 18, and at locality 8, plate 27. Occurrences of these minerals near Iron City, Wayne County, were noted by Wade [4] and the writer.[5] No iron pyrites, siderite (iron carbonate), or hematite (the red, anhydrous iron oxide) were observed in the area. Considered as a whole, it appears that the recoverable iron ore, if the material can be considered as ore, is extremely siliceous and contains little or no lime carbonate. The presence of manganese oxide intimately associated with the iron may, however, enhance its value for special uses. There are a few areas where the iron and manganese oxides are contained in residual chert and clay rather than in chert ledges in place. This residual material resembles that in which the brown iron ores of the western Highland Rim are found, but it is not so rich in iron.

Manganese minerals.—The manganese minerals are oxides, predominant among which is impure psilomelane, a hydrous manganese manganate (H_4MnO_5) in which barium or potassium may replace part of the manganese; more or less pyrolusite, manganese dioxide (MnO_2), also has been observed in thin streaks of fibrous material in the chert at a few localities. The manganese oxides occur much as do the iron oxides, along fractures in the chert and replacing it in seams that reach thicknesses of 2 to 3 inches in places. They occur also in isolated spots, kidney-shaped lumps, and rarely as small stalactites. In the upper mineralized ledges the manganese oxides are associated with iron oxides, but lower down, especially where the chert is decomposed to a white, sandy friable material (erroneously termed tripoli, locally), the lumps and streaks of manganese oxide are often found practically free from ferruginous chert. Where it is associated with ferruginous material, the manganese oxide appears as isolated dark bluish-gray streaks, spots, and patches in the brown iron oxide. In localities where the manganiferous material is in residual chert, it is usually found in separate lumps in clay or as crusts and fragments adhering to loose lumps of chert in the residuum. The manganese oxide is rather misleading in appearance, for some of the purest-looking material when analyzed shows surprisingly high percentages of silica and iron, indicating that the ores have been formed by replacement of chert and that the process has generally been far from complete.

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[4] Wade, Burce, op. cit., p. 110.

[5] Burchard, E. F., The brown iron ores of the western Highland Rim, Tennessee: Tennessee Dept. Education, Div. Geol. Bull. 39, p. 188, 1934.

PETROGRAPHY OF SPECIMENS

Seven polished specimens, five of which are shown in plates 14, 15, 16, 17, *A*, inclusive, and regarded as typical of these deposits, were examined in detail by Dr. Thomas G. Andrews, of the University of Alabama, with the aid of the reflecting microscope and chemical tests.[6] The gold chloride test was used to distinguish areas of pyrolusite. The following descriptions are based on Dr. Andrews' notes.

In general the specimens consist of fractured chert, which, under near-surface or supergene conditions, has been seamed and partly replaced by oxides of iron and manganese. The white or light-gray chert contains fragments of indeterminable fossils and where unreplaced by metallic oxides contains many microscopic cavities, which doubtless have resulted from the solution of carbonate. Much of the chert is hard and coherent, but some is porous and friable. The solution of the interstitial carbonate and the formation of the cavities are believed to have occurred before the deposition of the metallic oxides. Infiltration and replacement of the chert by the metallic oxides has taken place from the fracture surfaces, and color differences in the borders of the fragments show a decrease in amount of oxides toward the center of the fragment. However, the greater part of the metallic oxides fills cavities of variable size. The metalliferous minerals in the order of abundance are limonite, psilomelane, pyrolusite, goethite, and manganite.

The deposits at the localities from which these specimens were taken are described further on pages 235–245.

Specimen from locality 3 (pl. 18).—In this specimen the unreplaced chert is porous, and borders of the fragments are discolored by manganese oxides. Though psilomelane may be present in minor quantity, the principal manganese minerals are pyrolusite and manganite. Pyrolusite seems to have formed at the expense of manganite. Limonite occurs with the manganese minerals.

Specimen from locality 12 (pl. 18).—Limonite, which is mostly light brown, is the most abundant material in this specimen (see pl. 14). Later limonite, which takes a bright polish, fills small openings and, with associated manganese oxides, fills a fissure crossing the specimen. Psilomelane is the dominant manganese mineral, but the specimen contains scattered areas of pyrolusite, most of which lines small pits and cracks.

Specimen from locality 5 (pl. 18). —The porous chert in this specimen (see pl. 15, *A*) contains fragments of unidentifiable fossils, and the many fractures in it are filled with vuggy limonite. Fossil frag-

[6] Thiel, G. A., The manganese minerals; their identification and paragenesis: Econ. Geology, vol. 19, p. 107, 1924. Short, M. N., Microscopic determination of the ore minerals: U. S. Geol. Survey Bull. 825, pp. 168–169, 1931.

ments with oolitic structures are recognizable in limonite that replaces the chert. A dark-colored limonite, which takes a bright polish, is associated with the more abundant medium-brown limonite, and, with a minor amount of pyrolusite, seems to be later in age than the brown limonite.

Specimen from locality 22 (pl. 18).—Oxides of both iron and manganese occur in this specimen (see pl. 16), which has a stalactitic structure. A polished surface truncating the stalactites shows the various minerals in concentric arrangement. Limonite forms the cores of the stalactites and is surrounded by layers of psilomelane. In a few of the stalactites the psilomelane is coated with a thin layer of pyrolusite, which in turn is covered by limonite and which probably has formed from alteration of the psilomelane. A layer of brownish material, which is believed to be a mixture of limonite and psilomelane, surrounds the limonite core in a few of the stalactites. Goethite in concentric layers occurs at one edge of the specimen, and a few small grains of manganite occur between stalactites as though formed after the deposition of the other minerals.

Specimen from locality 15 (pl. 18).—This specimen (see pl. 15, *B*), has a layered structure and consists almost entirely of psilomelane, though manganite, pyrolusite, and limonite are present in minute areas. The slightly different color of the central layers probably indicates a greater proportion of admixed iron oxide. Soft brown limonite occurs in small pits.

Specimen from locality 1 (pl. 23).—In this specimen (see pl. 17, *A*), fractures in the chert are filled with oxides of iron and manganese, and some of the late fractures are filled with pyrolusite and a few grains of manganite. Manganese oxides, chiefly pyrolusite, have also invaded and replaced the chert.

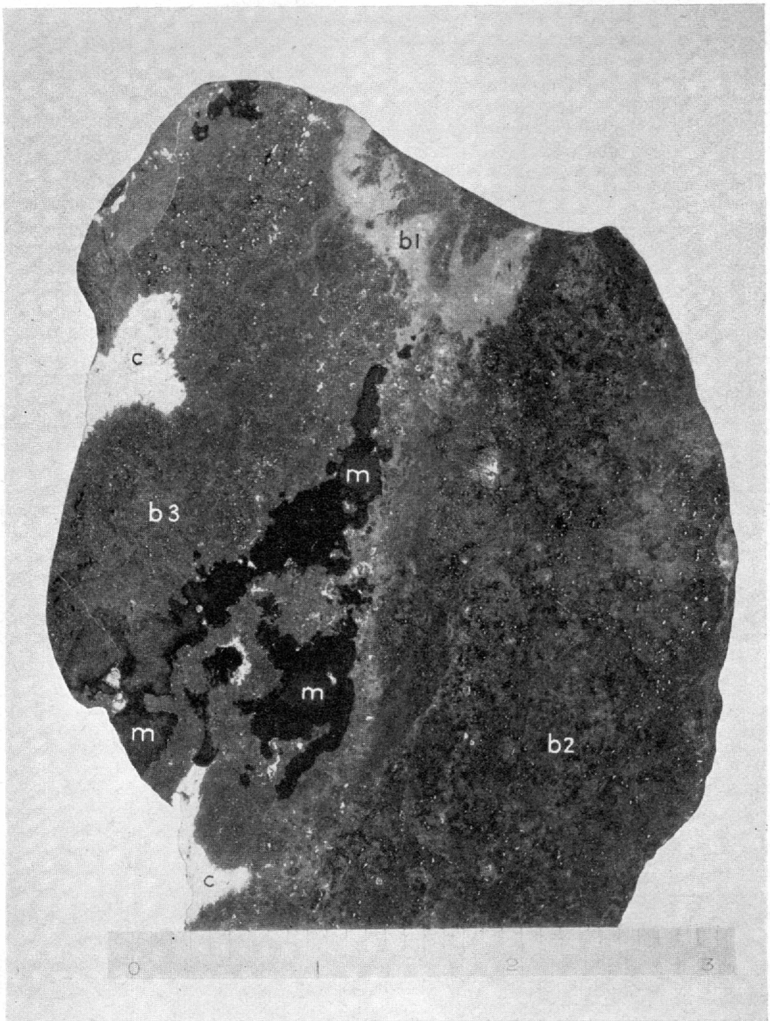
Specimen from locality 2 (pl. 27).—This specimen is composed of chert discolored and partly replaced by limonite. A narrow band consisting of both hard and soft layers of psilomelane with some pyrolusite occurs on one side of the specimen and is apparently part of the lining of an open cavity.

DESCRIPTIONS OF DEPOSITS

The mineralized deposits where prospected or noted in outcrops will be described in the following order:

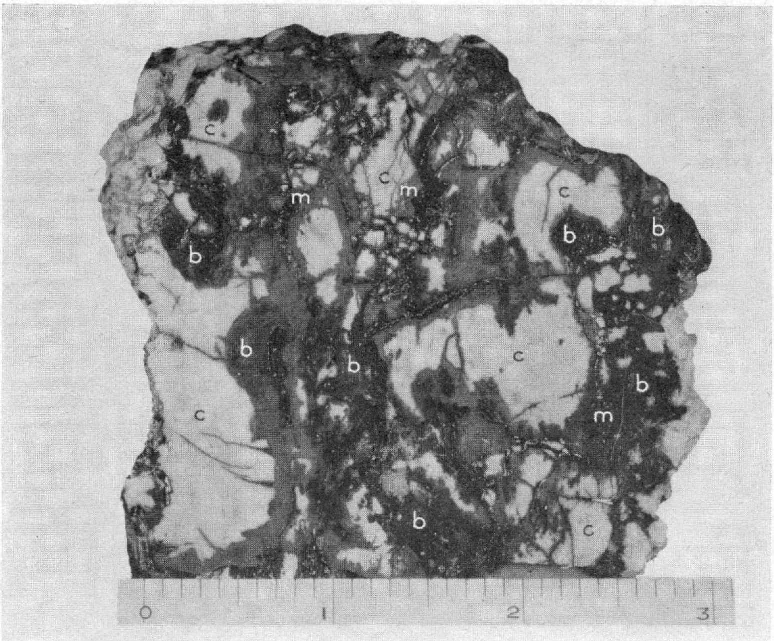
In Perry County along State Highway 20, in the northeastern part of the Linden quadrangle (see p. 235); along Sassafras Stand Ridge, in the eastern part of the Linden quadrangle. (See pl. 18.)

Near Highway 20, in the western part of the Graves Spring quadrangle. (See pl. 23.)



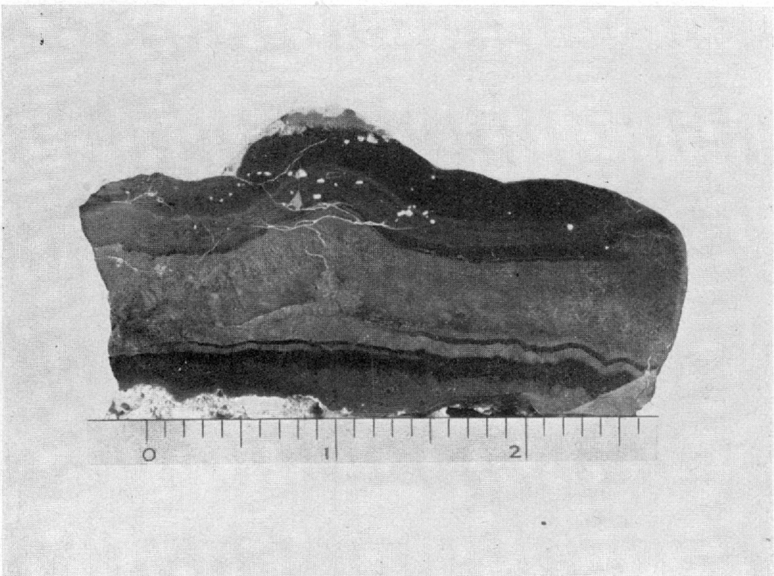
POLISHED SURFACE OF BROWN CHERT FROM LOCALITY 12, PLATE 18.

Chert has been largely replaced by limonite, with a small area of manganese oxide cutting part way across specimen. c, Soft, decomposed chert from which iron oxide has been removed by leaching; b1, light-brown area partly replaced by limonite; b2, porous area unevenly replaced by limonite; b3, area containing maximum proportion of limonite; m, manganese oxides, psilomelane and pyrolusite.



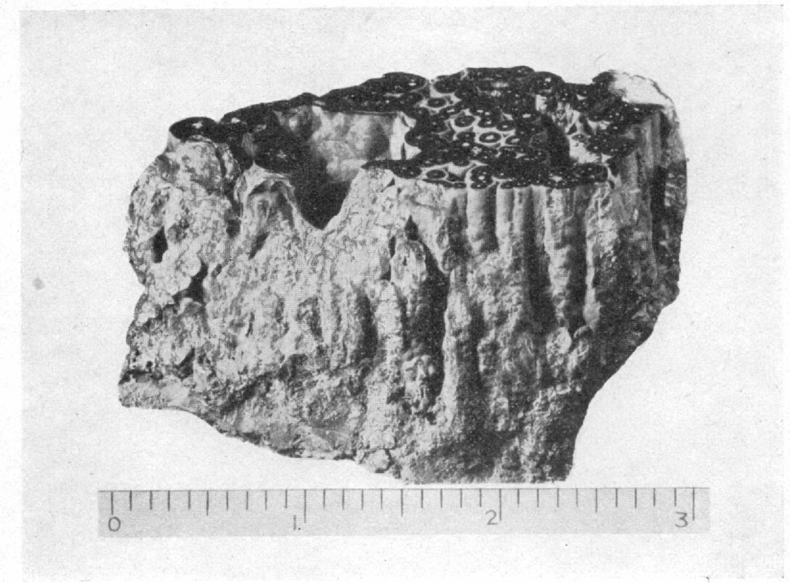
A. POLISHED SURFACE OF CHERT FROM LOCALITY 5, PLATE 18.

Chert is brecciated and replaced along the cracks and for some distance into the fragments by limonite and a minor proportion of manganese oxide. c, Unreplaced chert; b, limonite; m, pyrolusite.



B. POLISHED SURFACE OF MANGANESE OXIDE FROM LOCALITY 15, PLATE 18.

Specimen shows banded structure. Psilomelane is the predominating mineral. The middle lighter-colored band contains a small percentage of iron oxide. and a little pyrolusite has been shown to be present along the upper edge. Traces of decomposed chert are present on the outer surfaces of the specimen.

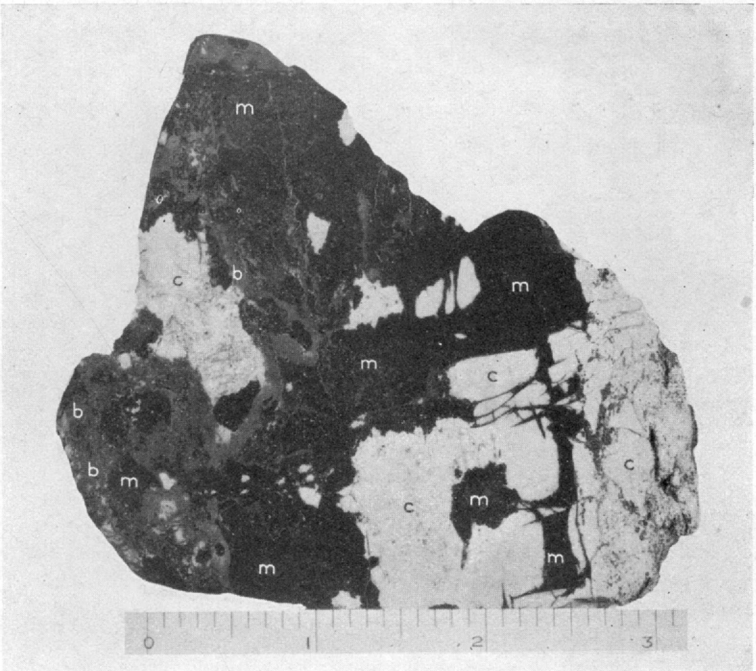


A. VIEW OF SIDE AND POLISHED TOP.

B. VIEW OF POLISHED TOP, SAME SPECIMEN.

The stalactites have limonite centers surrounded by concentric layers of psilomelane, pyrolusite, and limonite. At the right end of the specimen is a small fragment of light-colored chert below which are a few stalactites of goethite. The large cavity near the left end of the top is lined with limonite.

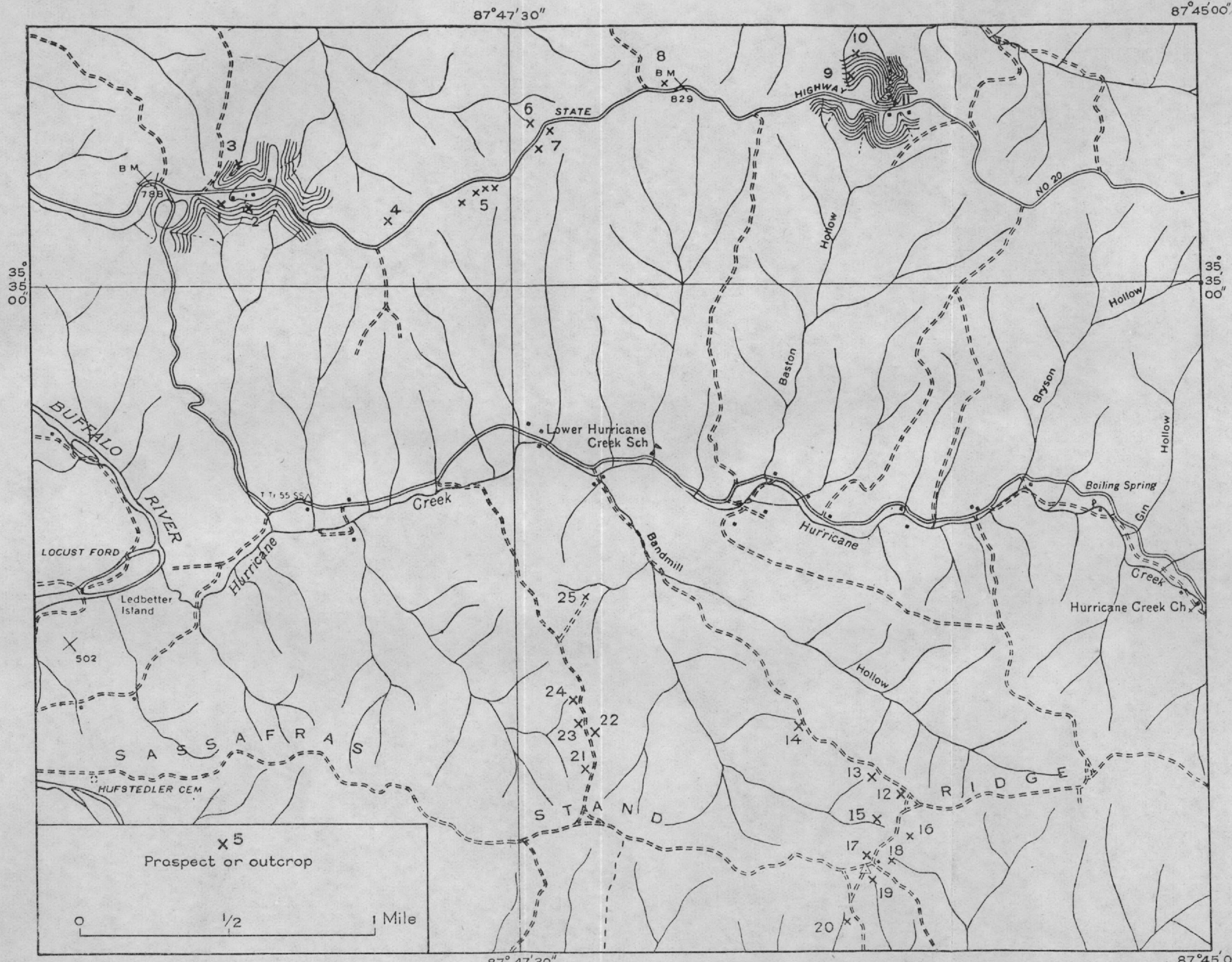
IRON AND MANGANESE OXIDES IN STALACTITIC FORM FROM LOCALITY 22, PLATE 18.



A. POLISHED SURFACE OF BRECCIATED CHERT FROM LOCALITY 1, PLATE 23.

The chert has been partly replaced by manganese and iron oxides. Replacement began in the fractures and extended into the chert fragments, but later fractures have cut the replaced areas and facilitated deposition of a later growth of manganese oxide. c, Unreplaced chert; b, limonite, in places in fine cracks; m, manganese oxide, mainly pyrolusite.

B. FACE OF PROSPECT IN MISSISSIPPIAN CHERT PARTLY REPLACED BY IRON AND MANGANESE OXIDES, SOUTH SIDE OF HIGHWAY 20, AT LOCALITY 5, PLATE 18.



LOCATIONS OF MANGANIFEROUS IRON OXIDE DEPOSITS IN EASTERN PART OF LINDEN QUADRANGLE, PERRY COUNTY, TENN.

In Lewis County, in the Kimmins quadrangle near Loveless school, 3 miles east-northeast of Hohenwald; at the mouth of Newberg Hollow, about 2 miles southwest of Hohenwald. (See pl. 24.)

Near Roane Creek and its branches in the southwestern part of the Lobelville and the southeastern part of the Daniels Landing quadrangles. (See pl. 25.)

On the ridge at the head of Craig Hollow and near branches of Little Spring Creek in the southern part of the Pine View quadrangle, 7 to 8 miles west-northwest of Linden. (See pl. 26.)

Near State Highways 20 and 100; about three-fourths of a mile north-northwest of Linden, in the Linden quadrangle; on the headwaters of Lick Creek in the Chestnut Grove quadrangle, about 2 miles north-northwest of Linden; northeast of Lick Creek in the southeastern part of the Pine View quadrangle, about 3 miles northwest of Linden. (See pl. 27.)

On State Highway 13, about three-fourths of a mile east of Flat Woods, in the Leatherwood quadrangle, the northeast quarter of the northwest quarter of the 30-minute Waynesboro quadrangle. (See pl. 28.)

The areas that have attracted the most attention are in the Linden and Graves Spring quadrangles. (See pls. 18, 23.)

In the following descriptions the locations of prospects have been given in considerable detail, because the country is not divided on the township-range-section system and because houses and distinguishing landmarks are scarce. Highway 20 winds for miles along a ridge around a succession of heads of hollows and branching spurs, and nearly every point on the road has a similar general appearance, so that for one who is not familiar with the entire route it is very difficult to find a given prospect or outcrop, especially during the season when the trees and bushes are in leaf. Moreover, the country is sparsely settled, and most of the inhabitants are renters who have not lived on their places very long and are unable to furnish information concerning the mineral outcrops or prospects.

LINDEN QUADRANGLE (eastern part)

(Plate 18)

HIGHWAY 20

State Highway 20, which connects the towns of Linden and Hohenwald, crosses the eastern part of the Linden quadrangle, following a high, narrow, winding ridge, the altitude of which ranges from 788 to 829 feet at certain bench marks. The rock forming the top of the ridge is Mississippian chert. The occurrence of mineralized fragments of chert in the talus slopes has led to prospecting in several areas, and the chert near the top of the ridge has been found to contain more or less manganiferous limonite, or brown iron ore, at a fairly definite horizon.

About 2¾ miles via Highway 20 southeast of Linden a bench mark shown on the map (pl. 18) to have an altitude of 788 feet marks the western limit of the manganiferous areas on this highway ridge, for west of this bench mark the highway goes down the valley of a small creek and passes below the mineralized chert horizon. The mineralized chert is exposed on both sides of a cut on Highway 20, about 500 feet east of bench mark 788. The ledges, which appear to have a low eastward dip, do not exceed 5 feet in thickness. They have been more or less replaced by limonite but contain a small proportion of psilomelane in spots and streaks that represent replacements generally beginning along fractures and borders of cavities in the chert. Some interesting hydrated iron phosphate minerals, such as cacoxenite in minute tufts of golden fibers, beraunite in minute crusts and globules of garnet-colored crystalline material, and strengite in small botryoidal deposits of pinkish color, were found in cavities in the chert.

In the next half mile east of bench mark 788 on highway 20 several prospects have been opened, and the ferruginous chert beds may be seen in the cut of Highway 20 where it passes through a low knoll east of bench mark 788. As this area is typical of the local mineralization, a plane-table sketch has been made showing the contours near the top of the ridge. Two prospects examined in this area are south of the highway, and one is north. The first prospect (locality 1, pl. 18) is south of the highway, about 1,400 feet east of bench mark 788 and about 200 feet southwest of the westernmost house. This is a small cut in massive, brecciated chert beds about 3½ feet thick, which are partly replaced by limonite containing a few spots of manganese oxide. Some of the chert is scarcely mineralized at all. Another slightly higher ledge 1 foot thick, which shows some iron and manganese oxides, is exposed about 8 feet farther north. These ledges face southwestward on a hollow that leads into a branch of Hurricane Creek and are at barometric altitudes of about 804 to 810 feet.

The next prospect toward the east (locality 2, pl. 18) is south of the highway and about 1,800 feet in an air line east-southeast of bench mark 788. It is at an altitude of 790 to 800 feet, at the head of a southward-trending ravine about 200 feet S. 40° E. of the westernmost house. Chert ledges approximating a total thickness of 12 feet here have been freshly broken, affording a very good view of the mineralized deposit. There is a question as to whether the whole thickness represents beds in place, as it is possible that some of the lower beds may have broken from higher ones and settled to their present position. The prospecting has been too superficial to demonstrate the continuity of the beds into the hill for more than a very few feet. The chert is much brecciated and partly replaced by iron oxide with relatively little manganese oxide. The chert also contains many small cavernous openings lined with black iron oxide, which may be mistaken for manganese oxide unless carefully examined under a field lens. In fact, much of such material has heretofore locally been considered to be manganese oxide. About 115 feet lower than this prospect a spring flows from limy, cherty beds that show no manganese or iron oxides.

North of Highway 20, about 1,600 feet east of bench mark 788 and a little east of north of the westernmost house of the group, is another prospect (locality 3, pl. 18). This prospect is about 20 feet lower than the highway, near the head of a northward-trending ravine. At the time of visit an old sawdust pile stood just above and at the east side of the deposit. Ledges of fractured chert cropping out for about 15 feet vertically show more or less iron oxide deposited as a cement in the fractures of the chert and forming mammillary and concretionary crusts within cavities in the chert. The iron oxide is reddish in places as if burned in a brush fire. These ledges may be traced for 75 to 100 feet along the hillside toward the northeast. Manganese oxide is not abundant in the ferruginous chert, but where present it shows as definite small dark spots and rounded concretionary masses the size of bird shot or small peas. In places it is possible to recognize pyrolusite, but almost everywhere psilomelane is present, together with limonite. An analysis (No. 1, table 2) of mineralized chert from this locality shows 38.10 percent of silica, 34.15 percent of iron, and only 2.61 percent of manganese. A polished specimen from this locality is described on page 233.

The next prospect toward the east (locality 4, pl. 18) that was examined was about 180 feet northwest of Highway 20, about 4,500 feet in an air line east of bench mark 788. Ledges of mineralized chert are exposed about 10 feet below the top of the ridge on the right-hand side of a hollow leading into the headwaters of Jack Branch, and some prospects have been cut about 5 to 15 feet lower. The highway here is about 850 feet above sea level. The prospects are in ledges that have slumped down lower than their original position. Iron and manganese oxides have partly replaced the chert, which is both massive and brecciated. Iron oxide predominates, and it is doubtful if a manganese oxide concentrate could be produced economically.

About 4,000 feet southwest of bench mark 829, on the south side of Highway 20, at altitudes of 835 to 850 feet, several prospects have been opened in fractured ferruginous chert more or less stained dark by organic acids on the weathered surfaces. (See locality 5, pl. 18.) The prospects are mostly within 100 feet of the highway, and possibly some of them are in masses of chert that have slumped below their natural position, as those at the east end of the group are lower than those farther west. Manganese oxide is present in minor proportions with the iron oxide in the chert. As most of the prospects in the mineralized area have been opened on steep hillsides, it has been difficult to photograph the openings, but at one of the openings at locality 5 it was possible to obtain a fair representation of the face of the cut, as shown on plate 17, *B*. Fractures have been penetrated by solutions carrying iron oxides, which have partly replaced the adjacent chert, and open spaces have been lined and partly filled with lustrous black iron oxide. This black iron oxide has often been mistaken for manganese oxide, which in places appears to have alternated in deposition with the iron oxide (see pl. 19). A polished specimen from this locality is described on page 233.

About half a mile west of bench mark 829, on Highway 20, some prospects have been opened on a ridge and the northeast side of a ravine (see locality 6, pl. 18). The general altitude of the mineralized chert here is about 820 feet, or 10 feet lower than the highway level, and there is much float chert at and below this horizon. The largest prospect cut is about 20 feet long and 3 feet high, in chert ledges that appear to be in place. The top layer is ferruginous, with manganese increasing downward and penetrating fractures in the chert, but it is not very rich or abundant at the best.

On the south side of Highway 20, at the head of a hollow about half a mile in an air line southwest of bench mark 829, or nearly on the opposite side of the ridge from locality 6, there was noted the outcrop of a ledge or else of a large boulder nearly in place of ferruginous chert, at an altitude of about 820 feet (see locality 7, pl. 18). Some manganese oxide streaks are present in the chert. On the west side of the same hollow at an altitude of 820 feet, about 120 feet south of the highway, ledges of ferruginous chert crop out on the hillside, and a small prospect made many years ago was noted. Traces of manganese oxide are present in the ferruginous chert ledge and also in float on the slope, practically up to the top of the ridge, at 835 feet barometric altitude.

The next examinations that were made toward the east were at the head of "Dogwood Hollow," the first northward-trending hollow west of bench mark 829 on Highway 20, where a ledge of chert nearly in place at an altitude of about 800 feet showed iron and manganese oxides (see locality 8, pl. 18). On the hillside below, many masses of similar chert have broken off and crept down the gulleys and slopes, probably as much as 100 feet vertically. Some manganese ore is reported to have been cobbed out and shipped from here. Analysis of a specimen from here (No. 2, table 2) showed 35.24 percent of silica, 35.26 percent of iron, and only 1.08 percent of manganese.

On the east side of a hollow, 3,000 feet east of bench mark 829 and about 25 feet lower than the top of the hill, some large masses of ferruginous chert nearly if not quite in place have been opened by prospecting (see locality 9, pl. 18). The chert is fractured, and some open fractures are lined with stalactites of hydrated iron oxide (black limonite). A few streaks of manganese oxide were seen on one boulder. On the same ridge, at distances of 450 and 675 feet north of locality 9, are some surface prospects and natural outcrops of similar ferruginous chert (see locality 10, pl. 18). The ore at none of these places appears promising.

On Highway 20, about 3,800 feet east of bench mark 829, several prospects were examined on the "Oguin" property. A small area here has been sketched on the plane table (locality 11, pl. 18). Several prospects have been opened. One prospect is in the head of a steep hollow on the north side of the highway, nearly opposite the Pittman house. Beginning about 35 feet lower than the highway, which is here at an altitude of about 839 feet, 10 or 12 prospect cuts have been made at intervals down the hollow for a vertical distance of about 60 feet. The masses of rock that have been prospected are ferruginous chert, with minor areas of manganese oxide. The prospectors evidently believed the rocks to be in place, but examination discloses that many slabs and boulders, probably including even the highest material prospected, have slumped or settled down from a higher level, so that instead of a thickness of mineralized beds in excess of 50 feet there is actually only one mineralized ledge not exceeding 5 feet in thickness. These prospects were first visited in company with Captain Pond, the State geologist, in July 1936, and since then much of the exposed mineralized material has been broken up in hand cobbing out the most highly manganiferous material, which was collected and sold.

SASSAFRAS STAND RIDGE

The next group of prospects to be described is on Sassafras Stand Ridge and branching ridges in the middle eastern part of the Linden quadrangle. These ridges, which constitute the main divide between Hurricane and Rockhouse Creeks, are reached and traversed only by old logging roads, some of which are now abandoned, and the mineralized localities can be reached only with considerable difficulty by automobile. The best route at the time these localities were visited leads southwestward on a graveled road from triangulation station T Tr

25 FR on Highway 20, in the Graves Spring quadrangle (see pl. 23), across hurricane Creek and up to Sassafras Stand Ridge, a distance of about 2 miles. Hurricane Creek must be forded, but is passable except at times of freshets. This road crosses Sassafras Stand Ridge and extends southward down to Cotton Branch, but it is necessary to leave it at triangulation station T Tr 26 FR and proceed west-northwest along the ridge on an old logging road, which winds up, down, and around through the woods for a distance of about 2.5 miles to a point within the Linden quadrangle, where the road forks. The northwest fork goes out the ridge toward Bandmill Hollow and Hurricane Creek, and the southwest fork continues southwest and west along Sassafras Stand Ridge. Another route by which Sassafras Stand Ridge might be reached in 1938 was to leave Highway 20 just west of where the Lewis County-Perry County boundary line turns southward from the highway and follow a graveled local road southward and southwestward about 1.2 miles to where a woods road branches off to the northwest along Sassafras Stand Ridge. From here, however, to the triangulation station T Tr 26 FR there are 2 miles of winding unsurfaced road, boggy in places, and in general worse than the ridge road beyond that triangulation point. These directions have been given in some detail, because without guidance it would be very difficult for a stranger to find the mineral deposits and prospects. There are no dwellings or cultivated areas along Sassafras Stand Ridge, and one might spend days in the woods without seeing a human being unless someone chanced to be cutting or transporting timber or firewood.

On Sassafras Stand Ridge, 2.5 miles from triangulation station T Tr 26 FR, about 200 feet west of the place where the road forks toward the northwest and southwest, and at the junction of a short road connecting the two forks, a prospect consisting of two cuts has been made (see locality 12, pl. 18). The cuts are below road level, which is at an altitude of approximately 860 feet here. At this place the vertical thickness of the mineralized beds is about 10 feet, but the mineralization is very uneven and spotty. At the top are heavy ledges of chert replaced in part by iron oxide, with manganese oxide increasing downward but probably nowhere constituting more than 30 percent of the minerals present. Below the hard top ledges the chert is decomposed in places to an iron-stained pulverulent material resembling tripoli but containing more grit. Streaks of manganese oxide follow former cracks in this decomposed rock and in places form crusts enclosing lumps of it. In the ferruginous material the manganese oxide is in sharply demarked streaks and spots and in places surrounds unreplaced chert, but the reverse relations may also be noted. In places the manganese is present in large enough streaks and lumps to make possible its separation by hand breaking and cobbing, and some ore is reported to have been recovered in this manner and shipped away in 1937. A polished specimen from this locality is described on page 233.

A photograph of the face of the south cut shows the irregular distribution of the darker areas of iron and manganese oxides. (See pl. 20, *A*.) At this south cut there has been excavated from open cavities in the chert some crusts having a mammillary surface in which the succession is chert; brown iron oxide or black manganese oxide, or both; black manganese oxide; and red iron hydroxide. An analysis (No. 5, table 2) of the red iron oxide shows that the red encrustation is a silicious, manganiferous, hydrated iron oxide between limonite and hematite.

To one who is familiar with iron and manganese ores, it hardly appears possible that the ore from this or similar showings can be as a whole of commercial value. Such a large proportion of chert would necessarily have to be taken with the ore as to render it prohibitively high in silica. A visual estimate does not indicate more than 5 percent of manganese oxide nor more than 20 percent of iron oxide in the mineralized ledges, the rest of the material being chert and clay. To obtain a sample that would reflect the average percentages of manganese and iron in the whole deposit would be impracticable, but an attempt was made to cob out by hand a sample of ferruginous manganese oxide, such as would have to be produced either by hand or mechanically if the material were to be marketed, and a small sample of good, nearly iron-free manganese oxide. Analyses of these two samples (Nos. 3 and 4, table 2) were made by the Federal Geological Survey. The percentages of silica, 43.70 and 35.95, are excessive; the percentages of manganese, 22.77 and 30.78, are neither of them high, but they would be acceptable for some metallurgical purposes if the silica were not so high and if the percentages of iron, 9.53 and 2.66, were correspondingly higher; the percentages of phosphorus, 0.09 and 0.02, are well within desirable limits; the percentages of cobalt, 0.19 and 0.27, and of nickel, 0.05 and 0.06, are of interest but not large enough to be of value under the circumstances. An analysis (No. 585, appendix table C) made by the Tennessee Valley Authority shows 42.61 percent of insolubles, 27.72 percent of manganese, and only 3.81 percent of iron. This corresponds fairly well with the analyses made by the Federal Geological Survey. These results are therefore rather discouraging to the hope that ore of commercial grade can be developed here.

At several places on the southwest side of the ridge, along the crest of which the logging road extends northwestward into Bandmill Hollow, are outcrops of mineralized chert ledges, and some of these have been prospected. At locality 13, plate 18, about 850 feet northwest of locality 12, a hard ledge of ferruginous chert crops out on the steep hillside about 15 feet lower than road level. Below the hard top ledge the chert has been leached to a state of friability to a greater extent than at locality 12. The resulting white sandy deposit is locally called "tripoli" but is coarser and more gritty than a true tripoli. It contains a small showing of manganese oxide in streaks and lumps, which follow fractures in the former chert. The quality of the manganese oxide here appears fairly good, but much silica is present. (See analysis 6, table 2, and analysis 581, appendix table C.)

Outcrops of ferruginous chert have been prospected a few hundred feet northwest of the "tripoli" prospect, at two places just north of and about 10 feet lower than the road. The material on the dumps indicates that the ore is lean and that the manganese oxide is subordinate in quantity to the iron oxide.

On the crest of the ridge, at locality 14, plate 18, about 2,100 feet northwest of locality 12, a pit and trench have been dug across the old logging road at an altitude of 828 feet.

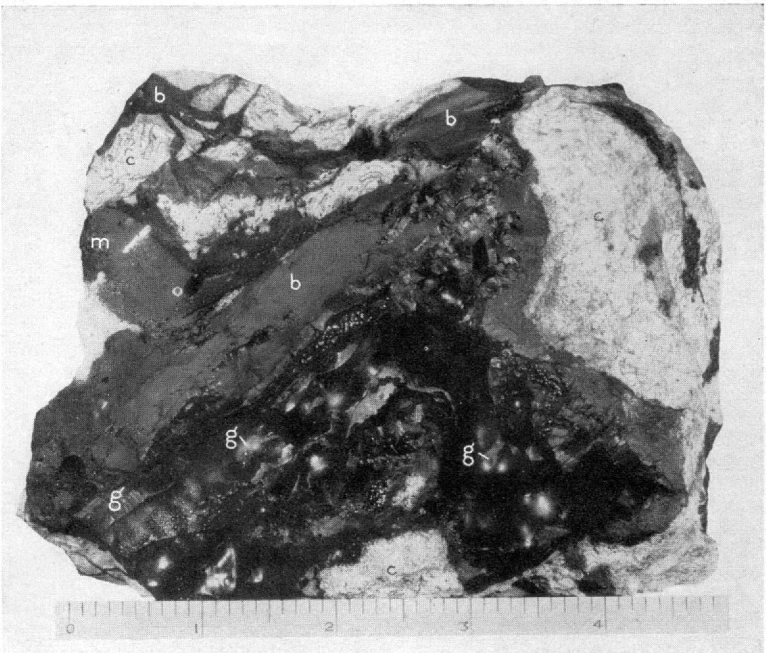
It is locally reported that about 20 tons of hand-selected manganese ore was shipped from this prospect to the blast furnace of the Tennessee Products Co. at Wrigley, Tenn. The following section is shown:

Section in pit and trench at locality 14, plate 18

	Ft.	In.
Chert, ferruginous, hard ledge	1–2	
Chert, decomposed, containing scattered spots of manganese oxide	2	
Chert, manganiferous		2–3
Chert, reddish, decomposed	1	6
Sand ("tripoli") derived from disintegrated chert	1	6

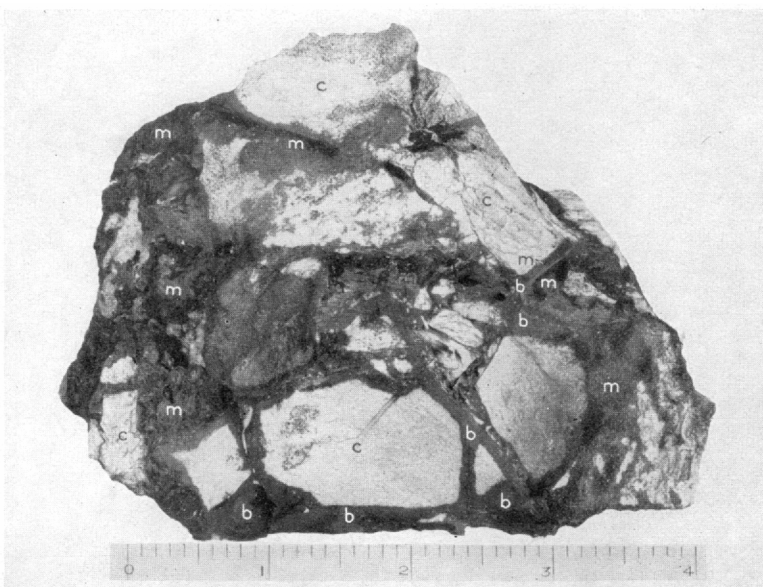
About 150 feet farther west, on the crest of the ridge, at 835 feet altitude, ferruginous-manganiferous chert, more or less fractured, crops out and has been blasted open. The showing of manganese is slight, but the partial replacement of chert by brown iron oxide, which predominates, is so uniform in places as to form a hard dense fine-grained chocolate-brown rock. Analysis 7, Table 2, shows that the iron in a specimen of this ferruginous chert amounted to 37.23 percent, the silica 35.96 percent, and water 8 percent. The silica is far too high to permit the use of this type of ferruginous chert as a source of iron.

No further showings of ore were seen northwest of here on the ridge road toward Bandmill Hollow, and this is to be expected, because the mineralized bed seems to be rising in that direction and the ridge becomes lower. About 200 feet southwest of the prospect trench and 10 feet lower is a prospect on the hillside, which shows ferruginous chert layers at the top with ferruginous-manganiferous chert layers and decomposed, sandy chert layers below. Crusts of red iron oxide are abundant.



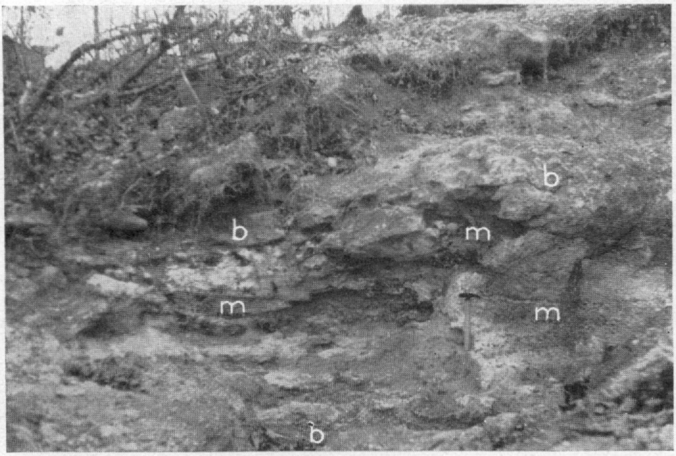
A, CHERT FROM LOCALITY 5, PLATE 18, PARTLY REPLACED BY IRON OXIDES.

c, Unreplaced chert; b, brown dense amorphous limonite; m, small spot of manganese oxide; g, glossy black limonite and goethite.



B, CHERT FROM LOCALITY 5, PLATE 18, SHARPLY FRACTURED AND PARTLY REPLACED BY IRON AND MANGANESE OXIDES.

c, Unreplaced chert; b, brown dense amorphous limonite; m, manganese oxides, psilomelane and pyrolusite.

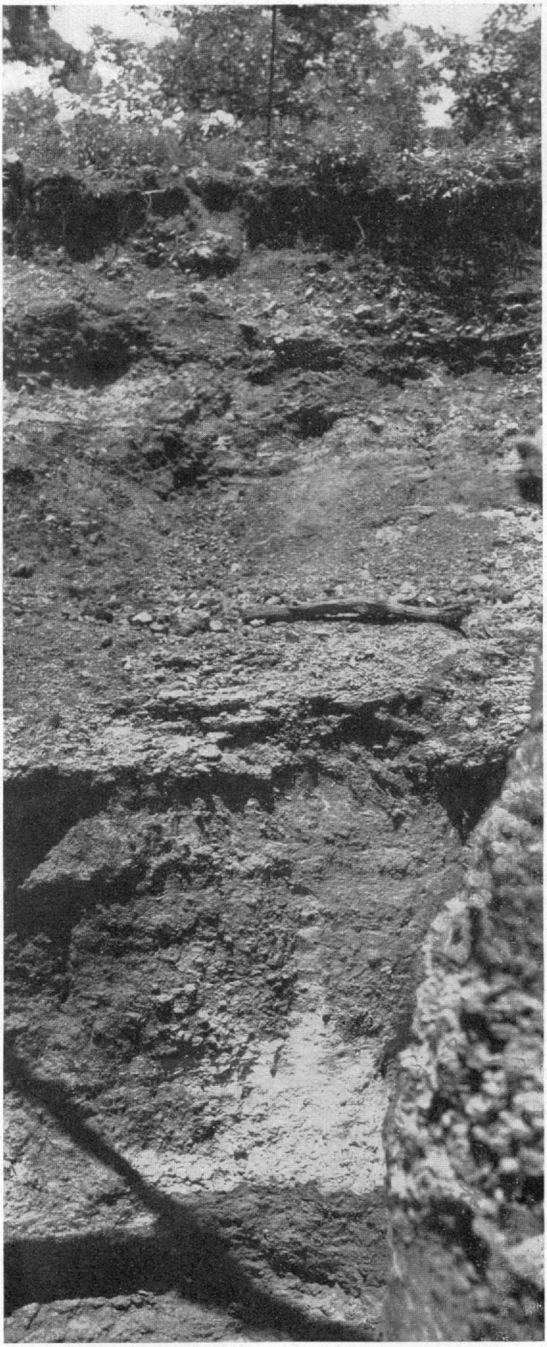


A. FACE OF SOUTH PROSPECT ON SASSAFRAS STAND RIDGE AT LOCALITY 12, PLATE 18.

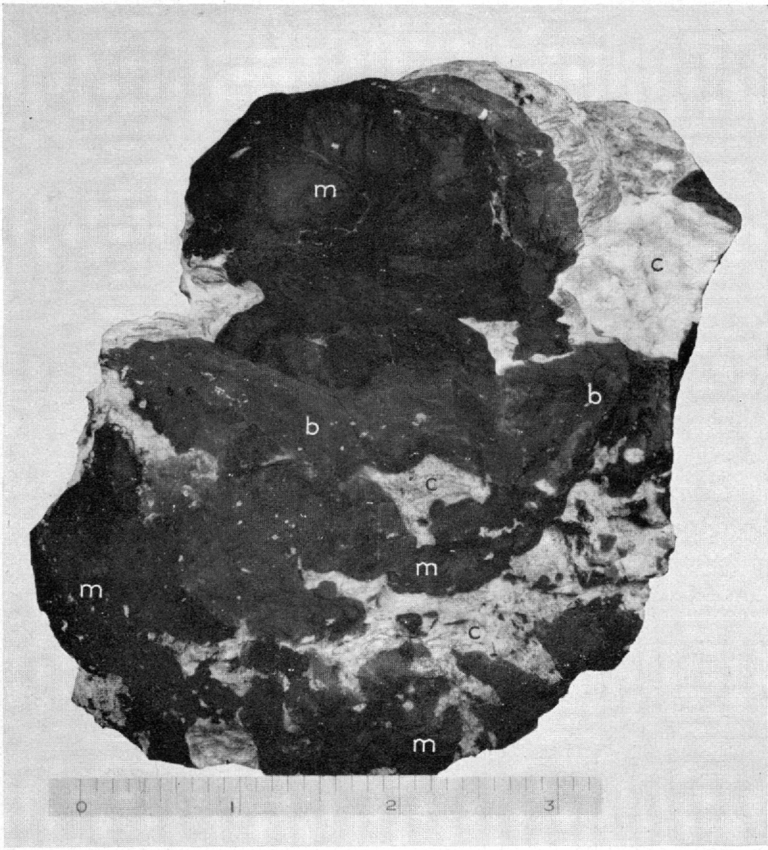
b, Ferruginous chert; m, manganiferous chert.

B. LEDGE OF HARD CHERT AT LOCALITY 23, PLATE 18.

Ferruginous and manganiferous chert at top and light-colored, friable silica in cave below.



SECTION OF PROSPECT AT LOCALITY 15, PLATE 18, SHOWING ABOUT 18 FEET OF MANGANIFEROUS CHERT DEBRIS AND BEDDED CHERT.



CHERT FROM LOCALITY 15, PLATE 18, LARGELY REPLACED BY IRON AND MANGANESE OXIDES.

c, Soft, decomposed yellowish chert; b, brown dense amorphous limonite; m, manganese oxide, mostly psilomelane. At top of specimen the manganese oxide is in concretionary forms with the unbroken surface covered by a dusty yellow chert powder (cf. pl. 15, *B*).

About 1,500 feet by road south-southeast of locality 12, plate 18, a triangulation station is indicated as "Ice" on the map of the Linden quadrangle, but the mark on the brass plate set in a concrete post is "Icf." This station may well serve as a starting point for describing the locations of the remaining deposits on Sassafras Stand Ridge. The true altitude of station Icf is not available, but by aneroid barometer an altitude of about 865 feet was indicated.

About 900 feet N. 15° E. of station Icf, at locality 15, plate 18, a pit about 22 feet deep has been dug in alternating layers of hard and soft disintegrated chert. (See pls. 21, 22.) A generalized section is given below.

Generalized section of pit at locality 15, plate 18

	Thickness (feet)
Soil, roots, and other material necessary to be stripped	2⅔
Chert, mostly hard, ferruginous, with brecciated areas and areas of white friable material containing manganese oxide. Irregular fractures carrying manganese oxide cut the chert at steep angles	2⅓–4⅔
Chert, disintegrated to yellow and white sand	1–2½
Chert, shaly, decomposed, more or less ferruginous	1–2½
Chert, white, friable with spots of manganese and iron oxides; average thickness about	6
Chert, ferruginous	⅙–⅚
Chert, hard, unevenly bedded, ferruginous	2½
Chert, decomposed, containing specks of manganese oxide	4

The hard top layers are replaced by brown iron oxide with a little manganese oxide, but in the hard chert layers below there was a higher proportion of manganese ore. The altitude at the top of this pit, as determined by aneroid barometer, is 835 feet, which indicates that the manganiferous beds are about 25 feet lower than those at locality 12. Some of the manganese oxide streaks appear to be fairly rich and attain thicknesses approximating 2½ inches, which is about the maximum observed for ore in place in this region; in fact, this prospect appeared to be one of the most promising of all those examined. A polished specimen from this locality is described on page 234.

Analysis 8, table 2, of a selected specimen of ore from this prospect shows 37.54 percent of manganese and only 1.82 percent of iron, but the silica, 33.24 percent, is rather high for metallurgical use and should be lowered by some method of concentration if the ore is marketed. Analysis 13, table 4, of a sample selected by G. I. Whitlatch, of the Tennessee Division of Geology, shows 42.70 percent of manganese, the highest percentage recorded in this report for an authentic sample taken from a natural outcrop. About 9 tons have been shipped from here to the blast furnace at Wrigley, Tenn.

About 900 feet northeast of station Icf a ledge of ferruginous chert with traces of manganese oxide crops out for a distance of about 50 feet (see locality 16, pl. 18). The ledge is about 1 foot thick and probably represents the "marker" mineralized bed of the area. Other outcrops of the mineralized chert were noted at localities 17, 18, 19, and 20, plate 18, at distances of about 250 feet north of, 500 feet east-northeast of, 300 feet southeast of, and 900 feet south-southwest, respectively, of station Icf. A short distance northeast of this station is the site of a house that was destroyed by fire subsequent to the summer of 1936. West of the site of this house is the head of a hollow, where there are several outcrops of ferruginous chert. On the north side of this hollow a prospect was noted in the chert, but no significant showings of manganese had been revealed. Boulders and debris consisting of mineralized chert derived from ledges that crop out just below the top of the ridge are distributed all the way down the hollow to a spring which is at an altitude of about 725 feet.

On the Sassafras Stand Ridge road, about 1 mile west of station Icf, a road branches off toward the north and northwest, and it is along this branch road that the next showings of mineralized chert were seen. On this road, about 1,000 feet north of the place where the road forks, is an outcrop of chert containing some reddish to brownish iron oxide and small spots of manganese oxide (see locality 21, pl. 18). The barometric altitude is about 790 feet.

About 1,500 feet north of where the road forks is a prospect (locality 22, pl. 18) in weathered chert beds showing 5 to 6 feet of meager mineralization by iron and manganese oxides, but some interesting specimens of iron and manganese oxides in stalactitic form were found in the topmost beds at the roots of a tree. Soft sandy chert containing bryozoans is exposed at the base of the prospect.

Analysis 9, table 2, shows that iron oxide greatly predominates over manganese oxide in this stalactitic ore and that the silica is comparatively low. A polished section of this material is described on page 234. Analysis 584, appendix table C, of a specimen of this ore also shows more iron than manganese, though the iron is not so greatly in excess, and it also shows considerably more silica than is shown by the Federal Survey analysis.

About 1,800 feet north of Sassafras Stand Ridge road, on the west side of the branch road, is a small cliff of chert having a maximum height of about 12 feet (see locality 23, pl. 18). The top 4 or 5 feet are of hard chert breccia cemented with iron and manganese oxides, of which the iron predominates. In the lower part of the cliff the chert is soft, and through weathering, wind action, and artificial means a shallow cave or shelter has been formed. A photograph of these beds is shown on plate 20, *B*. The altitude is about 810 feet.

At locality 24, about 300 to 700 feet north of the above-mentioned cliff, there are outcrops of massive ferruginous chert at the west side of the ridge road. Occasionally, a speck of manganese oxide may be seen. At about six-tenth mile north of the Sassafras Stand Ridge road a dim road, not shown on the map, turns northeastward toward Bandmill Hollow, and on the spur followed by this road some further outcrops of mineralized chert were seen (see locality 25, pl. 18). Where freshly broken, a small proportion of manganese oxide is seen to be mixed with the iron oxide. An analysis by the Tennessee Valley Authority (No. 583, appendix table C) shows 48.22 percent of insolubles, 22.91 percent of manganese, and 8.37 percent of iron. This place lies about 1½ miles due south of locality 7 on Highway 20 and is the last that was examined on Sassafras Stand Ridge. There seems to be very little difference between the character of the ore on the ridges north and south of Hurricane Creek.

GRAVES SPRING QUADRANGLE

(Plate 23)

The area in the Graves Spring quadrangle that had been prospected at the time of the writer's examinations is in the western part of the quadrangle, southwest of Highway 20 (see pl. 23). The route to Sassafras Stand Ridge, referred to on page 239 in connection with the descriptions of mineralized deposits on Sassafras Stand Ridge in the Linden quadrangle, begins at a bench mark on Highway 20 inscribed T Tr 25 FR, extends southwestward across the valley of Hurricane Creek, and then turns westward at bench mark T Tr 26 FR.

Near the west edge of the Graves Spring quadrangle, about eight-tenths mile south of bench mark 891 on Highway 20, are some prospects known as the "Johnson mines" (locality 1, pl. 23). These prospects are at an altitude of about 845 feet, on an escarpment facing 25° S. to 30° W. into the drainage of Inman Hollow. The prospects consist of two shallow cuts just below the brow of the hill. The eastern cut has a face about 4 feet high and a base about 30 feet long and 10 feet wide. The western cut, about 25 feet distant, is smaller. The mineralized rock is chert replaced principally by limonite, but it contains spots of manganese oxide, and within the area of these oxides are some specks of unreplaced chert. The beds appear to dip gently westward. The mineralized bed is about 3½ feet thick, 1 foot of which is weathered in places to a buff-colored sand, which approaches an ocherous condition where very fine grained. Where not disintegrated the brown iron oxide is very hard and is probably siliceous. The manganese oxide increases downward and predominates in the lower part of the bed. Below the mineralized bed lighter-colored fractured chert and sand containing very little iron or manganese is exposed. It is reported that some manganese ore was hand cobbed out of the mineralized chert here and shipped to a blast furnace. A polished specimen from locality 1 is described on page 234.

A heavy-liquid separation test made on a sample of ore collected from the "Johnson mines" is described by H. S. Rankin in the appendix. Analyses by the Federal Geological Survey (No. 10, table 2) and by the Tennessee Valley Authority (No. 582, appendix table C) give iron ranging from 2.80 to 5.05 percent, manganese 29.71 to 31.54 percent, and silica 38.88 to 41.15 percent.

There is another small prospect at about the same altitude, just around the brow of the hill west of the western cut, in which ferruginous chert, sparingly manganiferous, is displayed, and about 400 feet farther north ferruginous chert crops out in places on the west side about 10 feet below the top of the ridge. This locality seems to deserve more thorough prospecting, particularly in the cutting of trenches farther back into the ridge, as it has not been demonstrated whether or not the manganese oxides continue far under cover.

A few poorly preserved fossils were found in loose chert at the larger cut. G. H. Girty, in a memorandum dated December 14, 1938, states that the age is not certain but that the fauna may be of Warsaw or Spergen age.

On Highway 20, about four-tenths mile east of the west edge of the Graves Spring quadrangle, are two houses. The western one was formerly used as a store, and the eastern one was known as the Brewer house. About 600 feet southeast of the Brewer house some small prospects have been opened in the mineralized chert. (See locality 2, pl. 23.) These prospects are at the head of a small hollow, which trends S. 20° E. but within a short distance turns abruptly in a direction about S. 70° W. The top of the ledge here is at an altitude of about 830 feet. The highest prospect pit discloses layers of chert largely replaced by brown iron oxide and sparsely sprinkled with spots of manganese oxide. Another cut has been made about 35 feet west of and 5 feet lower than the first, and it shows a similar mineralization. Scattered down the hollow below are many boulders and slabs of mineralized chert. One of these, which was embedded in a horizontal position in the soil, had been broken by prospectors, and its freshly broken surfaces revealed chert that had been largely replaced by brown iron oxide and sparsely sprinkled with spots of manganese oxide. All these slabs and boulders have evidently become detached from and settled below a ledge that is not more than 5 or 6 feet thick. No ore of commercial value has been exposed here.

Farther east along Highway 20, near the heads of certain hollows within half a mile northwest of a bench mark that has an altitude of

861 feet (see pl. 23), a few small prospects show characteristic ferruginous and manganiferous chert a few feet below the crest of the ridge (localities 3 and 4, pl. 23). Half a mile northwest of bench mark 861 an old woods road, hardly more than a trail at the time of visit, leads about S. 70° W. from the highway through the brush along the crest of a spur of the ridge and down to Inman Hollow, a branch of Hurricane Creek. South of this old road two small prospect pits (localities 5 and 6, pl. 23) have been dug, one about 1,400 feet and the other about 2,900 feet southwest of Highway 20. These prospects are either in a mineralized ledge in place or in large boulders or slabs that are very nearly in place. The ore at these prospects is a much-fractured chert, with the fractures sealed with iron and manganese oxides, which have also replaced some of the chert. The appearance of the mass suggested that if the material were mined mechanical crushing might effect a fairly clean separation of the metallic oxides from the chert. Fifty-pound samples were therefore obtained from two of these pits (localities 5 and 6), and the results of heavy-liquid separation tests on them are given in table A of the appendix. Farther out on the main ridge along the old woods road, about 3,500 feet from Highway 20, at an altitude of about 875 feet, there is more or less float of ferruginous brecciated chert, some boulders of which have been broken, apparently in the course of a search for manganese. (See locality 7, pl. 23.) This is probably the same horizon that is at the surface at localities 5 and 6, although the latter are 20 or more feet lower in altitude. An eastward dip of the beds could account for the difference in altitude.

Heavy-liquid separation tests were made by the Tennessee Valley Authority on samples from localities 5 and 6, the results of which are shown in table A of the appendex.

KIMMINS QUADRANGLE

(Plate 24)

The zone of ferruginous-manganiferous chert that has been described as occurring in Perry County along State Highway 20 from about 2½ miles southeast of Linden eastward for 5 or more miles is reported also to extend for some distance into Lewis County in the vicinity of the same highway, but at the time of the present reconnaissance no systematic prospecting had been done, and the report could not be verified. However, float of mineralized chert was found in western Lewis County, and these fragments may eventually be traced to their source. The altitude of the surface gradually rises toward the east, and the rocks themselves, according to their structural relations, also have a slight eastward rise, which may exceed that of the surface, so that if the mineralized zone is persistent it formerly may have lain at a higher altitude than Hohenwald, if not now present in that vicinity. Actually, there are some iron and manganese deposits in the vicinity of Hohenwald, but they are of secondary and residual types rather than of minerals in chert beds in place. This lends weight to the possibility that the mineralized zone if projected eastward would lie higher than Hohenwald and that what is left of the mineralized chert is to be found only in unconsolidated residual surface materials. Examples of such concentrations are described at the two following localities.

Three miles east-northeast of Hohenwald, or about four-tenths mile east of Loveless School, and nearly at the east boundary of the Kimmins quadrangle, some peculiar, low-grade manganiferous deposits have been found in a field and broad shallow depression on the Lee Loveless farm 400 to 500 feet north of the highway. (See locality 1, pl. 24.) The altitude of the highway here is about 940 feet, or a little lower than Hohenwald. The manganiferous material is in dark spots or segregations of manganese oxide cementing together sand grains and pebbles of chert and quartzite into a somewhat earthy conglomerate. It crops out in lumps that have been locally termed "buckshot ore." A few small prospect holes had been dug here showing the manganiferous material to a depth of 2 or 3 feet. Some boulders of nonmanganiferous chert embedded in the manganiferous material yielded brachipods, bryozoans, and other fossils, which are characterized as follows by the late G. H. Girty in a memorandum dated December 14, 1938: "The collection from Lewis County, Tenn., numbered K–1, has the fauna and I believe represents the horizons of beds in the Waynesboro quadrangle that pass as St. Louis limestone". According to this view these fossils are from higher beds than those at the Johnson mines in Perry County (locality 1, pl. 23), described on page 245, which Dr. Girty has stated may be of Warsaw or Spergen age. The nonmanganiferous chert boulders thus probably represent material residual from the St. Louis limestone.

An analysis of this material, as reported in table 2, No. 11, shows only 4.26 percent of manganese and 10.60 percent of iron, the silica and alumina being 52.34 and 11.10 percent, respectively. However, analysis 12, table 4, gives a better showing—38.94 percent of manganese, 3.62 percent of iron, and 18.15 percent of silica.

Mr. A. C. Hargrove, of Hohenwald, reports that there was once an undrained area, or swamp, here. E. L. Spain, Jr., of the Tennessee Valley Authority geologic staff, reports having seen similar material near Guntersville, Ala., and the writer has observed such deposits in the process of formation in creek beds near Warrenton, about 4 miles west-southwest of Guntersville.

About 2 miles southwest of Hohenwald, on a steep hillside overlooking Rockhouse Creek Valley, at the mouth of Newberg Hollow (locality 2, pl. 24), several prospects have been cut. The barometric altitude at the road at the base of the hill was 840 feet at the time of visit. This may be a few feet higher than the correct altitude. Certain of the prospects on the hillside were 75 and 90 feet above the valley floor by barometric measurement. At the higher prospect there have been exposed lumps of conglomerate formed of rounded chert pebbles cemented together by sandy clay or siliceous cement, as is common with Tuscaloosa gravel, and into this gravel conglomerate some manganese oxide has penetrated, staining, cementing together, and partly replacing some pebbles. Masses of angular chert conglomerate that are present have been thus affected, also, but they contain a larger proportion of manganese. Fossil brachiopods similar to those found on the Loveless place were found in this chert, which is obviously residual from beds formerly at a higher level. The lower prospect showed manganese oxide in veinlets and coatings on pebbles and fragments of chert embedded in soil and clay similar to the deposits north of Roane Creek in the vicinity of Blue Sky. The manganese veinlets in places are as much as 1 inch thick, but most of them are thinner. The manganese oxide is lustrous black with a brownish streak and is slickensided in places, owing to movement of the masses of broken chert, as all the manganese-bearing chert and clay seems to be residual material that is gradually traveling down the hillside. Some brown iron oxide has also partly replaced fragments of chert. Small samples of selected and ordinary ore obtained here were analyzed at laboratories of the Federal Geological Survey and the Tennessee Valley Authority. Analysis 12, table 2, shows 41.72 percent of silica, 11.74 percent of alumina, 9.95 percent of iron, and 12.64 percent of manganese, and the analysis made in heavy-liquid separation tests (appendix, table A) on a picked sample of the best ore reveals 50.14 percent of insolubles, 10.99 percent of iron, and 12.3 percent of manganese. Analysis 12, table 4, gives a better showing—38.94 percent of manganese, 3.62 percent of iron, and 18.15 percent of silica.

Locality 2 is adjacent to the Nashville, Chattanooga, and St. Louis Railroad, and if workable deposits of ore are discovered here there should be no transportation problems to be solved.

DANIELS LANDING AND LOBELVILLE QUADRANGLES

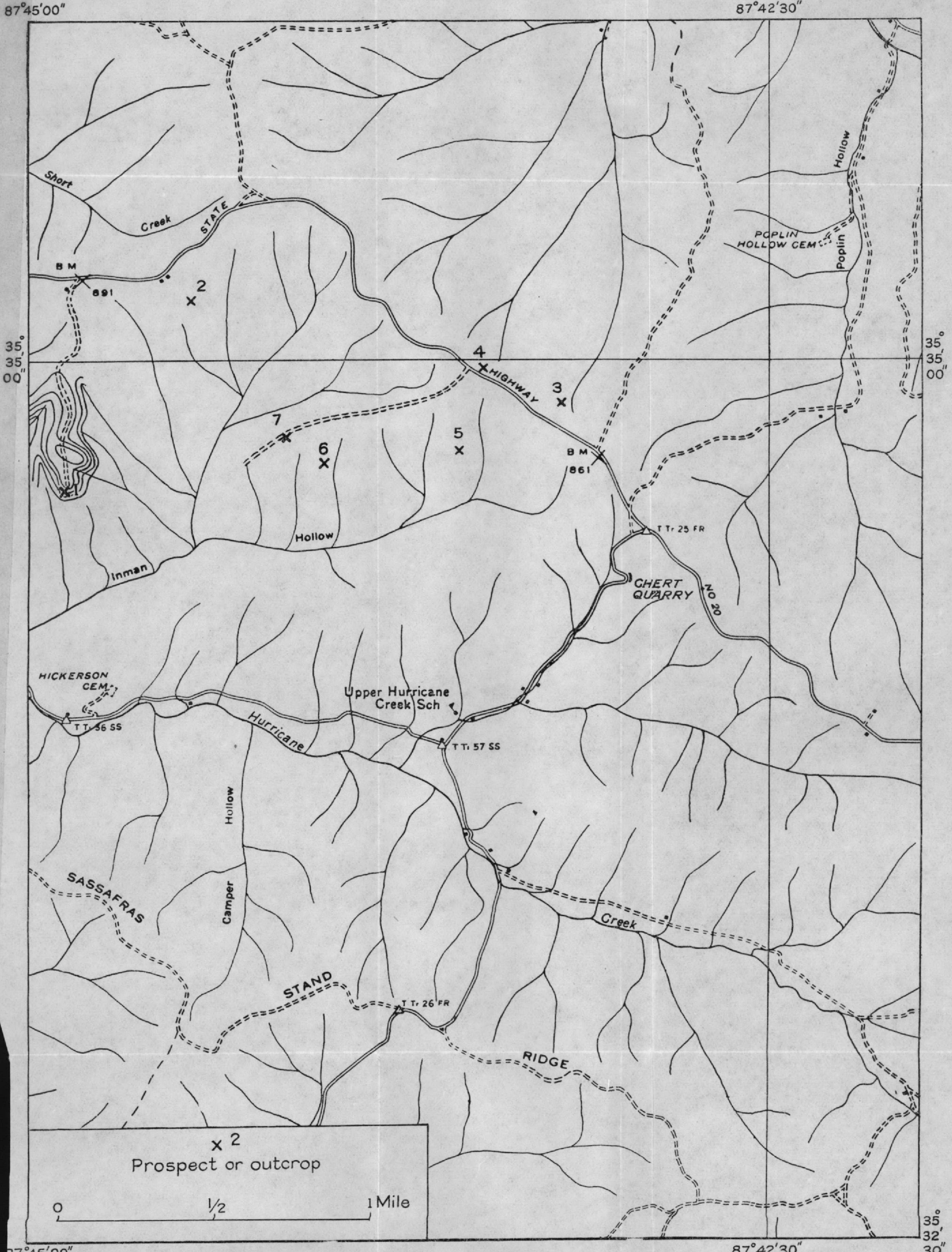
(Plate 25)

The mineralized deposits farthest northwest in Perry County that were examined are in the southwest corner of the Lobelville quadrangle and the southeast part of the Daniels Landing quadrangle. To reach these localities it is necessary to drive northward from Linden on State Highway 13 to De Priest Bend, thence west and northwest to the north border of the Chestnut Grove quadrangle near an airway beacon, then across the southwest corner of the Lobelville quadrangle along the Roane Creek Road and into the Daniels Landing quadrangle to the site of a former postoffice called Blue Sky. The distance by this route from Linden to Blue Sky is approximately 15 miles.

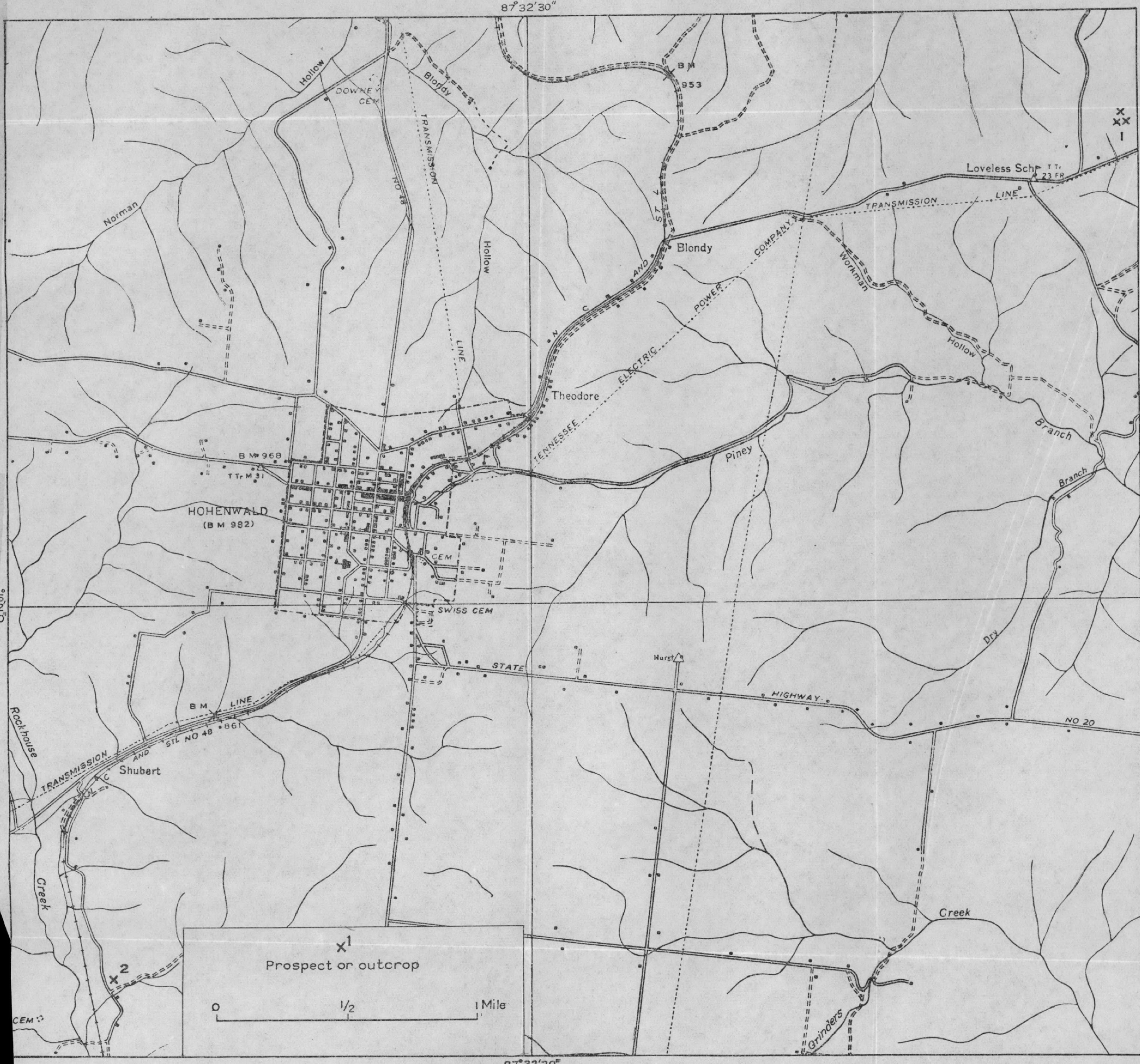
The distinguishing characteristic of the mineralized deposits in the vicinity of Blue Sky, north of Roane Creek, is that the manganiferous chert occurs as residual debris in clay, sand, and soil on hillsides or in the bottoms of streams, and is thus at lower levels than that of the original bed in place. Some small prospects were noted on the north side of the Roane Creek road, about three-tenths mile southeast of Blue Sky, approximately on the boundary line between Lobelville and Daniels Landing quadrangles. The largest prospects (see locality 1, pl. 25) are four-tenths to five-tenths mile east-northeast of Blue Sky, just over the line within the Lobelville quadrangle. The prospects consist of several open cuts on both slopes of a small westward-extending stream valley and from stream level up to about 50 feet above the stream. Manganese oxide appears to predominate over iron oxide here, but analysis 588, appendix table C, indicates the contrary in the instance of a specimen examined by the Tennessee Valley Authority. Manganese oxide is often found in crusts of varying thickness on blocks of chert, and the surface of the manganese oxide shows slickensides caused by the movement of the mass of debris down the hill slopes, indicating that the deposition of manganese occurred while the chert was in place rather than after it had been incorporated into the residual mantle. A few pockets of fairly good appearing ore have been found, but they were not large enough nor abundant enough to encourage bringing in a steam shovel to mine the material. Some float lumps or crusts of manganese oxide 4 to 6 inches thick were noted in the streams northeast of Blue Sky within the Lobelville and Daniels Landing quadrangles.

Several prospects have been opened in the hills north of Roane Creek, two-tenths to three-tenths mile west of Blue Sky (see localities 2 and 3, pl. 25). These prospects are at altitudes ranging from about 550 to 615 feet. The zone showing the best manganiferous material seemed to be about 30 feet thick. This zone is composed of reddish clay and partly decomposed chert, with streaks and crusts of iron and manganese oxides parallel to the bedding planes of the lumps of chert. Some of the manganese oxide appears to be of good quality, but some of it is soft and impure, like wad. The parties prospecting this locality in the fall of 1937 hoped to find deposits that would warrant steam shovel operations, but they discontinued their efforts about the end of the year.

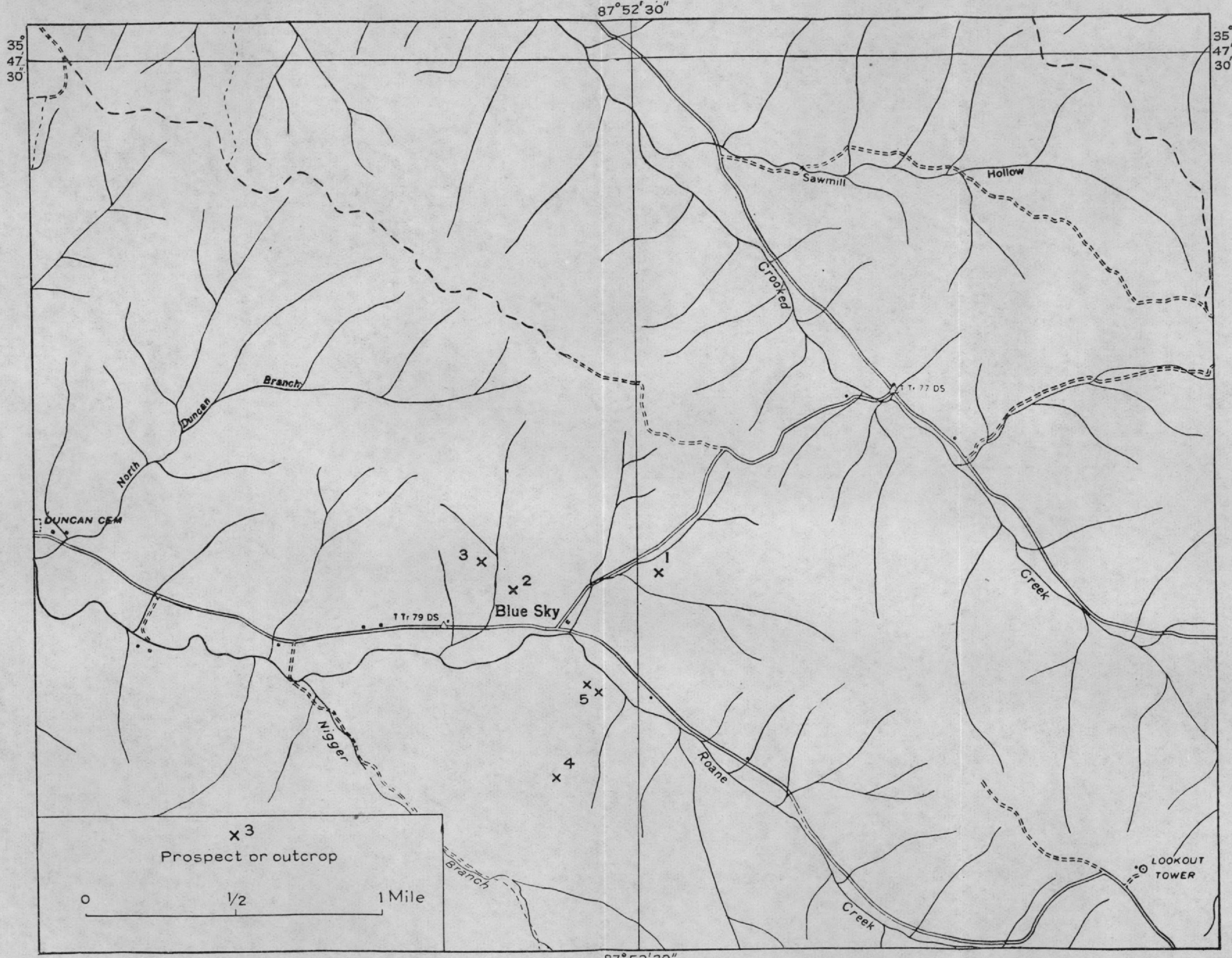
On the hillsides and in the streams there is much loose chert. Some is fossiliferous, containing Mississippian forms, such as corals, crinoid



LOCATIONS OF MANGANIFEROUS IRON OXIDE DEPOSITS IN WESTERN PART OF GRAVES SPRING QUADRANGLE, PERRY COUNTY, TENN.



LOCATIONS OF MANGANIFEROUS IRON OXIDE DEPOSITS IN EASTERN PART OF KIMMINS QUADRANGLE, LEWIS COUNTY, TENN.



LOCATIONS OF MANGANIFEROUS IRON OXIDE DEPOSITS IN SOUTHEASTERN PART OF DANIELS LANDING QUADRANGLE AND SOUTHWESTERN PART OF LOBELVILLE QUADRANGLE, PERRY COUNTY, TENN.

stem plates, bryozoans, and brachipods. Pieces of chert containing *Lithostrotion canadense*, a coral of St. Louis age, were found in the creek northeast of Blue Sky. These pieces appear to be residual from rocks that once lay above the mineralized chert beds and indicate the pre-St. Louis age of the manganiferous material.

South of Roane Creek, in the vicinity of Blue Sky, the position of the mineralized chert is different from that north of the creek. On the north side of the creek, for instance, no manganiferous chert was seen that was positively in place, but near the top of the ridge (locality 4, pl. 25), between Roane Creek and Nigger Branch, at an altitude of about 685 feet, there is much brecciated chert in place, cemented and partly replaced by iron and manganese oxides. Iron oxide predominates here, but in places manganese oxide is sufficiently abundant to have aroused the interest of prospectors. Such places occur around the heads of hollows that extend northward and southward from the ridge. At successively lower places, however, there are mineralized masses and boulders of chert obviously not in place, which have also been prospected. One of these places (locality 5, pl. 25) is on the northeast slope of the ridge, near the flood plain of Roane Creek, about 1,100 feet S. 22° E. of Blue Sky, and others were encountered by the writer while going southward up a hollow that opens out into Roane Creek south of Blue Sky.

The chert in some of the brecciated deposits is remarkably fresh, unaltered, and brittle, and appears as if it might be susceptible to fairly good separation from the iron and manganese oxides by crushing. The general appearance of the ore suggests a range in concentration ratios of 10:1 to 50:1. This area is remote from rail transportation, but the Tennessee River, with its promise of future water traffic, is only about 6.5 miles downgrade from Blue Sky.

Table 3 contains 15 partial analyses made by the Tennessee Products Corporation on samples submitted by Mr. John Sweeney, whose prospects were north of Roane Creek near Blue Sky at localities 1, 2, and 3, pl. 25, but it cannot be stated definitely which localities are represented by the analyses or whether the specimens are actually from the Blue Sky area. Apparently the material for which analyses are given in table 3 is not of commercial grade, as the manganese ranges from 1.92 percent to only 13.40 percent and the silica from 29.72 percent to 49.15 percent. Two analyses of black lump material, Nos. 2 and 7, table 4, probably represent the black lump manganese oxide commonly found in small branches flowing into Roane Creek from the north. The amount of manganese in these specimens, 38.55 and 43.55 percent, is comparatively good, but the silica in analysis 7 is high. Table 4 gives 3 analyses (Nos. 9, 10, and 11) of material from Roane Creek, which show great variability and no great merit in the ore. Number 11 may represent a fair grade of brown iron ore. Analyses 589 and 590 in table C of the appendix are of manganiferous iron ore that has less silica than iron, which is unusual.

PINE VIEW QUADRANGLE (southwestern part)

(Plate 26)

A few showings of ferruginous chert with traces of manganese oxide were seen in the Pine View quadrangle, north of the divide between Little Spring Creek and the head of Craig Hollow (see locality 1, pl. 26) and north of Little Spring Creek (see locality 3, pl. 26). These localities were reached from Linden by driving out State Highway 20 and 100 for 7 miles to the mouth of Craig Hollow, its junction with Cypress Creek, in the northern part of the Pope quadrangle, thence by foot trails north and northwest more than 2 miles to a point beyond Little Spring Creek. At locality 1, pl. 26, which is well down a hollow that drains into Little Spring Creek from the southeast, there was noted a ledge of ferruginous chert with small spots of manganese oxide. This ledge measured 2 feet 7 inches in thickness and was not in place. It was at an altitude of about 600 feet. It had probably been let down gradually from a higher altitude than the present top of the ridge, for no similar rock was in place on the ridge where traversed on this trip.

From locality 1 the traverse was continued down to Little Spring Creek, down it to the next hollow that comes in from the north, and then up that hollow about 1,500 feet, but not as far as the next divide. Here, at locality 3, plate 26, boulders of brecciated, sandy, ferruginous chert, containing a little manganese oxide were found on the hill slopes up to an altitude of 650 feet. None of this material is suitable iron or manganese ore, and it seems doubtful if any of it is in place. Such mineralized boulders as were seen could logically be residual from a bed of chert that formerly overlay the area but that has been gradually worn away by erosion by local tributaries of the Tennessee River.

On the ridge at the head of Craig Hollow the surface is strewn with loose gravel containing here and there lumps of gravel conglomerate. On the crest of the ridge, at an altitude of about 700 feet, the trail forks, and about 650 feet east of where it forks and a little south of the eastern trail a mass of gravel conglomerate known locally as the "Standing Rock" rests like a sentinel, overlooking a southwest slope (see locality 2, pl. 26). The mass is about 15 feet high, and the top is a little lower than the crest of the ridge. The loose gravel on the ridge and the gravel in the mass of conglomerate are all of medium-sized, rounded chert pebbles and cobbles. No quartz pebbles were found. The larger pieces of chert are subangular, but their edges are rounded. The mass of conglomerate is cemented by material having a low percentage of iron oxide, and the pebbles are oriented sufficiently to show horizontal bedding, especially along the ferruginous planes.

This gravel resembles that of the Upper Cretaceous Tuscaloosa gravel of northern Alabama and probably may be correlated with isolated areas of Tuscaloosa mapped on the geologic map of Tennessee in Wayne, Lewis, Hickman, and Dickson Counties, Tenn.

PINE VIEW, CHESTNUT GROVE, AND LINDEN QUADRANGLES (adjacent corners)

(Plate 27)

Two and one-half to 3 miles northwest of Linden, in the southeastern part of the Pine View quadrangle, on the headwaters of a northeastern branch of Lick Creek, mineralized chert cropping out on the inter-stream ridges has attracted attention, and some prospecting has been done in this locality. The outcropping ledges may be seen near the heads of hollows 1,000 to 1,500 feet northeast of the Lick Creek road at altitudes of more than 700 feet, or nearly at the top of the ridge.

At locality 1, plate 27, about on the east edge of the Pine View quadrangle, prominent ledges of ferruginous, manganiferous chert crop out on the west side of a small hollow. The beds have a low dip, S. 70° W., so that they lie at a slightly higher altitude, about 710 feet, on the east side of the hollow and are about 25 feet below the top of the ridge. The mineralized ledges are 3 to 5 feet thick. The chert is brecciated and fairly well cemented and replaced by iron oxide, but the manganese oxide is not abundant. These ledges are underlain by softer, decomposed chert containing only a little iron. This soft material generally breaks down to a talus of small grayish-white fragments, but at one place the talus was much darker, owing to the presence of many small pieces of manganese oxide. In the hollow below the ledges there is much float mineralized chert, but on the ridge only a few pieces of slightly ferruginous chert were seen. The ridge was followed toward the northwest, and on the top some debris of porous chert was noted, believed by some geologists to be of Warsaw age, which places the mineralized chert beds in the following descriptions as pre-Warsaw.

At the head of the second hollow from that last mentioned four or five prominent outcrops of ferruginous chert occur at an altitude of about 700 feet (see locality 2, pl. 27). The hard ledges are 5 to 10 feet thick, but no decomposed lighter-colored beds similar to the lower beds of the mineralized section at locality 1 appear in the section. The top ledges appear to carry a little manganese oxide within the brown areas of ferruginous chert, but as only 4.15 percent of metallic manganese was shown by an analysis made at the Tennessee Valley Authority laboratories (No. 586, appendix table C), the quantity of that metal does not seem to be significant, nor is there sufficient iron for the chert to be valuable. A polished specimen from this locality is described on page 236.

Several showings of ferruginous chert containing manganese oxide were seen on the ridge between Mill Hollow and Choate Hollow. At the time of visit there was no opportunity to make even a careful paced traverse to these localities; therefore, their location on the map (pl. 27) is only a rough approximation. At locality 3, plate 27, which is nearly the highest part of the ridge (barometric altitude 755 feet), mineralized masses of chert were noted. These masses lie on a flat surface, do not form a cliff, and may have settled down slightly from their original position. According to analysis 587 of table C in the appendix, 5.73 percent of iron and 25.73 percent of manganese were found in samples of this chert. About 750 feet southwest of here, approximately at locality 4, ferruginous, manganiferous chert is exposed at the top of the ridge at an altitude of about 750 feet, and approximately at locality 5, plate 27, a few massive slabs of ferruginous, manganiferous chert crop out on the top of the ridge at an altitude of about 740 feet. Faint scattered spots of manganese oxide are present, but not to the extent required by an ore. Other deposits of ferruginous chert are reported at the heads of hollows branching southeastward from Choate Hollow. This ridge is extremely rough and brushy and is difficult to traverse but roads could be built upon it. If ore were found in quantity rich enough for mining, it would probably have to be carried by trucks down the Lick Creek road to the Tennessee River, a distance of about 8 miles.

About 2 miles in an air line N. 25° W. of the center of the village of Linden, on the headwaters of the northern branch of Lick Creek, in the Chestnut Grove quadrangle (see localities 6 and 7, pl. 27), some outcropping ledges and some large masses of chert not in place were found to contain iron and manganese oxides, the former greatly predominating. The mineralized part of the beds in place measured 2 to 2½ feet in thickness, and below this was a firm layer of light-colored chert. To reach these deposits State Highway 20 and 100 was followed for about 1¼ miles from Linden, then the Lick Creek graded road for about four-tenths mile northward, and then a woods road for about five-tenths mile northward. Travel from there was by foot to an intersection where a road comes in from the southeast. From this point a trail was followed for about 1,500 feet northwestward to the creek, then the creek was followed downstream for about 1,600 feet. The showings of manganese oxide seen in this vicinity were not encouraging for commercial development.

The only other traces of mineralization noted in the Chestnut Grove quadrangle were on State Highway 13, about nine-tenths mile northwest of Beardstown, where a bed of fractured chert less than 1 foot thick strongly stained by iron oxide and exhibiting a few dark spots of manganese oxide crops out on the west side of the road. This locality is not included in any of the maps given. This occurrence seems significant only as indicating the wide distribution of these oxides. The altitude at this locality is lower than that of the majority of the other mineralized beds in the area, which may be due to an abrupt down bending of the strata locally or to the beds having been broken off from ledges higher up and settling down to their present position.

About one and three-quarters miles in an air line west-northwest of the center of the village of Linden, in the northwest corner of the Linden quadrangle, is a small area in which mineralized chert has attracted attention. To reach this locality from the center of Linden requires a drive of about 2.2 miles out Highway 20 and 100 to the mouth of a hollow, locally called "Linden Hollow," which comes into Cypress Creek from the southeast. The mineralized beds crop out on the borders of this hollow 50 to 75 feet above the botton, depending upon the distance from the mouth of the hollow. On the east side of Linden Hollow, about 1,500 feet from the highway and almost beneath the power line of the Tennessee Electric Power Co., a prospect (locality 8, pl. 27) has been cut in a ledge of ferruginous, manganiferous chert about 4 feet thick, at an altitude of about 680 feet. The cut is about 20 feet long and goes back 4 or 5 feet at the base of the face. Iron predominates at the top, with manganese oxide increasing below but nowhere being as abundant as iron oxide. At the east end of the cut the chert below the top ledges is soft, and the manganese oxide could be separated by washing and concentration. In the limonitized chert at this prospect hydrated iron phosphate minerals similar to those near bench mark 788, pl. 18, were noted. They included golden yellow fibrous cacoxenite, lustrous, garnet-colored beraunite, and a greenish mineral that resembles dufrenite. These minerals are generally found within cavities.

The mineralized ledge shows prominently on the ridge at the west side of Linden Hollow, at the mouth of a small branch coming in from the southwest, about 600 feet from the highway. Here it is at an altitude of about 690 feet. The bed crops out along the west side of this ridge for several hundred feet southward (see locality 9, pl. 27), and boulders of mineralized chert are abundant on the slopes of the ridge. At one place, in an old road in the hollow west of the ridge, a boulder had been broken by blasting, revealing a good showing of manganese oxide. The boulder was below the natural position of the ledge. Like the mineralized chert ledges between Linden and Hohenwald, the hard beds at the top are underlain by soft, fractured chert, which is easily eroded and leaves overhanging ledges that break off and contribute boulders that gradually work their way down the slopes and give an erroneous impression of the thickness of the deposits.

LEATHERWOOD QUADRANGLE

(Plate 28)

The Leatherwood 7½-minute quadrangle comprises the northeast quarter of the northwest quarter of the Waynesboro 30-minute quadrangle.

In southern Perry County about three-fourths of a mile east of the post office at Flat Woods, on State Highway 13, at the crest of a hill overlooking Buffalo River to the south (approximately at locality 1, plate 28), are ledges of ferruginous, manganiferous chert. Altitudes near the Buffalo River range from 556 to 572 feet, as shown on the planimetric map of the Leatherwood quadrangle, and that of the mineralized beds may approximate 750 feet. Discontinuous prospects, each having a length of about 50 feet, have been opened around the contour of the hill on opposite sides of the head of a steep ravine and 20 to 30 feet below the south side of the highway. Hard ferruginous ledges of chert about 5 feet thick with minor showings of manganese are overlain by several feet of decomposed chert containing fragments of manganese oxides. Some iron oxide and silica have been leached from these beds, leaving the chert soft and ocherous. Including the hard and soft beds there are altogether about 5 feet of beds containing more or less manganese, some of which is of good quality in nodular and mammillary forms. On the highway to the east at a lower altitude than the prospects, gray calcareous shale crops out, which indicates that the mineralized horizon here bears a stratigraphic relation to the Ridgetop shale similar to that on Highway 20 farther north, between Linden and Hohenwald.

WAYNESBORO QUADRANGLE

The mineral resources of the Waynesboro quadrangle were studied by H. D. Miser in 1920. With regard to manganese ore in the quadrangle, mainly south of Flat Woods, Miser makes the following general statement.[7]

> Manganese ore has been prospected for at a number of places in the Waynesboro guadrangle. It was first prospected for about 1880 at a locality on the T. S. Hassell property, 3 miles west-northwest of Waynesboro, and in recent years, during the Word War when there was a great demand for domestic manganese ores for which high prices were paid, work has been done at this and at other places. Two carloads of low grade ore were shipped from the Wade-Reynolds prospect 1 mile southwest of Hardwick, but it was not used on account of the

[7] Miser, H. D., Mineral resources of the Waynesboro quadrangle, Tenn.: Tenn. Geol. Survey Bull. 26, p. 120, 1921.

high silica content. Also a carload of ore was marketed from the T. S. Hassell property; this was shipped to the Tennessee Coal, Iron & Railroad Co. at Birmingham, Ala.

The manganese deposits are of small size, and the ore contains a high percentage of silica whose separation from the ore would require treatment in a concentrating plant. The writer's opinion is that no manganese ore in the quadrangle can be mined and marketed with a profit whenever normal prices are paid for manganese ores and that only a small quantity of ore can be mined and marketed with a profit during times of high prices, such as those that were paid during the World War. There may, however, be discovered small deposits of manganiferous iron ore that may be of commercial importance.

Miser then describes the deposits known at that time, and his descriptions and illustrations of polished specimens[8] show that the manganiferous deposits of which he writes are very similar to those that the writer has been studying farther north in Perry County. Significant similarities are that the manganiferous deposits in both areas, where they are in bedded chert are in the Fort Payne, and where they are in residual material the chert is apparently of St. Louis age; that the iron oxides are most abundant in the hard upper mineralized beds, with manganese oxides more abundant below; that the chert is usually softer and more friable with depth; and that the range in chemical composition is about the same, with generally moderate percentages of manganese and excessive silica, so that the outlook for commercial development under normal conditions of markets and prices is not encouraging. It is probable that additional deposits have been discovered in the Waynesboro quadrangle since the report by Miser was published and that, if demand and prices for manganese rise, still further discoveries will be made.

ECONOMIC CONSIDERATIONS

PROSPECTING AND PRODUCTION

It has been shown that considerable prospecting of manganiferous zones in Mississippian chert has been done along Highway 20 within 6 or 7 miles southeast of Linden, on Sassafras Stand Ridge about 2½ miles south of Highway 20, and in widely scattered areas west and northwest of Linden and northeast and southeast of Hohenwald. As the manganiferous zone is near the top of the old highland level, outcrops are often found on opposite sides of narrow ridges, and it is locally believed that the mineralized zone extends continuously through the ridges and plateaus, generally at a moderate depth beneath the surface, and in the light of geologic evidence this seems to be a reasonable possibility. However, prospecting has been shallow and superficial and has failed to disclose conclusive evidence as to the

[8] Idem, pl. 12, *A*, *B*.

extent of the deposits. In no place has a tunnel or a trench been dug entirely through or across a narrow ridge following the mineralized zone, nor has the test pitting on the slopes of a ridge been continuous or spaced sufficiently close to demonstrate the continuity of the deposits for more than a few yards. In certain places ferruginous and manganiferous chert is found on the top of a ridge, which may indicate that the mineralized zone formerly extended through the ridge at that level and has finally been exposed by erosion of the ridge down to the present level. On the other hand, the pockety nature of deposits of manganese and iron oxides is well known, and it may be that such deposits as have been traced to their natural position by float and have been exposed to a depth of a few feet by digging and blasting are merely local concentrations of these oxides. Only by deeper, wider, and more thorough digging of prospect pits and tunnels and by drilling on the level areas will the necessary information be acquired. In view of what is now known of conditions it may seriously be questioned whether the expenditure of further funds would be warranted. Certainly the results of the work thus far have been discouraging, and further work should be undertaken with the realization that it is more or less of a venture.

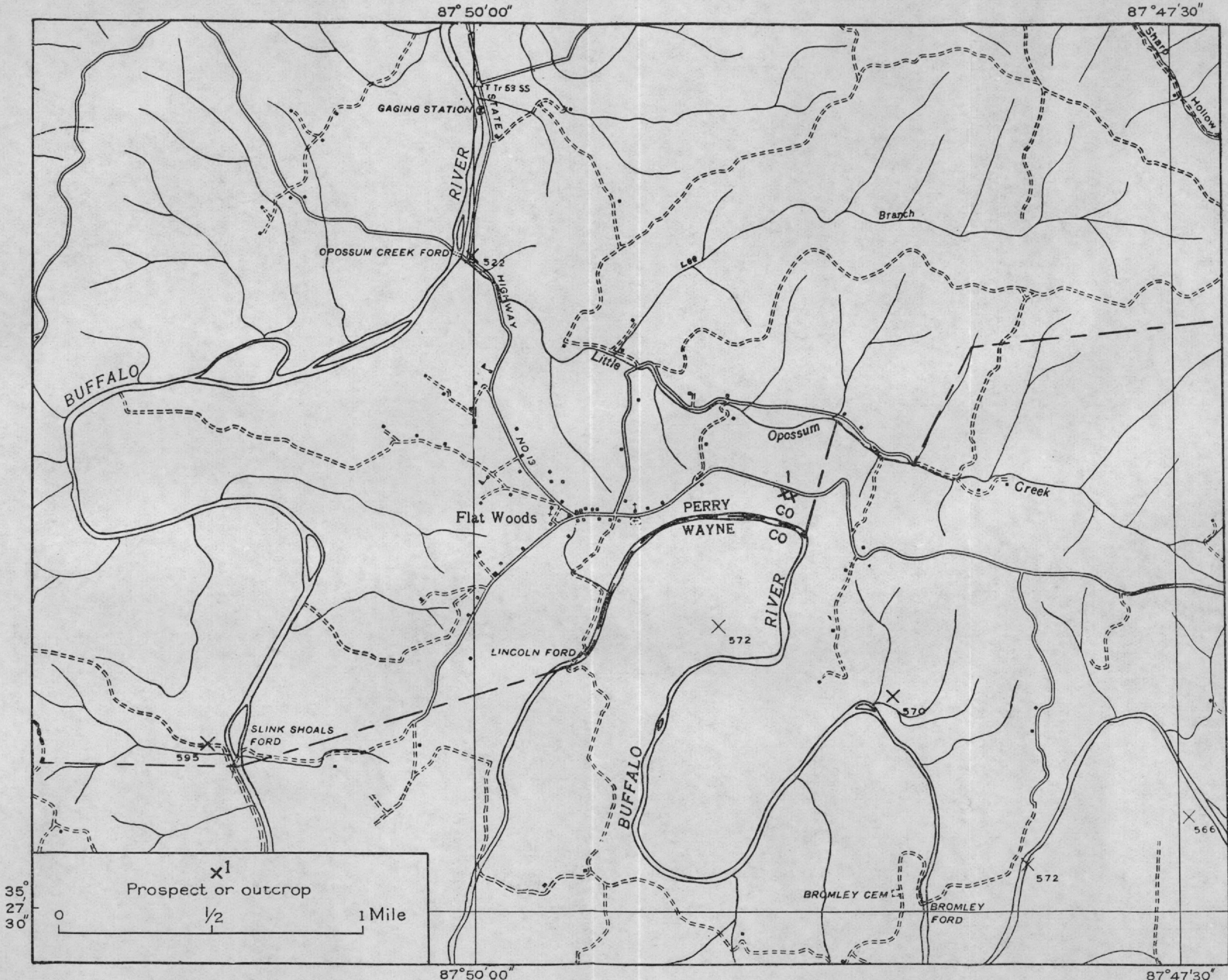
In the prospecting that has been done there has accumulated at various places a small quantity of mineralized chert, which might be treated if there were a concentrating mill in the vicinity but which is not large enough to warrant the erection of a mill. Some of this material is fairly good ore, and efforts have been made to concentrate it by hand cobbing and picking. Several shipments, aggregating approximately 50 tons, of this hand-picked manganiferous to manganese ore are reported to have been sent to a blast furnace in west-middle Tennessee. One shipment of 9 tons of ore netted the owner of the deposit a higher price than would have been paid for limonite and a lower price than would have been paid for good manganese ore, but the price may have been based on separate prices per unit for iron and manganese.

MINING

If mineralized deposits of commercial grade and size are discovered, many of them will doubtless be near the tops of the ridges, where the material might be quarried from open cuts, and if large-scale operations are warranted, steam shovels would be more efficient than hand methods. However, most of the deposits crop out on steep hillsides, which would introduce some difficulties in installing a shovel. Where the overburden of barren rock, disintegrated rock, and soil, is too thick, underground mining would be the only alternative.

LOCATIONS OF MANGANIFEROUS IRON OXIDE DEPOSITS IN SOUTHERN PART OF PINE VIEW QUADRANGLE, PERRY COUNTY, TENN.

LOCATIONS OF MANGANIFEROUS IRON OXIDE DEPOSITS IN ADJACENT CORNERS OF PINE VIEW, CHESTNUT GROVE, AND LINDEN QUADRANGLES, PERRY COUNTY, TENN.



LOCATION OF MANGANIFEROUS IRON OXIDE DEPOSIT IN NORTHERN PART OF LEATHERWOOD QUADRANGLE, PERRY COUNTY, TENN.

CONCENTRATION OF THE ORE

In the absence of actual mining there are no data that might indicate the probable proportions of ore and waste. These, so far as observed, vary greatly from place to place, but nowhere were the observed proportions, even of brown iron ore or limonite, comparable with those of successfully mined deposits. It is doubtful if any deposit seen would yield on a commercial scale material from 5 cubic yards of which 1 ton of ore could be recovered, and for the most part the estimated proportion would appear to be nearer 20 or 25 to 1.

Some of the chert is in a finely fractured state. Its appearance and brittle condition suggest that the cementing iron and manganese oxides might be effectively separated from the chert by crushing and that heavy-liquid separation might then be successfully used to float off the chert. Accordingly, the interest of the Tennessee Valley Authority was enlisted to the extent of cooperating in the collection of samples and in making laboratory tests. These tests included heavy-liquid (thallium formate, 2.9 specific gravity) separation, table tests, agglomeration tabling, and chemical analyses, the results of all of which are given in the appendix. The conclusions reached by the Tennessee Valley Authority investigators appeared unfavorable to carrying the study any further.

TRANSPORTATION

The ability to get a product to market quickly and cheaply is generally vital to the development of natural resources. Some of the manganiferous deposits in Perry and Lewis Counties are near the well-paved but winding State Highway 20, which leads to the Nashville, Chattanooga & St. Louis Ry. at Hohenwald. In the other direction the same highway leads to the Tennessee River, which some day may be a commercial cargo carrier. The Nashville, Chattanooga & St. Louis Ry. no longer reaches the west side of the Tennessee River at Perryville. Other deposits, such as those on Sassafras Stand Ridge, are less accessible and involve some steep grades, but the roads on this ridge can easily be put in better shape, and the connection with Highway 20 can be greatly improved by graveling a fairly level stretch of about 2 miles. With a moderate amount of road improvement it would be possible to reach all parts of the field. It thus appears that truck transportation to railroad or river and road improvement would be the first steps to be considered.

MARKETS FOR MANGANESE AND IRON ORES

Perry and Lewis Counties are situated in the western Highland Rim region of Tennessee, a region famous for its former considerable production of charcoal iron and other special irons. If manganiferous iron ore of good quality can be produced in commercial quantity, a small market for it should be available at at least two blast furnaces for making high-manganese pig iron that are still in existence in the area, and, if high-grade manganese ore for ferroalloys or chemical use can be produced, there should be a market for it at the more distant metallurgical furnaces and chemical plants at St. Louis, Mo., Pittsburgh, Pa., Birmingham, Ala., and Chattanooga and Kingsport, Tenn., and eventually, when more industries have been developed nearer at hand, in the Muscle Shoals and Decatur areas in Alabama.

COMPOSITION OF SPECIMENS

More than 50 analyses of manganiferous, ferruginous cherty material have been tabulated in tables 2 to 4 and table C in the appendix, not including the analyses of concentrates. These analyses are not all comparable. In nearly all of them manganese and the insolubles were determined, but in several of them iron was not determined. A rough count of the distribution of percentages of the important constituents of the materials brings out some significant facts. In more than half of the specimens the insolubles (silica, or silica plus alumina) exceed 35 percent, and may exceed the percentage of either iron or manganese or even the total of these metals. More than half of the specimens contained less than 15 percent of iron and 15 percent of manganese. A few specimens contained more than 35 percent each of iron and of manganese, and these were chiefly hand-picked samples. It is difficult to determine from these analyses just what type of ore we are dealing with or whether the material can be considered as ore at all. The truth probably is that the material for the most part falls below the standards of present-day commercial grades of ore, but where it is high in iron it can be considered manganiferous iron ore and where high in manganese it is likely to be a ferruginous manganese ore. Much material may be near the border line and may become of interest in the event of a national emergency through which imports of manganese ores are restricted or cut off. The percentages of insolubles, iron, and manganese as distributed among specimens are summarized in the following table:

TABLE 1.—*Distribution of insolubles, iron, and manganese*

Percentages	Number of specimens			Percentages	Number of specimens		
	Silica or insoluble	Iron	Manganese		Silica or insoluble	Iron	Manganese
Less than 1	....	2	1	30–35	5	2	4
1–5	13	11	8	35–40	11	3	5
5–10	3	6	18	40–45	9	3	2
10–15	1	3	4	45–50	6	2	1
15–20	1	1	3	50–52	3	....	1
20–25	1	3	2				
25–30	2	1	4		55	35	52

TABLE 2.—*Analyses of manganiferous material from Perry and Lewis Counties, Tenn.*

[Analysts: 1, 2, 5–13, J. G. Fairchild, U. S. Geol. Survey; 3, 4, Charles Milton, U. S. Geol. Survey]

	1	2	3	4	5	6	7	8	9	10	11	12	13
Silica (SiO_2)	38.10	35.24	43.70	35.95	34.56	34.28	35.96	33.24	4.30	38.88	52.34	41.72	51.34
Alumina (Al_2O_3)						1.64					11.10	11.74	11.56
Ferric oxide (Fe_2O_3)	48.80	50.38	13.63	3.81	41.78	.65	53.20	2.60	71.30	7.22	15.14	14.22	4.98
Manganous oxide (MnO)			29.40	39.75									
Manganese dioxide (MnO_2)[1]	4.13	1.72			8.72	58.63	.11	59.35	10.23	47.03	6.74	20.00	19.55
Potassium oxide (K_2O)						2.44		1.13		1.47			
Water (H_2O)	7.42	8.82			6.14	2.46	8.00	2.58	11.05	2.84	11.92	9.70	9.14
Titanium dioxide (TiO_2)						None					.80	.90	.56
Phosporus pentoxide (P_2O_5)			.20	.05		.25		.05		.25			
Barium oxide (BaO)						None		.10		.10		.69	
Iron (Fe)	34.15	35.26	9.53	2.66	29.25	.45	37.23	1.82	49.90	5.05	10.60	9.95	3.48
Manganese (Mn)	2.61	1.08	22.77	30.78	5.51	37.05	.08	37.54	6.46	29.71	4.26	12.64	12.35
Phosphorus (P)			.09	.02									
Cobalt (Co)			.19	.27					.10				
Nickel (Ni)			.05	.06									

[1] Calculated from MnO.

1. Locality 3, pl. 18. Near bench mark 788, Highway 20. Ferruginous, manganiferous chert.
2. Locality 8, pl. 18. Near bench mark 829, Highway 20. Ferruginous, manganiferous chert.
3. Locality 12, pl. 18. Sassafras Ridge. Ferruginous, manganiferous chert.
4. Locality 12, pl. 18. Sassafras Ridge. Picked sample, manganiferous chert.
5. Locality 12, pl. 18. Sassafras Ridge. Encrustation of iron and manganese oxides on chert.
6. Locality 13, pl. 18. Sassafras Ridge. Concretionary manganese in decomposed chert.
7. Locality 14, pl. 18. Sassafras Ridge. Ferruginous chert.
8. Locality 15, pl. 18. Sassafras Ridge. Selected manganiferous ore.
9. Locality 22, pl. 18. Sassafras Ridge. Stalactitic iron and manganese oxides.
10. Locality 1, pl. 23. Johnson prospects. Ferruginous, manganiferous chert.
11. Locality 1, pl. 24. 3 miles northeast of Hohenwald. Pebbly conglomerate with iron-manganese oxide matrix.
12. Locality 2, pl. 24. 2 miles southwest of Hohenwald. Manganese oxide in residual chert.
13. Locality 3, pl. 25. West of Blue Sky. Manganese oxide in residual chert.

The percentage of water in many specimens indicates that the iron is probably present as a mixture of hydrates that would fall between goethite and limonite. Several minor constituents were determined in some of the specimens. Titanium dioxide (TiO_2) was present in 7 specimens, ranging from traces up to 0.9 percent; phosphorus pentoxide (P_2O_5) was present in 14 specimens, 13 containing less than 1 percent each and 1 containing 1.88 percent; cobalt was present in 6 specimens, each containing less than 1 percent; and nickel was present in 5 specimens, each containing less than 1 percent. References to many of these analyses have been made in the description of the deposits.

Analyses of manganiferous material from Perry, Lewis, and other counties in Tennessee are given in the following tables.

TABLE 3.—*Analyses of manganiferous material from Perry County, Tenn.*

[J. T. Jones, Tennessee Products Corporation, analyst]

No. 4976	A	B	C	D	E	F	G	Special
Insoluble	33.23	35.05	39.50	41.44	43.27	49.15	--------	37.00
Manganese (Mn)	5.08	4.50	5.58	5.97	7.63	8.22	1.92	13.40
No. 4977	**A**	**B**	**C**	**D**	**E**	**F**	**G**	
Insoluble	29.72	31.56	35.92	38.74	42.72	47.56	--------	--------
Manganese (Mn)	5.87	5.96	6.75	7.48	8.56	9.20	2.88	--------

Samples submitted by Mr. John Sweeney, whose prospects were in the vicinity of Blue Sky. (See pl. 25.)

TABLE 4.—*Analyses and tests of manganiferous material from Perry and other counties, Tennessee*

[Analysts: 1-13, D. F. Farrar, Tenn. State Div. Geol.; 14, Sloss-Sheffield Steel & Iron Co., Birmingham, Ala.]

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Silica (SiO_2)	-------	-------	[1] 24.15	[1] 18.83	9.32	-------	28.00	-------	42.40	47.35	7.62	18.15	10.87	[1] 41.17
Ferric oxide (Fe_2O_3)	22.06	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
Iron (Fe)	15.44	-------	7.68	2.10	3.43	-------	1.56	37.52	3.12	12.05	43.74	3.62	4.24	20.07
Manganese (Mn)	-------	38.55	31.77	36.05	51.07	8.50	43.55	2.04	26.96	18.54	9.60	38.94	42.70	9.36
Phosphorus (P)	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	.14
Barium (Ba)	-------	-------	-------	-------	-------	-------	Trace	Trace	-------	-------	-------	-------	-------	-------

[1] Insoluble.

1. Submitted by C. F. Pennington, Hohenwald. Location of sample not given. Chert colored by iron oxide.
2. Submitted by C. F. Pennington. From Roane Creek. Hard blue-black lump.
3, 4. Submitted by C. F. Pennington. Location not given.
5. Submitted by Truman Stark, Linden. Location of sample not given.
6. Submitted by Truman Stark. Brown iron ore mixed with chert.
7. Submitted by C. F. Pennington. Black lump.
8. Submitted by C. F. Pennington. Brown, weathered specimen.
9-11. Submitted by John Daniels. From Roane Creek, 7 miles west of Lobelville.
12. Submitted by A. C. Hargrove, Hohenwald. From locality 2 miles southwest of Hohenwald.
13. Submitted by G. I. Whitlatch. From locality 15, plate 18. Selected manganese ore.
14. Submitted by A. C. Hargrove. Location of sample not given.

APPENDIX

CONCENTRATION TESTS ON MANGANESE FROM PERRY COUNTY, TENNESSEE

By H. S. RANKIN [1]

This work was done in collaboration with Ernest F. Burchard of the United States Geological Survey, who is mapping the manganese deposits which occur in Perry County, Tenn. The writer was in the field with Dr. Burchard April 13 to 20, 1938, and personally collected the samples. The tests were made at the Minerals Testing Laboratory at Norris, by F. A. W. Davis and Lynn L. McMurray under the direction of the writer. E. C. Houston made the heavy-liquid separations and ran all the analyses given in this report.

LOCATION AND OCCURRENCE OF DEPOSITS

As these deposits will be covered by the U. S. G. S. report they will not be discussed, except very briefly, and the location maps are used to show the points at which samples were taken. The numbers of the deposits are the same as those used by Dr. Burchard in his field work. The ore occurs as a replacement or enrichment in what is thought to be the Fort Payne chert. The mineralized chert apparently has a definite horizon, and the manganese is usually overlain by a ferruginous chert.

SAMPLING

Six large samples of about 50 pounds each and 10 small samples were taken. The large samples were taken at localities that would represent a fair average for the district. Where possible these samples were trenched from bottom to top of the deposit and represent material that would have to be handled in mining the deposits. The large samples were used for the concentration tests. The small samples were taken for analysis.

HEAVY-LIQUID TEST

For the heavy-liquid tests the 50-pound samples were crushed to a maximum size of one-half inch, thoroughly mixed and quartered

[1] Chief of Minerals Research Division, Tennessee Valley Authority, Norris, Tenn.

down to small samples of about one-half pound each and prepared for heavy-liquid tests. By trial it was found that the ore would have to be reduced to about 14 mesh in order to thoroughly free the manganese and chert. Therefore, the half-pound samples were passed through a roll crusher and sized until all passed a 14-mesh screen. They were then washed on a 60-mesh screen to remove the clay.

The table below gives the results of the heavy-liquid separation at specific gravity 2.9.

TABLE A.—*Heavy-liquid separation*

Locality	Specific gravity 2.9		Chemical analysis of sinks and floats				
	Sinks (percent)	Floats (percent)	Mn	Fe	Insolubles	Loss at 100°	
5, pl. 23	45.4	54.6	25.6	8.3	40.3		Sinks.
12, pl. 18	79.2	20.8	34.0	2.5	37.8		Do.
	80.4	19.6	30.8	4.4	39.8		Do.
14, pl. 18	34.7	65.3	36.4	1.9	31.5		Do.
1, pl. 23	60.8	39.2	29.5	3.1	43.7		Do.
15, pl. 18	87.6	12.4	36.4	2.6	33.9		Do.
6, pl. 23	79.7	20.3	33.1	4.0	34.8		Do.
1, pl. 24	0	100.	3.74	11.8	69.3	2.06	Floats.
2, pl. 24	81.9	18.1	1.1	4.48	88.7	.037	Do.
			10.1	23.52	35.2	1.52	Sinks.
			12.3	10.99	50.14	1.70	Picked sample best ore.

The heavy-liquid separation shows the sinks to have a very high insoluble content. A careful examination of these sinks with a binocular microscope showed that a good separation had been made, the sinks containing very few mixed grains and only on an occasional fragment of chert which was probably entrapped in the separation.

From these tests it was concluded that this ore could not be brought to a satisfactory grade by gravity separation because of the high insoluble content of the sinks and, therefore, that extensive work would not be warranted. However, one table test was run on a composite sample as a check on the above conclusions.

TABLE TEST

The crushed samples, with the exception of one that was eliminated because of its low manganese content, were mixed together, crushed to −6 mesh, and screened into the following sizes: −6 to +14, −14 to +20, and −20 to +60 mesh. The −14 to +20 mesh was the only size table. This ore was classified into spigot products and an overflow product. The overflow contained very little manganese and was not tabled.

The −14 to +20 sizing of this ore was chosen for tabling as it was thought that the results on this size would produce the best concentrate that could be expected by gravity separation. An examination with the binocular microscope showed that the crushing was fine enough to liberate the visible chert, and, by confining the feed to a comparatively narrow size range and then classifying into three products, the results should represent as good a concentrate as it is possible to obtain by tabling. The results checked closely with those obtained with heavy-liquid separation.

The ore responded well to the action of the table, and the concentrate was taken so that a clean product was obtained, throwing all contaminated ore into the middlings.

TABLE B.—*Table separation*

	Weight (percent)	Analysis (percent)			Ratio of concentration [1]	Percent recovery [2]
		Mn	Fe_2O_3	Insoluble		
Concentrate:						
First spigot	34.6	35.9	2.1	33.5	2.8	
Second spigot No. 1	4.0	36.2	1.9	33.2	25.0	
Second spigot No. 2	17.2	31.2	2.9	39.0	5.8	
	55.8	34.2	2.3	35.1	1.9	83
Middlings:						
First spigot	3.2	25.5	2.9	48.5		
Second spigot	17.6	14.6	2.1	68.1		
	20.8	16.6	2.2	64.4		
Tails:						
First spigot	4.3	2.0	2.9	89.0		
Second spigot	5.8	4.6	1.0	88.6		
	10.1	3.5	1.8	88.8		
Overflow	13.3	2.6	1.1	89.1		
Composite heads	100.0	23.2	2.0	53.9		

[1] The ratio of concentration is the number of units of feed required to produce one unit of concentrate.
[2] Percent recovery is the manganese in the concentrate divided by the manganese in the feed.

AGGLOMERATION TABLING

Agglomeration tabling was tried on a portion of the −20 to +60 mesh size. A sample of the concentrate analyzed 36.4 Mn, 1.7 Fe_2O_3, and 35.1 insolubles. While this is two points higher than was obtained by tabling, it was only a small sample and is probably higher than could be obtained in a regular run.

CHEMICAL ANALYSES

TABLE C.—*Chemical analyses*

[E. C. Houston, assistant chemist, analyst; Norris, Tenn., June 9, 1938]

	581	582	583	584	585	586	587	588	589	590
Manganese (MnO)	43.90	40,70	29.50	25.03	35.75	5.35	33.19	21.41	8.56	12.00
Silica (SiO_2)	36.63	41.15	46.66	24.71	40.18	49.37	48.47	7.14	17.44	10.37
Iron (Fe_2O_3)	1.28	4.00	11.96	35.20	5.44	31.04	8.19	48.00	57.28	59.20
Alumina (Al_2O_3)	1.88	1.20	2.24	4.40	4.64	4.72	1.00	3.36	4.64	5.16
Phosphorus (P_2O_5)	.18	.13	.18	.92	.20	1.88	.14	.45	.24	.23
Calcium (CaO)	.1	.1	.1	.1	------	------	------	------	------	------
Magnesium (MgO)	.1	.1	.1	.1	------	------	------	------	------	------
Titanium (TiO_2)	Trace	Trace	Trace	Trace	------	------	------	------	------	------
Nickel (NiO)	.103	.031	------	------	------	------	.00	------	.108	------
Cobalt (Co_2O_3)	.1	.1	------	------	------	------	.1	------	.1	------
Sodium (Na_2O)	1.06	------	------	------	------	------	.92	------	------	------
Potassium (K_2O)	1.75	------	------	------	------	------	.35	------	------	------
Less at 110° C	.75	.64	.38	.42	.52	.69	.26	1.87	1.48	1.04
Less at 900° C	8.18	7.33	6.39	9.65	9.87	6.01	7.47	14.27	8.86	10.77
Total determined	96.01	95.18	97.31	100.33	96.60	99.06	100.29	96.50	98.60	98.77
Insolubles	37.04	41.73	48.22	25.31	42.61	52.09	49.30	9.32	21.01	14.14
Manganese (Mn)	34.03	31.54	22.91	19.42	27.72	4.15	25.73	16.60	6.64	9.30
Iron (Fe) calculated from Fe_2O_3)	.896	2.80	8.37	24.64	3.81	21.73	5.73	33.60	40.09	41.44

Laboratory number and locality:
581, locality 13, pl. 18.
582, locality 1, pl. 23.
583, locality 25, pl. 18.
584, locality 22, pl. 18.
585, locality 12, pl. 18.
586, locality 2, pl. 27.
587, locality 3, pl. 27.
588, locality 1, pl. 25.
589, locality 4, pl. 25.
590, locality 5, pl. 25.

CONCLUSIONS FROM LABORATORY WORK

In view of the low-grade concentrate obtained it was concluded that further work would not be warranted at this time. The detailed chemical analysis shows that most of the insoluble material is silica and evidently is combined in the ore fragments in a finely divided state, making the concentration of this ore to a commercial grade very difficult, if possible at all.

NOTE ON THE SILICA CONTENT OF THE ORE

By E. L. SPAIN, JR.

From a memorandum to Mr. H. S. Rankin, Minerals Testing Laboratory, Norris, Tenn.

You might be interested in a petrographic examination I made of some of the manganese ore from Perry County, Tennessee. While talking with Doctor Burchard and reading over your report, he made the suggestion that possibly microscope work might explain why such a high silica content was still present even after tabling or flotation. He gave me several pieces of the best looking ore to examine.

I pulverized the material as fine as I could in a small mortar and made up a few slides. The results after examination were as follows: (1) The free chert was apparently entirely liberated even before complete pulverization. (2) There is a very large amount of finely divided crystalline silica present.

A great deal of this material was liberated when the ore was finely ground so that I was able to obtain some idea about the approximate particle sizes. I find that the predominant size ranges between 0.005 and 0.01 mm. with the average about 0.006 mm. There is however a large amount of silica particles which range down to 0.001 mm., or 1 micron. I did not attempt to measure anything smaller, although there is undoubtedly material below this size.

These small silica particles are apparently scattered rather evenly through the ore. Even after the ore was pulverized as described, many fragments were still visible in the particles of ore. Although I am not well acquainted with the separation processes which you have been using, such a condition would probably make any clean separation very difficult even after fine grinding.

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