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Walter F. Pond, State Geologist

BULLETIN 39

The Brown Iron Ores of the Western Highland Rim, Tennessee

By Ernest F. Burchard
Geologist, United States Geological Survey
With Data on Lewis County by Reese F. Rogers,
on Wayne and Lawrence Counties by Hugh D. Miser,
and on Hardin County by Willard B. Jewell.

Prepared in co-operation with the United States Geological Survey

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FOREWORD

Tennesseans of the older generation are well acquainted with the large and important iron mining and furnace industry which operated in western middle Tennessee during the latter part of the nineteenth century. Others know of it by tradition and those who live on the region from Stewart to Wayne counties have seen the old ore pits, some of them covering many acres, and the old furnaces as well as those operating at present.

This report gathers together all the information available concerning the old furnaces, the mines worked in the past, some of which are still in operation, and the many prospects which indicate the possibilities for renewed production. The theory of the origin of the deposits has been discussed only to the extent that it may contribute to the better understanding of the conditions of occurrence, exploitation and prospecting. The estimates as to the reserves in the different deposits are particularly valuable, not only as to the individual deposit, but also in estimating the possibilities of reviving the industry in the region.

While conditions at present are perhaps none too favorable for expansion of the iron ore mining and furnace industry, it may well be that the increased rate of industrial production necessary for the working out of the Tennessee Valley Authority work to its full fruition will make possible a revival of the iron industry in this region on a modern basis of production.

WALTER F. POND, *State Geologist.*

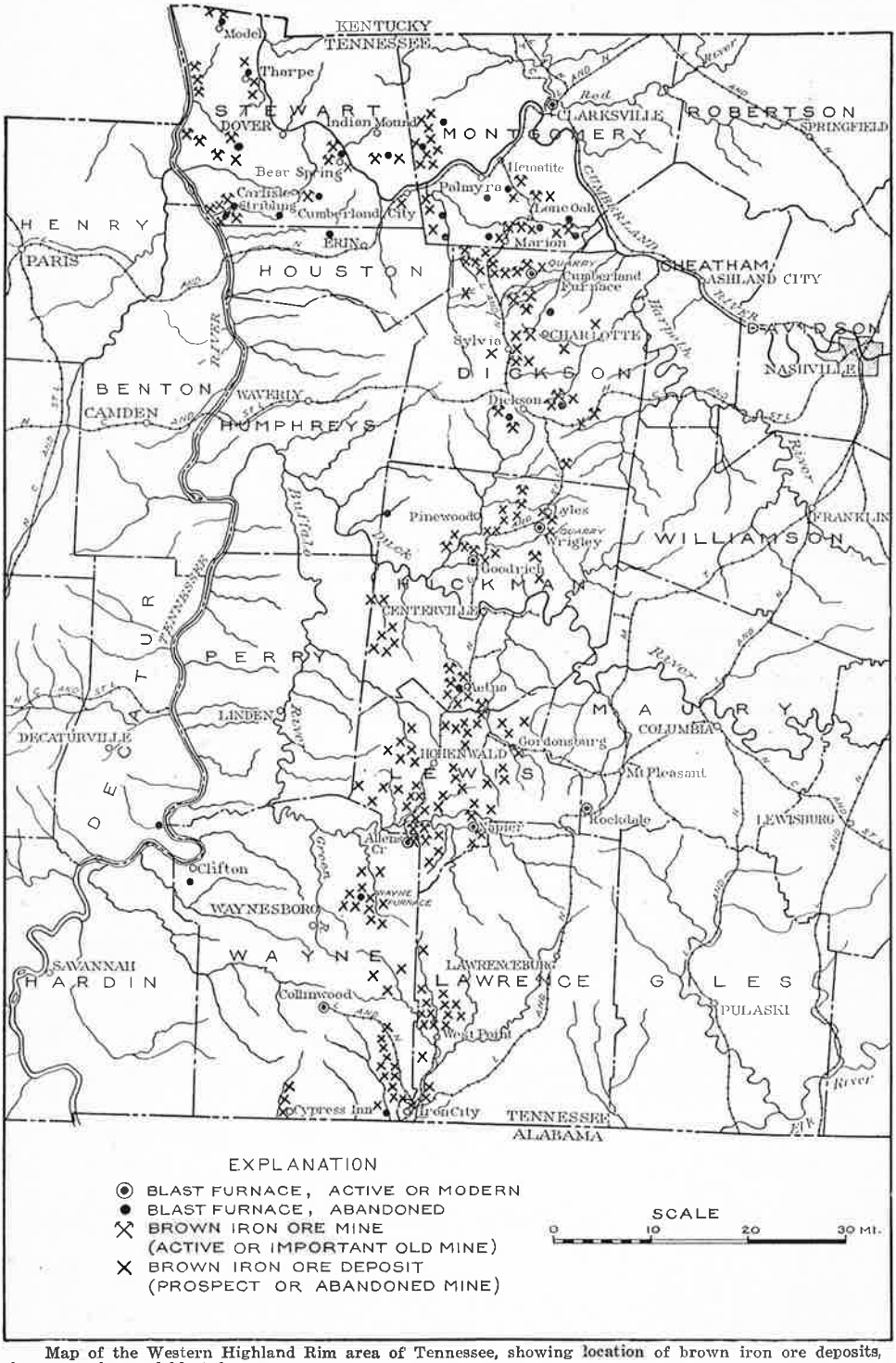
ERRATA

Page 12: Location of Cross Creek furnace should read seven miles north of Bear Spring.

Page 29: In table of ore analyses the names of the last two localities should read Vanleer and Pinkney.

Page 30: In table of altitudes of deposits the name of the county following Hickman should read Lewis.

Page 85: In table of analyses the percentage of insoluble in Sample 1 should read 13.84.



Map of the Western Highland Rim area of Tennessee, showing location of brown iron ore deposits, mines, quarries, and blast furnaces.

ABSTRACT OF THE REPORT

The highland region in the Tennessee River valley in West-middle Tennessee has long been a producer of brown iron ore, from which special grades of pig iron including charcoal iron, high silicon iron, and high-iron ferrophosphorus have been made locally.

The rocks associated with the iron ores are of Mississippian age, consisting in ascending order of the the Fort Wayne chert, the Warsaw formation (cherty limestone and a little sandstone), and the cherty St. Louis limestone. Unconformably overlying these formations are disconnected patches of Upper Cretaceous gravel, sand, clay, and ferruginous conglomerate. The rocks in general lie nearly horizontal and have been subjected to long and deep weathering, especially the cherty limestones, so that in most places on the uplands they are covered with a deep residual mantle of more or less cherty red clay. The iron ore, in irregular masses, veins, lumps, and fragments, is inclosed in the residual clay and chert débris lying above cherty limestone. The bodies of ore-bearing material range in size from small, isolated pockets containing a few hundred tons of ore to groups of deposits extending over hundreds of acres and to depths of 30 to 100 feet that have yielded more than one million tons of ore by means of steam-shovel stripping and mining.

The "brown ore" consists of limonite and goethite with other hydrous oxides of iron in minor proportions. Because of its intimate association with clay, chert, gravel, and sand it has to be cleaned and concentrated by washing, screening, and jigging, but after this treatment it still contains considerable impurity. As used in the blast furnaces the composition of the ore usually ranges as follows: Metallic iron, 38 to 52 per cent (averaging about 46 per cent); insoluble material, 10 to 38 per cent (averaging about 25 per cent); phosphorus, 0.12 to 1.30 per cent, mostly between 0.30 and 0.50 per cent; manganese, 0.10 to 1.30 per cent, mostly between 0.20 and 0.50 per cent; and combined water about 10 to 12 per cent.

Most of the ore appears to have been formed in the Tertiary period, although solution and redeposition are going on at present. The source of the iron oxide formed during the Tertiary is believed to have been glauconitic beds of Upper Cretaceous age that formerly overlay the region and extended farther east than the present belt of ore deposits.

The deposits of ore are distributed through six or seven counties and are too widely scattered to support operations on as large a scale as is common in the Lake Superior iron ranges. For this reason and because of its quality the ore will probably never be shipped in large quantities to distant blast furnaces but will continue to support a modest local iron industry. The unmined reserves of iron ore appear to be about 14,500,000 tons, not all of it available under present economic conditions, however.

The production of iron ore from this part of Tennessee from 1797 to 1930 inclusive has been about 8,560,000 gross tons, and the pig iron, including ferro-phosphorus, produced in the same period has been about 4,052,500 gross tons. Economic conditions have borne heavily on small merchant furnaces throughout the eastern United States since the World War, but, although the local output of pig iron has diminished, the manufacture of high-grade charcoal iron and blast-furnace ferrophosphorus has become stabilized and promises to hold an important place among the industries of Tennessee.

Much of the easily accessible ore has already been mined, and the cost of production will be higher in the future. Vital factors affecting the availability of a deposit of ore are its accessibility, its situation with regard to mining and washing, its location with respect to transportation facilities and markets, the demand for iron ore and pig iron, the content of phosphorus and silica, and the possibility of successfully beneficiating the ore. The present processes of beneficiation are susceptible of improvement, and upon their improvement the future of this iron-ore field probably depends to a greater extent than on any other single factor. Geophysical methods of prospecting, when they can be applied to finding brown iron ore, should be useful in finding buried deposits of ore that probably remain undiscovered in this field.

The Brown Iron Ores of the Western Highland Rim, Tennessee

By Ernest F. Burchard,
Geologist, United States Geological Survey

INTRODUCTION

General statement and acknowledgments.—A study of the brown iron ore deposits of the Western Highland Rim of Tennessee (Plate 1) has been carried on recently under a co-operative agreement between the Tennessee State Geological Survey and the United States Geological Survey. Most of the field work was done at intervals between October, 1921, and July, 1923, but the field was revisited in August, 1927, in order to record later developments. The writer was assisted in the field in 1921 by R. W. Smith, assistant geologist, and in 1923 by C. C. Anderson, topographer, both of the Tennessee State Geological Survey. Mr. Wilbur A. Nelson, then State Geologist, visited several mines with the writer and on these occasions as well as at times during the preparation of thi' report rendered helpful suggestions and guidance. Mr. H. D. Miser, of the United States Geological Survey, State Geologist from September 1, 1925, to July 1, 1926, who is especially familiar with the southern part of this area, co-operated heartily in the preparation of this report, and Mr. W. F. Pond, State Geologist, and Mr. W. F. Bailey of the State Survey accompanied the writer to several prospects, mines, and furnaces in 1927. Mr. H. W. Davis, of the United States Bureau of Mines, has compiled the statistical data on iron ore and pig iron. To all these gentlemen the writer desires to express his appreciation. Acknowledgments are also due to the owners of the property, to officials and employees of the iron mining and manufacturing companies, and to persons living in the vicinity of idle mining properties for their courteous treatment and for the large amount of information furnished by them.

Maps available.—In order to facilitate the study of the brown iron ore deposits the State Geological Survey prepared maps of Hickman and Dickson Counties on a scale of 1 mile to 1 inch, which show the culture and drainage, also special maps of the mining districts of Stribling, Stewart County; Marion, Montgomery County; Cumberland Furnace, Dickson County; and Aetna, Hickman County. The field work for these special maps and for

parts of the maps of Hickman and Dickson Counties was done by C. C. Anderson, who also did the preliminary drafting for all the maps. For the location of ore deposits in Stewart County a rural-delivery base map on a scale of 1 mile to 1 inch, prepared by the Post Office Department, was available. For Montgomery County a base map on the same scale, prepared by the United States Bureau of Soils, was available; portions of Dickson and Hickman Counties are also covered by the topographic map of the Columbia quadrangle, prepared by the United States Geological Survey. For Lewis County a map on the scale of 1 mile to 1 inch, showing the roads, drainage, and iron-ore deposits, had been prepared by R. F. Rogers in connection with his studies of that area in 1912-13. The iron ore bearing portions of Wayne and Lawrence Counties are shown on the topographic map of the Waynesboro quadrangle, prepared by the United States Geological Survey. Geologic maps of the Columbia and Waynesboro quadrangles on a scale of 1:125,000, and a general geologic map of the State of Tennessee on a scale of 1:500,000, published in 1923, were also available.

Field work.—The field work for the present report consisted of the examination by the writer of practically all the accessible brown iron ore deposits disclosed by mines, prospects, or outcrops in Stewart, Montgomery, Dickson, and Hickman Counties and of certain of the most important deposits in Lewis, Wayne, and Lawrence Counties, besides reconnaissances in Benton, Humphreys, Hardin, and McNairy Counties.

The deposits of brown iron ore in Wayne, Lawrence, and the southwestern part of Lewis County have been described by H. D. Miser in Bulletin 26 of the Tennessee State Geological Survey, published in 1921, and those of Lewis County by R. F. Rogers in Resources of Tennessee, Vol. 5, No. 3, published in 1915. The field work of Miser and Rogers having been done very thoroughly was not duplicated by the present writer except to visit certain active mines and to note their later developments. The report by Miser is available for distribution by the State Geological Survey, and so only abstracts of the descriptions are published here, although the locations of the iron-ore deposits in the Waynesboro quadrangle are shown on the maps accompanying this bulletin for the sake of completeness. As the report by Rogers has been for some years out of print, and as it describes a large number of undeveloped deposits of brown iron ore in the Western Highland Rim, the essential data on Lewis County are reprinted as a chapter of the present bulletin.

It was not planned to map the areal geology of the region, as that work would have involved more time and funds than could be allotted to the purpose, and sufficiently detailed maps were not available for the greater part of the area. Moreover, the detailed geologic mapping of this area will also require more paleontologic work than has been done, especially in the areas where Mississippian rocks underlie the iron-ore deposits. Nearly all the deposits were reached in a Ford car, although in rainy weather roads that

were unimproved were difficult to travel in places. In the examination of individual deposits by the writer the following data were recorded in so far as practicable, in accordance with an outline prepared by him for use in study of deposits of brown iron ore and bauxite.

Information recorded concerning brown iron ore deposits

Location.
Name and address of owner of property.
State of prospecting or developments.
Ore, character: Type, appearance; principal minerals; principal impurities; probable grades; proportion of ore and waste rock; typical specimens.
Topographic situation: Position; altitude above nearest important drainage and above sea level; relation to peneplanation and to deposits of gravel.
Outcrops or surface evidence of ore.
Extent and form of deposit; depth.
Overburden: Character and thickness.
Associated rocks: Age; character, dip, and strike; general structure; relation to ore deposits.
Ore available: Blocked out; estimated; possible.
Conditions affecting mining: Accessibility; topography; sites for buildings, washers, dumps, settling basins; water supply, timber, fuel, distance to railroads and places of consumption.
Methods of mining, washing, transporation, use of ore.
Representative chemical analyses of ores or products, property maps, engineers' reports, and records of production, if available.

OFFICIAL GEOLOGIC WORK

The State of Tennessee has carried on official studies of its geology and mineral resources during four periods. The first was under Gerard Troost, State Geologist from 1831 to 1850; the second under James M. Safford, State Geologist, beginning in 1854; the third from 1870 under J. B. Killebrew, Commissioner of Agriculture, Statistics, and Mines, until well toward the close of the nineteenth century; and the fourth period, from 1910 to the present time, under State Geologists George H. Ashley, 1910 to 1912, Albert H. Purdue, 1912 to 1917, Wilbur A. Nelson, 1918 to 1925; Hugh D. Miser, September 1, 1925, to July 1 1926; and Walter F. Pond since January, 1927.

During these several periods of activity the State Geologist or some member of his staff has devoted more or less attention to the subject of iron ore, for it early became recognized that Tennessee was liberally endowed with the two minerals most essential to civilization, iron and coal. In studying the iron-ore deposits Safford in 1855 divided the State geographically into four iron ore bearing regions, all differing more or less in geologic and mineralogic characteristics. They are:

1. The Eastern Region, which extends along the front of the Unaka

Mountains and contains brown iron ore (limonite), red iron ore (hematite), and magnetic iron ore (magnetite).

2. The "Dyestone" Region, which skirts the eastern base of Cumberland Mountain and Walden Ridge from Virginia to Georgia and extends laterally 10 to 20 miles into the Valley of East Tennessee and also includes Sequatchie and Elk Valleys. It contains the principal deposits of bedded red hematite, typified by the ores mined near Rockwood.[1]

3. The Cumberland Region, which is coextensive with the coal region in the northern part of the State and contains, interstratified with the shales of the coal measures, nodules, balls, flattened concretions, and bands of clay ironstone, or iron carbonate—sometimes called spathic iron ore. Ore of this type has not, however, proved to be important in Tennessee.

4. The Western Region, which occupies a wide strip of west-middle Tennessee from Kentucky into Alabama, and which is characterized by the presence of large quantities of brown iron ore, or limonite. It is with this region that the present report is concrened.

The scope of the work of the earlier geologists on the brown iron ores of the Western Iron Region is indicated in the following notes, but the early reports referred to contains so many interesting side lights on the mining and manufacturng of iron in former times that those who can do so are urged to read the reports themselves. As early as 1835 Dr. Gerard Troost had begun to study the distribution of the raw materials essential to the iron industry and to make statistical inquiries as to the number of iron works and their capacity in order to ascertain whether they were able to furnish all the iron necessary for consumption in the State and what quantity might remain for exportation into other States. Troost reported[2] that the iron ore used in most of the Tennessee iron works was the hydrate of iron.

"A compound of the several varieties of that ore, containing the *brown hematite,* the *brown iron stone,* in its different appearances, as *compact, cellular, stalactitical,* etc., intermixed with the red and yellow pulverent varieties. Such is the ore of which a great part of Dickson County is composed; it is also found in immense deposits in Stewart, Hickman, Perry, * * * and other counties. It occurs under a variety of circumstances and situations on the ridges or is accumulated on declivities at all elevations."

In his fifth report (Nov., 1839, pp. 41-43) Troost characterizes the iron ore of Blooming Grove Creek, Montgomery County, as the most valuable ore in Tennessee, because the iron it yields is very good, and he also makes mention of blast furnaces in Perry, Dickson, and Hickman Counties.

In Troost's sixth report (Oct., 1841, p. 22) there are observations on the geologic relations and probable mode of deposition of the brown iron ores in Perry County and mentions of certain blast furnaces in the region.

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[1]Buchard, E. F., The red iron ores of East Tennessee: Tennessee Geol. Survey Bull. 16, 173 pp., 1913.

[2]Troost, Gerard, Third geological report to the twenty-first General Assembly of the State of Tennessee, p. 30, Oct., 1835.

In Troost's ninth report (Nov., 1847, pp. 36-37) analyses of some specimens of brown iron ore from Perry and Hickman Counties are given.

In Safford's Geological Reconnaissance of the State of Tennessee, December, 1855, pages 47-50 are devoted to the Western Iron Region, including such topics as its extent and ore banks, how the ore occurs, varieties of ore, geologic relations of the region, furnaces, forges, and fuels, besides which are given tables of production of pig iron and castings by the several furnaces.

In Safford's Geology of Tennessee, 1869, the brown iron ores of the Western Iron Region are referred to in connection with the descriptions of the two classes of rocks with which they are associated, namely, the "Siliceous Group" of the "Lower Carboniferous," and the "Bluff group," alluvium, loam, and gravel. Safford noted the ferruginous character of the cherty *Lithostrotion*-bearing beds, which weather to a very red clay, and he was inclined to think that these beds may have been the principal and original source of the iron in the ore deposits. The great differences in richness of the deposits was a matter of comment even in the days when but little mining had been done, and the cream of the deposits had not been taken. Safford considered that the best of the banks afforded on an average from one-fourth to one-third ore out of the material removed. The ore banks of Hickman County—more than twenty in number—are pointed out by him as illustrations of the best deposits in the region, and a short description is given of the Aetna deposits. In 1869 the deposits in Hickman County had not been adequately developed, principally on account of the lack of means of transportation. Statistics of furnaces and products are also given in Safford's report.

A later important report was that of J. B. Killebrew, on the Iron and Coal of Tennessee, issued in 1881. In this report 36 pages are devoted to a description of the Western Iron Region by counties, and several additional pages contain data on furnaces and production. The report is illustrated by a map showing the distribution of the brown-ore deposits in the area between the Nashville, Chattanooga & St. Louis Railway in Dickson County on the north and Wayne and Napier furnaces on the south. Although these early reports mention deposits of ore here and there that either have been worked out since the reports were made or else did not prove of importance, and therefore are not included in our present-day lists, there seems to be no mention in them and no notation on the map by Killebrew of the now famous Allens Creek deposits in northeastern Wayne County and southern Lewis County. Killebrew's descriptions of the iron-ore deposits throughout the region depict them much as the surviving banks appear today. A high tribute is paid to the quality of the pig iron made in Stewart County, which was rolled into boiler plate and made into thousands of boilers, many used on Mississippi River steamers, none of which were ever known to have exploded.

In the interval between the publications of Commissioner Killebrew and the re-establishment of the State Geological Survey under G. H. Ashley in 1910 a detailed geologic study was made of the area of the Columbia quadrangle by C. W. Hayes and E. O. Ulrich, of the United States Geological Survey, in 1899-1900, and the results were published in 1903 as the Columbia Folio (No. 95) of the Geologic Atlas of the United States. The Columbia quadrangle includes within its western portion a small strip of the southern part of Dickson County, the part of Hickman County from Centerville, eastward, and the northeastern corner of Lewis County. The following description of the iron-ore deposits in the Columbia quadrangle is given in the Columbia Folio, page 6:

"Iron-ore deposits of sufficient size to be commercially important are confined to the northwest corner of the quadrangle. The largest deposit is at Nunnelly. Within an area a mile and a half in length east and west and three-quarters of a mile broad north and south large deposits of limonite, or "brown ore," are found embedded in red clay. Some waterworn pebbles are found at the surface, sometimes cemented into a conglomerate by the iron oxide. It appears probable, therefore, that the region has been covered by alluvial deposits, but that they have been almost entirely removed, and the great depth of clay found associated with the iron is doubtless residual, being derived from the weathering of the St. Louis limestone. Abundant fragments of chert, associated with the clay and iron, are a proof of this origin. The iron occurs in irregular pockets, frequently in the form of geodes, which range in size from a few inches to several feet. The workings at Nunnelly have reached a depth of 60 feet, and a shaft put down 60 feet farther is reported to be still in iron-bearing ground. Three other deposits of limonite occur to the northeast of Nunnelly, but these are small and unimportant in comparison with the deposit above described. In the adjacent quadrangle to the west very extensive deposits of iron ore occur. These have been worked for many years at Aetna and Mannie. They closely resemble the Nunnelly deposits, and in every case are associated with more or less waterworn gravel. The exact conditions under which these iron ores were segregated are not clearly understood. Evidently conditions at these particular points were favorable for the deposition of the iron, which replaced the limestone removed by solution. Being pocket deposits, it is impossible to tell in advance how much ore they will yield. Even with the most thorough prospecting considerable uncertainty necessarily remains. The Nunnelly deposit has been worked for a number of years, being in part utilized at the Goodrich furnace and in part shipped to other iron-making districts."

Geologic work done in the Western Highland Rim iron-ore area during the present State Geological Survey and prior to the study here reported consisted of a reconnaissance by A. H. Purdue of the deposits in Wayne and Lewis Counties in 1912, a detailed study of the deposits in Lewis County by R. F. Rogers in 1912-13, and a detailed study of the deposits in the Waynesboro quadrangle, embracing most of Wayne County and parts of Lawrence and Lewis Counties, by H. D. Miser in 1913, 1914, and 1920.

In 1914 there was published a paper on the geology of Perry County and vicinity by Bruce Wade, as listed below. This paper contains the following statement with regard to iron ore.

"*Iron ore.*—Limonite or brown iron ore is common in this area and has been closely prospected by agents for iron-ore companies but is nowhere being worked at

present. Over fifty years ago iron was mined near the heads of Sugar and Cedar creeks. There was a single furnace at Sugar Creek, and a double-stack furnace on Cedar Creek. Both were run by water-power blast. This iron ore occurs in the St. Louis formation in the form of geodes, lump and shot ore, associated in an irregular manner with chert and clay, in pockets. It is doubtless residual, having been derived from the weathering of the St. Louis limestone."

The report by Miser (Bulletin 26) is available for distribution by the State Geological Survey. The locations of the iron-ore deposits in the Waynesboro quadrangle are shown on the maps accompanying that bulletin and on Plates 1, 25 and 27 of the present bulletin. The data by Rogers on Lewis County are reprinted as a chapter in the present bulletin.

The following publications comprise the principal State and Federal Geological Survey papers that discuss the brown iron ores of the Western Highland Rim in Tennessee:

Official Survey papers on brown iron ores of Western Highland Rim

Troost, Gerard, Third geological report to the General Assembly of the State of Tennessee, October, 1835; Fifth geological report, November, 1839; Sixth geological report, October, 1841; Ninth geological report, November, 1847.

Safford, J. M., Geological reconnaissance of the State of Tennessee; First biennial report for 1855, Nashville, 1856; Geology of Tennessee, Nashville, 1869.

Killebrew, J. B., and Safford, J. M., Resources of Tennessee, Nashville, 1874.

Killebrew, J. B., Iron and coal of Tennessee, Nashville, 1881.

Hayes, C. W., and Ulrich, E. O., United States Geological Survey, Geologic Atlas, Columbia folio (No. 95), 1903.

Purdue, A. H., The iron industry of Lawrence and Wayne counties: Tennessee State Geological Survey, Resources of Tennessee, vol. 2, No. 10, pp. 370-388, October, 1912.

Wade, Bruce, The Geology of Perry County and vicinity: Resources of Tennessee, Tennessee State Geological Survey, vol. 4, No. 4, pp. 150-179, October, 1914. (Makes only very brief reference to iron ore.)

Rogers, R. F., The iron ore deposits of Lewis County: Tennessee State Geological Survey, Resources of Tennessee, vol. 5, No. 3, pp. 91-146, July, 1915.

Miser, H. D., Mineral resources of the Waynesboro quadrangle, Tennessee: Tennessee Geological Survey Bulletin 26, 1921, 171pp.

Burchard, Ernest F., The brown iron ores of West-Middle Tennessee: United States Geological Survey Bulletin 795-D, pp. 53-112, 1927.

Jewell, W. B., Geology and Mineral Resources of Hardin County, Tennessee State Geological Survey, Bulletin 37, 1931, 117pp.

THE EARLY IRON INDUSTRY

The iron industry in the Western Highland Rim of Tennessee had its beginnings in the historical Cumberland Furnace locality, in Dickson County, where in 1797 the first iron ore was dug and the first iron was made west of the Cumberland Mountains. It was at Cumberland Furnace that the cannon balls used by General Jackson in the battle of New Orleans were made. A furnace is reported to have been built on Yellow Creek in Montgomery County in 1802. All the early blast furnaces were small stone affairs (Plate 2, A and B), using charcoal as fuel; some were supplied with

blast from water power, but others had steam blast. Both cold blast and hot blast were employed, and a change was often made from one to the other. The capacity of these small furnaces was from 3 to 6 tons of pig iron. During the first 30 years of the nineteenth century the iron industry expanded slowly in West-Middle Tennessee, and in 1831 there were only six blast furnaces in operation, but four years later Troost[3] gives a list of 27 furnaces, of which 4 were in Stewart County, 6 in Montgomery, 6 in Dickson, 2 in Hickman, 3 in Wayne, 2 in Perry and 1 each in Lawrence, Hardin, Humphreys, and Williamson. Of the output Troost says:

"Perhaps the number of furnaces in Middle Tennessee is greater than that enumerated above * * * . Now if we suppose that each of them produces on an average one thousand tons of metal per year, it will give the immense quantity of 27,000 tons of iron."

To these various furnaces were attached bloomeries and refining forges, some of them extensive, and at two of them there were even rolling mills and nail factories. At this time a large rolling mill, belonging to the Cumberland Iron Works, was operated at Bear Spring, Stewart County, which was able to ship its produce by the Cumberland, Ohio, and Mississippi, Rivers to Memphis, Vicksburg, and New Orleans. According to Killebrew[4] the first pig iron made in Stewart County was produced at the Cumberland works in 1830, and the first cargo was shipped to Pittsburgh in 1831.

For the 20 years following 1835 there is little record of the development of the industry, but there is evidence that in 1854 it was more than holding its own, as is shown in the table on page 224, derived from Safford's Geological Reconnaissance, 1855. Safford records a production of 37,283 tons of pig metal and castings from a total of 31 furnaces in the Western Highland Rim region, several of them being at the same localities as furnaces listed by Troost in 1835. Safford was evidently more interested in geologic problems than in the technology and production of iron, for in his Geology of Tennessee, published in 1869, is found the same table of blast furnaces and their production that was given in his reconnaissance in 1855.

The report by Killebrew contains much interesting material for the student of early history of the iron industry and is the most comprehensive of the early reports on this iron-ore region. Good pen pictures of the character of properties essential for a large charcoal-iron business and technical descriptions of early furnaces are given. Extracts from his descriptions follow:

"The two largest iron proprietors in Stewart County are, first, the Cumberland Iron Works Company's property * * * and, second, the La Grange property. * * * These two companies own 100,000 acres, which connect and run together for 12 miles on the crest of Tennessee Ridge, which is the watershed beween Tennessee and Cumberland Rivers. The Cumberland Iron Works property contains 60,000 acres of

[3]Troost, Gerard, Third Geol. Rept., pp. 28-29, 1835.

[4]Killebrew, J. B., Iron and coal of Tennessee, p. 99, 1881.

land, and is the best charcoal-iron property in the United States—perhaps unsurpassed in the world. It has 30,000 acres of original growth of timber now standing, while the second growth coming on covers 20,000 acres, 6,000 acres of which are in good condition for making charcoal. This property lies on both sides of Cumberland River and has a front on either side of five miles. Five streams fed by innumerable springs flow through this immense domain and enter Cumberland River from the north and the south. The ores on the north side of the river and adjacent to Bellwood Furnace are in two high ridges lying between Cross and Cub Creeks, and these ridges are covered with fine rich soil, the growth of which is walnut, poplar, sugar tree, hickory, beech, oak, etc. (An analysis of this ore shows 57.84 per cent. metallic iron.) * * * The ores on the south side of the river are in almost every hill, ridge, and ravine within a circle of 10 miles in diameter, the principal deposit of which, however, is in the two high ridges, already mentioned. * * * (Analysis of this ore shows 59.21 per cent. metallic iron, and one of pipe ore shows 59.98 per cent.) * * * These are the ores that have been smelted at Dover, Bear Spring, and Bellwood furnaces from 1829 to this day and which establish the superiority of Tennessee iron. And although these deposits have been drawn upon to supply ore to from 1 to 5 furnaces for nearly half a century, it is nevertheless true that the ores of this property are not yet developed—the bottom has never been reached, the extent of the deposit is not known, and what has been done in 52 years only goes to show that the ores of this property are practically inexhaustible."

"Thirty thousand acres of this estate are suitable for cultivation, and will produce profitably tobacco, wheat, corn, oats, barley, potatoes, bluegrass, herd's grass apples, peaches, grapes, etc.; and fully 15,000 acres are No. 1 land; * * * There are four furnace sites on this property, Dover, Bear Spring, Bellwood, and Randolph, all of which have been improved and are so located that timber, iron ore, farming land, fire-clay, limestone, and water are convenient and abundant to all. Stone coal of excellent quality for coking is within 100 miles by rail."

At the conclusion of his description of Cumberland Furnace, Dickson County, Killebrew says: "For three-quarters of a century iron has been manufactured here, and there is no reason for believing that it will not be made on the same spot a century hence."

(In 1924 nearly one-half of a century had passed since Killebrew wrote the above comment, and iron was still being made on the old site).

As to the Aetna property in Hickman County Killebrew comments:

"The Aetna property, located by the Hillmans, confessedly makers of the best iron ever made in the United States, and purchased after long experience in the business, may be said to be the center of the Western Iron Belt. Lying remote from rail and river, its thirty-five or forty thousand acres of coaling and iron lands, as well as the other iron lands of Hickman, have attracted but little attention. It is however, a remarkable fact that, although fifty miles from the nearest railroad at Nashville before the war and almost as far from steam transportation on the river, Aetna furnace made iron which brought, by reason of its superior quality, three dollars more a ton than any other iron in the market. * * * This superior price alone, perhaps, enabled the proprietors to make iron here when conditions of transportation were hauling to Duck River six miles and flat boating to the Tennessee, 50 miles. With better transportation there are here three elements of profit—extraordinary quality, cheapness of mining and production, and superior quality and price."

In his description of the Warner furnace, then being built near Lyles, on the site of the present Wrigley furnace, Killebrew comments favorably on

the new departure, which had an iron shell 55 feet high with 11-foot bosh and would be supplied with ore by an iron hoist. Charcoal was to be charred in ovens at the furnace. This furnace possessed the advantages of new rail transportation, ample water supply, iron-ore deposits within 500 yards on both sides above furnace level, timber abundant, of fine quality, and convenient, and plenty of limestone within 200 yards. Killebrew's comment is as follows:

"All eye witnesses agree that no single location in the southern or western states yet discovered can compare with it in extent of ores and forests combined, and while Birmingham in Alabama may surpass it in the manufacture of cheap grades of iron, Hickman, Lawrence and other counties of the western Belt can have no competitor for making the best grades."

In the southern counties Napier Furnace and Wayne Furnace were noted by Killebrew. At the old Napier furnace in 1880 the ore cost $1 a ton and the charcoal 5 cents a bushel; labor cost was $2.25 a ton of iron made, making the cost of charcoal iron at the furnace $14 a ton. Hauling to the railroad 20 miles distant at Mount Pleasant cost $2.50 a ton additional.

In commenting on economic conditions in the Western Iron belt Killebrew points out that the superior quality and great quantity of the iron ores, the vast supplies of timber, convenient and abundant limestone, and cheapness of mining and production all combined to give the iron makers of the region a false sense of security, and they had continued up to that time to make iron according to ancient methods, although they really could not compete with more-modern furnaces situated upon lines of transportation, which, nevertheless, were using inferior ores. Therefore he hailed with delight the introduction of modern methods at Warner Furnace also the building of railway lines into the iron ore bearing territory.

In his discussion of conditions in the iron industry Killebrew[5] points out contrasts between certain earlier times as, for instance, 1854, when 31 furnaces produced more than 36,000 tons of pig iron and castings, and 1874, when 11 furnaces produced more than 50,000 tons of iron, and 1881, when one furnace then building, he stated, would probably produce more iron than all of the thirty-one in 1854.

In the early days one cause of the decrease in the number of furnaces was the lack of cheap transportation; pig iron had to be hauled laboriously over bad roads in wagons to river and railroads. Another cause of the decrease was the change in labor conditions. Formerly in connection with the blast furnaces were large farms, on which the laborers were employed when the furnace was not in blast and raised grain and forage crops needed for the sustenance of men and animals. The concentration of iron manufacture

[5]Killebrew, J. B., op. cit., pp. 135-136.

in the coal field has also operated to reduce the number of small charcoal furnaces in the desolate wild woods far from transportation.

Since Killebrew's report was published, operation of nearly all the old stone-stack charcoal furnaces has been discontinued, and iron making has been concentrated on a larger scale at fewer places. The old charcoal furnace that continued operating latest is the Dover, in Stewart County (Plate 9, B), and it is reported that iron was made here as late as 1920. Many of the old stone stacks are still standing, others are represented only by a few stones, and the sites of others can be identified only by the remains of piles of blue and green glassy slag, overgrown with underbrush, by the side of a stream deep in the solitude of the woods. Modern blast furnaces have been erected at Clarksville, Cumberland Furnace, Wrigley, Goodrich, Aetna, Napier, Rockdale, and Allens Creek, but those at Clarksville, Goodrich, and Aetna have been dismantled.

Although the capacities of the present furnaces are greater than those of their predecessors, they are very modest compared with the largest furnaces in the Pittsburgh and Birmingham districts. The combined capacity of those recently or at present active is, however, probably greater than that of all those existing in 1881. Most of the present-day furnaces are described in the subsequent text on the ore deposits, by counties, but the following list summarizes early data concerning most of the furnaces of which there are records. Tables on pages 223 and 226 give production of iron ore and pig iron in this region.

Blast furnaces in Western Highland Rim, Tennessee

Furnace	Remarks	Reference (see list on p. 7)
Stewart County		
La Grange.		
At Stribling		Troost, 1835, p. 29
	Built 1832	Am. Iron and Steel Assoc.: Iron works of the United States, 1876, p. 42
	Steam power used	Safford, 1855, p. 53
	Changed January, 1857, from hot to cold blast	Lesley, J. P., Iron manufacturers guide, 1859, p. 131
	New stack built 1880	Killebrew, 1881, p. 104
Dover.		
At Carlisle	Built 1828, abandoned 1834; rebuilt 1854, repaired 1873	Troost, 1835, p. 29 1876, p. 42

Furnace	Remarks	Reference (see list on p. 7)
Bear Spring.		
At Bear Spring	Built 1832, abandoned 1854, rebuilt 1873	Troost, 1835, p. 29 Am. Iron and Steel Assoc., 1876, p. 42
	Stopped 1854, machinery removed to Dover No. 2	Lesley, 1859, p. 132
	Water power used	Safford, 1855, p. 53
	Stack 37 feet high, built of limestone. Steam power used	Killebrew, 1881, p. 103
Brunsoni.		
Location not recorded		Troost, 1835, p. 29
Saline.		
Fourteen miles northwest of Dover	Built 1853; ran but one year	Lesley, 1869, p. 130
	Steam power used	Safford, 1855, p. 52
Great Western.		
At Model	Built 1854	Lesley, 1859, p. 130
	Steam power used	Safford, 1855, p. 53
Iron Mountain.		
At Tharpe	Built 1854	Lesley, 1859, p. 131
	Steam power used	Safford, 1855, p. 53
	Built 1847, rebuilt 1856	Lesley, 1859, p. 131
	Steam power used	Safford, 1855, p. 53
Bellwood.		
Half a mile north of Cumberland River north of Bear Spring	Steam power used	Safford, 1855, p. 53 Killebrew, 1881, p. 101 Lesley, 1859, p. 132
Cross Creek.		
Seven miles north of	Built 1853	Lesley, 1859, p. 132 Safford, 1855, p. 53
Rough & Ready.		
Five miles east of Bear Spring	Built 1850	Lesley, 1859, p. 132 Am. Iron and Steel Assoc., 1876, p. 42
	Steam power used	Safford, 1855, p. 53
Dover No. 2.		
At Carlisle	Rebuilt 1854	Lesley, 1859, p. 133
	Steam power used	Safford, 1855, p. 53

Furnace	Remarks	Reference (see list on p. 7)
Union.		
Two miles south of Cumberland River at Bowling Green	Built 1853	Lesley, 1859, p. 133
	Steam power used	Safford, 1855, p. 53
Ashland.		
Eight miles southeast of Bowling Green	Built 1851 with the dressed stones of the Van Buren stack (built by Brunsen more than 20 years earlier)	Lesley, 1859, p. 133
	Steam power used	Safford, 1855, p. 53
Eclipse.		
On Hurricane (?) Creek, south of Dover and east of Stribling	Built prior to 1855	Lesley, 1859, p. 132 Am. Iron and Steel Assoc., 1876, p. 42
	Steam power used	Safford, 1855, p. 53
Clark.		
One and three-fourths miles east of Stribling	Built 1854	Am. Iron and Steel Assoc., 1876, p. 42 Lesley, 1859, p. 131
	Steam power used	Safford, 1855, p. 53
	Furnace 38 feet high, built of stone with fire-brick hearth	Killebrew, 1881, p. 105
Randolph.		
Near Bear Spring		Killebrew, 1881, p. 102
Montgomery County		
Helen.		
At Clarksville	Built 1892, first operated December 8, 1895	Am. Iron and Steel Inst., 1920, p. 296
Phoenix.		
Location not recorded	Steam power used	Safford, 1855, p. 52
Montgomery.		
Location not recorded	Steam power used	Safford, 1855, p. 52
Poplar Spring.		
North of Cumberland River, 7 miles west-northwest of Palmyra	Steam power used	Safford, 1855, p. 52
Mount Vernon.		
At Eaton station	Built 1833	Troost, 1835, p. 29 Am. Iron and Steel Assoc., 1876, p. 42
	Built about 1838	Lesley, 1859, p. 134

Furnace	Remarks	Reference (see list on p. 7)
Blooming Grove.		
North of Cumberland River, 8 miles northwest of Palmyra		Troost, 1835, p. 29
	Built in 1834, abandoned to ruin 10 or 12 years before 1859	Lesley, 1859, p. 133
Tennessee.		
On Middle Fork of Bartons Creek in southeast corner of county	Steam power used. Abandoned 1851	Lesley, 1859, p. 135
Lafayette.		
On north fork of Bartons Creek in southeast corner of county		Troost, 1835, p. 29
	Abandoned many years before 1859 and in ruins	Lesley, 1859, p. 135
Washington.		
One mile northeast of Lone Oak station		Troost, 1835, p. 29
	Abandoned 20 years before 1859 and fell to ruins	Lesley, 1859, p. 134
Louisa.		
One and one-half miles southeast of Louise station		Safford, 1855, p. 52 Lesley, 1859, p. 134
Sailors Rest.		
On Yellow Creek, near south line of county	Built 1854	Lesley, 1859, p. 133
	Steam power used	Safford, 1855, p. 52
Yellow Creek. (Steele Furnace).		
On Yellow Creek, 3½ miles from south line of county	Built 1802	Lesley, 1859, p. 133
	Built 1802	Swank, J. M., Iron in all ages, 1884, p. 225
	Steam power used	Safford, 1855, p. 52 Troost, 1835, p. 29
O. K.		
Two miles west-northwest of Marion	Burnt down and rebuilt about 1857	Lesley, 1859, p. 134
	Steam power used	Safford, 1855, p. 52

Furnace	Remarks	Reference (see list on p. 7)
Dickson County		
Cumberland.		
At Cumberland Furnace		Troost, 1835, p. 28
	Built between 1790 and 1795; rebuilt 1825	Swank, 1884, p. 224
	Built about 1790	Lesley, 1859, p. 135
	Built 1825	Am. Iron and Steel Assoc., 1876, p. 42
	Steam power used	Safford, 1855, p. 52
	Stack of limestone. First iron made in 1797 (?)	Killebrew, 1881, pp. 111-112
Barton's.		
Location not recorded		Troost, 1835, p. 28
Carroll.		
Four miles south of Cumberland Furnace		Troost, 1835, p. 28
	Steam power used	Safford, 1855, p. 52
	Rebuilt 1853	Lesley, 1859, p. 135
Belleview.		
On Little Jones Creek, 3 miles south of Charlotte		Troost, 1835, p. 28
	Built about 1825; ran until 1834 and was then abandoned	Lesley, 1859, p. 135
Laurel.		
Three miles north-northeast of Burns		Troost, 1835, p. 28
	Built 1815, rebuilt 1854. Furnace abandoned and a camp-meeting pulpit erected in the run-out arch	Lesley, 1859, p. 136
	Steam power used	Safford, 1855, p. 52
Richland.		
Location not recorded		Troost, 1835, p. 28
Worley.		
Two and one-half miles west of Dickson	Built 1844, rebuilt 1854	Lesley, 1859, p. 135
	Built 1847	Am. Iron and Steel Assoc., 1876, p. 52
	Operated 6 months preceding June 1, 1880, by Warner Bros., making 1,250 tons of pig iron with coke as fuel	Killebrew, 1881, p. 112
	Steam power used	Safford, 1855, p. 52
Jackson.		
Five miles east southeast of Burns (?)	Built 1833	Lesley, 1859, p. 136
	Steam power used	Safford, 1855, p. 52

Furnace	Remarks	Reference (see list on p. 7)
Piney.		
On Beaverdam Creek south of Burns (?)	Built 1832	Lesley, 1859, p. 135
	Steam power used	Safford, 1855, p. 52
Hickman County		
Piney.		
Location not recorded		Troost, 1835, p. 29
Lee		
On Sugar Creek 9½ miles west-northwest of Nunnelly		Troost, 1835, p. 29
Aetna.		
At Aetna	Built 1846	Lesley, 1859, p. 136
	Steam power used	Safford, 1855, p. 52
Oakland.		
Seven miles northwest of Centerville (?)	Built 1854. A new stack was to be built after 1859	Lesley, 1859, p. 136
	Steam power used	Safford, 1855, p. 52
Warner. (Wrigley Furnace)		
One and one-fourth miles south of Lyles	Building in 1881. Could be run as hot blast or with coke	Killebrew, 1881, p. 119
	Rebuilt 1918-19	Am. Iron and Steel Inst., 1920, p. 62
Standard.		
At Goodrich	Built 1885, rebuilt 1891	Am. Iron and Steel Inst., 1920, p. 62
Perry County		
Cedar Grove.		
Two miles east of Perryville	Steam power used	Troost, 1835, p. 29 Safford, 1855, p. 52 Lesley, 1859, p. 136
Lewis County		
Napier.		
At Napier	Built 1860, ran 3 months; started again 1867 or 1868, ran 6 months; put in blast again 1873 or 1874, ran 12 months; put in blast again April, 1880. Stack is limestone for 12 feet, then brick to top; 32 feet high	Killebrew, 1881, p. 127

Furnace	Remarks	Reference (see list on p. 7)
Wayne County		
Rock House.		
Location not recorded		Troost, 1835, p. 29
Forty-eight. (Wayne Furnace.)		
Five miles east of Waynesboro		Troost, 1835, p. 29
	No. 1 built 1846, was of brick. No. 2, same as No. 1. Was to be torn down and replaced by a single stack	Lesley, 1859, p. 137
	Built 1856	Am. Iron and Steel Assoc., 1876, p. 42
	Steam power used	Safford, 1855, p. 52
Marion.		
Two miles south of Clifton	Steam power used	Safford, 1855, p. 52
	Made cannon balls used in Mexican war	Lesley, 1859, p. 137 Killebrew, 1881, p. 130
Furnace Landing.		
One mile west of Clifton		H. D. Miser, personal communication
Lawrence County		
Buffalo.		
Location not recorded		Troost, 1835, p. 29
Decatur County		
Brownsport.		
Ten miles northwest of Clifton		Safford, 1855, p. 52
	Built 1848. Steam power used	Lesley, 1859, p. 136
	In blast in 1877	Killebrew, 1881, p. 130
Decatur.		
Six miles west of Clifton		Safford, 1855, p. 52
	Built 1854. Steam power used	Lesley, 1859, p. 137
Bob's Landing.		
Left bank of Tennessee River 6 miles northwest of Clifton		H. D. Miser, personal communication
Maury County		
Rockdale.		
At Rockdale	Built 1890; idle 1898-1902; revived 1902	Am. Iron and Steel Inst., 1920, p. 164

GEOGRAPHY

The Highland Rim of Middle Tennessee is a dissected plateau that surrounds the Nashville Basin, stands at a higher altitude, and slopes gently westward. The western part of the Highland Rim, in which the deposits of brown iron ore are found, extends from north to south across Tennessee, west of the longitude of Nashville and Columbia and east of Tennessee River, except where consolidated rocks of Paleozoic age are exposed on the hills west of the river in Benton and Decatur Counties (Plate 1). Two master streams control the drainage of the area—Tennessee River on the west and south and Cumberland River on the north. The largest two streams of the next order of size are Duck River and Buffalo River, and there are innumerable smaller streams, for the region is in general liberally supplied with rainfall.

The surface of this part of the State has been rather intricately dissected by stream erosion and is consequently hilly, but there are large areas of the flat-topped ridge land in the north and smaller areas in the south, as well as some fairly wide stretches of bottom land along the larger streams throughout the area. The altitude ranges generally from 500 to 950 feet above sea level, but the extremes are the level of Tennessee River at about 350 feet and the highest interstream area at about 1,050 feet altitude. A new relief map, prepared by the United States Geological Survey in co-operation with the State of Tennessee, brings out the general surface features much better than the ordinary "flat" map. This map was issued in 1927 and may be obtained from the State Geologist at Nashville.

The largest towns are Clarksville and Dickson, and other important places are Centerville and Lawrenceburg. Three county seats—Charlotte, in Dickson County, Dover, in Stewart County, and Waynesboro, in Wayne County—are not on railroads, all being reached by automobile, and Dover also by launch or steamboat on Cumberland River. Iron-ore mining has not been extensive enough nor steady enough to build up any large towns, but certain villages, including Cumberland Furnace, Lyles, Wrigley, Nunnelly, Aetna, Allens Creek, and Iron City, owe their existence chiefly to the mining industry, and other places have had alternations of activity and idleness. Aside from mining the chief occupations in this part of Tennessee are agriculture and lumbering. There are still many areas that produce hard woods, but most of them have been cut over many times. General farming and tobacco raising are carried on in the northern part of the area on the upland and in the valley areas, but in the southern part, where there is less level upland, farming is largely confined to the flood plains of the streams. Except a few highways between important places the roads were not well cared for at the time the field work was done, and in wet weather automobile travel was difficult on the ordinary country roads.

The railroads generally follow the ridges and are therefore somewhat circuitous. Two railroads cross the area, the Louisville & Nashville line,

which extends from Memphis to Louisville via Clarksville, and the Nashville, Chattanooga & St. Louis line, from Memphis to Nashville. Ore-bearing territory is tapped by branch lines of the Louisville & Nashville from Clarksville to Pond, near Dickson, with a spur from Van Leer to Cumberland Furnace, and of the Nashville, Chattanooga & St. Louis from Dickson to Allens Creek. The Columbia, Florence & Sheffield branch of the Louisville & Nashville Railroad passes close to iron-ore deposits at Iron City, Lawrence County, and maintains short branches to Pinkney and to Napier. A railroad known as the Tennessee Western was built from Iron City to Collinwood to furnish transportation to Collinwood, where a charcoal by-product plant and blast furnace were constructed during the World War, but the activities of these plants were short lived. This railroad was projected northward to the locality of the former Wayne Furnace, in order to tap the local iron-ore deposits, but construction work did not progress beyond the preparation of the grade and laying of ties a few miles from Collinwood. It is reported that the original plan contemplated building this line on to connect with the Nashville, Chattanooga & St. Louis Railway at Allens Creek, a difficult piece of work because of the roughness of the country to be traversed.

In the northern part of the iron-ore area Tennessee River and Cumberland River afford potential water transportation for ore from deposits within easy wagon or motor-truck haul. None is being shipped in this way at present, but in very early days of the iron industry pig iron from local charcoal furnaces was transported extensively on these rivers, and later iron ore was shipped by boat down to blast furnaces in Kentucky.

GEOLOGY

STRATIGRAPHY

The rocks that form the surface of the Western Highland Rim region are sedimentary and range in age from Ordovician to Quaternary. The Ordovician rocks are exposed along the eastern edge of the rim and extend down the valley of Duck River as far as Centerville. Other exposures are near Clifton on Tennessee River, in the valley of Shoal Creek northeast of Iron City, and in a small upthrust area near Cumberland City. These rocks consist, in Middle Tennessee, of bluish-gray, fossiliferous limestone and calcareous shale of various characters; the limestone is phosphatic at many horizons. Silurian rocks lie next above those of the Ordovician system. They also are exposed along the eastern border of the Rim and at the bottoms of portions of the valleys of Tennessee, Duck, Buffalo, Harpeth, and Cumberland Rivers and in Shoal Creek and many other tributaries of Tennessee River. The Silurian rocks consist of evenly bedded, in places dense, crystalline, massive to shaly fossiliferous limestone. The lower beds are variegated, and the upper part is gray and in places contains chert. The Devonian rocks,

which are next in succession, crop out in the western valley of Tennessee River and consist of thick beds of chert, or novaculite, interbedded with thin, pure, white limestone and siliceous limestone and shale. Overlying this Devonian chert is a thin sandstone and above that a black shale (the Chattanooga shale), which is of Devonian or Mississippian age. The rocks of Ordovician to Devonian age are not closely associated with the deposits of brown iron ore and need not be described further. Their general distribution is shown on the geologic map of Tennessee, issued by the State Geological Survey in 1923, and descriptions of the formations with detailed mapping in portions of the Western Highland Rim area will be found in publications by Miser[6] and by Hayes and Ulrich.[7]

The consolidated rocks that are nearest the surface in most of the area containing the brown iron ore are of Mississippian age. The three Mississippian formations most closely associated with the ore are, in ascending order, the Fort Payne chert, the Warsaw formation, and the St. Louis limestone.

The Fort Payne chert is a calcareous chert or highly siliceous limestone associated in places with some gray shale. Some of the chert contains an abundance of fossil crinoid stems, and here and there brachiopods are present. The formation is 100 to 200 feet thick in Wayne and Lawrence Counties but apparently becomes thicker toward the north. It is exposed on the hill slopes and in the upper parts of the valleys of the smaller streams in the southern part of the region, but north of Duck River the exposures are not so extensive and are confined more to the vicinity of Tennessee and Cumberland Rivers. More or less tripoli, a soft, fine-grained, porous material, is formed by the weathering of beds in the upper part of the Fort Payne chert, and the occurrence of this material, as well as the abundance of crinoid remains, aids in the identification of the beds. In places residual clay covers the outcrop, but the clay from the Fort Payne can generally be distinguished from the red clay of the higher Warsaw and St. Louis limestones by its yellower color.

The Warsaw beds are believed to lie unconformably on the Fort Payne chert. They are composed of massive, pure limestone and cherty limestone and contain sandstone beds. The limestone weathers to a deep-red, cherty clay, and this clay contains in a few places residual boulders of a more or less saccharoidal sandstone, which was probably originally calcareous. The Warsaw beds and their residual clay, which is difficult to distinguish from that of the overlying St. Louis limestone, underlie most of the upland area south of Duck River. North of that river they extend back from the borders of the valleys for various distances to points where they pass below the St.

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

[7]Hayes, C. W., and Ulrich, E. O., U. S. Geol. Survey Geol Atlas Columbia Folio (No. 95), 1903.

Louis beds. A piece of chert pronounced by Charles Butts to be typical of the Warsaw was found as far north as Slayden, Dickson County. The thickness of the Warsaw is not definitely known but probably exceeds 150 feet.

The St. Louis limestone consists of blue and gray, massive, cherty limestone, which weathers to reddish clay and loose fragments of chert. Weathering has produced a residual mantle of clay and angular fragments of chert from a few feet to 100 feet thick. The characteristic red clay residual from the limestone contains a fossil coral, *Lithostrotion canadense,* which forms compact masses reaching a foot in diameter, and which is believed to have been derived from basal beds of the formation. Beds containing this coral in place have been noted in only a few places in the northern part of the State. The geologic map of Tennessee shows that the St. Louis is the surface rock of most of the higher plateau lands north of Cumberland River and smaller areas southward to Duck River; it is overlain in a few places by Cretaceous gravel. It has therefore been so much exposed to weathering that the whole thickness of the formation is probably nowhere present. The part still remaining north of Cumberland River may reach a thickness of 200 feet, but the formation is much thinner in the area between Cumberland and Duck Rivers, and according to Charles Butts it may not be present at all in the southern counties. H. D. Miser, however, believes that chert and clay residual from the St. Louis and possibly some limestone are present in Wayne and Lawrence Counties. Cherts containing fossil lithostrotions have been found by the writer in southern Wayne County.

The residual clay, whether it be from the Warsaw or St. Louis, contains a large portion of the deposits of brown iron ore in the area.

Disconnected remnants of deposits of Upper Cretaceous rocks, the Tuscaloosa and the Eutaw formations, overlie the Mississippian rocks and their residual clays in a few places east of Tennessee River. The Tuscaloosa, which consists mostly of gravel, contains partly rounded pebbles of chert derived from Carboniferous rocks, and in places the gravel has been cemented by iron oxide into a hard conglomerate. In Wayne County the gravel of the Tuscaloosa occurs as a mantle on the higher hills and ridges; it thins out entirely toward the north but thickens to as much as 150 feet toward the southwest corner of the county, where it is overlain by the Eutaw sand. This sand is red, weathering to gray at the surface, is extremely fine grained, contains flakes of mica and streaks of gray clay, and attains a maximum thickness of 50 feet. These Upper Cretaceous deposits are the lowest of the Gulf embayment and mark the eastern limit to which such deposits are now present in Tennessee. Evidently they were spread over most of the region and probably were formerly overlain by higher glauconite-bearing formations, such as the Selma and Ripley, that are present west of Tennessee River. In several places north of Wayne County Tuscaloosa gravels are found on the interstream areas, as near Aetna and Coble, Hickman County; near Tennes-

see City, Dickson County; and near Bear Spring and in the northwestern part of Stewart County on the ridge between Tennessee and Cumberland Rivers. Masses of the gravel conglomerate consisting chiefly of chert pebbles are occasionally found to contain a few smoothly rounded pebbles of quartz or quartzite, and larger quantities of similar pebbles are commonly found lying loose on the tops of the highest hills in the southern counties of Tennessee and in northern Alabama. Gravel of this type in northwestern Alabama has been included in the Tuscaloosa by students of Coastal Plain geology, although the source of the pebbles is wholly different from that of the chert gravel and can not be traced to any of the older rocks exposed in the region. These quartz and quartzite pebbles may be of Tertiary or later age, and their presence in the ferruginous conglomerate in the Tennessee River Valley region may be accounted for by assuming that the materials of this conglomerate, which is found in detached masses not buried under heavy cover, have been reworked with later material and the whole cemented together in recent times by iron oxide from solution in surface waters. Conglomerates of this sort are being formed now where chalybeate waters are issuing into gravel fans near the levels of present streams.

Outline of post-Devonian geologic formations in Western Highland Rim area of Tennessee

System	Series	Formation	Thickness (feet)	Lithology and distribution
Quaternary	Recent	Alluvium terrace deposits	1–30	Gravel and silt in stream flood plains. Grave and loam on stream terraces
Cretaceous	Upper Cretaceous	Eutaw sand	0–50	Gray to red micaceous sand with some clay. Found on higher lands in southwest and northwest parts of area
		Tuscaloosa gravel	0–150	Gravel with small quantities of clay and sand Gravel chiefly of chert derived from Mississippian rocks. In many places, especially in the northern part of the region, the Tuscaloosa apparently contains some red loam. Caps higher ridges and hills mostly in southwest and northwest parts of area
Erosion interval				
Carboniferous	Mississippian	St. Louis limestone	50–200	Blue and gray massive cherty limestone, weathering to red clay and broken chert, underlies a large part of the upland north of Cumberland River and smaller areas south to Duck River Over-burden of red clay, in places 100 feet thick, contains deposits of brown iron ore in many places
		Warsaw formation	150–200+	Massive pure and cherty limestone with a few sandstone beds. Probably occupies most of upland area south of Duck River. Weathers to deep-red clay containing fragments of chert and boulders of sandstone. The thick residual clay which underlies the general upland level contains deposits of brown iron ore in many places
		Fort Payne chert	100–200	Gray cherty crinoidal limestone, calcareous chert and gray shale. Exposed on hillslopes not far below the general upland level
		Ridgetop shale	0–90	Gray, platy siliceous shale, glauconitic near base. Recognized in Wayne and Lawrence Counties
Erosion interval				
Devonian or	Upper Devonian	Chattanooga	0–37	Black platy shale with thin, fine-grained phos-

The deposits of Quaternary age comprise terrace gravel, stream gravel, and alluvium, and are not commonly associated with the brown iron ores.

The essential features of the rocks later than the Devonian in the brown iron ore bearing area are summarized in the preceding outline, and their general distribution will be found on the geologic map of Tennessee referred to above.

STRUCTURE

The topographic features of Middle Tennessee are directly related to the structural geology of the region. The outstanding feature of a geologic map or east-west cross-section of this part of the State is the Nashville uplift, an elliptical area that extends in a southwesterly direction across the State, in which the rocks, mostly Ordovician limestones at the surface, have been gently folded into a broad, low dome. Surrounding the Nashville uplift is the Highland Rim, a border of hills whose summits reach so nearly the same altitude that when viewed from a distance they present a comparatively even sky line. These hills, whose tops are nearly horizontal, are remnants of an extensive plateau or highland developed on Mississippian rocks, below which the Ordovician beds dip gently away from the uplift.

The northern part of the Nashville uplift is drained by Cumberland River and its tributaries and the southern and western parts by tributaries of Tennessee River, which flow southward and westward, cut through the border of hills, and deeply dissect the country beyond. The rolling surface of the uplift slopes gently northward and westward, and it is lower at its borders than the Highland Rim, thus taking the position of a topographic basin, particularly in the vicinity of Nashville and Cumberland River.

In the Western Highland Rim area the dips of the rocks are nearly everywhere so slight that locally the beds appear to be practically horizontal. A notable exception is the Wells Creek basin, just southwest of Cumberland City, where there is apparently an abrupt uplift, roughly circular and about one and three-fourths miles in diameter, in which rocks down to the Ordovician are brought to the surface within the area of Mississippian rocks. The general dip, as indicated by the geologic map of Tennessee, is toward the west and southwest away from the Nashville uplift; in some places the dips are measurable but rarely exceed a few degrees. Where detailed geologic mapping has been done on a topographic base, as in the Waynesboro quadrangle, it has been possible to delineate several gentle anticlinal and synclinal folds, and these have been shown on the geologic map[8] by means of structure contours on the Chattanooga shale. Many of the larger streams in the Waynesboro quadrangle occupy synclinal folds, hence most of their tributaries flow toward the axes of these folds and with the dip of the rocks.

[8]Miser, H. D., Mineral resources of the Waynesboro quadrangle, Tenn.; Tennessee State Geol. Survey Bull. 26, Plate I, 1921.

The relation of this folding to the distribution of the iron-ore deposits is probably significant although not thoroughly worked out because of the lack of detailed topographic maps or accurate levels.

THE IRON ORES

DISTRIBUTION

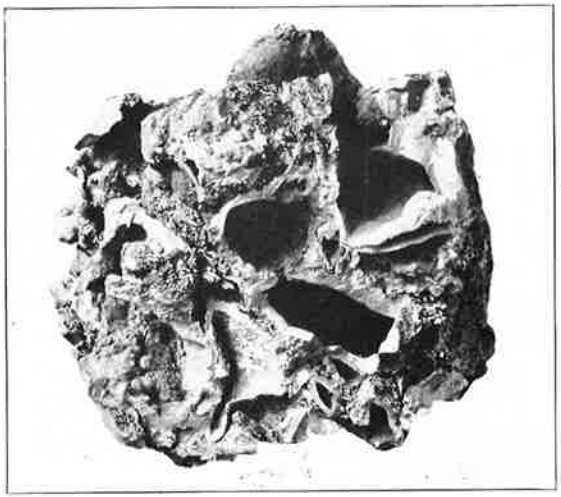
The deposits of brown iron ore that are described in this bulletin occur mostly in a belt that lies east of Tennessee River and extends from the north to the south boundary of the State, a distance of 115 miles. This belt is generally about 15 miles wide from east to west, but in the northern part of the State, in Stewart and Montgomery Counties, it is about 40 miles wide, as shown on Plate 1. Some of the deposits, as in Stewart County, are near Tennessee River, but most of them are in the second tier of counties east of the river and 15 to 40 miles distant from it. The counties that contain most of the iron-ore deposits are, beginning at the northwest, Stewart, Montgomery, Dickson, Hickman, Lewis, Wayne, and Lawrence. Minor deposits in Decatur, Hardin, Houston, Humphreys, and Perry Counties have been noted in other State Survey reports or reported by local residents, and some notes are given in this report concerning deposits in Hardin, Benton, and Humphreys Counties and on limonite found west of Tennessee River in McNairy County. Brown iron ore is found also in the vicinity of Tennessee and Cumberland Rivers farther north, in western Kentucky, and farther south, in the vicinity of Russellville, Colbert County, Alabama. The area in the three States may be regarded as the brown iron ore area of the western Tennessee River Valley. There are no large towns close to any of the iron-ore deposits, but Clarksville, Mount Pleasant, Columbia, and Nashville are not far beyond the boundary of the iron-bearing area.

OCCURRENCE AND CHARACTER

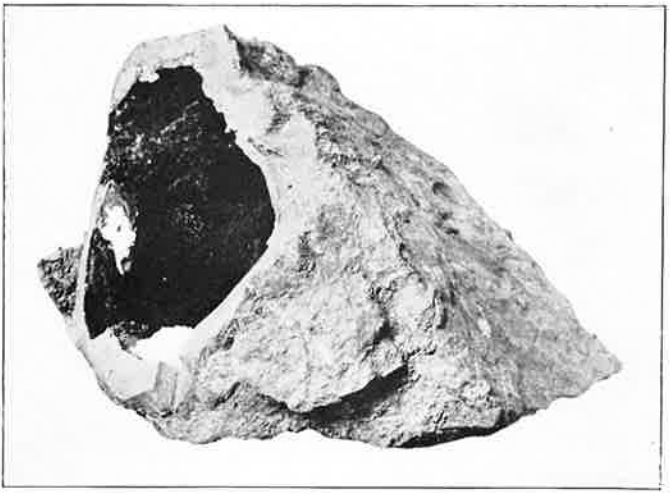
Position and form of deposits.—The deposits of brown iron ore throughout the western Highland Rim area of Tennessee display considerable similarity in their general form and position. The ores are inclosed in clay and chert débris lying above beds of cherty limestone that have been subjected to deep weathering, so that the upper and lower limits of the ore bodies are uneven. Many of the deposits occur on the borders or near the crests of narrow ridges and tend to conform to a certain extent to the upper hill slopes, so that they can not be said to lie in a horizontal position, although locally there is a certain degree of uniformity in the attitude of the deposits. Other deposits occur on the slopes or well down toward the levels of the valleys, but even in these positions there is a considerable thickness of residual clay or chert, or both, between the ore and the underlying consolidated rocks. Near the surface the ore occurs in loose fragments from the size of shot to boulders several feet in diameter; at greater depth it is in large irregular-shaped

(A) Remains of Lee furnace on Sugar Creek in northwestern Hickman County, operated prior to 1835.

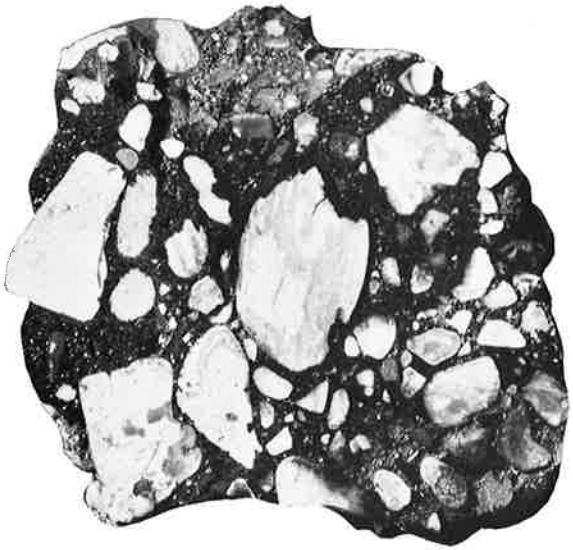
(B) Ruins of Van Leer furnace on Butler Creek, 2¼ miles west-southwest of Iron City. Operated from 1832 to 1837.



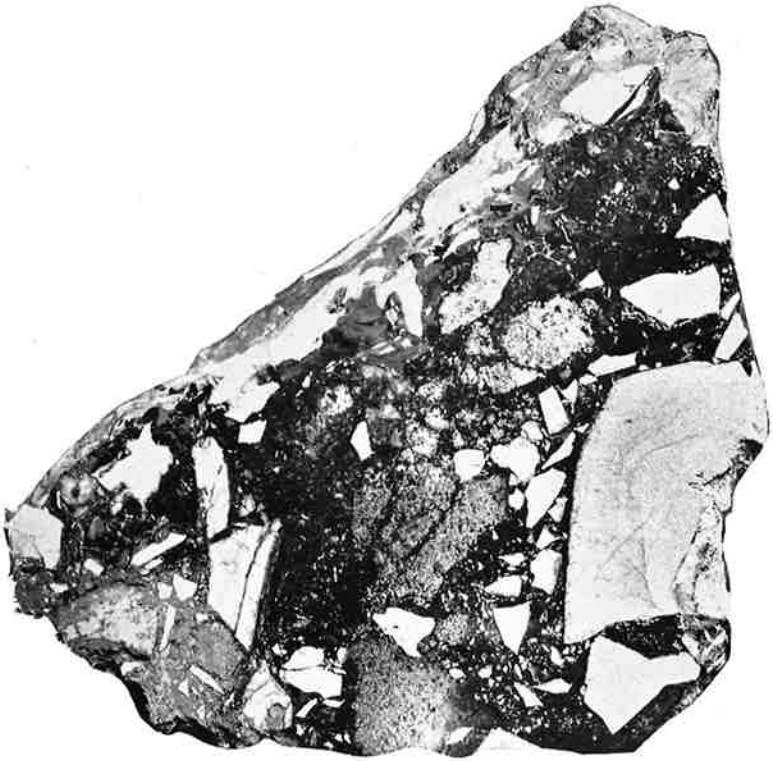
(A) Brown iron ore containing irregular cavities, from Robinson (White-Littrell) mine, 2 miles southwest of Corning, Wayne County. Two-thirds natural size. (After H. D. Miser.)



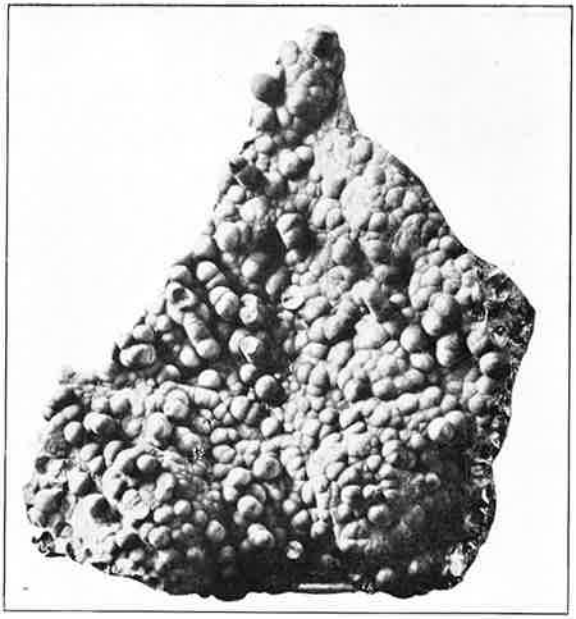
(B) Brown iron ore in form of angular-shaped "bombshell" from Lee Hollow mines, 2 miles east of Wayne furnace, Wayne County. One-third natural size. Contains small amount of soft chert adhering to inner surface of cavity. (After H. D. Miser.)



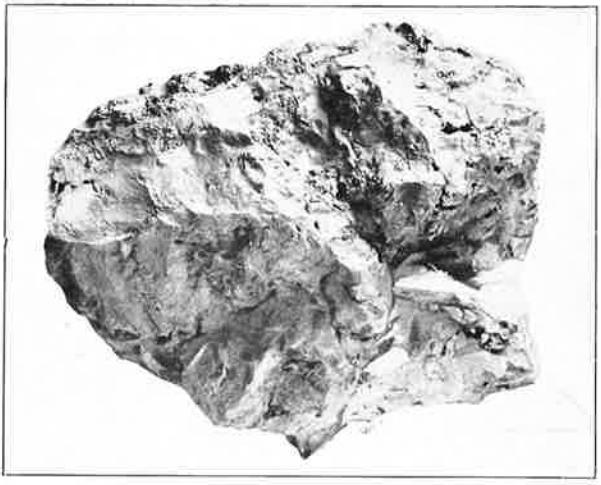
(A) Rounded pebbles of chert partly replaced and cemented together by limonite. Black rim around middle pebbles shows extent of replacement. From Bell mine, near Cumberland furnace, Dickson County. Natural size.



(B) Fractured chert partly replaced and cemented by limonite, from Napier mine, Lewis County. Faint-gray areas show fragments of chert in various stages of replacement, but the dense-brown areas of limonite have resulted from almost complete replacement of chert. Two-thirds natural size.



(A) Brown iron ore with a botryoidal surface. From East Furnace Ridge mine at Wayne furnace, Wayne County. Two-thirds natural size. (After H. D. Miser.)



(B) Brown iron ore of massive, compact type. Two-thirds natural size. (After H. D. Miser.)

masses, in veins, some of them forming branching networks, and in large clay-filled crusts. Where erosion on a hillside has been rapid, a solid mass of ore or of ferruginous conglomerate may become exposed before being broken down into loose lumps, but the best place in which to study the ore is in an active mine cut.

In places the presence of good ore is indicated by outcrops of lumps and scattered boulders and fragments of limonite and by the presence of fine gravel of limonite, or "shot ore," scattered over the surface and embedded in very red subsoil. In places ledges of chert-gravel conglomerate cemented firmly by brown iron oxide crop out prominently on the hillsides, but these masses do not constitute very rich ore. Most commonly the ore is covered with soil, clay, gravel, sand, and other unconsolidated material to a depth of a few feet to 30 feet or more, so that an overburden of barren material must be removed before mining can begin.

The deposits are extremely varied in size, ranging from a pocket containing a few hundred tons of ore, or hardly enough to pay to mine even by hand methods, to groups of deposits extending over hundreds of acres and to depths of 30 to 100 feet and originally capable of yielding more than 1,000,000 tons by means of steam-shovel stripping and mining. Locally the ore deposits whether mined or not are spoken of as "ore banks" or simply "banks."

Types of ore.—The ore consists principally of limonite, and the great variety of forms assumed by this mineral is of interest. The shot ore is fine-grained material, usually more or less rounded, that has been derived by natural disintegration of larger fragments and masses of ore. The individual fragments are rich in iron, and where they occur in abundance in the clay they are mined and recovered by washing. Many large lumps and boulders of limonite are found to be hollow, like geodes, and to contain clay, sand, gravel, or chert (Plate 3). The cavities in many such lumps are lined with glossy, black limonite. The ore exhibits great differences in texture, ranging all the way from dense and solid to earthy, porous material. "Honeycomb" ore consists of hard limonite in thin webs with open spaces between them, and there is much ore containing irregular-shaped, small cavities (Plate 3). According to the mode of its deposition the ore shows certain characteristics. So much chert has been replaced by iron oxide in this field that the term "chert-replacement ore" is suggested. At first glance ore of this type appears to be breccia in which angular fragments of chert are cemented together by limonite, but close observation discloses that limonite has replaced the chert to a greater or less extent, proceeding along the angular fractures in the rock. Plate 4 illustrates specimens of this type of ore. The natural breaking down of material of this type has yielded a great deal of limonite in the form of fragments of crusts, gravel, and shot ore, and crushing and washing are employed to recover this ore. Clay has also been replaced by iron oxide to a small extent, low-grade ore being thus

formed. More or less commonly the limonite, where deposited from solution in an open cavity, is botryoidal and stalactitic. This ore is generally of relatively high grade, as is also the massive, compact type. Both of these types of ore are shown in Plate 5.

Mineral composition.—The brown iron ores appear to consist of a mixture of hydrous iron oxides, in which the iron is present in the ferric form as the sesquioxide (Fe_2O_3). As the great bulk of the material is hydrated, there is probably very little hematite, or nonhydrous ferric oxide, present. The more-common hydrated ferric oxides are limonite, goethite, and turgite, but in this field limonite and goethite seem to be the principal minerals. It is not unlikely that there is more goethite present than has been heretofore suspected. Examination under the microscope by C. S. Ross of a specimen of powdered ore, clean and well separated from gangue material, indicated that it was mostly crystalline material with the indices of refraction corresponding to goethite. This result confirmed a chemical analysis of a sample from the same specimen, made at Wrigley Furnace, which showed more metallic iron than is contained in limonite, or about the percentage necessary for goethite.

The principal impurities in the ore are clay, chert, sand, and gravel. The clay and chert are residual from the Mississippian limestone, and the sand and gravel from the Cretaceous and later formations, although much of the gravel probably has been derived ultimately from the Mississippian beds. Some rather rare iron phosphate minerals, strengite, beraunite, cacoxenite, and dufrenite, have been found in boulders of chert breccia cemented with iron oxide at the Van Leer mine, in Wayne County. (See pages 189 and 190).

A statement of the relations of the iron oxide minerals may be of interest here. Beginning with hematite, which contains no water, the formulas of the other oxides may be so arranged as to show a close relationship, in which, if the ferric oxide is regarded as constant, the proportion of chemically combined water steadily increases and the iron decreases.

Composition of certain ferric-oxide minerals[a]

Name of mineral	Chemical formula	COMPOSITION		
		Iron oxide (per cent)	Water (per cent)	Iron (per cent)
Hematite	$2Fe_2O_3.0H_2O$	100.0	0.0	70.0
Turgite	$2Fe_2O_3.1H_2O$	94.7	5.3	66.2
Goethite	$2Fe_2O_3.2H_2O$	89.9	10.1	62.9
Limonite	$2Fe_2O_3.3H_2O$	85.5	14.5	59.8
Xanthosiderite	$2Fe_2O_3.4H_2O$	81.6	18.4	57.0
Limnite	$2Fe_2O_3.6H_2O$	74.7	25.3	52.3

[a]Eckel, E. C., Iron ores, their occurrence, valuation, and control, pp. 25, 27. New York, McGraw-Hill Book Co., Inc., 1914.

In his report on the brown iron ores of the Waynesboro quadrangle, which is an important part of this ore field, Miser[9] in using the first five minerals of this table commented on the composition of these iron oxide minerals as follows:

[9]Miser, H. D., op. cit., p. 49.

"From this table it will be seen that the five minerals in question make up a perfect series with respect to their percentages of combined water, beginning with hematite, which contains no water, and showing gradually increased amounts to the other end of the series. The table also shows a decrease in the percentages of iron from hematite toward the other end of the series. The percentages of iron as given in the table are theoretical and will never be found in the ores in the Waynesboro quadrangle, because all of the ores contain more or less impurities.

"The four hydrous oxides, turgite, goethite, limonite, and xanthosiderite, are commonly grouped under the name of brown iron ores, or limonite. It is probable that if the product from any particular brown-ore deposit in the Waynesboro quadrangle be carefully examined, it will be found that much of the ore is limonite proper, with much geothite and smaller proportions of the other two hydrous oxides. Hematite, if present in the quadrangle, occurs in very small quantity. * * *

"Limonite is not crystallized; most of it is massive, though some of it has botryoidal surfaces and has a fibrous structure. It has a brown or nearly black varnish-like surface, and the color of freshly fractured surfaces ranges from light to dark brown. The streak is yellowish brown.

"Goethite resembles limonite and has a brownish-yellow to ocher-yellow streak, whereas both hematite and turgite, which often resemble limonite, have red streaks. Xanthosiderite occurs as fine needles or fibers and as ocher and is golden yellowish or brown to brownish-black in color."

Chemical composition.—No complete chemical analyses of specimens of brown iron ore from this field are available, but there are many partial analyses of prospect samples and of the ore as prepared for the blast furnace either by washing and screening or by hand picking and dry screening. Local ores that have been used in the blast furnaces of the region generally range as follows in the constituents that are ordinarily determined in commercial analyses: Metallic iron (Fe), 38 to 52 per cent, but averaging about 46 per cent; insoluble material (mostly silica (SiO_2) and alumina (Al_2O_3), 10 to 38 per cent, and averaging about 25 per cent; phosphorus (P), 0.12 to 1.30, mostly between 0.30 and 0.50 per cent (the percentage of phosphorus appears to increase from north to south through the field); manganese (Mn), 0.10 to 1.30, mostly between 0.20 and 0.50 per cent; and combined water about 10 to 12 per cent. Improved methods of ore concentration have recently succeeded in raising the content of iron in the washed ore. Analyses have been made of specimens of pure iron oxide, separated from gangue material, that showed more than the percentage of iron required for limonite, thus suggesting the presence of goethite, a suggestion which has been confirmed by microscopic examination.

The run of mine washed ores generally range lower in iron and higher in insoluble material than prospect samples. This is probably unavoidable, because the prospecting is done by hand and the greater part of the clay, chert, and sand are eliminated, whereas mining with the steam shovel can not be done so selectively and involves the incentive toward obtaining a large quantity production by speeding up work and advancing into leaner ore bodies; moreover the limitation of efficiency in the ore washers affects the product. This difference between the character of prospect samples and

that of run of mine ore as it reaches the furnace will be apparent to any one who examines the records of analyses at the blast-furnace laboratories, and it should be taken into consideration in interpreting the analyses of prospect samples when planning new or additional mining developments. The optimistic frame of mind induced by the generally high quality of prospect samples has been impressed upon the writer by an examination of a number of analyses of brown iron ore recorded in an unpublished report on the ores of the western iron ore region, made by Maj. G. D. Fitzhugh to the vice-president of the Louisville & Nashville Railroad Co. in 1890. This report was based on a very thorough study by Major Fitzhugh of a large number of the ore deposits, many of which have since yielded a large quantity of ore. Wherever it was found necessary, test pits were dug to determine the thickness of the ore, and samples that were believed to represent the average quality of the ore that might be recovered were taken for analysis. The report recorded 67 analyses, and 57 of these showed metallic iron higher than 50 per cent. The range was between 35 and 60.5 per cent, and the average for the whole 67 analyses was about 53 per cent of iron. It is probably safe to say that the average yield of iron from the mines in this region since 1890 has by no means reached this figure.

The first table below presents analyses of samples of iron ore from different parts of the ore-bearing region, and the second table consists of representative analyses of ores from the mines as prepared for use in the blast furnaces. Several of the analyses in the two tables represent ores from the same deposits, and they bring out clearly the contrast between the quality of prospect samples and that of mine-run ore, even though the latter has been screened and washed. Other analyses will be found among the descriptions of iron ore deposits, pages 37 to 212.

Analyses in percentages of samples of brown iron ore, Western Highland Rim area, Tennessee

Locality	Authority[a]	Iron (Fe)	Insoluble	Manganese (Mn)	Phosphorus (P)	Sulphur (S)
Carlisle, Stewart Co	B	53.18	9.00	0.24	0.23	.....
Louise, Montgomery Co	F	51.77	7.16[b]	1.82	.10	0.02
Mt. Vernon, Montgomery Co	F	53.03	6.12[b]	Tr.	.29	.12
Charlotte, Dickson Co	F	55.60	9.86[c]	.36	.26	.09
1.3 miles northwest of Hortense, Dickson Co	T	52.69	10.36	.18	.31	.....
Iron Hill, Dickson Co	F	52.89	8.85[b]	1.65	.058	.052
Nunnelly, Hickman Co	T	52.73	11.31[c]	.41	.38	.....
Aetna, Hickman Co	F	57.85	3.99[b]	.58	.31	Tr.
Napier, Lewis Co	F	56.40	5.35[b]	.46	.602	.037
Nixon Bank, Lewis Co	M	47.07	18.42[b]	.....	.64	.042
Grinders Bank, Lewis Co	M	50.46	12.39[b]	.....	.841	.221
Allens Creek, Wayne Co	M	56.89	4.21[b]	.....	1.372	.007
Wayne Furnace, Wayne Co	M	52.28	9.41[b]	.....	.88	.....
Pinkney Mine, Lawrence Co	M	54.17	6.01[b]	.....	1.302	.004
Seavy-Lull Mine, Lawrence Co	M	54.02	6.93[b]	.....	1.07	.014

[a] B, The former Bon Air Coal and Iron Corporation; F, Major G. D. Fitzhugh, unpublished manuscript; M, H. D. Miser, Tennessee State Geol. Survey, Bull. 26; T, Tennessee State Geol. Survey, D. F. Farrar, chemist.

[b] Silica (SiO_2).

[c] Silica (SiO_2) + alumina (Al_2O_3).

Analyses in percentages of screened and washed brown iron ore, Western Highland Rim area, Tennessee

Locality	Authority[a]	Iron (Fe)	Insoluble	Manganese (Mn)	Phosphorus (P)
Stribling, Stewart Co	B	40.21	33.49	.....	0.43
Louise, Montgomery Co	W	44.09	23.60	.....	.....
Louise, Montgomery Co	W	38.67	31.30	.....	.....
Cumberland Furnace, Dickson Co	W	40.08	28.38	0.20	.62
Stokes, Dickson Co	W	42.79	27.36	.42	.14
Iron Hill, Dickson Co	B	51.67	11.52	.27	.195
Iron Hill, Dickson Co	B	43.47	26.60	.40	.116
Nunnelly, Hickman Co	B	49.27	18.70	.20	.36
Nunnelly, Hickman Co	B	44.04	22.42	.20	.44
Aetna, Hickman Co	B	48.61	18.47	.22	.27
Aetna, Hickman Co	B	43.69	21.64	.49	.176
Napier, Lewis Co	R	(average) 50	.....	.....	.50
Allens Creek, Wayne Co	M	(average) 47	15 to 18[b]	.25 to .30	.80 to 1.25
anleer, Wayne Co	O	48	10[b]	.40	.50+
nkney, Lawrence Co	M	(average) 47	17.50[c]	.70	.....

[a]B, The former Bon Air Coal and Iron Corporation; M, H. D. Miser, Tennessee State Geol. Survey, Bull. 26; R, R. F. Rogers, Resources of Tennessee, vol. 5, No. 3, July 1915; O, Owners of mine, W, Warner Iron Co.

[b]Silica (SiO_2).

[c]Silica (SiO_2) + Alumina (Al_2O_3).

TOPOGRAPHIC RELATIONS

Most of the iron ore bearing area is within the western part of the Highland Rim, the dissected plateau that surrounds at a higher altitude the Nashville Basin in west-middle Tennessee. The region is very much dissected by streams, and its altitude ranges from about 350 feet at Tennessee River in Stewart County to about 1,050 feet above sea level on the flat-woods in Lewis County. Locally, of course, there is less relief, the altitude of the smaller stream valleys ranging from 500 to 750 feet and that of the ridge crests from 850 to 1,000 or more feet. These ridge crests probably represent the remains of a peneplain of Tertiary or Pleistocene age, to which the name Highland Rim peneplain has been applied.

Many of the deposits of ore-bearing clay, chert, and gravel occur on or near the crests of the ridges and in the borders of flat, interstream areas. An inspection of the general map, Plate 1, will show the large number of ore occurrences that are remote from the streams and consequently on the upland, particularly in Dickson, Lewis, and Wayne Counties, but the same map shows also in these counties and in all the others many deposits that are close to good-sized streams and consequently well below the level of the old peneplain. In fact, in Stewart County, large deposits are found practically at the levels of the flood plains of Tennessee and Cumberland Rivers, which have cut to the lowest altitudes in this part of Tennessee, considerably below 400 feet. The highest altitudes at which the brown ore has been found are more than 1,000 feet in Lewis and Wayne Counties, and thus there is an extreme vertical range of about 650 feet, which represents the difference be-

tween the lowest stream cuttings and the highest interstream areas in this part of the Tennessee River Valley.

A study of the barometric altitudes of more than 200 deposits, recorded by Miser, Rogers, and the writer, shows the following range by counties. More careful instrumental work might modify some of the data.

Range in altitudes of deposits of brown iron ore in Western Highland Rim area of Tennessee

County	Number of deposits	Altitude (feet above sea level)
Stewart	22	365 to 650
Montgomery	10	475 to 700
Dickson	32	550 to 900
Hickman	20	600 to 900
...ws	30	700 to 1,050
Waynesboro quadrangle (portions of Lewis, Wayne, and Lawrence Counties)	90	750 to 1,000

The altitudes of the ore deposits may be summarized in another way, which will bring out the percentage distribution of the deposits between certain altitudes.

Percentage distribution of deposits of brown iron ore according to altitudes

Approximate altitudes (feet above sea level	Approximate percentage of deposits	Approximate altitudes (feet above sea level	Approximate percentage of deposits
350 to 400	1.2	701 to 750	9.8
401 to 450	2.0	751 to 800	13.9
451 to 500	3.3	801 to 850	16.3
501 to 550	1.6	851 to 900	16.7
551 to 600	4.1	901 to 950	10.2
601 to 650	4.1	951 to 1,000	8.2
651 to 700	7.3	1,001 to 1,050	1.2

This summary shows that 57 per cent of the deposits, or the majority of those studied, are between altitudes of 750 and 950 feet. Many of these, together with those above 950 feet, amounting to 9.4 per cent additional, are at or near the crests of the ridges, and about 33 per cent are lower than 750 feet and for the most part are not on the crests of ridges.

The first table shows that the highest deposits are in Lewis County, and these happen to be surface showings of limonite near the Lewis Monument, which stands in the north border of the extensive flatwoods area north of Buffalo River, one of the largest high, flat, interstream areas in the region. The table also shows that there is a gradual decrease in altitude of deposits from south to north, which happens to be the direction of flow of Tennessee River. The decrease in altitude of the deposits, however, is very much greater than the fall of the river and is not directly related to the local drainage, except that the general level of the old peneplain, represented by the hills of the Highland Rim, descends slightly northward toward Cumberland River. The deposits in Lewis, Wayne, and Lawrence Counties are more commonly on or near the crests of the ridges than those in the counties

farther north, but detailed studies when more topographic maps become available may indicate that some of the lower deposits of ore have been developed on lower erosional areas. The topographic relations of many of the lower deposits, however, indicate a downward migration of the limonite, and some deposits are even now forming through the action of spring waters. The ground-water level varies with the seasons but is probably permanently above the botton of the deepest parts of most of the deposits, for the mine pits usually collect and hold water after they are abandoned unless they are provided with drainage. Erosion has doubtless greatly reduced the size of the areas of iron ore that formerly occupied the high levels and probably is now carrying away more iron than is being deposited.

Another approach to the question of the topographic position of the ore deposits may be made through an analysis of the production of deposits according to their altitude. In Stewart and Montgomery Counties, at the north, many of the ore deposits are not far above the levels of Tennessee and Cumberland Rivers and none of them is above the 700-foot level, but none of the mines in these two counties can be regarded as among the large producers in this region. Farther south, in Dickson, Hickman, Lewis, Lawrence, and Wayne Counties, it is found that most of the deposits that have yielded large production are from 720 to 1,000 feet above sea level, or only slightly below the highest local levels. These high-level deposits have yielded between 90 and 95 per cent of the brown iron ore mined in these five counties, and as their yield is probably roughly in proportion to their magnitude, it appears that the bulk of the ore in the region has occupied a horizon that may perhaps be correlated with the Highland Rim peneplain.

GEOLOGIC RELATIONS

The deposits of brown iron ore in the Western Highland Rim of Tennessee overlie areas of nearly horizontal Mississippian rocks, chiefly cherty limestones, of which the Fort Payne, Warsaw, and St. Louis formations have been recognized. Of these the St. Louis is the latest, or stratigraphically the highest. The ore deposits themselves are generally found in the upper part of a mantle, in places 100 feet thick, of cherty clay residual from the weathering of the calcareous parts of the limestone and in a few places in remnants of deposits of sand and gravel of Cretaceous (?) or later age overlying the residual clay. Nowhere in this part of Tennessee was any ore noted less than about 50 feet above the underlying limestone, but in northern Alabama near Russellville deposits of brown iron ore belonging to this general belt are found in clay residual from the Bangor limestone of Mississippian age and in the overlying unconsolidated Cretaceous and Tertiary (?) deposits, in very close proximity to the surface of the limestone. The Bangor limestone is a later deposit than the St. Louis, Warsaw, and Fort Payne formations. In some mine pits, as at the Red River mines west of Lyles and at the Nunnelly and Aetna mines, a light-colored clay, termed "white horse" by the

miners, undelies the ore in places or forms pinnacles that extend upward into the reddish, ore-bearing clay and thus form walls at the sides of the ore deposits. (Plates 22 and 23). It might even happen that some of this "white horse" clay, through the slumping down of a sharp pinnacle or through the falling of a mass of ore into a depression resulting from a cave or solution channel in the limestone below, has reached a position above some ore. This relation is not normal, however, for the "white horse" clay is residual from a portion of the Mississippian limestone that was deposited long before the iron ore was formed. This clay may represent a general horizon in the limestone, but if so the fact can not at present be established. In places where the "horses" or pinnacles of white clay are present the solid limestone may be less than 50 feet below or distant from the ore. In other districts where brown iron ore is mined, for instance Russellville and Woodstock, Alabama, a cut through a clay "horse" often reveals hard limestone within, but the writer has not observed this occurrence in the Tennessee area under discussion. Associated with the brown ore in the Red River and Napier mines and overlying the clay that is residual from the limestone, is a reddish clay mottled with thin, wavy fragments or streaks of greenish-gray sandy clay. This mottled clay is associated with red loam and gravel and very probably was not derived through weathering of Mississippian limestones but may be of Tuscaloosa (Upper Cretaceous) or even later age. In the Alabama brown-ore districts mentioned above the clay of the Tuscaloosa is of lighter colors but is mottled in places. The important fact to be recognized in connection with these clays is that when the "white horse" is encountered underlying or surrounding a pocket of ore it is useless to explore this clay in search of further ore, for experience has shown, both here and elsewhere, that it marks a limit of the ore-bearing material and will within a short distance give way to limestone.

The cherty clay that contains the deposits of ore has probably been derived through weathering of all three Mississippian formations mentioned above. In some places fossils characteristic of the St. Louis limestone, such as the coral *Lithostrotion,* are found in the residual chert; in others, the residual material contains lumps and boulders of saccharoidal sandy rock characteristic of beds in the Warsaw; elsewhere the predominant residual chert may contain fossil crinoids and brachiopods characteristic of the Fort Payne chert; but there are places where the associated clay appears to contain fossiliferous material from all three of the limestone formations, thus indicating that a very long period of weathering and a considerable thickness of rock have been involved in the production of this clay. The clay from the St. Louis limestone generally displays a deep-red color in surface exposures,

SUGGESTIONS AS TO ORIGIN AND AGE

The occurrence of the brown iron ore in the residual clay in the western Highland Rim area as well as in other similar brown-ore fields of the South can not be easily or simply explained. Several modes of origin have been suggested by different writers. Some of the ideas advanced may possess elements of probability, and the true explanation of the origin of the ores may involve portions of several hypotheses. One hypothesis that has had many adherents is that the iron, now found in lumps, veins, and masses of iron oxide in the clay, was once disseminated, possibly as iron pyrites through the limestone beds that have weathered to form the clay, and that the insoluble portions of the limestone, including the chert and clay minerals, have remained together with the iron oxide, which has been concentrated in this residual material. Iron is a very widely distributed element and is found in practically all rocks, and, although the total quantity present in these limestones was doubtless considerable and probably contributed to the iron oxide now found in the clay, the deposits can not reasonably be ascribed wholly to this source. Even if the quantity of iron originally present had been adequate—which is open to question—much of the disseminated iron oxide, which is somewhat soluble, would have been carried away in solution and in suspension during the long periods of weathering that were required to remove several feet of limestone and would thus have been lost. It is necessary, therefore, to seek a larger source of supply of iron, and this, it is believed, may be found in the ferruginous sediments of Cretaceous and Tertiary age that formerly overlay this region but are now present east of Tennessee River only as isolated remnants on the western Highland Rim. The ferruginous character of the sediments of the Coastal Plain in many places in the southern States is well known, and the influence of this ferruginous material upon the formation of iron-ore deposits is readily apparent at Woodstock and Russellville, Ala.; Shreveport, La.; Atlanta, Tex.;[10] and Hickory Flat, Miss.;[11] and the deposits of the western Highland Rim area of Tennessee are probably no exception to this influence.

The close association of iron ore, both limonite and siderite, with glauconite in Tertiary sands and clays in northeastern Texas, described in U. S. Geological Survey Bulletin 620, points strongly to the possibility that glauconite was the mineral that originally contained the iron in those deposits. Glauconite, or greensand, is a hydrous silicate of potassium and iron. In a

[10]Burchard, E. F., Iron ores in the Brookwood quadrangle, Ala.: U. S. Geol. Survey Bull. 260, pp. 321-334, 1905; Geology and development of the brown ores of the Woodstock and Champion districts, Ala.: U. S. Geol. Survey Bull. 400, pp. 150-169, 1910; Brown iron ores of the Russellville district, Ala.: U. S. Geol. Survey Bull. 315, pp. 152-160, 1907; Iron-bearing deposits in Bossier, Caddo, and Webster Parishes, La.: U. S. Geol. Survey Bull. 620, pp. 129-150, 1915; Iron ore in Cass, Marion, Morris, and Cherokee Counties, Tex.: U. S. Geol. Survey Bull. 620, pp. 69-109, 1915.

[11]Lowe, E. N., Iron ores of Mississippi: Mississippi Geol. Survey Bull. 10, 1913.

series of five analyses of glauconite given by Clarke[12] the percentage of iron (Fe) calculated from the contents of ferric and ferrous iron ranges from 16 to 19.7 per cent. Glauconite is widely distributed in several formations of the Costal Plain, and in western Tennessee and northeastern Mississippi the Ripley and Selma formations, of Upper Cretaceous age, contain more or less of this mineral. It is believed that the glauconite in these and associated formations as well as in certain Tertiary formations is a possible and adequate source of the iron in the iron carbonate and limonite associated with the bauxite found in northeastern Mississippi.[13] There is evidence that these glauconite-bearing formations formerly extended farther east into Tennessee and Alabama and overlay the Mississippian rocks in the area that is now the western Highland Rim, and so it seems entirely possible that during the leaching, weathering, and erosion of the glauconite-bearing beds surface waters gathered and distributed large quantities of iron salts in solution until finally they became concentrated in the Tuscaloosa gravels and on and within the clay and chert that are residual from the underlying Mississippian limestones. This process was not direct or simple, however, for it doubtless was closely related to the physiographic history of the region, and the iron oxides may have passed through several stages of concentration before arriving at their present condition and position. The absence of deposits of brown iron ore from the eastern part of the Highland Rim lends support to the idea of the influence of glauconite-bearing formations on the ore deposits here described. This absence is due to the fact that the deposits of the Coastal Plain probably did not extend eastward across the Nashville uplift but only up on its west flank, thus lying in a favorable situation for westward drainage and concentration of iron-bearing waters on the surface of the present belt of cherty limestone.

In his discussion of the iron-ore deposits of the Waynesboro quadrangle Miser[14] recognizes the importance of the formations of the Coastal Plain as contributors of iron minerals. He states that the source of the iron is not known, but that it is believed to have been either the St. Louis limestone or rocks of Upper Cretaceous age or both. He observed few or no iron minerals in the exposed portions of the St. Louis limestone, and he cites the fact that at many places iron oxide forms a cementing material in Tuscaloosa gravel, producing hard conglomerate. The occurrence of this iron cement in the gravel indicates to him that the gravel or the Eutaw or higher beds are the source of this iron also that they may have contributed to the brown iron ores of the Waynesboro quadrangle.

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[12]Clarke, F. W., The data of geochemistry, 5th ed.: U. S. Geol. Survey Bull. 770, p. 522, 1924.

[13]Burchard, E. F., Bauxite in northeastern Mississippi: U. S. Geol. Survey Bull. 750, p. 115, 1925.

[14]Miser, H. D., Mineral resources of the Waynesboro quadrangle, Tenn.: Tennessee Geol. Survey Bull. 26, pp. 61-62, 1921.

Miser[15] has noted also the relationship of many of the brown-ore deposits in the Waynesboro quadrangle with the Highland Rim peneplain, stating:

"In a region of low relief, such as that on a peneplain, rock decay and solution would probably be more active than rock disintegration and removal, whereas in a region with considerable relief rock decay and solution would be less important in comparison with rock disintegration and removal. It therefore appears probable that the deep weathering of the St. Louis limestone to form as much as 100 feet of residual materials took place in large part during the existence of the Highland Rim peneplain, though it has doubtless continued to some extent down to the present."

It appears very probable, therefore, that much ferruginous material derived from glauconite-bearing beds was concentrated in swampy places on this peneplain. The iron may have been held in solution as a carbonate through the aid of organic acids. The peneplain probably originally contained larger areas of Cretaceous gravel, sand, and clay than at present. The Cretaceous gravel afforded easy passageways for downward-moving solutions, which deposited iron carbonate as a cementing material within the gravel. The carbonate by later alteration to hydrous iron oxide formed with the gravel the ferruginous conglomerate that is fairly common in isolated remnants of the Tuscaloosa in Tennessee but more abundant near Russellville, Ala. The larger masses of limonite naturally formed at the base of the gravel, where precipitation was favored physically and chemically by contact with the less pervious limestone and took place in the hollows on the limestone surface that were formed by solution. Such deposits are also particularly typified by the deposits at Russellville, where considerable thickness of Cretaceous gravel still remains. With the removal of most of the Cretaceous gravel by erosion and the subsequent deep weathering of the Mississippian rocks in the Tennessee area conditions favored the development of the present limonite deposits through a further downward migration of the iron-bearing solutions and settling of the existing masses of limonite into the residual clay and chert. Possibly the downward movement was halted in places by more-impervious limestone beds, which have subsequently through weathering agencies been reduced to still lower levels, leaving a considerable thickness of comparatively impervious clay or "white horse" between the ore and the present limestone surface. Also it would seem that in the western Highland Rim area the solubility of the limestone along joint openings and the porosity of the residual chert and clay of the Mississippian formations have afforded easy access for surface waters bearing iron in solution, and that these waters in percolating downward have deposited iron minerals in places where conditions favored precipitation. Masses of ore thus formed in cavities have been left as residual deposits in clay when the surrounding limestone has weathered away.

A detail in deposition that is more pronounced in the brown iron ore of the western Highland Rim of Tennessee than in other ores of this type in

[15]Miser, H. D., op. cit., pp. 57-59; also unpublished paper read at meeting of the Society of Economic Geologists, New York City, May 18-19, 1923.

the South is the large extent to which chemical reaction has taken place between the residual chert and the hydrous iron oxide. Replacement of chert, sand, and clay by iron oxide has been so extensive as to indicate a thorough saturation of the residual materials with iron-bearing solutions, which further strengthens the view that the iron has been concentrated from an external and more abundant source that lay above rather than segregated within the beds themselves.

The broader features of geologic structure have probably influenced the localization of the deposits of brown iron ore. Synclinal troughs might be expected to direct the flow of iron-bearing waters, but on the other hand surface valleys developed on anticlinal axes may have been influential. The areal geology of the western Highland Rim of Tennessee, except in the Columbia and Waynesboro quadrangles, has not been worked out in sufficient detail to show more than the broader features of the structure of the Mississippian rocks, and a study of the distribution of the brown-ore deposits as plotted on the geologic map of the State printed in 1923 on the 1:500,000 scale affords only vague suggestions of gentle synclinal or monoclinal structure in the vicinity of the ore depostis. The linear distribution of these deposits, however, suggests that they may have followed to some extent the axis of a former extensive system of caves. Collapse of the roofs of the caves would have dropped masses of clay, chert, and ore into relations such as are now found in many places. Deposits of limonite that occur below the general level of the majority of the deposits in a given locality may be ascribed to comparatively recent deposition by chalybeate (iron-bearing) waters. Such deposits are found in creek beds and on the slopes of stream valleys and generally form a cement in gravel or chert débris and partly replace these materials. Some of them are evidently in process of formation at present.

Probably there is not sufficient knowledge of the details of the physiographic development of the Western Tennessee Valley region to permit conclusions to be drawn with great assurance as to the influence of peneplanation on the formation of the deposits of hydrous iron oxide, and the same may also be true with regard to deposits of hydrous oxides of iron, manganese, and aluminum in other parts of the South, or to enable definite correlations to be made between widely separated deposits. If, however, the deposits of brown iron ore in the Western Highland Rim of Tennessee were deposited, as suggested in the above outline, during and since the development of the Highland Rim peneplain, which according to geologic evidence was formed during the Eocene epoch, it naturally follows that the ore deposits themselves are probably in part of Tertiary age and in part probably of later age, perhaps of the Pleistocene.

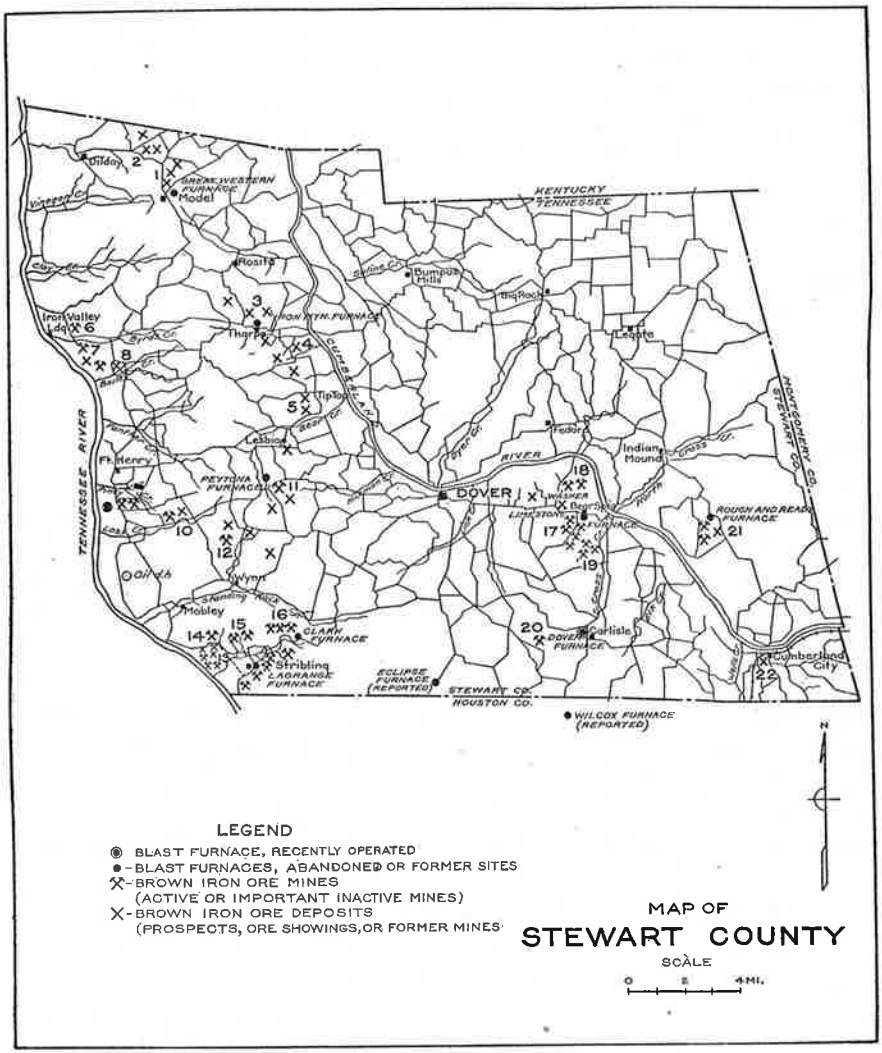
Recognition and correct interpretation of the geologic relations of the deposits of brown iron ore are of more importance in making explorations for ore than a theory as to their origin. The geologic relations can be ascertained fairly definitely, but the questions of origin will always involve more or less uncertainty and grounds for disagreement.

DESCRIPTIONS OF IRON ORE DEPOSITS

STEWART COUNTY

The brown iron ore deposits in Stewart County lie mainly between Cumberland and Tennessee Rivers (Plate 6). Within a very few years some of the ore has been used in local blast furnaces, and in 1927 a little ore was mined in connection with testing some deposits. The deposits appear to be grouped in certain areas, one group being in the northwestern part of the county, where a few deposits yielded ore, which was used in the Great Western furnace at the village of Model. At Tharpe another furnace was running in the early days and derived its ore from deposits in the vicinity of that village. Along Tennessee River deposits have been noted near the mouths of Byrds and Bailey Creeks also south of Fort Henry and in the vicinity of Stribling, on Leatherwood Creek about 2 miles from Tennessee River. Two blast furnaces utilized the ore in this vicinity—the La Grange furnace at Stribling and the Clark furnace one and one-half miles farther up Leatherwood Creek. Near the south boundary of the county, also on Leatherwood Creek about 6 miles east of Stribling, is the reported site of the Eclipse furnace, which was said to have derived its ore from near-by ore banks. Between Stribling and Cumberland River are several deposits of iron ore that were mined for the old Peytona furnace, which was situated on the headwaters of Bear Creek about six and one-half miles west of Dover. An important area is in the vicinity of Bear Spring, where a furnace was operated for many years. The blast furnace that was in operation latest in this county was the Dover furnace at Carlisle, where it is reported iron was made during and even after the World War. Another group of deposits lies north of Cumberland River near the site of the Rough and Ready furnace, about 3 miles south-southeast of Indian Mound. The Stribling furnace was once connected with the Louisville & Nashville Railroad at Danville by a branch line 6 or 7 miles long, but that line has long since been abandoned. The furnaces at Carlisle and Bear Spring were likewise on a branch, which connected with the Louisville & Nashville at Tennessee Ridge, but this branch has been taken up since the World War. Other charcoal furnaces, reported as operating in early days but not located in the course of this survey, are the Randolph furnace, on Lick Creek south of Dover, and the Bellwood furnace, the location of which could not be ascertained. Besides these blast furnaces there were many forges, and it is reported that an establishment known as the Cumberland Rolling Mills was situated near Dover. In Houston County, south of Stewart County, were the Brunsoni furnace and the Wilcox furnace. In addition to the ore that was consumed locally some ore from the vicinity of Tennessee River was transported by water to furnaces near Paducah, Ky.

It seems probable that there are more ore-bearing areas in this county than is indicated by the scattered groups of deposits mentioned above. Only



Map of Stewart County, showing locations of iron-ore deposits, mines, and blast furnaces

those deposits have been mined that were within wagon haul of the furnaces to which the ore was delivered, and therefore in areas more remote from the furnaces ore may very well exist that was not drawn upon in the early days of iron making.

In 1881 Killebrew stated that there were large deposits of iron ore on the north side of Cumberland River, which had not been developed at all because they had not been needed, and they may exist today, as there has been little or no mining in that part of Stewart County for 50 years.

Deposits near Model.—The Great Western furnace (see Plate 7, A) at Model is reported to have been built in 1857 and was operated about one and one-half years. Lack of capital and a threatened insurrection of negroes are reported to have caused the shutdown. The ore supply was obtained from banks on the hills in the surrounding country. Immediately northwest of the village (locality 1, Stewart County[16]) are deposits of quartz gravel and ferruginous conglomerate at the top of the ridge, at an altitude of about 650 feet, and from altitudes 560 to 600 feet is a terrace showing fragments of chert and of limonite. Limestone exposed in the valley at altitudes of about 500 to 525 feet is reported to have been used in the construction of the furnace as well as for flux in making iron.

On land of T. G. Askew and the A. B. Smith Lumber Company, about one and one-half miles north of Model (locality 2, Stewart County), are 10 or 12 shallow pits from which ore was dug for the Great Western furnace. The ore deposits ranged in altitude from about 555 to 580 feet, but the neighboring hills rise to greater altitudes and are evidently capped with gravel, as is indicated by float pebbles around and above the pits. Some fragments of limonite of good quality was noted, but much of the visible ore débris is sandy and light colored and contains some pebble conglomerate.

Deposits near Tharpe.—At Tharpe is the site of the Iron Mountain furnace. This furnace is reported to have been operated only about two years and to have discontinued operation four years before the Civil War, on account of an uprising of negroes. According to the quantity of slag in the vicinity of the ruins it does not appear to have made a very large production of iron. Apparently there was not a very abundant supply of iron ore in the immediate vicinity, as the only evidence of mining now visible consists of a few small pits on the neighboring hills (locality 3), but it is reported that ore was hauled from the Iron Valley ore banks near the confluence of Byrds Creek and Tennessee River also from deposits southeast of Tharpe as far as Tip Top. On land of George Brennan and others 1½ miles southeast of Tharpe (locality 4) good ore in pipe-shaped masses was obtained from a pit on the bottom land of Barretts Creek at the point of a spur, at the altitude of about 400 feet. Other sources of ore supply for the Iron Mountain furnace were shallow pits on the Rowlett place west of Tip Top.

[16]The locality numbers refer to the county maps.

Deposits near Tip Top.—Half a mile southwest of Tip Top (locality 5), on land of C. S. Carney, W. H. Whitford, and M. P. Riggins, float limonite of sandy and cherty character and generally of low grade, is exposed to a considerable extent on the upland at an altitude of about 600 feet. In a field on the Whitford place so much cherty limonite is plowed up as to be a nuisance in cultivating, and it has been gathered into piles outside the field. These piles appear to contain about 75 per cent of chert. On the hill slopes surrounding the fields there are masses of ferruginous conglomerate containing some quartz pebbles.

On the place of J. R. Rowlett, about a quarter of a mile north-northeast of the Whitford place, are four or five old pits at an altitude between 550 and 575 feet where ore was dug and screened for use in the old Iron Mountain furnace at Tharpe. The dumps show light-brown ore waste. These pits are on the southeast brow and slope of a small ridge. Some fine float ore is lying along the road and paths in the vicinity, but the indications are not promising for a large ore reserve.

Deposits near Byrds Creek.—About 7 miles west of Tharpe on the north side of Byrds Creek, on the left side of a small hollow that drains into the creek near its mouth, are three or four small cuts in the hillside, also on the south side of Byrds Creek in the same vicinity are five or six openings (localities 6 and 7). These diggings are known as the Iron Valley ore banks and are understood to be on the land of Mr. A. H. Thomas who lives near by. Openings are 20 to 30 feet above the drainage at an altitude of about 450 feet at the top. These openings give evidence that the extent of the remaining ore is probably small. The overburden is chert débris, clay, and gravel 10 to 15 feet thick and more or less pockety, and the materials associated with the ore are of similar character. Masses of ferruginous chert crop out on the hillsides. One narrow cut that has been made through solid chert beds probably followel a ferruginous streak or vein. Some ore piled near the openings is of fair quality. Some is lump ore of the honeycomb variety, but most of it is of the chert-replacement type.

These deposits are well situated for mining and water transportation. It is reported that ore was shipped from here by way of Tennessee River to Paducah, Ky., as well as by wagon to the furnace at Tharpe. There was formerly a mule tramway running to the river about three-fourths of a mile distant, and a washer stood on the river bank. Lump ore was cobbed by hand and shipped directly from the mines without washing. The openings on the south side of Byrds Creek were also connected by tramway with the landing.

Deposits near Bailey Creek.—About three-fourths of a mile northeast of the mouth of Bailey Creek are the old Brantley ore banks, owned by J. E. Carr and others dwelling in the vicinity (locality 8). The old mine pits were cut back into the left bank of a small branch flowing into Bailey Creek from the north. These openings extend northeast along the hillside about 600 feet and are 15 to 20 feet deep. Their altitude is about 440 feet. The

cuts were evidently made many years ago and are caved and thickly overgrown with brush, so that they do not show much ore. Some of the dumps and waste banks show sandy ferruginous crusts and fragments of low-grade limonite. The ore was evidently mostly of the chert-replacement type, although a little associated gravel was noted. Evidently not much good ore was left after mining ceased. The associated rock is principally chert, some of it being of a white variety. It is reported that ore was hauled by wagon to Tennessee River at St. Johns landing.

Deposits near Fort Henry.—One and a half miles south of Fort Henry just east of the flood plain of Tennessee River are the old Paynes ore banks, which consist of pits and trenches on the north side of a small creek. (Locality 9). These pits extend about 800 feet back into the hillside from the floor of the hollow. Some range in altitude from 420 to 460 feet and another level shows pits at about 500 feet altitude. There are probably two acres of old diggings and dumps here, occupying a narrow spur between two hills. The vertical range in ferruginous material amounts to 80 feet, but ore was probably not continuous throughout this distance. The associated rocks are chert, clay and gravel, the gravel containing quartz pebbles characteristic of the Cretaceous. A small pile of ore remains at the mouth of the hollow on the river road, showing ore mainly of the chert-replacement type and some honeycomb ore of good grade. The dumps show much chert that has been cobbed out of the ore, and it is probable that most of the best ore has been worked out. Ore was formerly shipped down Tennessee River from Paynes landing to the furnace of the Paducah Iron Company, which is reported to be the owner of the property.

Two and a half miles southeast of Fort Henry, on the north side of Lost Creek (locality 10), are the old Lost Creek ore banks, also belonging to the Paducah Iron Company. On the east and west sides of a hollow a quarter of a mile north of Lost Creek Church are several small openings in masses of limonite that have replaced or partly replaced chert. The altitude of the deposits is about 500 feet. The deposits are pockety and evidently were 10 to 20 feet thick. They are situated on the sides of the hollow where there is considerable overburden. The associated rock is chert, and the ore is limonite of the chert-replacement type, some of it good-grade honeycombed laminated ore. Two stock piles, apparently containing more than 100 tons of clean-cobbed lump ore, were noted here in May, 1923.

Deposits in Peytona furnace locality.—The Peytona furnace site (locality 11) is about 6 miles due west of Dover, near the headwaters of Bear Creek. There are many shallow pits in the surrounding country from which limonite was obtained for the Peytona furnace. These pits are not situated on the tops of the ridges but 20 to 100 feet lower, at an altitude of about 585 feet. They are evidently about at the base of deposits of Cretaceous gravel that cap the ridges but still some distance above drainage level. The deposits here are apparently of irregular outlines and depths, following the contours

of the hills and extending downward because of secondary deposition. The range in depth is probably 10 to 40 feet. Probably the better part of the ore had been worked out upon the abandonment of the furnace.

Deposits northeast of Mobley.—About 3 miles northeast of Mobley and 8 miles southwest of Dover are the old California ore banks (locality 12), understood to be the property of the Ayer-Lord Tie Co. The old mine pits, 10 to 15 feet deep, cover an area between 2 and 3 acres on terraces at the sides of a north branch of Standing Rock Creek. These terraces are at altitudes between 530 and 580 feet and are 75 to 100 feet lower than the top of the neighboring ridges.

The overburden in places consists of 8 to 10 feet of white chert and clay. As a rule the ore does not show much at the surface, but masses crop out in the hillsides. The associated materials are chert, clay, and gravel. Cherty limestone lying nearly flat was noted in the creek bed about 50 feet lower than the iron-ore deposits. Deposits of Cretaceous gravel cap the ridges above the ore deposits. The ore visible in the waste dumps was of fair grade and some of it consisted of crusts of rich, black and dark-brown limonite, but there is more or less sandy and cherty material present.

The old mine openings appear to have comprised between 2 and 3 acres within an area of probably 8 to 10 acres that has been more or less prospected and dug over in favorable places when mining was active. Probably some ore still remains in this property, because mining was suddenly terminated by the Civil War. The ore was cobbed and screened then hauled up over the ridge to the Peytona furnace, a distance of about 2½ miles. The only possible outlet now would be by wagon road to Tennessee River, a distance of at least 5 miles, thence by boat to markets either up or down the river. The nearest good supply of water for washing is in Ribbon Branch half to three quarters of a mile distant.

Deposits near Stribling.—Pig iron was produced from local ores before 1900 at La Grange furnace at Stribling, on Leatherwood Creek about 1 mile northeast of Tennessee River, and at Clark furnace on the creek about 1½ miles above Stribling. Neither of these furnaces is now standing. When active the La Grange furnace was connected by railroad with the Louisville & Nashville Railroad at Danville, on Tennessee River 6 miles south. This branch line has long since been removed.

In May, 1923, the property was reported to be owned by the La Grange Plantation Company, Inc. The plantation is reported to comprise 27,000 acres of land, mostly timbered, but 350 acres more or less is bottom land in the valleys of Tennessee River and Leatherwood Creek. This bottom land is farmed, soya-bean hay being the principal crop. Five or six large mine pits and many smaller ones were noted. Some of these pits are in the low foothills of chert that border the valleys, and others are at the base of the foothills, practically at flood-plain level. Considerable mining was done in this area, as is shown by the size of the pits, some of which are as much as 600

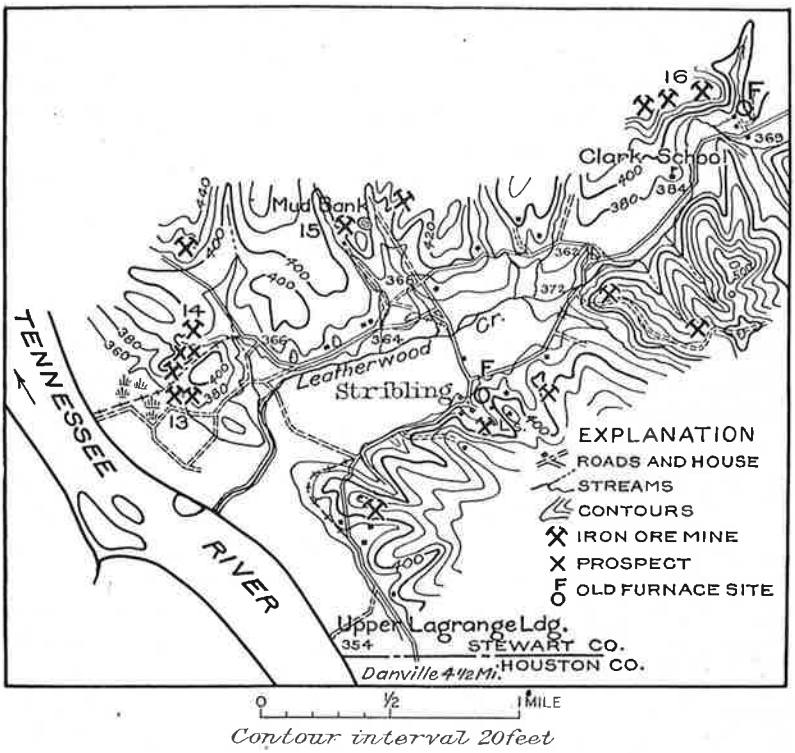


FIGURE 1.—Map of Stribling and vicinity, showing locations of brown iron ore mines and blast furnaces.

feet long, 200 feet wide, and 40 feet deep. The local topography and the locations of these pits and furnaces are shown in figure 1.

The Swamp Bank mines (localities 13-14), consisting of the Clark, Franklin, Carney, Mallory and Sterling pits, 350 to 400 feet long and 25 to 40 feet deep, have been excavated in a worn-down spur of the upland west of Leatherwood Creek and less than half a mile from its mouth. The altitude of these pits ranges from 365 to about 390 feet. At the time of visit water stood in the lowest pits, which were poorly drained, being on the edge of a swamp on the flood plain of Tennessee River. The rocks associated with the ore are clay and disintegrated chert, some of which is white and passes over into the "white-horse" clay, common in some other brown-ore deposits in this region. No limestone was found closely associated with the ore, although this rock was quarried for flux at about the same level in a pit a short distance south of the La Grange furnace and was encountered in several drill holes. The ore in the Swamp Banks is not generally of high grade, as sandy crusts are common, but some good needle ore was noted. As these deposits are topographically among the lowest brown ores of this region, the question naturally arises as to whether they were formed in this situation at the same time and in the same manner as the deposits on

higher levels. There is some evidence that waters carrying iron in solution, which have descended from higher levels, have formed mammilary sheets of ore, generally siliceous, but rich in spots. In places a mass of horizontally bedded limonite 6 to 10 feet thick has been exposed in a few open cuts. In one cut this mass of ore contains an interbedded layer of chert 6 to 8 inches thick, (See Plate 8, A), and the relations suggest that the limonite has been deposited here through the replacement of chert. Ferruginous conglomerate is also present, and pockets of angular to subangular creek gravel show in the banks and talus. Although many masses of ore are exposed in the pit banks, the question arises whether an ore reserve lies below water level, where pumping would be necessary in mining. The La Grange property in this vicinity has been thoroughly prospected as described on pages 45 and 46.

North of the Swamp Bank pits is an old "tunnel" mine, situated on the point of a ridge at an altitude of about 420 feet. According to notes by C. C. Anderson, this opening is about 20 by 25 feet and 6 to 8 feet high and was excavated by hand. The deposit appears to have covered about an acre and to have had a thickness of 6 to 15 feet. There is a light covering of soil, chert, and clay. The ore is very bouldery and contains much chert and clay. As in most deposits some high-grade needle and botryoidal limonite are present. The ore appears to be mostly of the chert-replacement type, and the proportion of ore to waste appears to be favorable. Probably if the other mines were reopened in the Stribling locality the deposits in the vicinity of this tunnel would contribute a share of ore, but they are not considered sufficiently large to open independently.

The Mud Bank mines are also among the large openings in this vicinity. These openings (locality 15) are in a branching hollow northeast of Leatherwood Creek about three-fourths of a mile northwest of the site of the old La Grange furnace, at an altitude of about 400 feet. A few pits were situated 20 to 30 feet above the floor of the hollow on the chert hillsides, but the deep pit of the mine is not so far above the floor of the hollow. The large pit is about 175 feet by 350 feet with banks rising to a height of 35 feet above the water that occupied a good part of the area of the pit when visited, as shown in Plate 8, B. Ore is exposed in the west end of the pit. This ore is good in spots but is generally sandy and appears to be of the sand and chert replacement type. Very little gravel of the Cretaceous deposits that are ordinarily found on the high hills in this part of Tennessee was noted in this locality.

The mines north of Clark School (locality 16) supplied the Clark furnace with ore. The ore bank is on a spur of the ridge, at an altitude of about 500 feet, and the pits are 25 to 30 feet deep. The overburden is reddish sandy clay and disintegrated chert. The old ore dumps appear to consist of waste material from which practically all the ore had been separated. The ore is said to have lain under considerable overburden, and as slumping

down of the sides of the pit would effectually conceal any possible showings, very little ore can be seen. The Clark furnace is reported to have been shut down in 1891 or 1892, and there has been no mining since that time.

The following analyses reported as of "Stribling" ore were obtained from undated records of the laboratory of the former Bon Air Coal & Iron Corporation at Wrigley furnace in May, 1923. If this ore came from deposits near Stribling in carload lots, it must have come before the railroad from Danville to Stribling was removed, for the expense of hauling to the railroad a material so high in silica and so low in iron would hardly have been justified. Phosphorus, it will be noted, is higher than is desirable for charcoal iron.

Analyses of brown iron ore from Stribling (?) mine

Car loads	Iron (Fe)	Insoluble	Phosphorus (P)	Manganese (Mn)
.....	40.04	35.78	0.43	.....
.....	40.21	33.49	.43	.....
.....	33.70	37.37	.43	.....
.....	33.79	39.90	.44	0.23

In the spring and summer of 1930 a thorough campaign of exploration of a part of the La Grange properties at Stribling was carried on by a large company interested in obtaining supplies of iron ore. The area most intensively prospected was that described above as the Swamp Banks, about half a mile square, beyond which a string of drill holes extended northeastward about half a mile toward the Mud Bank mine. Topographic maps were made on a scale of 200 feet to 1 inch, with contour intervals of 5 feet, and ten cross sections were prepared on a scale of 100 feet to 1 inch. Nine of these sections ran south across the Swamp Bank area at 200-foot intervals, and the tenth section extended northeastward between the Mallory pit and the Mud Bank. In addition to the maps and sections graphic records were made of all drill holes and test pits. The large-scale topographic maps enabled all drill holes and test pits to be plotted accurately according to geographic location and altitude, so that the cross-sections show in their true relation the profiles of the mine pits, the depths of the test holes, and the thickness and position of the deposits of ore, where any were found. The results of this painstaking work, which have been made available to the writer, bring out some interesting facts.

In the prospecting 30 churn-drill holes and 24 test pits were put down by the exploring company, and records of 8 churn-drill holes put down by the owners of the property were available for comparison. The sludge from the drill holes put down by the exploring company was analyzed throughout the depth of most of the holes for its content of iron and in 11 holes for its content of silica. The sludge was first washed free of clay, which made up about one-half of its volume. If a zone showed a fair content of iron,

apparently 15 per cent or more in the sludge, the material was subjected to separation in a heavy liquid, acetylene bromide. This heavy liquid has a specific gravity of 2.95, so that silica, with a specific gravity of 2.63 will float upon it, and limonite, with a specific gravity of 3.6 to 4, will sink in it. The records of these tests show the thickness of ore-bearing ground tested, the percentage of material that sinks in the heavy liquid, and the percentages of iron and of silica by analysis in the "sinks."

A summary of the results of the prospecting shows that the depths of the 30 churn-drill holes put down by the exploring company ranged from 25 to 151 feet, and that the ore-bearing cherty clay was encountered in 8 holes, in thicknesses ranging from 15 to 75 feet. The sludge carried from 1 to 27 per cent of iron and 95 to 44 per cent of silica. In the 8 holes that were ore bearing the sinks ranged from 5 to 52 per cent, and these sinks carried 43 to 54 per cent of iron and 23 to 10 per cent of silica. In the 8 holes drilled by the owners 3 showed no ore, and the composition of the material from the others was fairly comparable with that of the material from the 8 ore-bearing holes drilled by the exploring company. Of the 24 test-pits, which ranged from 10 to 38 feet deep, only 3 showed ore, the maximum thickness of ore-bearing chert encountered being 29 feet.

The sink and float tests were of interest as indicating the applicability of this method for laboratory use, and the results are considered to have been practically the same as could have been obtained on a large scale by using mechanical methods of concentration under water. Use of the heavy-liquid separation on a commercial scale is reported to have certain disadvantages as applied to this type of iron ore. For instance, the ore has a high porosity, which would require that it be ground to a powder, too fine for blast-furnace use unless sintered; the intimate mixture of chert with the ore makes a separation by this liquid, except on the very fine sizes, no better than could be obtained by concentration under water; and finally the cost of the heavy liquid is regarded as too great.

Taken altogether the prospecting did not yield sufficient ore to make up a few carloads to be shipped to milling plants in Missouri and Minnesota, where it had been planned to make concentration tests on a commercial scale. Prior to the exploration it seemed possible that ore might be present in much of the area between the old pits and to a depth as great as in the former workings, but the painstaking survey and testing to which the property has been subjected show that the ore was apparently confined to lens-shaped bodies that, for the most part, have been already excavated. It thus appears that the existence of an iron-ore reserve of economic importance in the vicinity of Stribling has not been established, and that the low-cost ore has been mostly exhausted. Mining would be handicapped in part of the area tested by heavy overburden and in low places by water, although plenty of water would, therefore, be available for concentration of ore.

Deposits near Bear Spring.—The Bear Spring locality has been one of the most important iron producers in Stewart County. The old charcoal furnace, built of rock in 1873, still stands on the south side of the road west of the spring (see Plate 7, B), and when active derived its ore supplies chiefly from deposits within a radius of 1¼ miles, although originally there were some 57,000 acres in the Bear Spring furnace property, including its timber lands. The Bear Spring locality was at one time connected with the Louisville & Nashville Railroad by a branch railroad from Tennessee Ridge, Houston County. This branch has now been entirely removed.

The high parts of the ridges south of Bear Spring furnace nearly all contain ore, and many large and small openings are still available for inspection. One of these is the "Grave Yard" ore bank (locality 17), at an altitude of about 550 feet. The ore here lies from 10 to 20 feet below the surface and may have a thickness of 25 to 30 feet. The ore is generally a fair grade of limonite, mostly of the chert-replacement type, but contains a good deal of cherty conglomerate in places. There is considerable wash ore in the screened dumps all around the Grave Yard workings, and some ore shows in the sides of the pits. Talus, however, covers much of the walls, so that the ore can not well be seen. There are masses of lean chert-replacement ore and ferruginous material of the clay-replacement type, which is of too low a grade for the blast furnace but contains here and there very rich streaks of limonite. Systematic prospecting by drill is reported to have been done on the areas between the pits, and this is said to have shown ore corresponding to that already mined. It is reported locally that the early mining was very carelessly done and that for every ton of ore recovered 2 to 3 tons was buried or rendered inaccessible, owing to the reckless and greedy methods followed by the miners, working on a tonnage basis, who sought only the most easily obtained and best quality ore. The ore from these openings was hauled by wagons to a small washer near the Bear Spring furnace. Some was mined by steam shovel, but much was won by hand. There is probably a large quantity of ore still in the ground here, and much might be recovered by rewashing the old dumps. Water stood in the bottoms of some of the old pits, probably due to heavy rains that had fallen shortly before the time of visit. Most of these pits could be drained easily if mining should be resumed. A deposit of ore associated with chert débris, clay, and gravel was formerly worked at the head of a hollow on the opposite side of the road and a little west of the Bear Spring blast furnace. This was known as the "Hotel" ore bank, and the ore was delivered by wagon to the small washer near the furnace.

A little more than half a mile north of Bear Spring on a ridge between Bear Spring and Cumberland River are three to four mine pits, known as the Skunk Hollow workings (locality 18), where ore lies in round pockets under a cover of 25 to 30 feet of chert débris, gravel, and clay, at an altitude of 450 to 475 feet. The ore found here probably extends below the bottom

of the pits. A large washer was erected several years ago near the head of Skunk Hollow and was supplied with water piped from Bear Spring about 1 mile distant. The washer consisted of two 25-foot logs, one rougher rotary screen, one picking belt, ore bin, ore box and elevator, rotary screen, 4-celled jig, elevator for ore and waste chert, and loading bin over the railroad siding. This washer had not been operated for two or three years, possibly longer, prior to 1923 but was then in fair shape. The washer is about three-quarters of a mile from the main Bear Spring road, and a railroad spur ran to it over which ore was shipped to the blast furnace at Clarksville. Some ore carrying 48 per cent iron was shipped in 1920. The rails have since been removed from this spur.

Clarksville parties are reported to own much of the ore land in the vicinity of the Bear Spring furnace. The most recent developments in the Skunk Hollow locality are reported to have taken place in 1927, when the Tennessee Products Corporation took options on and prospected some of the property. About 200 tons of ore was mined and put through the washer, including treatment in McLanahan-Stone jigs, and yielded ore of high grade, showing a range of 48 to 53 per cent iron, 8 to 19 per cent insolubles, 0.18 to 0.22 per cent phosphorus, and 0.18 to 0.28 per cent manganese.

Shipment of the ore was made to the Wrigley furnace in Hickman County, which required a long truck haul to the railroad, and this together with the freight charges made the ore too expensive at the blast furnace. There is much ore still available here, but it will probably have to be utilized at some place where advantage could be taken of water transportation. It is suggested that the ore be loaded on cars, which might be barged up Cumberland River to Hematite station on the Louisville & Nashville Railroad.

One and a quarter miles south of the Bear Spring furnace is the Potato Patch Hollow mine (locality 19), owned by parties in Clarksville. The old mine pits and prospects are of irregular branching plan and are situated near the tops of the ridges and spurs at altitudes of 530 to 570 feet, approximately 150 feet above the level of Bear Spring. The main pit extends about 500 feet in a direction N. 30° E., is 60 to 80 feet wide, and 20 to 30 feet deep. Mining is said to have begun before the Civil War, and there were extensive operations with steam shovel and washer between 1900 and 1903, followed by "wagon mining" on a small scale about 1912-13. Before the railroad was removed ore was shipped from here to the blast furnace at Clarksville as well as to the Bear Spring furnace. The ore overburden consists of pockets of clay and chert débris from a few feet to 15 feet thick. A fine-grained siliceous limestone resembling "cotton rock" outcrops about 50 feet lower than the bottom of the workings. The ore is limonite of fair grade, mostly of the chert-replacement type, but contains considerable angular chert conglomerate. The impurities are chert, silica, and ocherous clay. Conglomeratic and cherty ferruginous material outcrops in places. From the evidence afforded by prospects and by the walls of the old mine openings considerable

(A) Stack of Great Western furnace at Model, Stewart County, erected 1854.

(B) Stack of Bear Spring furnace at Bear Spring, Stewart County, erected 1873.

(A) Face of brown iron ore ledge in Swamp Bank of La Grange property, Stribling, Stewart County. Right end of ledge at hammer handle shows a band of chert.

(B) Mud Bank brown iron ore mine, La Grange property, Stribling, Setwart County.

(A) Lock D on Cumberland River just below Dover, Stewart County, 1923.

(B) Dover furnace at Carlisle, Stewart County. Latest old-type charcoal furnace to be operated in Tennessee.

ore still remains in the areas between the old pits, and there is probably some ore below the bottoms of the pits and some that might be recovered from the old dumps. Conditions are favorable for mining except that water for washing must be piped from South Cross Creek about three-quarters of a mile distant. The hard-wood timber suitable for making charcoal has been very nearly exhausted from this vicinity, so that none of the old charcoal furnaces may be expected to resume operations, but it still might be feasible to barge ore from this vicinity on the Cumberland River. Navigation on Cumberland River is aided by Lock D below Dover (Plate 9, A).

Deposits near Carlisle.—One and one-half miles west southwest of Carlisle on land reported to belong to Clarksville parties are deposits of limonite (locality 20) that have been mined to supply the blast furnace at Carlisle. These deposits lie on the north border of the valley of a small branch of South Cross Creek at an altitude of about 500 feet. The old mine opening extended about 150 feet east and west, about 60 feet into the hillside, and is about 25 feet deep. The continuation of the ore beyond this pit is uncertain, but it is likely to continue for an equal distance westward. The iron-bearing material outcrops at the surface on the crest of the ridge and is associated principally with disintegrated chert and residual clay. Much of the chert is in rounded knobs and balls. Pockets of light-colored gravel were noted also in association with the ore. Flat-lying limestone is prominently exposed on South Cross Creek at Carlisle at a level about 100 feet lower than the iron-ore deposit, but none was noted closer to the deposit. The ore consists of limonite that has replaced or partly replaced and cemented masses of chert and is present also as the cementing material in pebble conglomerate. A notable proportion of the limonite is honeycombed in structure. The ore is generally of low grade but by cobbing some was obtained for use in the furnace. A few piles of low-grade lump ore were in the pit at the time of visit. The location is favorable for mining, except that water to supply a washer would probably have to be pumped from South Cross Creek, one and one-half miles distant. The latest mining here is reported to have been done about 1870.

The Dover charcoal furnace at Carlisle, which is shown in Plate 9, B, is said to have been in operation during and since the World War and is the latest blast furnace to have been operated in Stewart County. Its capacity is 15 to 20 tons of pig iron per day. Ore supplies for the late operation were obtained from deposits near Bear Spring and were transported on the railroad that extended from Tennessee Ridge to Bear Spring by way of Carlisle.

An analysis of the cold-blast charcoal pig iron from the Dover furnace, made by the Bon Air Chemical Co., December 2, 1926, showed the following percentages: Silicon, 1.70; sulphur, 0.024; phosphorus, 0.42, and manganese, 0.18.

Dr. Richard Moldenke[17] has published the following historical note on the Dover furnace.

"One of the most interesting furnaces—the only cold-blast furnace of the South today—is that at Carlisle (Bear Spring). Mr. Graham Macfarlane, the president of the Dover Iron Company, has communicated the following to the writer as historical of the region. 'Dover furnace was built in 1828 by Pennsylvania ironmasters; Woods, Yeatman & Co. of Nashville financing and eventually operating the property. In 1840 they had three furnaces: Dover, Bear Spring, and Bellwood. The estate comprised 110,000 acres of virgin forest, with extensive ore and limestone deposits therein. Part of the iron was direct metal and went into sugar kettles up to 84 inches in diameter. Connected with the business was a rolling and nail mill. The firm owned 350 slaves and hired many others. Corn, hay, hogs, and other provender to the extent of 5,500 tons per annum was raised on the spot, and had a value of $350,000, the owners living like feudal barons. The steamer Yeatman took the first cargo of Dover iron to Pittsburgh. In February, 1862, a day after the fall of Fort Donelson, Foote sent a gunboat and destroyed Bellwood furnace and rolling mill. After the Civil War Dover furnace was put in blast and Bear Spring furnace rebuilt. Charcoal is made in open pits or heaps, covered with leaves and coal dust. It is made in the woods and the charcoal hauled several miles to the furnace. One cord thus yields 33 bushels of charcoal and it takes 165 bushels of charcoal to make a ton of cold-blast pig iron. No by-products are recovered, and the yield is only two-thirds that of the regular retort distillation process.'"

In northern Houston County, about 3 miles south of Carlisle and not far from the railroad, is the reported site of the Wilcox furnace, which may indicate the presence of ore deposits south of Carlisle.

Deposits southeast of Indian Mound.—About 3 miles southeast of Indian Mound is the site of the Rough and Ready blast furnace. Iron ore was obtained from old pits around the edge of a hollow that opened west-northwest into drainage that flows into Cumberland River. These pits (locality 21) are about half a mile south of the site of the furnace and extend for a length of a quarter of a mile or more with a width of more than 200 yards. The pits are on gentle hill slopes from an altitude of 575 to about 635 feet. Most of the pits are shallow, but the lowest ones, which are in the heads of small ravines, show faces of 15 feet or more. In one ravine a drift has been run back under the bank, and ore has been mined from underground. Water flowing down from the top of this opening is now depositing iron oxide. The deposit ramifies over 2 or more acres but seems to lie more or less in the form of a thin blanket on the hillside and rarely shows more than 10 to 15 feet depth. The overburden, which consists of clay, chert débris, and gravel, appears to have been thin near the top of the ridge but in the ravines attained a thickness of 5 to 6 feet. The material associated with the ore was chert, clay, and gravel. In the upper parts of the deposit the outcrops of pebble conglomerates cemented by limonite doubtless suggested the presence of ore below. Lower down the chert-replacement type of ore predominates, and in the ravines limonite has replaced some clay. The ore was dug by hand and cobbed free of chert, yielding good crusts and shells of limonite. From the mine workings the ore was carted to the furnace over rough and difficult

[17]Moldenke, Richard, Charcoal iron, pp. 23-24, Lime Rock, Conn., Salisbury Iron

roads, piled up on wood ricks, and then burned to free it of clay and decrepitate it, after which it was screened before being fed into the furnace. This burned ore is said to have worked better in the small furnaces of the time than ore that was not so treated. On account of the practice of burning the ore preliminary to its use in the furnace and the shortage of water supply no washer seems to have been employed at these mines. There does not seem to be an important reserve of brown ore here for further mining, although if deposits should be found by further prospecting it would not be difficult to transport the material to Cumberland River, as at present a logging railroad runs to this vicinity from the river, over which hardwood logs and ties are transported to barges. Other ore pits are reported to have been opened farther southeast on both sides of the furnace hollow. The mineral rights on the Rough and Ready tract are reported to be held by Evansville, Ind., parties.

Operation of the furnace is reported to have continued up to about 1870, and pig iron was carted to the river, down which it was shipped by barge. The timber on this tract is said to contain the last of the original stand in this part of Tennessee, although only a few of the original trees remain. Charcoal making 50 to 75 years ago removed most of the first growth, and most of the timber now being cut is large second-growth material.

In 1881, according to Killebrew[18] the Rough and Ready property comprised 8,000 acres, and every variety of limonite was found there in all directions from the furnace for 5 or 6 miles.

Deposits near Cumberland City.—One small deposit of limonite in southeastern Stewart County deserves mention, chiefly because of its location. One-quarter of a mile southwest of Cumberland City (locality 22) at an altitude of about 482 feet, 100 feet higher than the Louisville & Nashville Railroad at the station or about 140 feet above Cumberland River, a small showing of limonite has been exposed in a prospect on the land of L. E. Thomas of Cumberland City. The limonite occurs in crusts, geodal lumps, and as cement in gravel and cherty conglomerate, also to a small extent as a replacement of chert. Outcropping masses of this material and lumps of limonite plowed up in the neighboring fields led to the prospecting of the locality, and it is said that there is considerable limonite scattered all along the ridge south of Cumberland City. There is not a sufficient showing of limonite here to promise a workable deposit.

BENTON AND HUMPHREYS COUNTIES

Neither Benton nor Humphreys County has produced a notable quantity of iron ore, and but few deposits are known to exist within their boundaries. In August, 1927, E. F. Burchard, accompanied by W. F. Bailey of the State Division of Geology, made a hasty inspection of certain deposits reported to occur in these counties.

[18]Killebrew, J. B., op. cit., pp. 99-100.

The largest showing of ore that was seen in Benton County was on the "Scarborough" property about 2 miles in an air line east-northeast of the town of Faxon, on the Louisville & Nashville Railroad. The ore was disclosed in and about some old pits on the top of a ridge composed of Mississippian chert, 2,000 to 2,500 feet southeast of the house of Robert Gross, which is on the south side of the railroad. Some lumps of limonite appeared to be of very good quality, but others were more or less cherty, suggesting that replacement of chert had been the method by which the limonite had been deposited. One-fourth of a mile east-southeast of the prospect pits a hillside outcrop shows sandy, cherty limonite. It was reported that this ore was mined in a small way during the Civil War for use in a furnace near Tennessee River, also that ore from here was shipped by the river to the La Grange furnace in southwestern Stewart County. It seems possible that these reports refer to one and the same furnace.

A specimen of ore averaged from a number of lumps in the vicinity of the old pits showed the following analysis.

Analysis of ore from 2 miles east-southeast of Faxon

(D. F. Farrar, analyst.)

Iron (Fe)	Insolubles	Phosphorus (P)	Manganese (Mn)
48.92 per cent	14.76 per cent	0.47 per cent	1.85 per cent

This tract is well situated with reference to transportation, being only about half a mile south of the Louisville & Nashville Railroad and 2 miles or less by road from Tennessee River. The general associations of the ore are similar to those in the vicinity of Stribling, Stewart County, and seem to indicate that the ore would contain considerable chert, but that it might be present in fairly large masses.

In Humphreys County there are several places where iron ore has been found along the ridge half a mile to 1 mile north of the Nashville, Chattanooga & St. Louis Railway and 3 to 6 miles west of Waverly. One of these is on land of Hon. C. W. Turner, about 3 miles west of town and two-thirds of a mile from the railroad, where limonite outcrops in places in the creek bed and on the south face of the ridge. The ridge is composed of Mississippian chert, and fossil lithostrotions, characteristic of St. Louis beds, were noted. The quality of the ore appeared good, but the outcrops suggested a pockety form rather than continuous large masses of ore. A specimen chipped from representative pieces of ore at a small prospect opening gave the following analysis, which shows good quality in the ore except that the phosphorus is a little higher than is desirable.

Analysis of iron ore from 3 miles west of Waverly

(D. F. Farrar, analyst.)

Iron (Fe)	Insolubles	Phosphorus (P)	Manganese (Mn)
52.69 per cent	9.26 per cent	0.58 per cent	1.10 per cent

Another place where float limonite was seen is on an old road that ascends the ridge a short distance northwest of Franks siding. This locality

is about 6 miles west of Waverly and half a mile north of the railroad. It is reported that many years ago ore was obtained in the vicinity of Franks and reduced in the Fairchance furnace, which stood 10 or 12 miles northwest of Waverly.

Specimens of iron oxide cementing pebbles of chert sent to the State Division of Geology were traced to a source on the Griffith property a short distance east of Hustburg, about half a mile east of the Waverly-Camden road. This material is exposed in a gully eroded in a deposit of chert gravel. The ferruginous material occurs in a layer 1 inch to 3 inches thick and is exposed for a distance of a few rods, dipping with the bed of gravel toward the southeast. This material does not constitute an iron ore itself nor can it be regarded as an indication of a valuable deposit anywhere else in the vicinity. It is simply a recent deposit of iron oxide from water seeping through the gravel.

In southeastern Humphreys County a massive outcrop of limonite was seen at the side of a branch on land of L. D. and Jesse Rice, 3 miles east-southeast of Bold Springs. This is a long distance from a railroad, but it appears possible that larger deposits of ore might be found by prospecting in this vicinity.

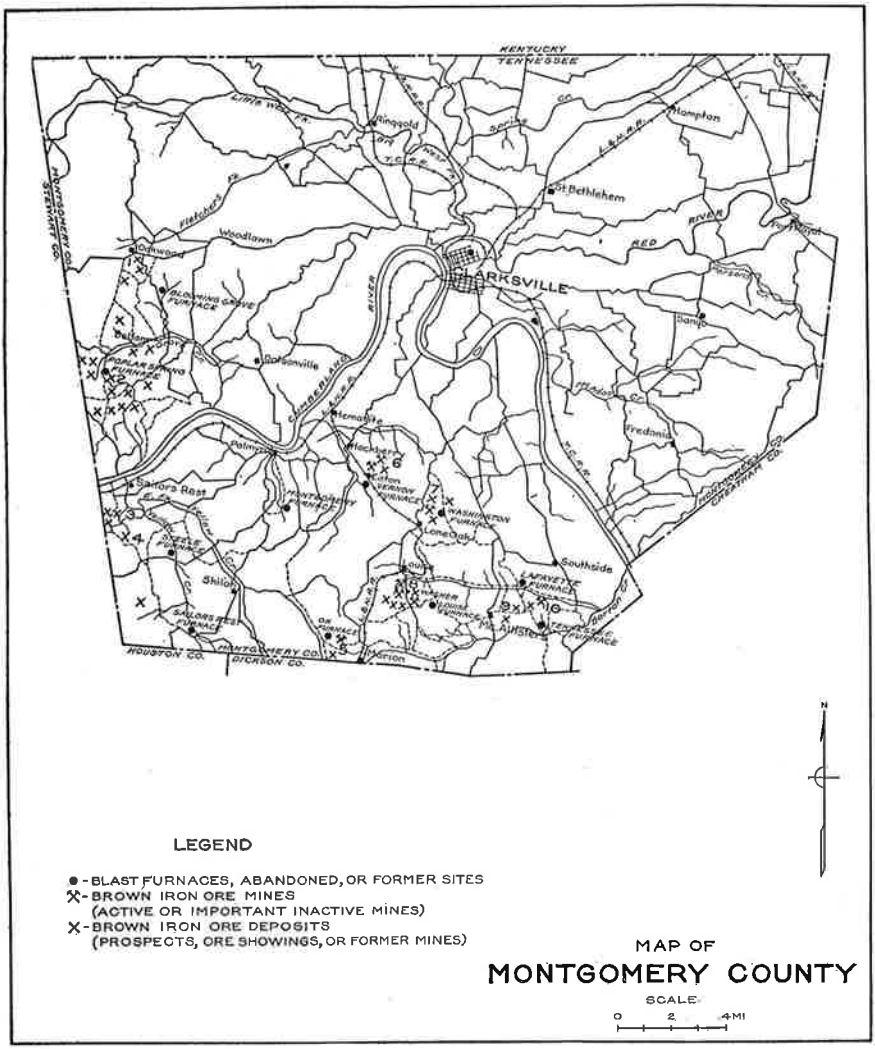
Deposits of iron ore have been reported as occurring on the J. A. Turner land on Blue Creek, south of McEwen; on the Holland land, on Little Hurricane Creek; and on the Evans and Stinnett tract, about 12 miles south of McEwen, about 3 miles from Duck River, and near Sugar and Tumbling Creeks. This ore-bearing area is adjacent to that in northwestern Hickman County near Duck River, and it is probable that the ore associations are similar—much chert being present and the ore being found in pockets at various horizons from the ridge tops down to stream levels.

Killebrew[19] states that Humphreys County has a number of beds of iron ore but that no furnaces have been erected therein, although in 1854 there was a forge in the county, which made in that year about 100 tons of bar iron.

MONTGOMERY COUNTY

The iron-ore deposits in Montgomery County are confined to the southwestern third of the county, and most of them are south of Cumberland River (Plate 10). The sites of eleven old blast furnaces were noted during the inspection of the iron-ore deposits, and these do not represent all that have been in existence. The most northwestern site, that of the Blooming Grove furnace, is about 2 miles southeast of Oakwood or 10½ miles west-southwest of Clarksville. The Poplar Spring furnace site is about 5 miles south of Oakwood. These two sites are north of Cumberland River. South of the river the Steele furnace stood on Yellow Creek about 3½ miles southeast of the Sailors Rest station on the Louisville & Nashville Railroad, and the site of the Sailors Rest furnace was on Yellow Creek about 6 miles south-

[19]Killebrew, J. B., op. cit., p. 108.



Map of Montgomery County, showing locations of iron-ore deposits, mines, and blast furnaces.

east of Sailors Rest station. Another old furnace, known as the Montgomery, was about 2 miles south-southeast of Palmyra. The O. K. furnace was on the East Fork of Yellow Creek about 1¾ miles northwest of the station of Marion on the Louisville & Nashville Railroad. The Vernon furnace, shown in Plate 11, A, still stands alongside the Louisville & Nashville Railroad tracks near Eaton flag stop. One mile northeast of Lone Oak station on the same railroad is the site of the Washington furnace, and 1½ miles southeast of Louise station is the site of the Louise furnace. The Lafayette furnace was on the north fork of Barton Creek about 1¾ miles northeast of McAllisters Cross Roads, and the Tennessee (Watson?) furnace was about 2 miles east of McAllisters Cross Roads on middle fork of Barton Creek. Other furnaces reported are Robinson furnace near Palmyra and Jones furnace on Budds Creek, somewhere near Vernon furnace.

The iron-ore deposits in this county are in scattered localities tributary to the above-mentioned furnaces. None of them was being worked at time of visit except deposits near Louise.

Killebrew[20] states that the ore in the Steele bank, near the Steele furnace was entirely free of flint (chert), and that less than two tons of ore were required to make one ton of iron.

Deposits in the Oakwood-Poplar Spring locality.—Nearly all the iron-ore deposits in this locality apparently have not been worked for many years, to judge from the growth of timber over the old openings. Most of these old openings are on the wooded uplands at altitudes of 580 to 600 feet, some of them within half a mile south of Oakwood post office (locality 1, Montgomery County), and others are on the hills in the vicinity of Poplar Spring furnace site (locality 2), from 2 to 4 miles from Cumberland River. The surface rock is disintegrated chert and red clay and shows little or no Cretaceous gravel. The openings are shallow and are in reddish, cherty clay containing a little fragmentary limonite. Very little ore was seen on the old dumps. There was so little evidence of ore remaining in this locality that further prospecting is not encouraged. The roads are very rough, steep, and tortuous, and it would be difficult to transport ore even to Cumberland River without considerable work being done to prepare the roads for heavy hauling.

A deposit near Cumberland River that was not visited by the writer is described by Killebrew[21] as follows:

"Another very extensive bed of ore is Bryan's bank, which lies on the north bank of Cumberland River, 12 miles below Clarksville, opposite Palmyra, which is a station on the railroad. This ore is mainly pipe, with some honeycomb. It has been dug to the depth of 85 feet without exhaustion. At this depth the water level was reached, and the diggings extended laterally. The deposit extends in an irregular line running northeast and southwest and comes to within 3 feet of the surface. It increases in compactness with the depth. The elevation of the hill above the water

[20]Killebrew, J. B., op. cit., p. 106.

[21]Killebrew, J. B., Iron and coal in Tennessee, pp. 107-108, 1881.

level of the river at low water is 90 feet. This hill is bisected by a little stream that enters the Cumberland. On the northeast of this stream several pits have been sunk and the same quality of ore found, showing a width of quite 400 yards. It passes across the river and reappears on the southern side. For making a tough iron no ore yet found in the State is superior to this. It is also much richer than is usual with limonite, yielding from the furnace 49.61 per cent, without roasting. In other words, a ton of pig was made from very little over two tons of raw ore. It is very uniform in quality, and the deposits singularly free from pot or black-jack ore. The porosity of the ore makes it easy to smelt, and it is a favorite with all furnace men who have tried it. Much of it has been shipped to Pittsburgh, and it has in every case given satisfaction."

Deposits near Sailors Rest.—One and a quarter miles south of Sailors Rest station near the Stewart-Montgomery County line (locality 3) are 10 or 12 old mine pits 5 to 20 feet deep along a ridge trending N. 30° W. The property is understood to be owned by Messrs. Munday, Gracey, and others. The altitude of the ridge is 475 to 485 feet, apparently about 100 feet higher than Cumberland River. The deposit that was worked apparently had an irregular branching shape along the ridge with a length of possibly 1,000 feet, a width of 200 to 300 feet, and a depth of 10 to 30 feet. The overburden is variable; in places ferruginous material comes to the surface, and in others clay and chert débris are 4 or 5 feet thick. The associated rock is clay and chert débris. At present but little ore is visible except fine shells and fragments of limonite, mostly of the chert-replacement type, although some is honeycombed and laminated. The soil consists of reddish clay containing a little wash ore, which indicates that possibly there is more ore between the old pits, but the probability of an important yield is not good. Ore was mined here, it is understood, to supply the Steele and Sailors Rest furnaces.

Three-quarters of a mile southeast of the locality last described is the old Steele ore bank (locality 4). This bank is at an altitude of about 500 feet on the east side of the road that follows the ridge. The pit is about 200 feet in diameter and 40 feet deep at the east side of the road, but becomes shallower according to the slope of the hillside toward the east. The walls of the pit show only chert, clay, and gravel with practically no ore. There is, in fact, so little ore within the pit or on the sides or on the dumps that the opening looks more like a gravel pit than an iron-ore mine. The ferruginous material that was seen was present as a cement in conglomerate or as fragments of crusts and honeycombed limonite. The pit is full of large trees, some more than 50 feet high, and water stands in low places after heavy rains. The ore lands in this vicinity are reported to be owned by parties in Clarksville and in Cumberland City.

Deposits near Marion.—One mile northwest of Marion (locality 5), on lands reported to belong to the Edwards, Bryant, Hodge and other families and in part to persons in Cumberland City, are many old mine pits worked 40 or more years ago to supply the former O. K. furnace, which stood near by on the East Fork of Yellow Creek (Fig. 2). The old workings

(A) Active cut at Louise mine, Montgomery County, 1923.

(B) Stack of Vernon furnace near Eaton flag stop, Montgomery County.

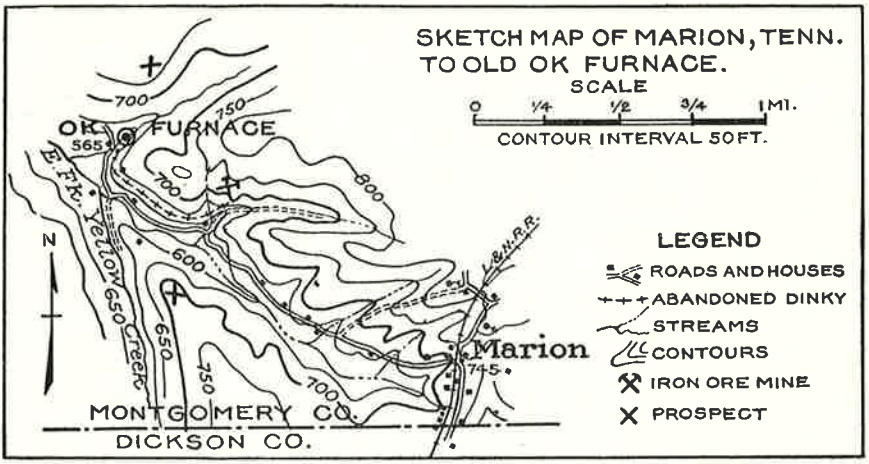


FIGURE 2.—Map of Marion and vicinity, showing location of O. K. furnace and brown iron ore mines.

are on the borders of the upland areas, the top of the pits having an altitude of about 665 feet, or about 150 feet above the creek level. The tops of the ridges are 25 to 30 feet higher than the mine pits. The ore deposits apparently were of irregular shape around the borders of the hill tops and extended to a depth of 40 feet or more as indicated by the old workings. The overburden is soil, clay and chert débris ranging from a few feet in thickness to pockets extending down 10 to 15 feet in the walls of the pits. The rock associated with the ore is chert, gravel, and clay. Limestone is exposed in the creek, dipping 3½° E. at the cave spring near the furnace site. In the ore workings there is some good honeycombed and laminated ore also some chert-replacement and conglomeratic ore in sight. Bouldery outcrops of lean ferruginous chert were noted. The Edwards bank is said to have been the chief source of ore for the O. K. furnace, and to judge from the piles of waste chert and gravel noted here evidently a large quantity of ore was hand cobbed, and the large quantity of slag at the old furnace site indicates that this was one of the most productive establishments in the early days of iron making in this vicinity. The general conditions here indicate that there should be considerable more ore in the hills in this immediate vicinity. Conditions for mining are favorable, but there appears to be no convenient washer site that would not spoil good bottom land along the neighboring stream, which flows into the East Fork of Yellow Creek.

Deposits near Vernon furnace.—Half a mile northeast of Eaton flag stop on the Louisville & Nashville Railroad (locality 6) are pits on the land of H. Davis of Hackberry, which supplied the Vernon blast furnace (Plate 11, A), and from which brown ore was mined as late as the fall of 1922 for the Helen furnace at Clarksville. The deposits are on the top and west side of the ridge east of Budds Creek, about 280 feet higher than the creek or at an altitude of about 680 feet. The ore deposits occupy irregular-shaped areas

on the ridges around the edge of the hollows, and are scattered over an area of perhaps 50 acres. The old pits showed depths of 25 to 30 feet, and ore is reported to have been found to depths of 40 to 60 feet in prospect holes. In addition to the Davis land there are several other tracts of ore-bearing land in this vicinity, one of them, 1 mile up Budds Creek above Vernon furnace, is reported to be owned by J. A. Moorefield and others by H. L. Williams, of Chicago. The overburden above the deposits consists of soil, clay, chert débris, and gravel 2 to 10 feet in thickness. The associated rock is clay, chert débris, and gravel of the Cretaceous type. Limestone was noted in the railroad cut 175 to 200 feet lower than the ore deposit. The ore in these deposits consists of limonite in loose fragments, crusts, and cherty conglomeratic masses. It ranges in grade from lean to rich, and if separated from the associated materials its average quality appears to be good. The chert is largely in rounded pebbles and fragments. An open prospect pit on the Davis land showed the upper 20 feet chiefly of gravel with a small proportion of limonite and the lower 20 feet chiefly of limonite with a small proportion of gravel. Conditions for mining are favorable, and there appears to be sufficient water in Budds Creek to supply a good-sized ore washer. Since the Vernon furnace was closed mining has been done only at intervals. The washer was operated in 1918 preparing ore for the Helen furnace of the former Red River Iron Co. at Clarksville, and hand cobbing and screening of the ore was done in connection with the mining in 1922.

Deposits near Lone Oak.—About 1 mile northeast of Lone Oak station, on the Matthews, Harris, Shedd, Holmes, and Williams farms (locality 7) are many old mine pits from which the old Washington furnace was supplied with ore, probably long before the Civil War. The iron-ore deposits were situated on two low ridges extending N. 70° E. at an altitude of about 620 feet and perhaps 100 feet above Hurricane Creek at the site of the Washington furnace. Other deposits of ore are reported to be found along the ridge toward the southwest, almost to Lone Oak. The ore where mined seems to have been in isolated patches or pockets at the highest points on the ridges. Depths of the pits were 25 to 30 feet. The overburden was thin and in many places the ore was exposed at the surface, and some is still being plowed up in the fields. The ore was associated with chert, gravel, and clay, a little of the gravel being of quartz. Limestone was noted in hollows near the creeks 75 to 100 feet lower than the ore pits. Some blocks of sandstone of the type usually associated with the chert of the Warsaw (?) horizon, said to have been used in lining the old furnace are scattered about. The ore consists of lumps and fragments of light to dark brown limonite. Bombshell and honeycombed ore are present, also the chert-replacement and conglomerate types. Large boulders of ore, one of them 3 feet by 4 feet, and much float lump ore were noted in the bed of the dry gully between the two ore-bearing ridges. This boulder ore was of the chert-replacement and conglomerate type.

Deposits near Louise.—Seven-tenths of a mile southeast of Louise station on the Louisville & Nashville Railroad (locality 8) are brown-ore deposits on property of the former Red River Iron Co. of Clarksville, said now to belong to persons in Chicago. The ore was being mined under lease by the Warner Iron Co. at the time of visit, May, 1923, and was shipped to Cumberland furnace. These are the Louise mines, where mining has been carried on at intervals from a time before the Civil War. The ore occurs on the uplands and borders of hollows that open into the drainage basins of the forks of Barton Creek. Altitudes of the ore deposits seem to range from 565 feet to 675 feet, being 75 to 185 feet above the neighboring drainage level. The deposits show depths of 30 to 50 feet and are reported to extend over more than 200 acres. The overburden is soil, gravel, clay, and chert débris, 5 to 20 feet thick, the chert débris lying mainly in pockets. Limestone is exposed on the north fork of Barton Creek and north of Louise station at 490 to 510 feet altitude. The ore worked in the main pit, about a quarter of a mile northwest of the washer, occurs in a mass of tabular form 20 to 30 feet thick. It consists of light to dark brown and nearly black limonite in crusts within clay. When broken down by blasting and pick and shovel the ore is very fine grained but is said to yield a product of good quality when washed. The light-brown crusts of limonite and the light-brown claylike masses, which readily break apart, are not acceptable ore, so that it is necessary to confine shipments to the darker material. In the ore there is also considerable pebble material, mostly of chert, but some quartz is present. The active mine pit is connected with the washer by a mule tramway, and the washer discharges into railroad cars. (Plate 11, B). The washer is situated in a hollow about 3,500 feet from Louise station and is connected with the railroad by a standard-gage track. The accompanying flow sheet of this washer was reported by Mr. C. C. Anderson. Analyses of the ore shipped from the Louise mines in 1923, given on page 75 showed 38 to 44 per cent iron and 23 to 32 per cent insoluble. The output from these workings was said to be limited by a scarcity of labor. It is reported that much good ore is covered in the old workings by careless mining in earlier days.

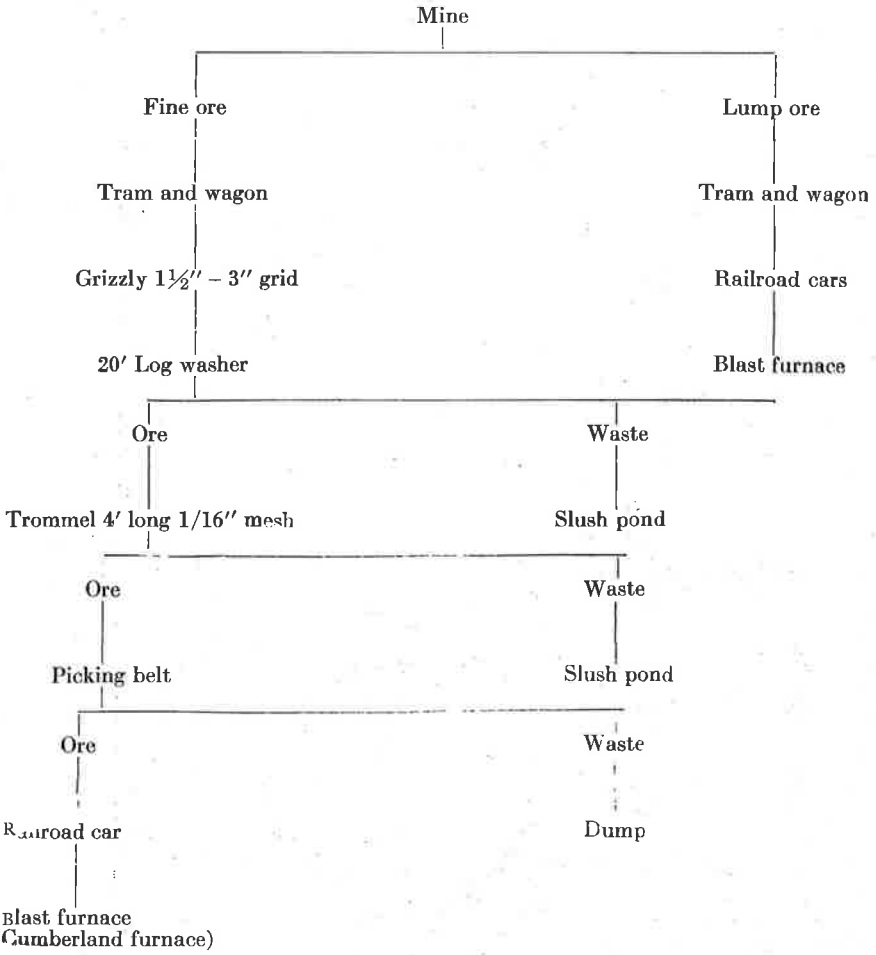
An estimate of cost per ton of the ore at Cumberland furnace in 1923 is as follows:

Royalty to owners	$0.35
Mining and washing	2.00
Rail haul	.60
	2.95

The old pit 500 feet up the hollow south of the washer is an irregular-shaped opening 30 feet or more deep, 70 to 80 feet long, and 40 to 50 feet wide, which shows walls containing much gravel and clay with lean ferruginous masses of chert and conglomerate. The base of the sloping walls

is hidden by talus and very little workable ore is in sight. This pit has evidently not been worked for a long time, and the tramway that passes it is no longer in use. Some openings high on the hill southeast of this pit show evidence of later working. A large "horse" of gravel and clay left in the old pit indicates that it was probably surrounded by ore-bearing ground. The ridge south of the washer contains 6 or 7 more large pits, ranging from 10 to 40 feet deep and covering a total area of 2½ to 3 acres, and there are also several prospect pits on top of the ridge. The ore deposits ranged from drainage level (about 540 feet altitude at the washer) to 80 or 100 feet higher. This ridge extends eastward beyond the Taber ore banks (locality 9), and according to reliable local report is spotted with ore in many places, but the depth and area of the deposits is very irregular and uncertain. The overburden is mainly chert, gravel, and soil and ranges from 1 to 20 feet thick. The gravel contains many pebbles of chert up to 2 or 3 inches in diameter also many large quartz and quartzite pebbles. The ore is associated with chert gravel, "horses" of light-colored clay, and boulders of iron-cemented conglomerate. The ore seems to have been chiefly light brown and of the clay-replacement and conglomerate-cement types. Some scattered pieces of rich needle ore and dark limonite were noted, but not much lump ore of this kind is present. Much of the workable ore seems to have been removed and not much ore remains in the dumps. What is left consists of widely scattered bits of good ore or of conglomeratic ferruginous material.

Flow sheet of the Louise Mine washer operated by Warner Iron Co. Locality 8, Montgomery County
(By C. C. Anderson)



Deposits east of McAllisters Crossroads.—The Taber ore bank (locality 9) is situated about three-fourths of a mile east of McAllisters Crossroads on land of the former Red River Iron Co., said to belong now to H. L. Williams, of Chicago. This tract consists of about 40 acres of woodland and is a roughly elliptical area with the east-west axis about one-third of a mile long. The deposits are situated on the highest part of a ridge at an altitude of 650 to 665 feet and more than 100 feet above the Middle Fork of Barton Creek. The tract has been fairly closely prospected, but the pits were so old that the depth visible in them was only a few feet; one pit is said to have been 80 feet deep and to have showed ore all the way down. Ore fragments are scattered well over the surface, and lumps of ore outcrop

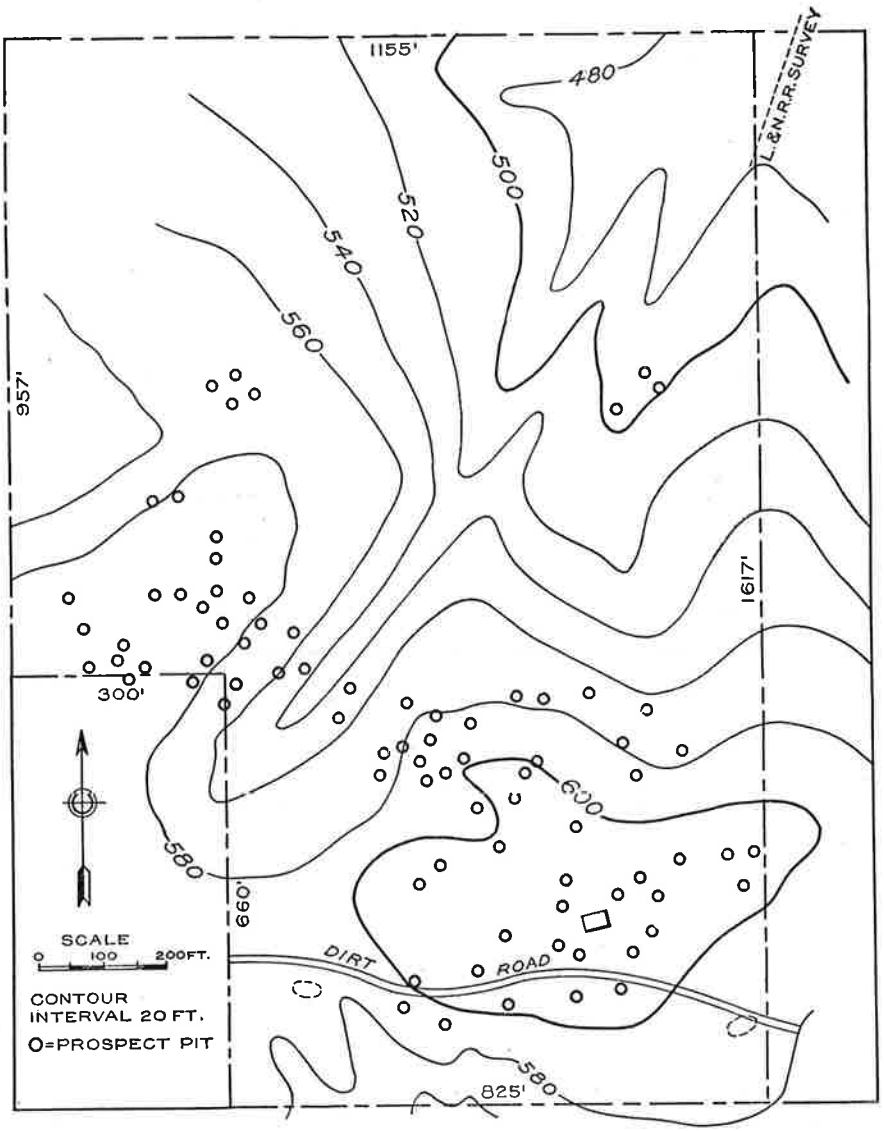


FIGURE 3.—Map of Taber brown iron ore tract near McAllisters Crossroads, 4½ miles east of Louise.

in a few places. Ore is also plowed up in the field east of the woods. The wagon road through the woods shows ore fragments and powdered ore, therefore the overburden is probably thin. Gravel, broken chert, and clay are associated with the ore. Limestone shows only in the lower parts of the creek valleys. Quartz pebbles were noted in the gravel with the ore and in conglomerate masses. The ore consists of limonite of the various types common to this region but apparently contains less conglomerate and chert than in most of the other places. The chunks and fragments of ore present are

largely of rich limonite. A severe wind storm passed through this property April 1, 1923, and tore up many trees, which showed signs of ore about their roots. The ore is situated favorably for mining, but water for washing would have to be brought more than half a mile from the Middle Fork of Barton Creek, or the washer might be built on the north slope of the ridge near the North Fork of Barton Creek, which is about 1 mile from the deposits. A railroad spur 3½ miles long would have to be built down the North Fork of Barton Creek to carry the ore to the Louisville & Nashville Railroad. No mining has been done on this property, and there seems to be a strong possibility that upon thorough prospecting it might be found to contain sufficient ore to warrant opening it and building a railroad spur. The topography and distribution of the prospect pits are shown on the map (Figure 3), obtained through the courtesy of the Red River Iron Co.

Other old mine pits and prospects were noted about 2 miles east-northeast of McAllisters Cross Roads on land of M. M. Dunn. (Locality 10). Considerable mining appears to have been done here many years ago, and there are a number of old mine pits and prospects, the depths of which ranged from 3 to 25 feet. The workings are on the ridge and upper part of the hills that slope northward to North Fork of Barton Creek. The altitude ranges from 660 to 675 feet and is from 235 to 250 feet above the principal neighboring streams. The land on which these pits are situated comprises 154 acres, of which possibly 30 acres formerly contained brown ore in an irregular branching area. The depth of the ore is uncertain but may average more than 30 feet. The overburden is thin and consists of clay and gravel, but generally ore débris is close to the surface. Chert, clay, and gravel are associated with the ore, but no limestone crops out except well below the levels of the ore deposits. Bedded chert was observed on the road to the Middle Fork of Barton Creek about 150 feet lower than the ore horizon. Some of the gravel associated with the ore is quartz; more gravel was seen on the road to the Middle Fork of Barton Creek than elsewhere in this vicinity, probably representing a deposit that has been washed down from higher levels. The limonite is of fragmentary, cherty conglomerate, some also of the clay-replacement type. Ore of the latter type crops out in masses in certain old pits but is probably not of high grade. It is reported that ore was mined here many years ago, for the old Watson (Tennessee ?) furnace near Middle Fork of Barton Creek about 1 mile south of the deposits, and the old pits appear as though most of the good, easily obtained ore had been mined out. Below the present levels, however, there may be some more ore, and prospecting in these places might be warranted. Local conditions are favorable for mining operations, but the distance to a railroad is about 5 miles.

DICKSON COUNTY

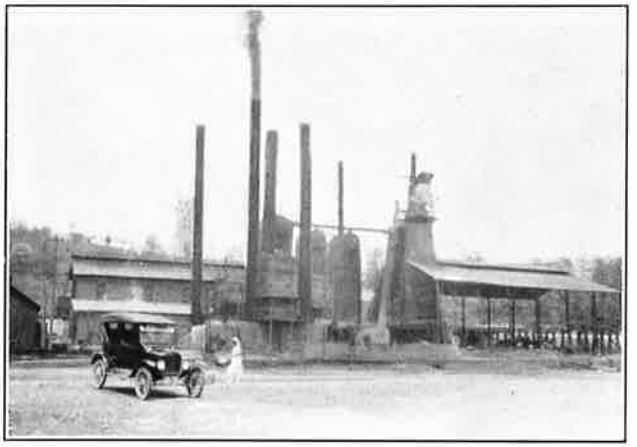
The brown iron ores in Dickson County are grouped mainly in six localities although some deposits are outside these areas. (Plate 12). The principal localities are in the vicinity of Slayden; in the vicinity of Cumberland furnace, near Sylvia and Hortense northwest of Dickson; southwest of Dickson near the site of the old Worley furnace; northeast of Dickson in the old Laurel furnace locality; and southeast of Dickson near Iron Hill. Other scattered deposits were noted in the vicinity of Charlotte, northeast of Tidwell, southwest of Herbertson School, and near the Houston-Dickson county line west of Vanleer and south of Tennessee City. In addition to the blast furnaces mentioned above there are reported to have been in Dickson County the Carroll furnace on Bartons Creek, about 4 miles south of Cumberland furnace, the Belleview furnace on Jones Creek, about 3 miles south of Charlotte, and Piney furnace on the headwaters of Piney River, besides several forges, among them the Steam forge, on Cumberland River near Betseytown. The ore deposits will be described beginning with those in the northwestern part of the county near Slayden.

Deposits near Slayden.—In several places northwest and north of Slayden there are deposits of brown iron ore near the headwaters of East Fork of Yellow Creek and Rainycamp Creek. About 3 miles northwest of Slayden are the old Grimes ore banks (locality 1, Dickson County), from which ore is reported to have been obtained for Sailors Rest furnace, in Montgomery County, 50 to 60 years ago. There are 6 to 8 pits lying in all directions from the cross roads. The altitude is about 650 feet, and the deposits may be said to lie well toward the top of the ridge. Chert débris, gravel, conglomerate, yellow to brown clay, and fragments of limonite are strewn about the pits. There is not much limonite remaining, so far as can be seen, and what is visible appears to be of rather inferior quality, light brown and sandy. Masses of chert partly replaced by limonite were noted, and the conglomerate contained a few pebbles of quartz, but the majority of the pebbles were of chert. One pit shows a pocket of gravel 6 to 8 feet deep, which seems to have slumped down from a higher place.

Two miles northwest of Slayden, or about 1 mile south of the Grimes ore banks, are some extensive old ore pits known as the Carroll ore banks. (Locality 2). These pits, which are 70 to 80 feet in diameter and about 15 feet deep, are on the east, south, and west sides of the crossroads at an altitude of about 680 feet. Ore obtained here is said to have been hauled to the Sailors Rest furnace. These pits show débris of brown ore associated with gravel and loose chert and more or less clay. Masses of ferruginous chert conglomerate are exposed in the sides of the pits. The ore is generally in small fragments, and what is left is not very abundant. Gravel, evidently derived from Cretaceous deposits, is more abundant here than farther east.

About a mile northwest of Slayden on land of James Gafford (locality

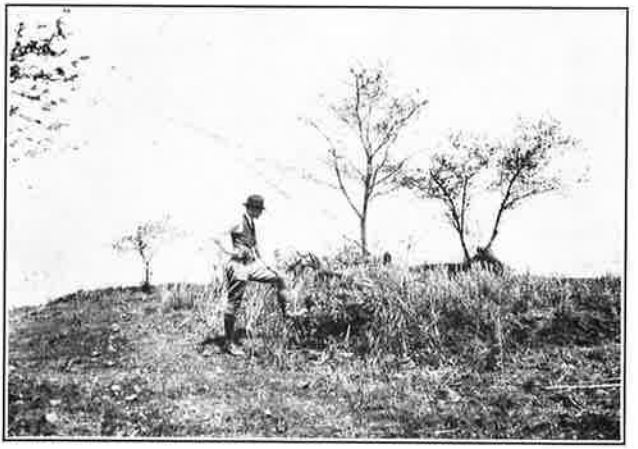
(A) Deposit of brown iron ore near Cumberland furnace, Dickson County, being mined by hand, hand cobbed, and dry screened.



(B) Blast furnace of Warner Iron Co. at Cumberland furnace, 1923.

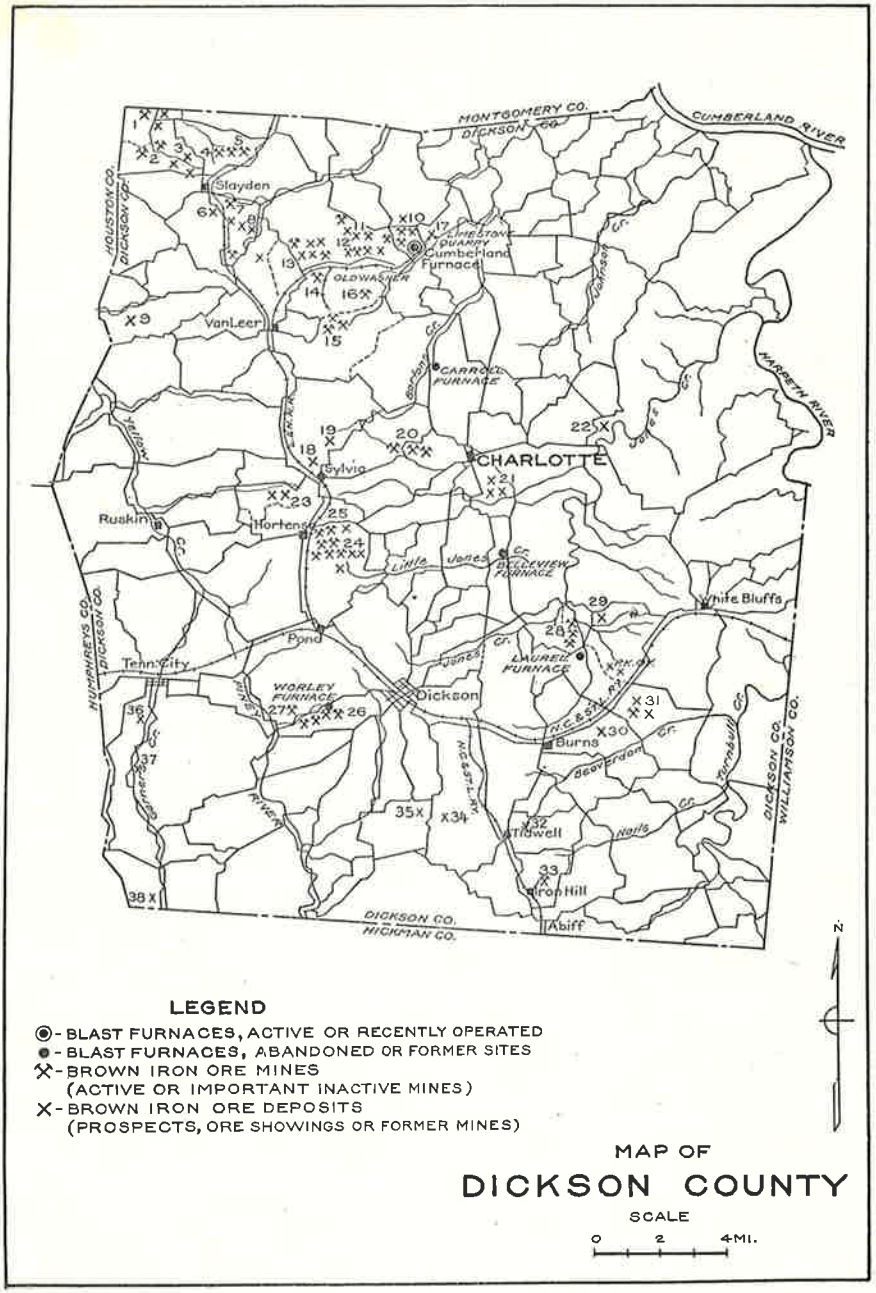
(A) Quarry of fluxing limestone near Cumberland furnace.

(B) Bell brown iron ore mine, 3½ miles southwest of Cumberland furnace.



(A) Outcropping ledges of limonite chert on "Ore Bank Hill," 4 miles northeast of Charlotte, Dickson County.

(B) Outcrop of limonite and conglomerate on Edwards place 1 1-3 miles northwest of Hortense, Dickson County.



Map of Dickson County, showing locations of iron-ore deposits, mines, and blast furnaces.

3), prospect pits were noted just below the crests of hills, on the slopes of several ravines, at altitudes of 625 to 645 feet. These pits were in irregular areas of small extent, and their depth did not exceed 10 or 12 feet, although probably they had been more or less filled by slumping down of the walls. The iron-bearing material apparently lay near the surface. Chert, clay, and gravel were the principal associates of the ore, which seems to have consisted of limonite cementing broken chert and conglomerate. Except for a few lumps of good ore most of the limonite seen about these pits was in thin crusts or small fragments. A very little "honeycomb" ore was noted, and this seems to be of better grade than the cherty ore, although it is associated with some clay and chert. Conditions are generally favorable for mining, but there is apparently very little ore remaining.

One and one-quarter miles north of Slayden on land of G. W. McCollum (locality 4) are many old mine pits and prospects on top of a ridge and down its north slope toward the East Fork of Yellow Creek between altitudes, 665 feet and 580 feet. These openings were made before the Civil War to supply ore to the Sailors Rest furnace. Ore-bearing chert shows at the surface in a number of places, and it seems that the overburden is small. Chert, clay, and gravel are associated with the ore, and limestone outcrops in heavy beds on East Fork of Yellow Creek 60 or more feet lower than the ore deposits. The limonite occurs as cementing material in chert conglomerate and as a replacement of chert. There is also a little ore in geodal lumps. In general the ore is siliceous and of poor grade. The old workings are scattered irregularly about an area of 2 to 3 acres, but from what could be seen it is believed that there is not a great deal more available ore here. The conditions for mining and washing are fairly favorable, but there would be a considerable grade up which to raise the ore to the Louisville & Nashville Railroad about 1 mile distant.

One and three-fifths miles northeast of Slayden on lands of some residents of Clarksville (locality 5) are some old prospects on the north side of a small branch of East Fork of Yellow Creek at altitudes of 630 to 700 feet. The ferruginous material is dark oxide of iron cementing chert conglomerate. The ore, therefore, occurs in crusts broken from the conglomerate, and some of this crustified material appears sandy and of little value as an ore. A large quantity of chert coated and cemented with limonite that occurs as débris on the hill slopes and in the gullies on this property evidently led to considerable prospecting. Near the junction of two hollows iron oxide is found in masses down nearly to water level, probably deposited by the action of spring waters.

A few old prospects were noted about half a mile south of Slayden on the edge of a hill west of the Louisville & Nashville Railroad, (locality 6). These pits are at an altitude of about 680 feet and about 150 feet above the nearest creek, where limestone is exposed. Ore is said to have been shipped from here to Clarksville, but there is little evidence of ore remaining in

these diggings. The dumps, which are chiefly of chert, show a few lumps of fair-grade limonite mingled with cherty conglomeratic material.

Half a mile southeast of Slayden, east of the railroad track on land of I. N. Thomason (locality 7), are numerous old pits on both sides of a small northward-flowing branch. The banks are 30 to 35 feet in depth and are opened along the hillsides for several hundred feet. The altitude is about 660 feet at the base of the cuts. It has been a long time since operations were active here, to judge from the large trees, which have grown up in the old pits. The ore is largely of pebbles and fragments of limonite in residual clay and chert and contains considerable sandy limonite showing "pipe" structure. A few large boulders and lumps of ore were noted in a gully west of the main workings, near the lowest drainage level, and apparently due to deposits from spring waters. Analysis by D. F. Farrar showed 59.35 per cent iron (Fe) and 4.52 per cent insoluble matter in a specimen of the "pipe" ore. As limonite free from all siliceous and other impurities contains only 59.8 per cent of iron, the question arose as to the mineral composition of this iron oxide. A powdered sample was examined under the microscope by C. S. Ross, of the United States Geological Survey, who finds that it is a fine-grained crystalline aggregate, probably a mixture of goethite and turgite. The indices of refraction of more than half the material agree with those of goethite, and much of the remainder has a higher index of refraction and otherwise resembles turgite in having a reddish-brown color. It seems doubtful if there is any hematite present.

One and one-quarter miles southeast of Slayden, on land of Tom Potter and John Smitto (locality 8), are old pits and prospects from which some ore was reported to have been mined about 1908, carted to the Louisville & Nashville Railroad half to three-quarters of a mile west, and shipped to Clarksville. The deposits are situated 10 to 15 feet below the top of the ridge bordering Crane Hollow, 125 feet above Little Bartons Creek and at an altitude of about 775 feet. This ore belt is reported to extend about 1 mile northwest-southeast and to be about half a mile wide in this locality except where it is cut into by ravines. There is little or no overburden at the border of the hill, but a few feet of chert and soil are found farther back on the top of the ridge. The ore is associated with chert and clay, and a short distance down the hollow limestone was noted about 90 feet lower than the ore deposits. Around the old dumps there is much débris of good-grade limonite in small lumps, which appear to have disintegrated from iron oxide cement in conglomerate or else from masses of chert-replacement ore. Some of this is high-grade "needle" ore. In the lower parts of the deposit, on the hillside, are masses of chert partly replaced by limonite. The ore appears to be richest near the top of the deposit. There are many prospect pits and test wells on the north side of this hollow and northwest along the ridge for half a mile, which are said to show iron ore, but the depth of the ore is unknown. From all outward appearances there may be a considerable tonnage of ore

still unmined in this locality. Most of the conditions essential for mining are favorable, and if ore of good grade occurs in commercial quantity, it should be possible to work these deposits when needed, as they are within three-quarters of a mile of the Louisville & Nashville Railroad. A washer might be set up near Little Bartons Creek, and from there to the railroad a cable tramway might be used, which would appear to be a convenient way to avoid the grade that would stand in the way of a railroad spur.

Reports of the occurrence of ore on Chilters Branch 4 miles southwest of Slayden or 4 miles west of Vanleer led to the inspection of some old prospects on land of J. J. Holley and others (locality 9), on the ridge south of Chilters Branch 155 to 220 feet above the creek or at altitudes of 665 to 730 feet. Along the narrow ridge and its branches and extending at about the same altitude beyond the Houston-Dickson county line to the vicinity of Yellow Creek limonite float was noted, chiefly on the slopes 50 to 60 feet lower than the highest parts of the ridge. If there are deposits of ore below the surface, the overburden is chert and soil, which is probably rather thick on the higher levels. Chert and clay form the rock that would be associated with the ore, but there is gray crystalline limestone in the creek valley 80 to 100 feet below the ferruginous horizon. Aside from the ore float the only ferruginous material noted in place is ore "blooms" of pebbly conglomerate cemented by limonite. One mass that stands about 8 feet above ground on the hill slope on the Holley tract consists largely of chert pebbles with limonite cement in too small proportion to constitute an ore. One small quartz pebble was seen in this conglomerate. A few lumps of good limonite were noted, but in general the indications do not seem encouraging for abundant deposits here.

Deposits near Cumberland furnace.—The deposits of limonite directly tributary to Cumberland furnace occupy the triangular area extending about 4 miles west and southwest of the furnace and having a north-south width of about 2½ miles at the maximum. The general distribution of these deposits is shown on the Dickson County map (Plate 12) and those in the immediate vicinity of the furnace are shown on the special map (Figure 4). In general the ore lies near the crests of the ridges and part way down their slopes. There were several active mines here in the spring of 1923.

Half to three-quarters of a mile northwest of Cumberland furnace (locality 10) are extensive old mine pits belonging to residents of Clarksville, who own the fee or mineral rights to between 1,500 and 1,600 acres of ore land in this vicinity. These pits are situated on top of a ridge at an altitude of about 745 feet or about 250 feet above Furnace Creek at Cumberland furnace. The ore deposit follows the crest of the ridge, is irregular in width, and is cut through in places by gaps or notches in the ridge. The depth of the ore may be greater than is indicated by the pits, but prospecting would be necessary to prove this. The overburden is soil, clay, and chert 2 to 5 feet thick, which lies above masses of cherty limonite interspersed with more

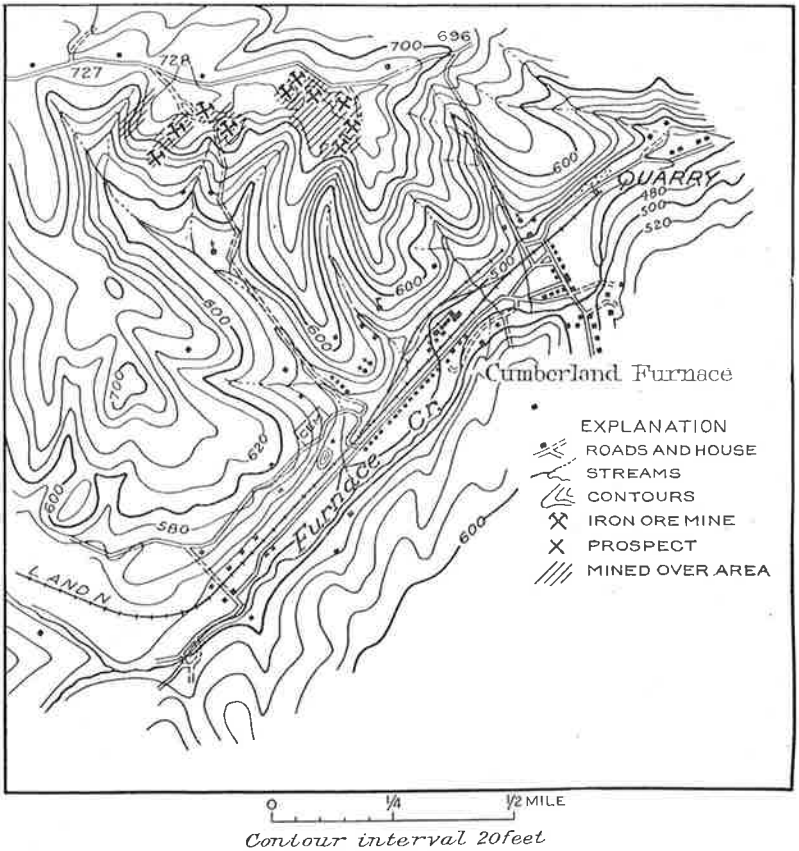


FIGURE 4.—Map of vicinity of Cumberland furnace, showing relation of ore-bearing land to the topography and to the blast furnace.

chert and clay. Limestone is exposed in the neighboring valleys 100 to 120 feet lower than the ore horizon. The limestone shows slight local dips, 3° N. 70° W. having been noted in one place. The ore here is of several types. Some is laminated nearly pure limonite, some is cherty, some is soft and ocherous, and some is spongy, containing much clay and decomposed chert. In the old pit masses of "white horse" clay occur. These pits are many years old and are reported to have been worked entirely by hand, no steam shovel being used. When visited mining was carried on in a small way by hand methods, in which the ore is screened and forked and the product hauled in wagons to the furnace. (See Plate 13, A). In May, 1923, ore of this sort brought $2.25 a ton at the furnace, out of which a haulage charge of 75 cents a ton was paid by the miner. For about half a mile west of this locality erosion has removed the ore-bearing ground, as may be observed from the road that borders the abrupt southern slope. According to old miners who have worked in this locality for 30 or 40 years, ore is believed to have extended downward 30 to 35 feet below the principal level, but it does not

extend down to the limestone, which is invariably overlain by hard clay and sand. The possible reserve of ore in this immediate locality is uncertain but not great, so far as shown by surface indications. The locality is convenient to the furnace, and the haul is down hill, and the general conditions warrant the surmise that if an easily moved steam shovel could be used here, it might be possible to get more ore by working the deposit on a larger scale.

The special map, on a scale of 2½ inches to the mile (Figure 4), shows the topographic relations of these ore deposits also those of the industrial settlement around Cumberland furnace. The limestone quarry from which fluxing stone is obtained is situated on the north side of Furnace Creek about three-eighths of a mile northeast of the blast furnace. This quarry will be described under Limestone for Flux (page 76).

About 1¾ miles west-northwest of Cumberland furnace on land owned by Clarksville parties are a number of old pits similar to those just described. They are situated around the heads of hollows opening to the southeast and on the margin of a spur of the ridge. (Locality 11). Several acres of old workings here are now overgrown with trees as much as 8 inches in diameter. The altitude of the ridge along the road is 720 to 740 feet with the drainage to the southeast into Dry Hollow Creek, a branch of Furnace Creek. The plan of the deposit is irregular and branching, following the axis and southern spurs of the ridge, and the depth of the ore may be 30 to 50 feet, possibly greater, but there are barren spots where no ore has been found. The character of the ore is so similar to that of the deposit described above that no separate description is necessary.

One-quarter to one-half mile southeast of the last-mentioned workings and a quarter of a mile north of the Louisville & Nashville Railroad, are several old mine pits long since abandoned. (Locality 12). These pits are on the top and south border of ridges directly north of Dry Hollow Creek at altitudes of 700 to 735 feet and about 150 feet above the creek. The principal old workings extend about a quarter of a mile east and west and 750 feet north and south with a depth of 20 to 35 feet, and ore is also shown in prospects toward the northwest and on the east side of a hollow across from the old mines. The overburden consists of soil, chert, and gravel a few inches to 3 or 4 feet thick, and unconsolidated chert, clay, and gravel are associated with the ore. The ore is conglomeratic and mixed with much clay, chert, and gravel, some of which is of quartz. The ore does not appear to have been very rich at this place. Some large masses of cherty, sandy ore are exposed in the sides of the pits. A noticeable quantity of red hydrous oxide of iron is scattered about. It would probably require 4 to 5 and possibly more yards of this ore-bearing dirt to yield, when washed, one ton of commercial concentrates. Some good ore is present, but the average would be of low grade. Little can be said regarding the definite reserve of ore still available here, but it is believed that prospecting should be done in order to ascertain whether ore may not occur here in quantities that would pay to

work at greater depths. In and around the hollows that open into Dry Hollow Creek in this vicinity there is considerable float of cherty limonite that has been washed out from its inclosing clay by surface water, and this may be an encouraging sign that further deposits may be expected.

About a mile west of the last-described locality or 2½ to 3 miles west of Cumberland furnace are still more mine pits, on the crest and south border of the ridge north of Dry Hollow Creek valley at an altitude of 730 to 750 feet or about 170 feet above the creek. (Locality 13). The old workings extend east and west along the ridge and are also on the west and east sides of a large branch hollow opening into Dry Hollow Creek. The depth of the ore-bearing material exposed by the pits is about 25 feet. The overburden ranges from 1 foot to 10 feet or more in places where pockets of barren chert extend down into the ore-bearing ground. Chert, clay, and a little gravel, some of which is of quartz, are mixed with the ore. The ore consists of limonite cementing masses of chert and as isolated fragments in clay, and some is conglomeratic. The proportion of ore in sight seems small—not more than one part in 10. Some of the ore is sandy, as though it represented a partial replacement of sandy layers of Warsaw (?) chert. It seems possible that there may be a little more ore below the present levels. Mining conditions are favorable here, and at the mouth of the hollow, half a mile to a mile south of the openings, is the side of an old ore washer formerly operated by the Red River Iron Company. At the time of visit some ore was being obtained from 2 or 3 openings in this locality, on the east side of the hollow, by hand mining, hand cobbing, and wagon hauling to the railroad, over which it was shipped to Cumberland furnace. The face of one of these openings is shown in Plate 13, A. The ore as hand cobbed is of higher grade than the average washer ore, and the operators will gladly buy it at market prices if the furnace is in operation. The mines are therefore likely to be operated in a small way so long as men can make wages at this kind of mining. Miners report that there is too much barren ground and too much "knot" ore or masses of chert containing little limonite to permit mining by steam shovel in this immediate vicinity.

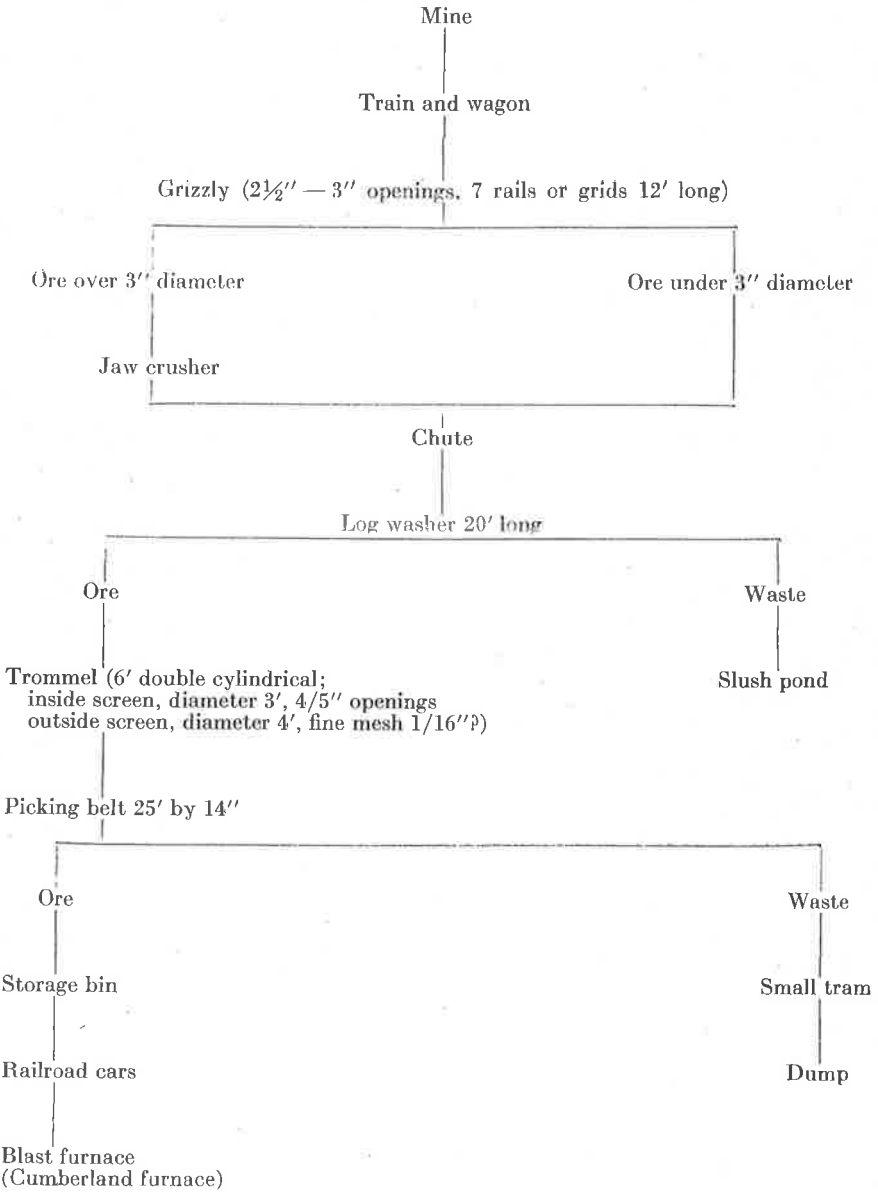
Three miles southwest of Cumberland furnace and about one-third of a mile south of Dry Hollow Creek is the Stokes ore bank (locality 14), operated in the spring of 1923 by the Warner Iron Company to help supply the Cumberland furnace. The workings are situated on the top of the hill west of a branch flowing north into Dry Hollow Creek. Considerable mining and prospecting by pits of various sizes has taken place all around the hill. The base of the working is about 50 feet above the level of the branch, and the hilltops are about 60 feet higher, or at an altitude of about 750 feet. The ore deposit as opened by the pits is roughly circular and about 1,200 feet in diameter, and the ore appears to occupy a zone 40 to 50 feet thick as opened, but it may go deeper. The overburden varies in thickness. In some places ore masses come to the surface, but at others there is much clay and

disintegrated chert above the ore. Gray crystalline fossiliferous limestone crops out in the railroad cut near the washer, about 40 to 50 feet lower than the ore workings. The surface of the limestone is overlain by red clay, but no ore is present in this clay immediately above the limestone.

The ore is composed principally of cherty limonite surrounded by chert, clay, and gravel. The grade of the ore appears generally to be fair, but a large quantity of dirt and waste must be moved in order to obtain the ore. Occasionally a cherty or conglomeratic mass crops out, but most of these lie a few feet below the surface and continue downward 5 to 8 feet or more. The situation seems favorable for mining, washing, and transportation. The washer has been built on the east slope of the hill, and water is brought to a tank in a 4-inch pipe from Dry Hollow Creek across the hill toward the west. The settling pond is in the hollow on the east side of the railroad spur. Mining was carried on by means of blasting, and the ore was loaded by hand on mule tramcars which carried it to the grizzly. At the time of visit, during a period of considerable rainfall, it appeared as though much waste material was being mined, which necessitated throwing a great deal of chert from the picking belt, also much fine ore was being lost because no jigs were in use. The mine is connected with the Louisville & Nashville Railroad in Dry Hollow by a spur which extends southward to the Bell mine, described below. The equipment and methods of operation of this washer are indicated in the following flow sheet.

Flow sheet of Stokes Mine washer operated by Warner Iron Co.
Locality 14, Dickson County

(By C. C. Anderson)



On the south side of Bell Hollow 3½ miles southwest of Cumberland furnace is the Bell mine (locality 15), which in the spring of 1923 was operated by the Warner Iron Co. The deposit extends east-northeast along the narrow ridge south of Bell Hollow Creek for a distance of nearly half a mile and is 500 to 1,200 feet wide and 40 feet or more deep. In places there is practically no overburden, and lumps of ore are exposed at the surface. The ore is associated with reddish and yellowish clay and considerable chert. Nearly flat lying limestone is exposed in the bluff of the stream about 75 feet below the bottom of the mine. The ore is the characteristic material of this field, consisting of solid lumps of limonite and of conglomeratic and cherty material cemented by limonite. The best ore seemed to lie in the lower part of the deposit. The mine consists of large cuts (see Plate 14, A) in the top of the ridge, at an altitude of more than 750 feet or 155 feet above Bell Hollow Creek. Ore is excavated by a steam shovel and is carried by tramcars drawn by a dinky engine to a grizzly at the top of the hill, from which it goes to a gravity washer at the top of a 100-foot bluff facing Bell Hollow. The material associated with the ore can not all be run through the washer. There are pockets of barren clay, for instance, which are excavated by steam shovel and dumped into hollows where mining will not be done. The material being excavated at the time of visit was reported to average 3 to 4 yards of dirt to 1 ton of ore, although some of it appeared to the writer to be leaner. The ore seems by no means to be exhausted in this tract, as there are areas adjoining the present pit on all sides except the south, which appear to be ore-bearing land, and if this horizon extends along the ridge both east and west of this property, the extension would contain a reserve of more ore than has been mined. It is also reported that there is ore below the level of the deepest cuts.

Two and three-tenths miles southwest of Cumberland furnace are some old mines on property of J. N. Stokes (locality 16). They consist of several pits at the side and end of the ridge, which trends in a south to southwest direction, and are said to have been worked about the time of the Civil War. The altitude of these pits is about 650 to 730 feet, the richest parts of the ore-bearing material being about 50 feet above near-by streams. The overburden consisted of broken chert and clay a few feet thick. There is no bedded rock in place, the associated material being residual chert and clay, but flat-lying limestone outcrops in Bell Hollow Creek. This deposit seems to have been composed of irregular pockets of limonite partly of spring-deposit origin, as it appears to occur at comparatively low levels topographically and is almost down to the level of the branch in places. The depth of the deposits in the highest faces of the pits was 60 to 70 feet. The ore was largely pebbly conglomerate cemented by limonite. There has been some replacement of chert and also of clay by limonite. The limonite is varied in composition. Masses of conglomerate and chert only sparingly ferruginous crop out at the sides of the pits, but there is little ore in sight. Some reddish

hydrous oxides of iron are present. Conditions for mining, washing, and transportation of ore are favorable, as there is plenty of water available, and the railroad spur might be extended from the Bell Mine about 1½ miles distant.

Analyses of iron ores.—The following analyses of brown iron ore are representative of the material, obtained from the vicinity of Cumberland furnace and the Louise mine, Montgomery County, being smelted into pig iron in 1923, according to laboratory records at Cumberland furnace. These analyses show the content of metallic iron to range from 34 to 49 per cent; the insolubles from 18 to 41 per cent; phosphorus from 0.22 to 0.62 per cent, and manganese from 0.20 to 0.42 per cent. The sulphur is reported to range between 0.002 and 0.006 per cent and is so low that it is seldom determined. The general tenor is a moderate percentage of iron with high insoluble material and indicates perhaps that it has not been feasible to wash the ores so thoroughly as might have been desired, especially when the insolubles exceeded the content of metallic iron. The ores were used in making a high-silicon pig, carrying 4 to 8 per cent silicon, in the spring of 1923. Some brown ore was also shipped to Cumberland furnace from the Percy mine, in the Allens Creek district, Lewis County, then owned by the Warner Iron Co., but later acquired by the Bon Air Coal & Iron Corporation (now the Tennessee Products Corporation). Beehive coke from Stonega, Va., and local limestone were used as fuel and flux. For a short period in the fall of 1924 ferrophosphorus was made at Cumberland furnace from local brown iron ore and ground phosphate rock from the Mount Pleasant, Tenn., field. In recent years the market for high-silicon pig iron has been so poor as to necessitate the shutting down of the furnace.

Analyses in percentage of brown iron ore from Cumberland furnace and Louise localities, 1923

Locality	Iron (Fe)	Insoluble	Phosphorus (P)	Manganese (Mn)
Bell mine	43.05	27.86		
	44.93	22.10		
	36.29	38.40		
	33.82	40.58	0.22	0.37
Stokes mine	42.79	27.36	.14	.42
	48.91	18.44	.18	.35
	41.61	27.54		
	38.96	32.78		
	45.78	24.22		
	38.87	33.64		
	41.92	25.16		
Wagon mines northwest of Cumberland Furnace	47.04	22.30		
	43.78	25.58		
	44.67	24.00		
	46.64	19.96		
	42.88	26.60		
	40.08	28.38	.62	.20
Hutton place three-fourths of a mile northwest of Cumberland furnace	38.60	32.70		
Outcrop near Sylvia	41.45	22.64		
Louise mines, Montgomery County	38.67	31.30		
	44.09	23.60		
	43.34	25.62		
	41.12	26.78		
	42.37	24.58		

Limestone for flux.—Fluxing material for Cumberland furnace is obtained from a large quarry (Plate 14, B) on the north side of Furnace Creek about half a mile northeast of the blast furnace. (Locality 17). The rock exposed consists of about 30 feet of high-grade limestone in the lower part of the bluff, overlain by beds about 50 feet thick which contain more or less chert, above which is an overburden of rock débris, clay, and soil from a few feet to 8 or 10 feet thick. The beds are probably of St. Louis age. The best rock is crystalline, gray, high-calcium limestone with stylolitic markings parallel to the bedding planes. It is reported to carry about 97 per cent calcium and magnesium (mostly calcium) carbonates. The base of the quarry is about at creek level, and the maximum height and length are respectively about 90 feet and 1,250 feet. The quarry floor has been worked back about 150 feet, and a large quantity of rock has been obtained here, as the quarry has probably been worked for more than 30 years. The rock is drilled and shot down and is broken where necessary by sledges. The chert is separated from the material from the upper portion, and the suitable fluxing stone is loaded by hand into mule carts, hauled to a skip, hoisted to a crusher where it is broken to about 2-inch size and fed into a bin which empties into railroad cars bound for the furnace. The full capacity of the plant is said to be about 100 tons a day, but this is seldom reached. Analyses of the stone from this quarry as used for flux are reported as follows:

Analyses of limestone from Cumberland furnace quarry

	1 Per cent	2 Per cent
Total fluxes ($CaCO_3$+$MgCO_3$)	91.36	95.86
Insoluble (mostly SiO_2)	6.92	2.67
Iron oxide and alumina (Fe_2O_3+Al_2O_3)	1.08	0.88
Moisture (H_2O)	0.64	....

Early iron industry at Cumberland furnace.—The following historical notes concerning early operations of Cumberland furnace were kindly furnished to the writer by Judge Joe B. Weems, of Dickson, Tenn., in May, 1923.

"The first adventure into the iron-making business west of the Cumberland Mountains was that of General James Robertson, who built and started the operation of Cumberland furnace in 1793.[22] It was located near what was then considered an inexhaustible supply of iron ore about 8 miles distant from Cumberland River.

"Montgomery Bell, while yet a young man, came from Pennsylvania to Tennessee and took charge of the furnace, managing it for General Robertson, the owner. Later he acquired it but did not operate it long, abandoning it for more suitable sites where water power could be utilized. Besides, Montgomery Bell was not an iron maker but an iron worker. His industries were such as utilized the iron. After the abandonment of the site by Montgomery Bell it was acquired by Anthony W.

[22] J. B. Killebrew in Iron and coal of Tennessee, p. 111, gives this date as 1797.

Vanleer, who became one of the most successful iron men in the country. He built up a very large estate and at his death owned Cumberland furnace and probably 20,000 acres of land surrounding it. His grandaughter, Florence Kirkman, inherited the property, and after her marriage to Captain J. P. Drouillard the business was incorporated under the name of J. P. Drouillard Iron Company, and a furnace was operated successfully under the management of Col. R. B. Stone until about 1889 when the Southern Iron Company acquired the property. Under the old management a large farming business was also done. All the labor was colonized in cabins erected in rows about the furnace and at convenient places on the farms. Fuel was secured from the timber cut and burned into charcoal, and the ore had to be dug from the surrounding hills. When converted into iron it had to be hauled 8 miles to Cumberland River. To perform the labor connected with this part of the enterprise many men and teams were required, and still more to cultivate and gather in the crops from the hundreds of acres of land under cultivation on the Furnace Farm. The business was organized and conducted with system and dispatch. The manager required every man to be in his place and do honest work. At the beginning of the day the sunrise whistle blew, and the sleeping day seemed to spring to life and action. The farm hands started from their quarters, the charcoal teams left the barns for the coaling grounds; the iron wagons drew toward the pig yards to get their load for the river. The farm hands went away whistling, singing, and hallowing; the teamsters were popping their long whips with short handles and jeeing and hawing their teams, and the old furnace was just a-heaving and sighing. For one from the dormant life of the back woods all that was an oasis of noise and activity in a vast desert of silence and rest."

(See Plate 13, B).

Deposits near Sylvia.—One-third of a mile north of Sylvia on land owned in Clarksville, a dozen or more shallow prospect pits were noted. (Locality 18). These are in a field at an altitude of about 850 feet, on the ridge that the Mineral Division of the Louisville & Nashville Railroad follows toward Clarksville. Ferruginous chert and limonite are scattered over an area of nearly 2 acres. This material evidently lies at very shallow depth, as it is plowed up in cultivating the fields, and this has caused the belief that important quantities may be present below the surface. The ore is rather siliceous limonite replacing chert also forming a cement in conglomerate. As an ore the surface material would probably be of too low grade and too scarce to mine, although it is near transportation. The prospect pits indicate that the residual ore is actually more abundant than the ore below ground, which is a natural consequence of weathering and concentration by rainfall and erosion of the soil.

One and one-tenth miles north-northeast of Sylvia on land of John Davis are a few very old prospects. (Locality 19). These are situated on ridge land at an altitude of 830 feet and 75 to 100 feet above the nearest creek levels. Several large limestone sinks were noted here. Limonite lumps are plowed up in the wheat fields and limonitic chert is scattered about in the wood lot. The overburden and associated rock are loose chert and soil. The limonite ranges in grade from rich to poor and siliceous. The types are those usual in this field; namely, conglomerate cement and replacement of chert.

There is hardly enough float ore or evidence of ore in the old prospects to warrant the expectation of an important quantity of ore here.

Deposits near Charlotte.—Two miles northwest of Charlotte on the Sylvia and Charlotte pike, on lands of George Wolf and Arthur Berry (locality 20), are several old pits where brown ore was dug, it is reported, at the time of the Civil War. These have been abandoned long enough for hickory and sycamore trees more than a foot thick to grow in the pits. The ore deposits mined here lie almost at the highest part of the ridge, at an altitude of about 830 feet and about 200 feet higher than the level of Town Branch at Charlotte. The old pits extend in two parallel strips about a quarter of a mile N. 80° E. with a width of 200 to 300 feet. The depth to which they were excavated was 10 to 15 feet. The overburden consists of cherty soil a few inches to a few feet in thickness. The material associated with the ore is broken chert, chert gravel, a few quartz pebbles and more or less fine-grained silica and clay. Slabs of pebbly and cherty conglomerate are also present. The ore is limonite apparently rather siliceous. There is so much waste in the form of red clay and gravel on the edges of the old pits as to indicate that the proportion of waste to ore must have been five or more to one. The presence of limonite was probably indicated by float fragments rather than by outcrops of ore unless ferruginous conglomerate may have cropped out. The grade of the ore appears to have been only fair. Most of the available ore was probably worked out here by hand, and the waste is too poor to be washed. The deposits are not particularly well situated for washing or transporting ore, as they are remote from a creek and nearly 3 miles from the railroad at Sylvia. The ore is reported to have been used at the old Carroll furnace 2½ miles north of here.

Three-fourths of a mile southeast of Charlotte on lands of L. A. Wilson and R. E. Corlew (locality 21) are some small old mine pits and prospect pits from which iron ore was mined and hauled to Cumberland furnace during the Civil War. These pits are on the ridge and upland 145 to 175 feet above Town Branch at Charlotte or 735 to 765 feet altitude. The cover over the ore is thin soil and forest mold. The old pits, now 8 to 10 feet deep, are partly filled with débris, and hickory trees 15 inches in diameter are growing in the bottoms. Nearly horizontal bedded limestone, probably of St. Louis age, crops out along Town Branch. The ore is limonite partly of the chert replacement and partly of the conglomeratic type. Some is quite siliceous. Very little ore is in sight here, but there are many areas between the pits that might be prospected with advantage, if it ever becomes feasible to haul ore to the railroad, a distance of about 6 miles.

Four miles east-northeast of Charlotte and about a quarter of a mile south of the Peabody School, on land of Mrs. D. Gillam (locality 22) considerable float and lumps of residual limonite occur in a high field known locally as the "Ore Bank Hill." There are 3 to 4 acres of land above the probable base of the limonite horizon, the altitude of which is about 700 feet

and about 275 feet above the creek near Peabody School. The thickness of the limonite-bearing ground appears to be about 35 feet. There is practically no overburden, as the ore is at the surface and outcrops in ledges a little below the top of the hill. A typical outcrop is shown in Plate 15, A. The ground is composed of chert, clay, sand, and limonite. No solid rock is associated with the ore, but in the creeks near Peabody School are extensive exposures of nearly horizontal limestone weathering into thin beds, and on the road up to the ore-bearing ground sandy chert beds, possibly of Warsaw age, outcrop about 80 to 100 feet below the top of the hill. Very little if any gravel of Cretaceous age is present. Some of the limonite exposed appears to be of very good grade, especially in float lumps, which afford good instances of chert partly to wholly replaced by limonite, but the outcropping ledges are cherty. There is a favorable showing of ore in places, but careful prospecting would be necessary in order to estimate the possible yield. Limonite probably constitutes less than 5 per cent of the whole, and the material would require a great deal of hand picking in order to separate the chert, which occurs in fragments about the same size as the pieces of ore. The site is rather inaccessible, and operations here would involve very difficult wagon haulage to railroad or to present furnaces. The ore could be trammed down to the neighboring streams for washing, but this would necessitate moving a large tonnage of waste.

Deposits northwest of Hortense.—One and one-third miles northwest of Hortense on land of William Edwards (locality 23), prospects for iron ore have been made on the hillside near a new tobacco barn and on the ridge toward the northeast. The prospect pits were 4 to 5 feet deep and generally showed ore the whole depth. The deposits are on a northeast-trending ridge at an altitude of about 850 feet, but ore has been traced nearly all the way down to a spring branch 50 feet lower. The deposits are said to extend along this ridge at intervals of half a mile or more and to be scattered throughout a 50-acre tract, but this statement could not be verified at the time of visit. The hillside outcrop appears to have been formed by spring action. The ore that was seen occurs practically at the surface, and it is associated with broken chert, clay, sand, gravel, and white siliceous material; limestone is found one-third of a mile southwest of these deposits, in the creek valley about 100 feet lower than the ore horizon. The gravel associated with the ore contains some quartz pebbles evidently derived from Cretaceous deposits and bears out the rule that toward the west gravel is more abundant than in the eastern parts of this iron-ore belt. The ore as seen in the outcrops is massive and conglomeratic, good in some spots and sandy and cherty in others. Plate 15, B, shows the position of one of these outcrops. It does not appear as though the average would be of very high grade, although one pit shows a large proportion of high-grade ore. It is reported that this tract was prospected in 1917 and that it was planned to begin operations, build a washer, which would be supplied with water from the big spring at the Zell Edwards place,

and build a tramway 1½ miles long to the railroad at Sylvia, but the project failed of execution. It would doubtless have been difficult to build a tramway through the rough country around the deposits, but the indications are that there is an important supply of ore on this place as yet untouched.

The following analysis was made by D. F. Farrar, of the Tennessee State Geological Survey, of a sample collected by E. F. Burchard from pits near the spring.

Analysis of brown iron ore from point near spring on Edwards place, 1 1-3 miles northwest of Hortense, in per cent

Iron (Fe)	Insoluble	Phosphorus (P)	Manganese (Mn)
52.69	10.36	0.31	0.18

Hortense mines.—One-fourth of a mile to one mile east and southeast of the railroad at Hortense there has been considerable mining and prospecting for brown ore, chiefly at the Hortense mines, where ore has been obtained at intervals since 1879, although not on an important scale until 1915. Much of the ore-bearing land in this vicinity is reported to be the property of Clarksville residents. The Hortense mines consist of a few small pits on the ridge east of Hortense at an altitude of about 925 feet, on both sides of the old Waverly and Charlotte stage road, and several larger pits ranging from 75 to 150 feet in diameter and up to 200 feet in length at lower levels. These larger pits stretch for a distance of three-fourths of a mile southeast of the wagon road, reaching to the headwaters of Little Jones Creek. (Locality 24). North of the road a few test pits showed some pieces of good ore and much chert and sandy rock merely coated with iron oxide. The pit nearest to and about 40 feet lower than the road is about 15 feet deep and 75 feet in diameter. It evidently has been pretty well cleared of its ore, as only a little fragmentary limonite of good quality shows around the walls, which are of dark-red clay. Chert fragments show partial replacement by limonite. On the cleared slope between here and the road are several gulleys, in which lumps of cherty limonite and lumps of limonitic chert too lean to be used as ore have been exposed by erosion.

An ore washer, torn down since mining operations ceased, was situated on the hillside bordering one of the upper branches of Little Jones Creek, about 2,000 feet southeast of the wagon road, and the larger ore pits were in this vicinity. The pit near the site of the washer is about 75 feet wide at the top, 100 feet long, and 30 feet deep. In this pit pink and white clays resembling those of the Tuscaloosa formation in Alabama are exposed, and a little gravel consisting of rounded pebbles of chert and limonite was noted. It is reported that a test well 80 feet deep in the bottom of this pit showed ore, but almost no ore remains in sight, and the ore that was mined must have occurred as a pocket, which has been completely exhausted. In the first large cut northeast of the washer much massive "dornick" ore, too lean and siliceous

for use, has been left after mining. This cut contained considerable water at the time of visit. A search was evidently made for more ore in this locality, as beyond the washer several prospect cuts have been opened, all of which show a very little cherty, gravelly ore. Prospect pits dot the hillside below the end of the old tramway below the washer site, but they show only yellowish clay for the most part.

Apparently the mines near Hortense were actively operated during the World War but have been idle since 1920. A spur track was extended from the Louisville & Nashville Railroad a distance of more than half a mile to the washer. A steam tramway followed the left bank of the creek for a distance of about 2,000 feet below the washer and finally crossed the creek to two cuts in the right bank. The washer discharged into one of the head waters of Little Jones Creek, and a series of settling ponds extended down this valley about half a mile. This washer was operated from about 1915 to 1920 and obtained water from three wells about 150 feet deep. Mining was evidently carelessly conducted here, as too much waste material was mined and run through the washer, but it was locally reported that 2 to 4 yards of the best ore-bearing material would yield 1 ton of ore. The cuts were mined with a steam shovel, and at times as much as 150 tons of ore a day were taken from favorable ground, but the average during active operations was not more than 100 tons a day. The ore was shipped by way of the Louisville & Nashville Railroad to the Helen furnace at Clarksville. The limonite seems to occur chiefly as a cement in conglomerate, and the breaking down of the conglomerate has yielded much of the wash ore. The extreme vertical range of limonite in this vicinity from the highest point on the hill east of Hortense to the lower end of the tramway is about 175 feet, but this height may be due to conformation of the ore horizon with the surface topography rather than to an actual vertical thickness of ore. About four-fifths of a mile northeast of Hortense a few shallow prospect pits and some float of limonite were noted on the slopes south of the old Waverly and Charlotte stage road. (Locality 25). Most of the limonite occurred 15 to 25 feet below the level of the road and 80 to 100 feet above the local streams. The ore fragments in places are of rich limonite, but the predominating material is of the chert-replacement and conglomeratic types. This occurrence probably represents an eastward extension of the deposits that were mined near Hortense, but the showing of ore seems not abundant enough to be important. If ore is present here in quantity sufficient for mining, stripping of soil and chert as much as 20 feet thick may be necessary.

Deposits near Worley furnace site.—The old Worley furnace was situated about 2½ miles west-southwest of Dickson on Worley Branch. South of the furnace site on land reported to belong to the former Bon Air Coal & Iron Corporation, on the upland about 125 feet higher than the creek or at an altitude of about 850 feet, are the largest open cuts from which ore was obtained for this furnace. (Locality 26). Some of these pits are 200 to 500

feet in length and of an irregularly branching form, according as the ore was followed on the spurs of the ridges. The deposit must have underlain an area of 50 acres, more or less, to a depth of 40 to 50 feet. The overburden was generally from 2 or 3 feet to 15 feet thick, but in places the ferruginous masses cropped out. The ore was associated with chert débris, red clay, and gravel. The chert débris contained loose fragments of limonite, some of which consist of rich crusts of bombshell ore, and the limonite also cemented and replaced masses of chert. The old waste dumps still show some fragments of good-grade ore, and in places in the upper parts of the walls of the deeper cuts some wash ore is still visible. The ore hill is red, which indicates the presence of ferruginous material. It is not believed that all the ore has been recovered from this property, and by careful and thorough methods of prospecting, mining, and washing more ore could probably be obtained. The topographic conditions for mining and washing ore are favorable, but a considerable grade would have to be ascended in order to reach the Nashville, Chattanooga & St. Louis Railway at Dickson. The stack of the old Worley furnace has nearly disappeared, only a few blocks of limestone still remaining at the back. It is reported that this furnace was operated a very short time after the Civil War.

On the north side of Worley Branch about one-third of a mile below the old furnace site are 5 or 6 old mine pits and trenches in about 3 acres of woodland. (Locality 27). The altitude of these pits is about 805 feet or about 70 feet above the creek valley. The pits show clay, chert, and gravel associated with lean, cherty, sandy limonite, beginning 2 or 3 feet below the surface and extending to greater depth. Some good-quality limonite in small crusts and fragments was observed. The ore is mainly of the chert-replacement type and overlies some chert conglomerate. A few quartz pebbles were noted on the surface near the top of the hill. Some cherty limonite outcrops in the road one-fourth of a mile southwest of here, below the house of J. L. Vineyard. It occurs near the level of the branch at an altitude of about 730 feet and probably represents recent cementing of gravel by iron deposited from water of springs and of the branch. Conditions for mining about these old pits would be as favorable as for those south of the furnace, but it is feared that there is less ore available for recovery.

Deposits near Laurel furnace site.—The site of the old Laurel furnace is about 3 miles northeast of Burns station on the Nashville, Chattanooga & St. Louis Railway. Iron ore has been mined in several places west and northwest of the furnace. Some of these ore workings are on the place of John Jackson and consist of many pits and trenches from which limonite was obtained prior to 1870. The diggings occupy an area about one-fuorth of a mile in diameter on the hill north of the old Presbyterian church (locality 28), the northeasternmost bank being on a steep hill overlooking Four Mile Branch. The altitude above the level of Four Mile Branch is from 35 to 150 feet, corresponding to an altitude of 635 to 750 feet above sea level. The

area worked over in the scattered pits is nearly one-fourth of a mile in diameter. All the hill is timbered and brushy, most of the growth having come up since the property was acquired by Mr. Jackson in 1870. Some prospect pits at the extreme top of the hill, at the northwest side of the property, seem to be above the horizon of the ore, but up to an altitude of about 735 feet an abundance of ore is shown on the prospect dumps. In intermediate areas and in surrounding fields an abundance of float ore, especially in small lumps, is shown at the surface. In early mining evidently only large lump ore was sought. No washers seem to have been employed, and a great deal of small to fine ore was left in the waste and could now probably be recovered by washing. The ore is associated with chert and clay, but limestone lies nearly horizontal in Four Mile Branch about 35 feet lower than the lowest observed ore diggings. The ore is limonite, chiefly of the chert-replacement type, but appears to be of better grade than the average in this county, as it contains less chert. Much of the ore is of the honeycomb and laminated types in lumps and crusts, and some ore is present in the form of fine sand. In places the ore occurs well toward the surface, but some prospects have been dug to a depth of 15 feet before ore was found, and in general it appears that much of the ore may lie comparatively deep. The ore land is reported to comprise 60 to 70 acres. The site appears to be excellent for mining and washing ore. A railroad spur about 2½ miles long would have to be built to the nearest point on the Nashville, Chattanooga & St. Louis Railway. An early blast furnace on this site was making cast iron about 1810 or 1811, according to Mr. Jackson, who has iron plates in his fireplace bearing those dates, and a later blast furnace is reported to have discontinued operations about 1853 or 1854. Pig iron made here is reported to have won first prize at an exposition in London, England, in 1851.

Nine-tenths of a mile northeast of the Laurel furnace site, or about one-fourth of a mile north of Happy Valley School (locality 29), at an altitude of 750 feet are four shallow prospect trenches on a cleared hill slope. These show only small fragments of limonite on the dumps, and it does not seem possible that any ore could have been obtained here.

Deposits east of Burns.—About 1¾ miles east of Burns there are several old pits and trenches on land of Sam Hogan (locality 30), about half a mile south of the Nashville, Chattanooga & St. Louis Railway, on the wooded hill slope at an altitude of 760 feet or more. The old prospects were scattered over a tract of 30 to 40 acres, but there is still considerable hill or ridge land in the vicinity of these deposits that has not been mined or prospected. As shown in the pits that have been dug, the ferruginous material lay 8 to 15 feet below the surface and was overlain and associated with chert and clay. Limestone was noted in the branch of Beaverdam Creek half a mile south of these workings, at an altitude some 100 feet lower. The evidence of ore was a little honeycomb limonite in good-sized lumps and some crusts on fragments of chert. The outcrops that were seen show only low-grade sandy

limonite. The general appearance of the diggings here suggests that they were made for the purpose of searching for rather than for mining ore, as there is no evidence of cleaning dumps or of waste material such as would have been produced in mining. Systematic prospecting might be warranted here on account of the desirable location for an ore bank, as it is easily accessible to the railroad and water supplies.

Three miles east-northeast of Burns on land of Claude Brown (locality 31) are several shallow pits and trenches nearly overgrown with woods, where ore is reported to have been obtained for the old Bell furnace on Beaver Dam Creek. These openings are on the top and east brow of a hill on the right side of a small branch that flows southeast into Beaver Dam Creek, and they are about seven-tenths to nine-tenths of a mile from the Nashville, Chattanooga & St. Louis Railway. Their height is about 100 feet above the branch level and their altitude between 650 and 700 feet. The ore that was obtained evidently was associated with much chert. Some fragments of good-quality ore including honeycomb material was noted. The deposits lie on narrow ridges so that the area of ore-bearing ground is necessarily limited, and conditions suggest that nearly all the ore-bearing material was mined out during the operation of the mines. If ore should be found here, the problems of water supply and transportation could be readily solved.

Deposits near Tidwell.—Three-quarters of a mile northeast of Tidwell station are the former Montgomery Bell ore banks, consisting of open cuts on the borders of an eastward-trending ridge between two small branches of Nails Creek. The printed map of Dickson County, issued by the State Division of Geology in 1923, seems to be in error here, as the streams draining this locality are shown as flowing into Beaverdam Creek instead of Nails Creek. The Montgomery Bell ore banks are said to have supplied ore to the Warner furnace before the Civil War. The land lies between the place of F. R. Burr on the west and that of Jackson Brown on the east, and it is understood to be owned by Dr. G. A. Slayden, of Dickson.

The limonite that is visible around the old pits appears in part to have replaced sandstone and in part to have cemented terrace pebbles and fragments of sandstone into masses of ferruginous conglomerate. Some of the limonite appears to have been deposited from spring waters, and masses of it, apparently recently formed, are exposed in the bottom and sides of the creek. The sandstone fragments may be from the Warsaw beds. Masses of *Lithostrotion,* fossil corals characteristic of the St. Louis limestone, occur on the upland and in the stream float, showing the probable former presence of St. Louis beds at higher levels than the ore.

R. W. Smith notes that the Montgomery Bell ore banks comprised a tract of at least 200 acres. He took two samples of ore, that from a small pit recently dug yielding the first of the following analyses and that from an old working on the north side of the branch giving the second set of results.

Analyses in per cent of ore from former Montgomery Bell mines

	Iron (Fe)	Insoluble	Phosphorus (P)	Manganese (Mn)
1	51.10	3.84	0.30	0.78
2	46.06	20.44	.44	1.32

The percentage of iron shown by these analyses is favorable, but the percentage of phosphorus appears higher than is desirable for present-day practice in making charcoal iron. A large series of analyses is, however, essential for determining this feature, and in view of the proximity of this ore-bearing tract to the railroad, and the short haul to a blast furnace it might be worthy of further thorough prospecting.

Deposits near Iron Hill.—About half a mile northeast of the Iron Hill station on the Centerville branch of the Nashville, Chattanooga & St. Louis Railway are the Iron Hill mines of the Tennessee Products Corporation. (Locality 33). The ore-bearing ground comprises a tract of several acres on a low wooded hill at an altitude between 850 and 900 feet. The outline and depth of the ore deposit are irregular, depending on the depth of weathering and the erosion of the old surface of cherty Mississippian rocks. These workings were visited in October, 1921, when they were inactive and the old pits partly filled with water, and in May, 1923, and in August, 1927, when mining was in progress in the new open cuts. (Plate 16, A). The overburden consists chiefly of soil and reddish loam from a few inches to 4 to 5 feet thick, with some chert débris. In places this loam lies directly on barren residue from chert. Occasionally a quartz pebble is found loose in the loam or cemented into bouldery masses of limonite and chert. In places the loam contains considerable quartz sand, and fragments of limonite are also present. Some "shot ore" is scattered over the surface and a few larger lumps may be seen here and there, but generally there is not much showing on the surface. The materials associated with the ore are light-colored chert, in angular fragments and pebbles, and red clay, both residual from rocks of Mississippian age. The solid rock is not visible here but crops out in the larger creeks at a lower level. The ore is most abundant in hollows between the residual chert masses. The ore is limonite, in places in solid masses that have replaced chert and clay, but generally it is full of irregular cavities. Some "bombshell" ore was noted, containing moist reddish clay inside the cavities. The inner surface of some crusts from this type of ore is coated with lustrous black limonite. There does not appear to be as much chert in the ore as farther north in Dickson and other counties, but generally the ore is only moderately high in iron, as the presence of considerable silica must influence this factor. The ore, fortunately, contains a relatively low percentage of phosphorus and the manganese is fairly uniform as shown in the analyses on pages 86 and 87. The proportion of waste clay and chert would be high if the whole of the deposit were mined out, but by selective methods, in which blocks and pinnacles of

residual clay, chert, and top soil are left, the mining may have succeeded in recovering 1 ton of ore to 5 yards of dirt, as is locally reported.

The deposit was first mined about 1891 and was prospected again in 1920. The early mining was done by hand, and the ore was washed but not in a thorough manner, because there remained in 1921 a pile containing about 1,000 tons of fine ore screenings. The old mine pits show walls of clay and chert rising about 20 feet above water and are said to have extended 8 to 20 feet below that level, making them in some places as much as 40 feet deep. The topography of the tract is favorable for mining, although the early mine pits had to be drained by pumping. There is more or less timber in the vicinity, but it is only a scrub growth of oak, sycamore, persimmon, and underbrush. The prospects made in 1920 indicated a sufficient reserve of ore to warrant new operations and the construction of a standard-gage spur track about 3,200 feet long from the Nashville, Chattanooga & St. Louis Railway to the new washer site. The new developments planned to yield ore for the washer comprised a tract of about 12 acres adjoining the old mine pits on the north, northwest, and northeast. This tract was prospected by a number of test pits and wells, most of which showed more or less ore of fair to good quality mostly in small lumps.

A record of the prospect pits and banks that showed ore with analyses of the ore sampled is as follows:

Prospect record and analyses of brown iron ore in Iron Hill mine workings, 1920

Prospect		Depth (feet)	Bottom	Quantity of ore	Analyses, percentages			
No.	Kind				Iron (Fe)	Insoluble	Phosphorus (P)	Manganese (Mn)
1	Pit	13	Clay	Poor				
2	Pit	7	Solid	Good	53.19	8.19	0.084	0.39
3	Pit	6	Solid	Good	52.43	10.04	.080	.42
4	Pit	9	Clay	Poor				
5	Pit	8	Solid	Good	49.19	13.38	.13	.29
6	Pit	7	Clay	Poor				
7	Pit	13	Clay	Poor				
8	Pit	11	Ore	Fair	50.31	12.85	.10	.37
9	Pit	10	Solid	Good	57.55	4.62	.079	.41
10	Pit	4	Solid	Good	52.28	9.26	.092	.36
17	Pit	7	Ore	Good	55.37	6.44	.082	.39
26	Pit	9	Solid	Good	54.94	6.69	.081	.39
1	Bank	12	Ore	Good	33.57	29.99	.09	.28
2	Bank	11	Ore	Good	32.81	38.30	.11	.26
3	Bank	24	Clay	Poor				
4	Bank	14	Ore	Fair	47.74	16.61	.15	.57
5	Bank	15	Ore	Good	35.75	28.24	.18	.29
6	Bank	13	Ore	Good	48.17	16.99	.13	.30
7	Bank	18	Ore	Fair	38.80	24.18	.14	.27
8	Bank	15	Ore	Good	42.07	22.15	.12	.27
9	Bank	17	Ore	Good	38.04	24.32	.10	.34
0	Bank	6	Ore	Fair	47.09	20.64	.19	.28
11	Bank	6½	Ore	Fair				
12	Bank	24	Ore	Fair	35.23	30.36	.18	.29
13	Bank	12	Ore	Good	40.55	19.65	.11	.91
14	Bank	13	Clay	Poor				
15	Bank	10	Ore	Good	33.65	31.65	.17	.30
16	Bank	14	Ore	Good	49.16	9.78	.72	1.00

A map and record of prospecting of the old Iron Hill mine workings by means of pits and drill holes, mostly within the old open cuts, and prospect openings in the banks of the cuts, furnished by the former Bon Air Coal &

Iron Corporation from which the above table was derived, showed ore in 8 out of 12 prospect pits, in 23 out of 39 drill holes, and in 13 out of 16 openings in the banks of the cuts. The thickness of ore-bearing ground ranged from 4 to 24 feet, mainly from 9 to 15 feet, and many of the prospects did not cut through the deposits. These prospects do not include those in the unmined area north of the old workings.

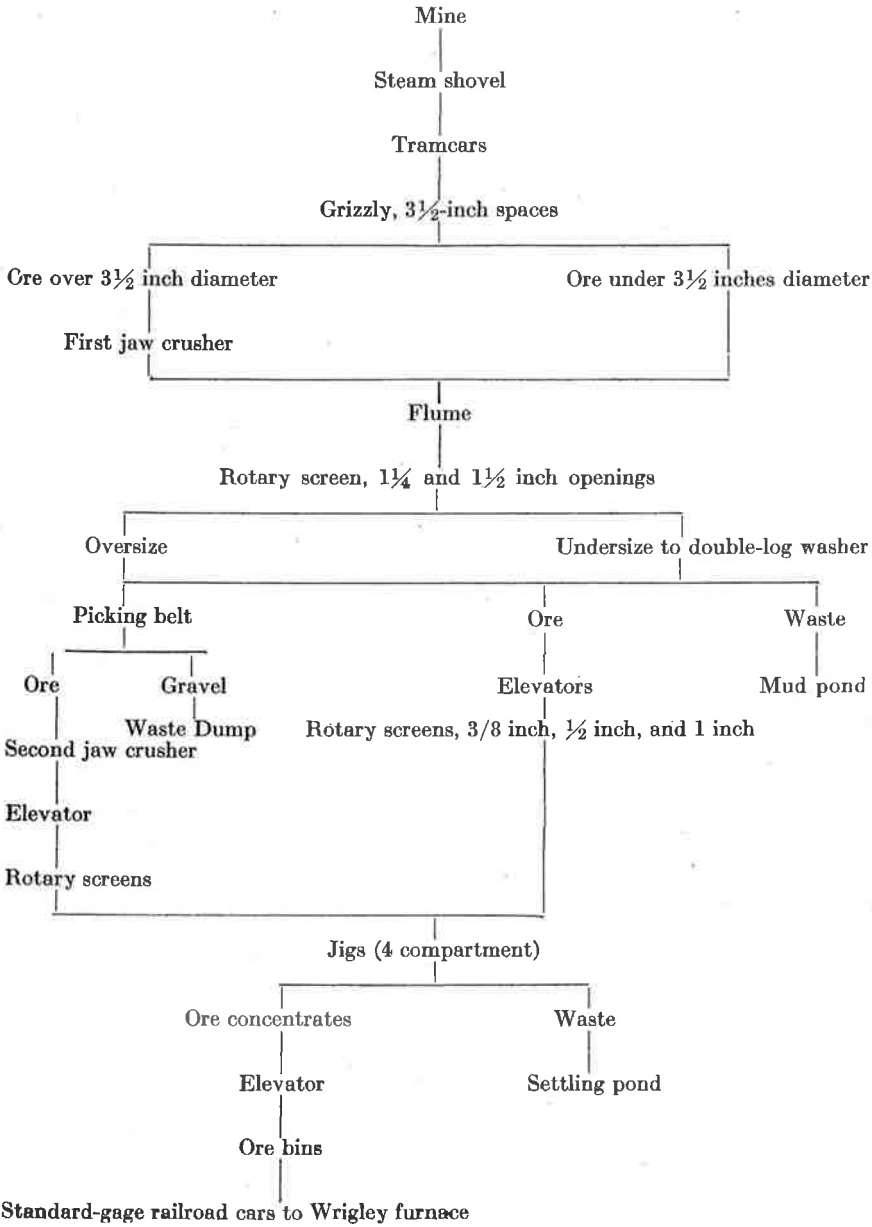
The following analyses, made at the Wrigley furnace laboratories, as were those included in the table of prospects, show an acceptable grade of ore.

Analyses of brown iron ore from Iron Hill mine

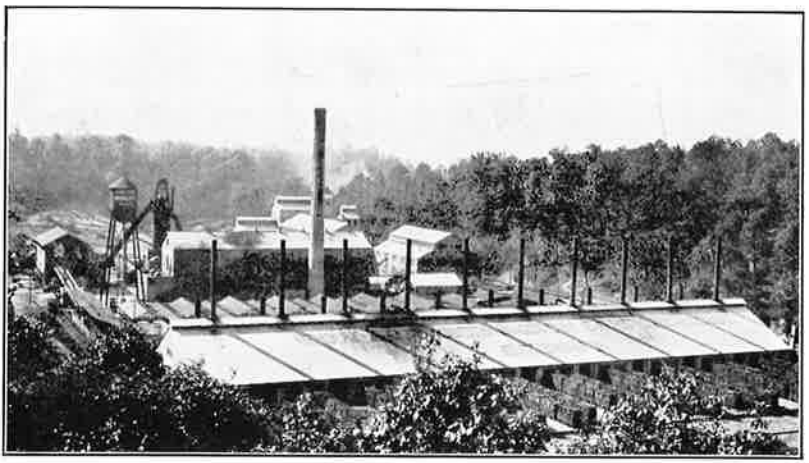
Date	Iron (Fe) Per cent	Insoluble Per cent	Phosphorus (P) Per cent	Manganese (Percent)
June 16, 1920	51.28	11.96	0.22	0.25
	40.37	24.04	.21	.27
	51.67	11.52	.195	.27
April 11, 1923	44.53	.....	.....	.....
	48.69	.....	.128	.73
April 24, 1923	43.47	26.60	.116	.40
January 4, 1927	52.20	14.60	.15	.....
January 13, 1927	47.20	19.30	.15	.....
January 18, 1927	50.20	15.00	.19	.....
May 28, 1927	53.40	12.84	.16	.....
July, 1927; composite analysis	50.70	15.22	.11	.19

In the spring of 1923 a cut for a dinky tramway in the new mine was being made by a tractor Erie steam shovel operated by two men. It was planned to use this shovel in mining the ore, working back toward the washer. From 1923 to late in 1927 much ground was excavated, including the ore-bearing hill between the washer and the old pits, and some of the recent pits reached a depth of 40 to 60 feet. The clay associated with the ore in this vicinity is deep red and yields more ore than a visual inspection would at first indicate. The ore concentrates from the washer as loaded into railroad cars appeared to be of good-grade, dark-reddish brown ore containing little visible impurity. In August, 1927, it was the opinion of miners that much of the available ore had been mined out, but that there might be a supply sufficient to last 1½ years longer at the rate of output then prevailing. The ore from this locality is very valuable on account of its low percentage of phosphorus, and its careful and thorough extraction is important. The washer erected in 1923, 50 feet west of the old Iron Hill open cuts (see Plate 16, A), was designed for a maximum capacity of 100 tons in a 10-hour day and usually produces about 75 tons a day. Ore is delivered in tramcars, and water is obtained from Nails Creek. A flow sheet indicating the equipment of this washer is given below.

Flow sheet of the Iron Hill ore washer operated by the Tennessee Products Corporation
Locality 32, Dickson County



(A) Washing plant at Iron Hill brown iron ore mine, Dickson County, August, 1927.



(B) Coking and by-product plant of the former Bon Air Coal and Iron Corporation, Wrigley, Hickman County, viewed from the north.

When the Iron Hill locality was visited in 1921, the Survey representatives were shown prospects on the Jackson Brown place, west of the Nashville, Chattanooga & St. Louis Railway, about three-fourths of a mile northwest of Iron Hill. The material exposed near the top of the south slope of the hill consisted of large masses of chert conglomerate cemented by limonite. The chert fragments are rounded to angular and from a fraction of an inch to 3 or 4 inches in diameter. The chert makes up more than 50 per cent of the mass, which therefore can not be regarded as rich enough in iron to constitute an ore.

Half a mile northeast of Iron Hill, on the sides of the hills sloping toward a branch of Nails Creek float limonite, principally in the form of shot ore, is abundant enough in several places to attract attention. In Nails Creek just below the mouth of this branch there was in August, 1927, considerable limonite sand and gravel, concentrated by the waters of the creek in hollows behind ledges of limestone in the stream bed. Whether this float ore comes from the vicinity of the Iron Hill mine workings or from unopened deposits of iron ore between here and the mines is a question of interest. It can hardly come from the Iron Hill ore washer, because the settling pond is over the divide toward the west and drains into the headquarters of Bear Creek.

Deposits near Herbertson School.—Herbertson School is about 3 miles southeast of Dickson and less than 1 mile west of the Nashville, Chattanooga & St. Louis Railway. On the upland southwest of the school iron ore has been mined in two localities. One of these, known as the Cavill tract (locality 34), is about two-thirds of a mile south-southwest of the school or 1,000 to 1,500 feet south of the local wagon road. Here several old pits of considerable depth and some scattered fragments of limonite testify to mining activity ended so long ago that large trees have grown in the pits. The ferruginous deposits were evidently localized near the escarpment where the upland breaks down into bordering ravines. Much of the ore is pebbly and sandy and appears to have been deposited from iron-bearing spring waters.

According to notes by R. W. Smith the Cavill tract contains 220 acres, of which possibly 75 acres lies on two low north-south ridges showing evidences of iron ore. The east ridge had several very old workings and old prospect holes. One of the old workings showed on the surface considerable shot ore, some good lump ore of the dense, massive type, and no pebbly ore, but the other openings showed considerable of the pebbly variety. On the west ridge a few old openings showed some good ore and much pebbly ore. The following analysis was yielded by a sample taken from a small pile of ore, mostly pebbly, thrown out from a hole on the west side of the property.

Analysis of ore from Cavill tract by percentage

Iron (Fe)	Insoluble	Phosphorus (P)	Manganese (Mn)
47.87	18.96	0.38	1.18

It seems probable that prospecting on the neighboring ridge land might disclose more ore of this character.

About 1 mile west-southwest of Herbertson School (locality 35) on lands of J. Lyle and J. W. Clifton are some shallow prospects from which some limonite was evidently taken many years ago. This locality does not promise to yield a large quantity of ore but might also be worth prospecting.

Deposits south of Tennessee City.—In August, 1927, a reconnaissance was made along Garners Creek from Tennessee City to the southwest corner of Dickson County. First, the deposit of gravel in the cut of the Nashville, Chattanooga, & St. Louis Railway one-third of a mile east of Tennessee City was examined for the presence of iron minerals. This deposit consists of light-colored chert gravel embedded in white to pink sandy clay and is probably of Tuscaloosa age. The pebbles are from a fraction of an inch to 2 inches in diameter, are subangular, mostly of hard, undecomposed chert, and many of them contain Mississippian fossils. The material is singularly free from ferruginous material, as it is not iron stained and contains no shot ore or gravel of limonite.

Limonite was, however, observed in at least three places south of Tennessee City. On the place of F. M. Lucas, about 1½ miles south of the Nashville, Chattanooga & St. Louis Railway on the west side of Garners Creek (locality 36), boulders of limonite and limonite-cemented conglomerate were found on the slope of the ridge some distance above the creek. This material was associated with chert and was not present in commercial quantity.

About 3 miles down Garners Creek from Tennessee City, on the Clifton place (locality 37), an outcrop of conglomerate containing a large proportion of limonite was noted. This outcrop forms the point of a ridge a few hundred feet east of Garners Creek, just north of where a small branch enters the bottom land of the creek. An old tobacco barn stands on the west side of the creek a short distance above this point. This mass of ferruginous conglomerate extends from near the level of the bottom land upward about 30 feet. It contains both rounded and angular chert pebbles, cemented together and partly replaced by limonite, and some limonite that may have been formed by replacement of sandy clay. The proportion of chert that would have to be separated in concentrating this ore is large, and it is doubtful if the deposit as shown on its outcrop could be worked commercially.

On the place of Melvin Harris on the west side of Garners Creek, about 1 mile south of Garners Creek School (locality 38), some limonite boulders of very good grade were seen well up on the cherty slope of a hill. The ore appears as if it may be residual from a deposit, which formerly lay at a higher level and which has been let down along with the erosion of its inclosing clay and chert. Very little time could be devoted to examining this material and none to the adjacent upland, but it appears as though the vicinity might

justify a careful search for more ore. The locality is, however, about 7½ miles from the railroad at Tennessee City, a long distance for hauling.

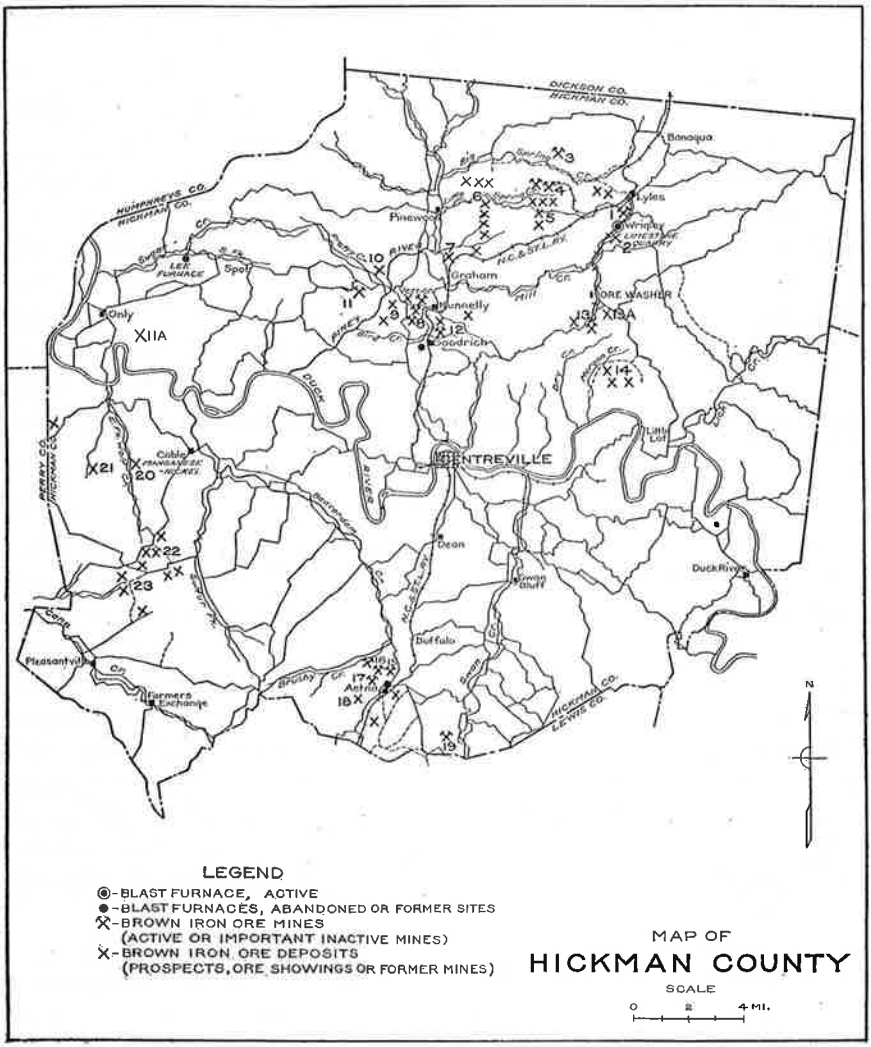
HICKMAN COUNTY

The brown iron ore deposits in Hickman County (Plate 17) are largely in the northern half of the county or north of Duck River and fall into three groups; namely, that between Lyles and Pinewood, that near Nunnelly, and some deposits near Dry Creek and Jerry Branch 5 to 7 miles south of Lyles, but there are also important deposits in the southern part of the county near Aetna. In the western part of the county southwest of Coble large tracts of land show signs of brown ore, but no intensive prospecting or mining has been done there. The only active blast furnace is that of the Bon Air Chemical Company at Wrigley, but furnaces were formerly situated on Sugar Creek in the northwest part of the county, at Goodrich near the middle, and at Aetna in the southern part. The iron-ore deposits will be described beginning with those in the north.

BLAST FURNACE AND BY-PRODUCT PLANT AT WRIGLEY

The most important blast furnace and incidental industrial development in Hickman County is at Wrigley, 1¼ miles south of Lyles. The Wrigley furnace of the Bon Air Chemical Co., a subsidiary of the Tennessee Products Corporation, is situated here on the site of the former Warner furnace, which was built about 1881. It is a single stack, 80-ton, skip-filled, modern, semi-cold-blast charcoal furnace, operated in connection with a large by-product plant built by the United States Government during the World War for the recovery of wood alcohol, acetic acid, and tar. The by-product plant, blast furnace, and limestone quarry are connected with the Nashville, Chattanooga & St. Louis Railway at Lyles by a spur track about 2 miles long, beyond which a narrow-gage tramway extends to the ore washer and the Johnson mines about 3½ miles farther south.

In the Wrigley plant the "by-product" is actually pig iron, as the products of wood distillation are the more important, and more capital is invested in the recovery plant and forests than in the blast furnace. In such a plant the charcoal would be a surplus product, and so its use in the blast furnace becomes the most natural outlet, although charcoal itself is one of the marketed products. The general principles involved in the wood distillation are the heating of oak and hickory wood in retorts until all the liquid and gaseous contents are expelled, the collection of these liquids and their fixation, and the use of the carbonized wood, or charcoal, in the blast furnace. The loss of weight in carbonizing the wood is about 70 per cent. The essential features of the plant, views of which are shown in Plates 16, B, 18, A and B, and 19, B, were as follows when visited in 1923: Wood, mostly of oak, 4-foot lengths is placed in steel buggies holding 2½ cords each; trains of



Map of Hickman County, showing brown iron ore deposits, mines, and blast furnaces.

4 buggies each are pushed into the retorts by means of an electrically driven transfer table and sealed within. There are 20 retorts, 53 feet long, 9½ feet high, and about 6½ feet wide, set in batteries of pairs, each with the necessary condensers and pipe lines for liquid and gaseous products. (Plates 18, A and B). The retorts each have two outlets into the condensers. They are fired with coal in double-end fire boxes and use also gas from the wood that can not be condensed to liquid. The liquid products of distillation are pyroligneous acid (which contains alcohol), acetic acids, oils, and tars. These products are collected from the condensers into a central tank and pumped into holding tanks in the stillhouse for further distillation and fixation. It requires about 24 hours for the carbonization of a charge of dry wood and 36 hours for green wood. When the wood has been carbonized, the steel cars, now containing charcoal, are drawn out of the end of the retort opposite the one which they entered and are quickly shut into the first set of cooling chambers and later are moved into the second cooling chambers. This cooling is necessary in order to prevent the combustion of the charcoal, which would take place if the red-hot material from the retorts were allowed to stand in the air. Eventually the buggies of charcoal are drawn out of the cooling chambers into sheds (Plates 18, A and B) and are gathered by an electric shifter similar to the one used in charging the retorts and moved to the coke storage house where their contents are dumped.

The production of raw liquor was reported as approximately 250 to 260 gallons from a cord of oak or hickory, but beech or maple will yield about 300 gallons to the cord. (Figures obtained at the plant of the Wayne Wood Products Co. at Collinwood were to the effect that under favorable conditions 200 cords of wood will produce 10,000 bushels of charcoal and 45,000 gallons of crude pyroligneous acid, from which are obtained 2,000 gallons of methyl alcohol, 2,000 gallons of tar and oils, and 40,000 lbs. of dry acetate of lime [23]). At the time of visit about 160 cords of wood was used per day in the Wrigley plant. The distilling plant, (Plate 19, B), equipped by E. Badger & Sons Co., of Boston, contains tar-settling tanks, digesting tanks, distillation tanks, lime mixers, and acetate of lime tanks, and the dryer building is equipped with an evaporator drum, a chain conveyor for calcium acetate slime, a woven-wire dryer, storage bins, and acetate baggers. The acetic acid is fixed as calcium acetate by addition of lime and water, and the crude, dried calcium acetate carries about 80 per cent of the pure salt. This material is placed in bags holding 120 to 125 lbs. In the spring of 1923 shipments of calcium acetate were being made to the Netherlands, where it was to be converted into methyl acetate for use in the manufacture of lacquers. Other uses in the chemical industries are to produce acetic acid, other acetates, and acetone.

[23] The Wayne plant is described in Tennessee Geol. Survey Bull. 26, pp. 169-171.

The principal uses for charcoal iron[24] are in the manfacture of chilled rolls, car wheels, chilled surfaces for crushing and grinding machinery, and for general castings that require a specially fine metal, such as small or medium-sized cylinders, or thin castings that require great strength with sufficient softness to machine well. Plate 19, B shows the modern blast furnace and stock of charcoal pig iron in June, 1923.

The following analyses, furnished in 1923, of charcoal pig iron made at Wrigley furnace show a range in silicon from 0.63 to 2.78, but mostly between 1.5 and 2.35, per cent; sulphur between 0.014 and 0.025; phosphorus between 0.56 and 0.72; and manganese between 0.22 and 0.72 per cent.

Analyses of charcoal pig iron from Wrigley furnace, Tennessee

Cast No.	Sample	Silicon (Si) Per cent	Sulphur (S) Per cent	Phosphorus (P) Per cent	Manganese (Mn) Per cen
1	1	2.25	0.014	0.595	0.50
2	2	2.35	.014	.572	.50
3	1	2.42	.014	.560	.52
4	1	1.75	.016	.568	.40
5	1	2.60	.015	.572	.38
6	1	1.75	.015	.572	.41
7	1	2.08	.015	.572	.43
8	1	2.56	.016	.600	.52
	2	2.78	.016	.600	
9	1	2.10	.016	.568	.48
10	1	0.63	.027	.632	.22
	2	.63			
11	1	1.14	.021	.608	.54
12	1	1.90	.018	.584	.92
	2	1.92			
	3	1.75			
13	1	1.97	.018	.590	.72
	2	2.06			
14	1	1.58	.017	.588	.64
	2	1.57			
	1	1.60	.015	.656	.60
15	2	1.95			
	3	1.15			
16	1	1.95	.015	.656	.56
	2	1.92			
17	1	1.75	.015	.688	.46
	2	1.81			
	3	1.26			
18	1	1.12	.020	.710	.50
	2	1.06			
19	1	2.13	.025	.720	.55
	2	2.18			
20	1	2.35	.025	.704	.58

The grading card referring to the Wrigley semicold-blast charcoal pig iron produced by the Bon Air Chemical Co. in 1927 shows the following standard grades and ranges in composition.

[24]Moldenke, Richard, Charcoal iron, Lime Rock, Conn., Salisbury Iron Corporation, 1920.

Grading card, Wrigley semicold-blast charcoal pig iron

Standard grades	Minimum silicon Per cent	Average silicon Per cent	Maximum silicon Per cent	Manganese Per cent
AA Scotch	2.63	2.75	3.25	0.50 to 0.70
A Scotch	2.37	2.50	2.63	.50 to .70
B Scotch	2.12	2.25	2.37	.45 to .65
C Scotch	1.87	2.00	2.12	.45 to .65
No. 1, low	1.65	1.75	1.87	.40 to .65
No 1, high	1.37	1.50	1.62	.40 to .65
No. 2, low	1.12	1.25	1.37	.30 to .50
No. 2, high	0.88	1.00	1.12	.30 to .50
No. 3, low	.63	0.75	0.88	.25 to .40
No. 3, high	.50	.55	.63	.20 to .35
No. 4, low	.40	.45	.50	.15 to .30
No. 4, high	.30	.35	.40	.15 to .25
No. 5, low	.20	.25	.30	.10 to .20
No. 5, high	10	.15	.20	Under .20
No. 6, white	.00	.05	.10	Under .12

Sulphur 0.02 approximately. Phosphorus 0.40—0.70

An article in the Manufacturers Record[25] tells much of interest with regard to the Wrigley plant. As to the products the following account is given:

"Some idea of the magnitude of the operations at the Wrigley plant may be gained from a statement that in 1926 it loaded 7,200 cars of products. In this output were included thousands of tons of Wrigley semicold-blast charcoal pig iron, millions of pounds of acetate of lime, millions of bushels of charcoal, and hundreds of thousands of gallons of methanol, or wood alcohol, wood oil, wood pitch and by-products.

"The output of the furnace, I was informed, is taken by manufacturers of chilled rolls, automotive parts, Diesel engines, crushers, and particularly of castings in which great strength, smoothness and close grain are essential—more specifically, in castings in which the factor of internal shrinkage or expansion must be overcome. The entire production of methanol of this plant is sold to refiners and is used, for the most part, in the manufacture of paints, varnishes, lacquers, dyes and as a solvent in many chemical formulae; also, it serves as an agent in the manufacture of formaldehyde and other widely known antiseptics. The acetate of lime is used largely in the United States and abroad in the manufacture of acetone, a solvent used in the making of explosives, photographic films, celluloid and other products, while an appreciable amount is used also in the manufacture of acetic acid for paint and varnish industries, and in the manufacture of various other chemicals. The wood oils and wood pitch go into the making of wood creosote paints and flotation oils for use in metallurgical processes, while, finally, the charcoal produced in the carbonization process, over and above the requirements for the Wrigley furnace is used very largely in the metallurgical industry and for domestic purposes."

At this point a note on the general enterprise of which the Wrigley plants are a part[26] may be of interest. The Tennessee Products Corporation began operations as such on March 1, 1926, as a consolidation of the properties and business of the Bon Air Coal & Iron Corporation, the Chattanooga

[25]Garner, George, The Tennessee Products Corporation unfolds some of the wonders of the South: Manufacturers Record, July 14, 1927, pp. 61-66.

[26]Idem, pp. 62-65.

Coke & Gas Co., and of J. J. Gray, Jr. With a capital of $31,000,000 the corporation is an industrial enterprise with more than 2,500 employes on its payrolls and more than 10,000 persons living in the towns over which it exercises supervision.

More than 150,000 acres of coal, timber, mining, and agricultural lands are included in the holdings of the corporation in Montgomery, Dickson, Hickman, Stewart, Lewis, Wayne, Lawrence, Maury, White, Cumberland, Van Buren, Putnam, Hamilton, and Davidson Counties, all in central Tennessee, and near the towns of Bon Air, Eastland, Ravenscroft, Clifty, Collinwood, Goodrich, Allens Creek, Aetna, Nunnelly, Wrigley, Iron Hill, Rockdale, Iron City, and Clarksville. The outbound carload movement of the corporation in 1926 aggregatd over 13,000 cars, and the revenue derived from inbound and outbound movements totalled more than $1,125,000.

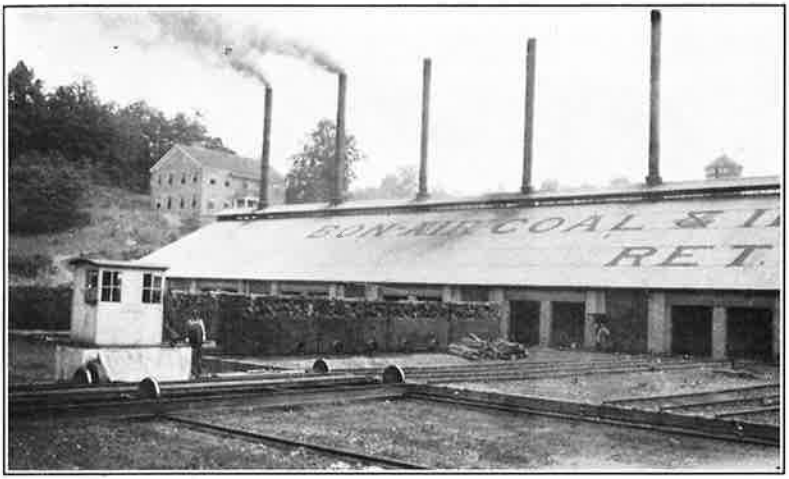
The coal operations are confined chiefly to the Bon Air Mountain, midway between Knoxville and Nashville on the Memphis to Bristol Highway. For half a century these mines have furnished high-grade coal for domestic and industrial use, and for many years the Nashville, Chattanooga & St. Louis Railway has been supplied constantly with steam coal from the mines.

At Alton Park, Chattanooga, is situated the Semet-Solvay coke and gas plant, equipped with 24 by-product ovens and annually producing large quantities of ammonia, coal tar, and motor benzol. The gas produced at the plant is metered for domestic purposes under a franchise to the Chattanooga Gas Company.

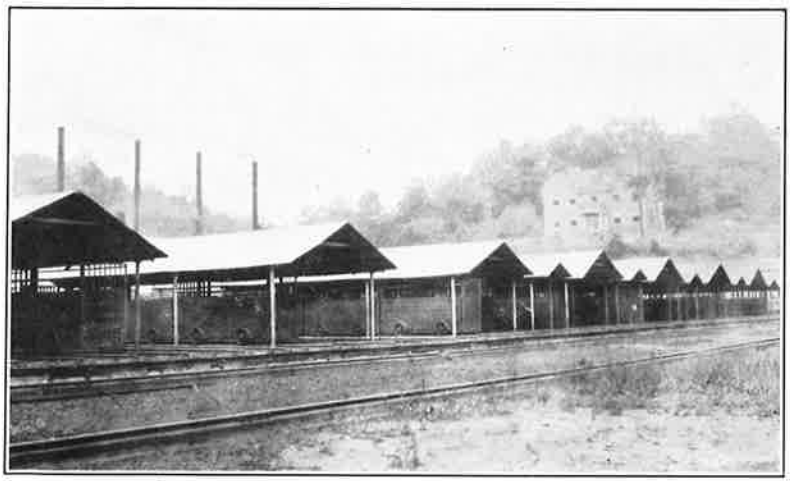
Production of industrial commodities and earning of dividends are by no means the only, or chief, activities of the Tennessee Products Corporation. Coincidentally it strives to develop fine American citizens and to assure the moral, mental, and physical advancement of all its employes and their families. Under the personal guidance of a Director of Welfare community meetings and entertainments are held regularly in the various towns and settlements of the corporation, houses are regularly inspected under sanitary regulations, able teachers are provided for the schools, and ample provision is made for religious instruction.

Wrigley furnace was drawing its supplies of brown iron ore in 1927 chiefly from the Iron Hill and Johnson mines, described on page 85 and 106-108, but ores from other places are also used as, for instance, brown ore from Cedartown, Ga., and occasionally a little low-phosphorus iron oxide sinter from the copper smelter at Copper Hill, Tenn., and high-manganese iron ore from the Lake Superior district. By using a mixture of brown ores in the proportion of about one-half from the Johnson mines, one-fourth from the Iron Hill mine, and one-fourth from Cedartown, Ga., the pig iron can be kept so as to contain nearly 0.50 per cent phosphorus, although the range is at times as wide as from 0.40 to 0.70 per cent.

Some composite analyses of these ores, made in July, 1927, by the Bon Air Chemical Co., are as follows:



(A) Charging end of retort house, Wrigley by-product plant of the former Bon Air Coal & Iron Corporation showing buggies loaded with wood ready to be moved into retort house by electric transfer table.



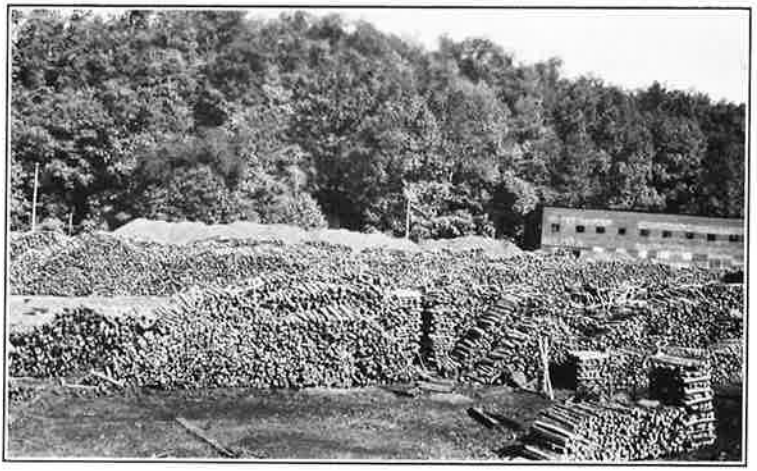
(B) Charcoal-cooling sheds south of retort house, Wrigley by-product plant.

(A) General view of Johnson brown iron ore mine, 4 miles south of Lyles, Hickman County.
(By courtesy of Tennessee Products Corporation.)

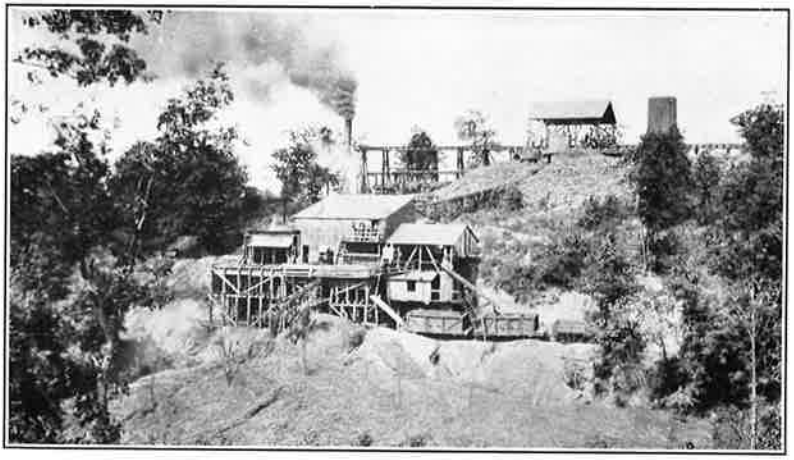
(B) General view of Wrigley by-product plant and blast furnace from south. Distilling plant at left.
(By courtesy of Tennessee Products Corporation.)

(A) Fluxing-limestone quarry and crushing plant of the former Bon Air Coal & Iron Corporation, half a mile south of Wrigley furnace.

(B) Near view of face of fluxing-limestone quarry of the former Bon Air Coal & Iron Corporation, half a mile south of Wrigley furnace.



(A) Hardwood for making charcoal at by-product plant of the former Bon Air Coal & Iron Corporation at Wrigley.



(B) Washing plant at Johnson brown iron ore mines, 3 miles south of Wrigley.

Composite analyses in percentages of brown iron ores used at Wrigley furnace, Tennessee

	Iron (Fe)	Insoluble	Phosphorus (P)	Manganese (Mn)	Silica (SiO_2)	Alumina (Al_2O_3)	Soluble alumina
Johnson mine	50.60	13.64	0.47	0.16	12.77	1.91	1.04
Iron Hill mine	50.70	15.22	.11	.19	13.82	4.48	1.40
Cedartown, Ga., mine	49.50	16.96	.12	.60	15.00	7.23	5.27

The sinter from Copper Hill, Tenn., analyzed Nov. 30, 1926, carried 63.17 per cent iron, 5.45 per cent silica, 1.15 per cent alumina, 0.017 per cent phosphorus, 0.13 per cent manganese, 0.045 per cent sulphur, 0.051 per cent copper, and a trace of zinc.

As it is very desirable that a supply of iron ore low in phosphorus continue available to Wrigley furnace, the opportunity for selling this grade of ore here is at present much better than for ores in this field that carry the usual percentage of that element.

Fluxing material.—Limestone of Mississippian age is exposed in proximity to the iron-ore deposits in the valleys of many streams in Hickman County, including Big and Little Spring Creeks, Barren Fork, Mill Creek and other tributaries of Piney and Duck Rivers. Many of the beds contain limestone of value for flux in the blast furnace and for the manufacture of lime. For these purposes freedom from chert, sandstone, and lime phosphate is essential, and location on or near a railroad is also essential for large operations.

Wrigley quarry.—The largest fluxing-stone quarry in the county is that of the Bon Air Chemical Co., situated about half a mile south of the Wrigley blast furnace, in the bluff at the left side of the North Fork of Mill Creek. (Locality 2, Hickman County). (Plates 20, A and B). In 1923 the working floor of the quarry was about 30 feet above the level of the creek, the length of the quarry face was about 550 feet, the height above the working floor was about 70 feet, and quarrying had extended back about 75 feet on the floor level. The horizon of the limestone within the Mississippian has not been determined, but it is probably either Warsaw or St. Louis. Sandstone, probably of Warsaw age, crops out at Wrigley at the side of the road a little northwest of the office building of the Bon Air Chemical Co. The following section is displayed in the quarry face.

Section of limestone quarry on Mill Creek near Wrigley Furnace, Tennessee

Working quarry:	Feet
Top, altitude about 765 feet.	
Overburden, soil, reddish clay, and rock débris (chert, limestone, and sandstone) in pockets	1 – 15
Limestone, weathered, buff-colored, contains a little sand and possibly magnesium carbonate	5 – 20
Limestone, dark-grayish, crystalline; contains specks of iron pyrites and of green-stained calcite	8 – 10

	Feet
Limestone, cherty, wedge from middle to northeast end of quarry	0 – 2
Limestone, massive, light-gray, crystalline, stylolitic; contains three or four bands of flattened cherty nodules in upper half	35
Main quarry floor, altitude about 690 feet.	
Face between working quarry and creek:	
Limestone, cherty, top irregular but becomes thicker at ends and below quarry floor. Contains in places on its upper surface a layer 1-8 inch to 1-4 inch thick of black bituminous matter	6 – 15
Limestone, gray, crystalline, fossiliferous, containing chert and bituminous sheets in places. Stylolitic markings are bituminous	20
Level of Mill Creek, altitude about 660 feet.	

Although considerable rock has already been quarried here, the reserves are still extensive, for the beds extend 500 feet or more through the hill to another hollow on the southeast and the hill slope back of the quarry which rises about 25 feet above the present quarry face probably contains additional beds of limestone. Preparations were also being made to work the beds just above the creek level in an opening extending about 400 feet northeast from the northeast end of the upper quarry. The good limestone from here will be used for furnace flux, and the chert will be separated and used for highway construction. The light-gray crystalline limestone, 35 feet of which was exposed in the main quarry, was reported to carry about 96 per cent calcium carbonate.

At the time of visit the main quarry was worked by blasting down rock, breaking with sledges, and loading into 2-wheel mule-drawn carts. From the carts the rock was dumped into a gyratory crusher and conveyed to a rotary sand screen from which fine and coarse materials fell into separate bins over the railroad track. According to S. C. Ferebee, the quarry foreman, the output ranged from 160 to 300 tons a day, averaging about 185 tons. Day labor was reported to be scarce and inefficient, and a change to a contract system was contemplated. A change from the five mule carts, then employed, to a tramway was also being considered. In 1923 the fluxing stone was being shipped to the Bon Air Co's. blast furnaces at Wrigley, Goodrich, and Allens Creek, but in 1927 the principal consumer was the Wrigley furnace.

Other blast furnaces.—One other blast furnace was active in Hickman County up to 1924. This was the Standard furnace at Goodrich, owned by the former Bon Air Coal & Iron Corporation. This furnace, forerunners of which date back prior to 1890, has recently been dismantled and removed. The old Lee furnace on Sugar Creek (Plate 2, A) has already been mentioned (page 16), and the remains of a more modern but long-abandoned iron blast furnace stood until recently at Aetna. The early Goodrich and Aetna furnaces were operated about 1890 as hot-blast charcoal furnaces, having capacities respectively of 28 and 45 tons of pig iron daily. On these properties also were charcoal ovens, one with a daily capacity of 48 cords and

the other of 60 cords of wood, and alcohol plants of 100 gallons and 125 gallons daily output, giving employment to 200 and 400 persons respectively at the furnaces and alcohol plants.

Deposits near Lyles.—On the ridge that borders the northwest side of the hollow in which Wrigley furnace stands there are old workings for brown ore at a point about four-tenths of a mile north-northeast of Wrigley furnace. (Locality 1, Hickman County). These workings are along the slope and 10 to 25 feet lower than the top of the ridge, at an altitude of 780 to 800 feet. Stripping of as much as 10 feet of chert and loam in places was required. The ore that was obtained here apparently was of low grade, sandy, cherty, and more or less mixed with clay. Mining is reported to have been done entirely by hand accompanied by hand picking and hand screening, after which the ore was carted to the furnace. There is no activity here at present, and mining could not well be done on a large scale unless the ore were transported for washing at some place in the valley below, where the furnace and chemical plant are situated. The occurrence of this ore is of interest mainly as showing evidence of the beds that contain workable deposits on the other side of this upland area near Big Spring Creek and Little Spring Creek.

About 3 miles northwest of Lyles and north of Big Spring Creek, on land of the former Bon Air Coal & Iron Corporation, is a deposit of brown ore on the border of the plateau (locality 3, Hickman County), at an altitude of about 800 feet. The ore is overlain by soil and clay loam 2 to 10 feet thick and is associated with loam and residual chert. Horizontally bedded cherty limestone outcrops about 100 feet below the brow of the hill in the bluffs of Big Spring Creek. These bluffs are picturesque, forming rounded pillars and faces 20 to 50 feet high overhanging in places and cut by joints and cave openings. The ore is limonite containing more or less fragmentary chert. This ore was mined by hand about 1891 and hauled by wagon to the former Warner furnace, now Wrigley furnace. Prospects are reported to show more ore north of here on the plateau, and inasmuch as mining has not been carried on on a large scale by means of steam shovels, there seems a possibility that the ore has not yet been exhausted here. The most feasible method for transporting ore from this locality would seem to be by an aerial tramway across Big Spring Creek valley to the locality of the old Red River mines (locality 4), whence, by reconstruction of the railroad spur that formerly ran to this locality from Bates Crossing on the Centerville Branch of the Nashville, Chattanooga & St. Louis Railway, the ore could be carried by rail to Wrigley furnace.

About 4 miles west of Lyles at the head of Mud Dam hollow, a northern tributary of Little Spring Creek (locality 4), are the old open-cut mines operated prior to 1910 by the Red River Iron Co., of Clarksville. The limits of this deposit are not known, but probably there is ore underlying the border of the flat-topped ridge at an altitude between 750 and 800 feet in the vicinity of the open cuts. The ore is limonite typical of this region, rich in places

but cherty in general. It appears a little less sandy than at Iron Hill, but the color is a lighter brown, which may indicate the presence of alumina and silica in undesirable quantities. An analysis made at Wrigley furnace showed 50.44 per cent metallic iron, 0.36 per cent phosphorus, and 0.44 per cent manganese. In the old pits on the west border of the plateau the red loam is well displayed in thicknesses up to 20 feet. This red loam contains more or less red clay and horizontal streaks of gray sandy clay. It is thought by some geologists to be of Tuscaloosa age, but as the Tuscaloosa in this part of Tennessee is characterized by a large content of gravel, it seems doubtful whether the red loam should be so classified or whether it is residual from the underlying formations. Some fragments of limonite are present in the loam and are more abundant near its base, where it rests on the chert and whitish clays residual from the Mississippian rocks. No underlying rock was found in place anywhere near the iron horizon. The surface of the weathered chert is irregular, showing ridges and reefs in the old open cuts. Lumps and boulders of fine-grained saccharoidal sandstone 3 feet or more in diameter are embedded in the red loam, and it is believed that these boulders of sandstone came from the Warsaw horizon. Ore was mined from these open cuts about 1905 and shipped over a spur track, which extended across the plateau about 2½ miles to the Nashville, Chattanooga & St. Louis Railway at Bates Crossing. The principal cuts are irregular in shape, the southeastern opening being from 50 to 250 feet wide, 400 feet long, and 20 to 35 feet deep. About 750 feet northwest of this cut is one that is 75 to 150 feet wide and 500 feet long. A washer is reported to have been employed near the northwest pit, obtaining its water from Big Spring Creek 1 mile distant. There appears still to be some ore southeast of the border of the southeast pit but more, perhaps, on the northwest side of the northwest pit. Irregular masses of ore may be seen in the walls partly surrounded by red loam. The loam appears to have been laid down on an uneven surface of cherty limestone, over which limonite deposits may have already been formed, so that it contains reworked fragments of limonite, chert, sandstone, and sandy clay. Some crust of limonite may have also been formed secondarily in the red loam. The deposits north of Big Spring Creek and those on the south side of the valley are apparently at about the same altitude and the same horizon and may have been continuous before the erosion of Big Spring Creek took place.

About 4 miles west of Lyles on land of F. C. Booker, on the upland both north and south of the Lyles-Pinewood wagon road (locality 5) are deposits of brown ore situated slightly below the west brow of the upland at an altitude between 750 and 800 feet. The extent of the deposit has not been determined, but prospecting by means of shallow pits has disclosed limonite in several places a few feet below the surface. Some "shot ore" shows on the surface in places. The limonite cements chert fragments and occurs fairly free of chert in places. In general the material appears slightly less siliceous than at Iron Hill, Dickson County. The associated rocks are

loam, residual chert, and a little gravel. A small deposit of rounded gravel, possibly of Tuscaloosa age, was noted at one prospect north of the pinewood road. Most of the gravel was chert, but a few pebbles of quartz were seen. If prospecting discloses sufficient ore here, a spur track about 2 miles long could probably be built over fairly level ground from the Nashville, Chattanooga & St. Louis Railway at Bates Crossing. Water would have to be obtained from Big Spring Creek, which might involve pumping about three-fourths of a mile.

Deposits near Pinewood.—On the upland north and south of Little Spring Creek (locality 6), about 2 miles northeast and east of Pinewood, ore deposits occur on the Brown, Clarke, and Graham tracts of land. Property maps show the north-side tract, at a distance of about 2,000 feet north of the creek, as having an east-west length of about 3,000 feet and consisting of 9½ acres. Prospect pits are shown as indicating ore principally at the east and west ends of the tracts, from a few feet to 60 feet thick. The south-side tract begins about 600 feet south of the creek and extends southward about 1 mile with a width of 250 to 1,500 feet, and comprises 44 acres. The property map shows prospects as indicating ore over most of the tract except at the middle, the thicknesses shown being from 3 feet to 30 feet. It is understood that some of the prospecting in this tract was done by means of gasoline drills for the Gray and Swab interests. Only the prospects north of Little Spring Creek were examined. They lie about 135 feet higher than the creek or at an altitude of more than 700 feet. Some good-grade limonite associated with chert and quartz pebbles was seen on the surface near the prospect pits. Other prospects, reported to show ore, are farther south and reach practically to the Nashville, Chattanooga & St. Louis Railway.

Deposits north of Graham.—About 1 mile north of Graham and about one-fourth of a mile northwest of the Nashville, Chattanooga & St. Louis Railway, prospects showing brown ore have been opened on land of W. S. Nunnelly. (Locality 7). Although there was no opportunity to examine this tract in detail, it was noted that the upland surface shows considerable reddish hydrous oxide of iron in the form of "shot ore," and this in connection with a good showing of ore around the prospect pits and the high altitude of the land (about 725 feet) indicate that an important tonnage of ore may be present here. The ore-bearing ground, however, is not sufficiently extensive to show in the railroad cut, although it is possible that the walls of the cut are below the ore horizon. In view of its proximity to the railroad this tract may be worthy of development. Other prospects showing brown ore were noted just north of the railroad near Browns switch, about three-fifths of a mile east of these Nunnelly prospects.

Nunnelly mines.—Half a mile west of Nunnelly station on the Nashville, Chattanooga & St. Louis Railway are the extensive Nunnelly brown ore mines (locality 8) on land of W. S. Nunnelly, of Vernon, Tenn., and

recently operated by the former Bon Air Coal & Iron Corporation. These mines rank among the largest producers of this region, having yielded more than half the iron ore recorded as produced in Hickman County between 1906 and 1927. The ore-bearing ground is on a ridge between small branches of Piney River, which flows about 1¼ miles west. Mining is said to have been carried on here for nearly 100 years, and about 20 acres are covered by the open cuts. The mining in this locality has necessitated the shifting of the wagon road to the south of the open cuts a distance of a quarter of a mile or more from its original location, shown on the topographic map of the Columbia quadrangle. That map shows the altitude to be about 675 to 725 feet. The open cuts range in depth from 20 to more than 100 feet, and an extreme depth of more than 130 feet has been reported, but this could not be verified, because the deepest cuts contained water at the times of visit in 1921, 1923, 1924, and 1927. The open cuts, which followed the ore body, are irregular, and some surround islands of ground that were regarded as containing too little ore to warrant mining. The open cuts range from 30 or 40 feet to 200 feet wide and the longest is perhaps half a mile long. Although water obscured the bottom of the deepest cuts and was said to be 10 to 40 feet deep, the shape of the visible portions of the cuts indicated that the surface of the chert and light-colored clay ("white horse") is extremely uneven, with deep depressions between ridges and pinnacles that reach nearly to the recent surface. (Plate 22, A). The cross sections of the cuts are V-shaped, and the brown ore lay in the troughs and well up on the flanks of the buried ridges, and some apparently has been worked into the red loam, which overlies in various thicknesses the surface of the Mississippian rocks in all of the local ore-bearing area. The overburden is chiefly red loam ranging in thickness from a few feet to more than 15 feet, and barren ground between the ore pockets reaches a much greater thickness in places. The ore is chiefly of the chert-replacement type and occurs as more or less cherty lumps and as small fragments and crusts mixed with loose chert and brown to red clay. Some masses several feet in diameter, too poor in iron and too large to handle for the sake of the small proportion of limonite present, have been left in the cuts. Such lumps that do not exceed 2 feet in diameter have usually been loaded on tramcars with the rest of the ore and have been thrown out at the grizzly. Some of these lumps contain interesting geodal cavities. In some of the western cuts chert-gravel conglomerate occurs cemented by sandy, dark-brown limonite, but the whole is too lean to constitute an ore. Boulders of this material are found well up in the overlying red loam. It is reported that for many years ore was shipped from here that carried 48 to 50 per cent metallic iron, but in later years 44 per cent iron was considered a good yield. The phosphorus is reported to increase toward the west. From 6 to 16 yards of dirt is reported to yield 1 ton of ore. Over much of the area the open cuts have been mined clean to the walls, and except for a minor quantity of surface ore in the red loam the chief hope of getting more ore here seems

to lie in the bottom of the pits, according to local reports. In order to get at this ore it has been proposed to cut a drainage channel from the adjoining valley on the north, in the belief that after the pits are drained a considerable quantity of ore may be made available. This possibility, however, has not been demonstrated, and if the walls of the abandoned cuts be projected downward it appears as though they would meet at the bottoms of the pits forming V-shaped openings, which may already have been worked to the limit of profitable ore extraction.

When these mines were visited in June, 1923, mining was in progress on the south side of the old workings. A tractor Marion steam shovel was used for excavating, and the ore-bearing material was hauled in tramcars by a dinky engine to the washer situated in a hollow north of the mine workings. At the washer the dirt was dumped on a two-compartment inclined grizzly, through which it was broken into a sump. A jet of water washed the ore-bearing dirt down a flume 225 feet or more in length to a trommel screen. The material passing the screen went to two 25-foot log washers, and the material over the screen emptied on a metal picking belt, which discharged lump ore into a bin at the side of the railroad spur. The logs discharged into a trommel screen, the oversize going to a picking belt of webbing and the undersize to a smaller trommel screen, which discharged into a 4-cell jig. The rock overflow from the jig went to a bucket elevator, which discharged chert and gravel into a bin, and the ore was carried by another elevator into another compartment of bins, which stand over the railroad spur. At the time of visit this equipment was in a rather worn condition and did not appear to be making a clean recovery, especially from the jigs. The average output was reported to be about 3 cars of 25 tons each of cleaned ore a day. It was reported that from 400 yards of dirt there might be washed sometimes as much as 3 cars of ore, and at other times only 1 car of ore. This corresponds fairly well with the statement made above as to the proportion of dirt mined to ore recovered. The rock picked out on the picking belt averages about 3 carloads to 1 carload of lump ore. The washer was connected by a spur track with the Nashville, Chattanooga & St. Louis Railway at Nunnelly. The principal parts of this washer have since been removed and rebuilt near the Johnson mines.

The following analyses of ore from the Nunnelly mines, made by the former Bon Air Coal & Iron Corporation, show a range in metallic iron generally between 44 and 50 per cent, insoluble between 18 and 30 per cent, phosphorus between 0.30 and 0.47 per cent, and manganese between 0.19 and 0.42 per cent.

Analyses of brown iron ore from Nunnelly mines, Tennessee

Date	Number of car loads	Iron (Fe)	Insoluble	Phosphorus (P)	Mangasen (Mn)
April 15, 1920	3	49.27	18.70	0.36	.12
April 18, 1920	6	45.78	22.64	.35	.22
April 26, 1920	3	43.98	22.94		
April 30, 1920	6	47.24	20.28	.42	.20
May 3, 1920	3	44.04	22.42	.44	.21
May 26, 1920	8	48.28	18.88	.42	.2
June 10, 1920	4	39.94	30.02	.47	
June 22, 1920	7	45.29	22.84	.43	.93
April 15, 1923	1 fine ore	49.96	17.60	.396	.00
April 15, 1923	1 coarse ore	47.84	21.40	.296	.92
April 21, 1923	2	45.96	23.50	.428	.00
					.70

Bordering the Nunnelly mines on the west and northwest are areas of probable ore-bearing ground, which have not yet been mined or thoroughly prospected. Ore is shown at several prospect pits on the W. S. Nunnelly home place on hills and ridges about half a mile east of Piney River (locality 9), at altitudes of 600 to 650 feet and 125 to 175 feet above the river. At one place a little ore is reported to have been mined, screened by hand, and hauled by wagon to the furnace at Goodrich about 1903. There is much float ore scattered over the surface and on the southwest slope of the hill, and "shot ore" has been washed down into the gulleys. Chert and red clay are associated with the ore as in the neighboring mines. Limestone lying nearly flat is exposed in the valley of the creek at Vernon about a quarter of a mile from the ore prospects and 50 to 100 feet below the ore horizon. It hardly seems as if sufficient prospecting has been done here to prove definitely that a minable reserve of ore exists on the land adjoining the Nunnelly mines on the west and northwest, but the present indications are favorable enough to warrant thorough and systematic prospecting. The ore is limonite generally of good appearance but cherty and sandy in places at the surface. A picked sample taken from the float ore from the whole tract shows the analysis by D. F. Farrar given below. Some boulders of pebbly conglomerate were noted west of the area considered as ore bearing. By concentration, as at the Nunnelly mines, there should be no difficulty in maintaining a merchantable grade of ore from this tract, provided, that prospecting proves the supposed extension of the ore bodies. The conditions for steam-shovel mining and concentration are favorable, as the deposit could be worked as an extension of the present Nunnelly mines. The public road lies between the present mines and the unmined tract, but it would be feasible to make a cut from the present mines under the road without shifting the latter.

Analysis of selected sample of float brown iron ore from W. S. Nunnelly farm, Tennessee

	Per cent
Iron (Fe)	52.73
Silica (SiO_2)	9.52
Alumina (Al_2O_3)	1.79
Phosphorus (P)	0.38
Manganese (Mn)	.41
Water expelled at 100° C.	.84
Total loss on ignition	11.54

Deposits west of Vernon.—About three-fourths of a mile northwest of the bridge crossing Piney River near Vernon are deposits of ore on land known as the Lee property. (Locality 10). This tract, which covers about 40 acres on the border of a south-facing hillside, at an altitude of 600 to 625 feet, one-fourth of a mile north of Pretty Creek appears to have been thoroughly prospect pitted to a depth of 18 to 20 feet, and a showing of ore was noted in most of the pits. The quality of the ore was generally fair, and it appeared to be good in places. Ore is reported to have been mined here about 1821 to supply the old Lee furnace on Sugar Creek. About 1910 the Red River Iron Co. installed a steam shovel to prospect the tract, but after spending about $30,000 and without shipping any ore gave up the development, according to local reports.

One other point at which ore was mined in this vicinity is about 1¼ miles west of Piney River just south of the Vernon and Only road, on lands belonging to W. S. Nunnelly and C. Blackwell. (Locality 11). The workings consisted of a few old open cuts on two points between south-opening ravines at an altitude of about 625 feet. The depth of these pits when visited was about 10 to 12 feet. There was no great showing of ore, but some float of good quality was seen. The pits show chert and "white horse" clay underlying the ore horizon as at the Nunnelly mines. The ore was mined by hand and hauled to the furnace on Sugar Creek, a distance of 7 or 8 miles, in 1821. No prospect pits were noted in the ground adjoining the old open cuts, but it is believed that this area would be worth prospecting at the horizon at which the ore was formerly mined. If a good body of ore were developed in this locality, the natural route for it would be by wagon or tramway to the Nashville, Chattanooga & St. Louis Railway at Nunnelly. As to the operations of the furnace on Sugar Creek, it is reported that the pig iron made there was hauled several miles to Duck River, where it had to wait for high water and was then carried to markets on flat boats. It often happened that both boats and pig iron were lost through floods. Plate 2, A shows the remains of this furnace.

The accompanying analysis was made by D. F. Farrar of a sample of ore collected by R. W. Smith.

Analysis of brown iron ore from old mines south of Vernon and Only road, 1 1-4 miles west of Piney River, Tennessee

(Sample washed and dried 24 hours at room temperature)

	Per cent
Iron (Fe)	49.70
Silica (SiO_2)	10.64
Alumina (Al_2O_3)	3.58
Phosphorus (P)	0.58
Manganese (Mn)	1.03
Water expelled at 100° C.	1.10
Total loss on ignition	12.24

Deposits near Only.—One and one-half miles southeast of Only (locality 11, A) on a 1,400 acre tract of land belonging to Messrs. Brown and Nunnelly, some prospecting was done for iron ore in 1905. The prospects then dug are reported to be mostly on the south side of Happy Hollow, three-fourths of a mile to one and one-half miles from the Horseshoe Bend of Duck River, and to have shown limonite at various altitudes on the hillside. This ore was not seen by the writer, but from descriptions furnished by men who did the prospecting it seems to resemble ore that has been deposited by iron-bearing spring waters and is probably present as a cement in chert-breccia and as a partial replacement of chert. If so, the ore is likely to be rather siliceous. The locality is not convenient of access, and transportation of the ore to the railroad would be difficult.

Deposits southeast of Nunnelly.—Three-fourths of a mile southeast of Nunnelly on lands of Tidwell and Walker are several old open cuts, known as the Easley mines, at altitudes of 680 to 725 feet. (Locality 12). Ore is reported to have been mined from these cuts in 1900-1903, hand cobbed, and hauled by wagon to the furnace at Goodrich. There is little evidence to indicate that there is more ore in this locality, but the ore débris that was seen indicated lump ore of good quality. It is also reported that on land of W. S. Nunnelly, four-fifths of a mile east of Nunnelly and north of the ridge road that extends from Nunnelly to Lyles by way of the Johnson mines, prospects indicate the occurrence of ore, but these prospects were not visited.

DEPOSITS BETWEEN MILL CREEK AND DRY CREEK

Johnson mines.—About 4 miles south of the Wrigley furnace on the plateau between the drainage basins of Mill Creek and Dry Creek, a tributary of Duck River, are the Johnson ore mines. (Locality 13). These mines are owned and operated by the Bon Air Chemical Co., of the Tennessee Products Corporation. The ore bodies are scattered over a tract of several hundred acres. The ore occurs at nearly the highest level on the upland, or at an altitude above the 850-foot contour as shown on the U. S. Geological Survey topographic map of the Columbia quadrangle. The mines consist of several large, shallow open cuts; those at the southeast represent mining done a number of years ago and those at the northwest were active when visited in 1927. The surface soil is from a few inches to 2 feet thick, below which lies reddish loam, clay, and chert which contains more or less iron ore in small fragments. There is practically no stripping in mining. The thickness of the ore-bearing material is generally between 12 and 15 feet but may be greater. The ore is associated with clay and chert, but neither gravel of Cretaceous age nor limestone of Mississippian age was noted in association with the ore. The chert contains fossils characteristic of the St. Louis. The ore displayed in the various open cuts occurs in crusts and small masses and is a fair grade of limonite, cherty in places and sandy at others. Large boulders of chert

partly replaced by limonite indicated that much of the ore has been formed in this way. The new mine has been opened for a distance of 1,000 feet or more in a southwesterly direction, and the ore was being mined by steam shovel from the second level in August, 1927. (Plate 19, A). This cut covers the northwestern part of the hill, the remainder of the hill lying between the active and the inactive cuts. Prospect pits indicate that the unmined portion of the hill contains a valuable reserve of ore.

The largest open cut of the former workings is about 225 feet by 500 feet in its major dimensions and as much as 15 feet deep in places, and there are a few smaller cuts branching from it. This cut has a flat bottom and shows no inliers of "white horse" clay. More or less débris of ore in small fragments in the bottom of the cut may have been left there after mining ceased, or it may indicate additional ore below. The early mines were at one time connected by a tramway with the railroad near Nunnelly and supplied ore to the blast furnace at Goodrich, but now the only evidence of the old tramway are portions of its grade.

The active mine is connected by a dinky tramroad with a washer near the head of a small branch of Mill Creek, about 1¾ miles toward the northeast. This washer (Plate 21, B) contains some of the machinery formerly at the Nunnelly mines. Water is pumped from Mill Creek 1¼ miles north through an 8-inch pipe line. The washed ore is hauled by tramroad to the blast furnace at Wrigley, 3¼ miles distant. The average output of the washer is about 100 tons of washed ore in a 10-hour day, which requires 300 to 400 cubic yards of ore-bearing dirt to go through the grizzly.

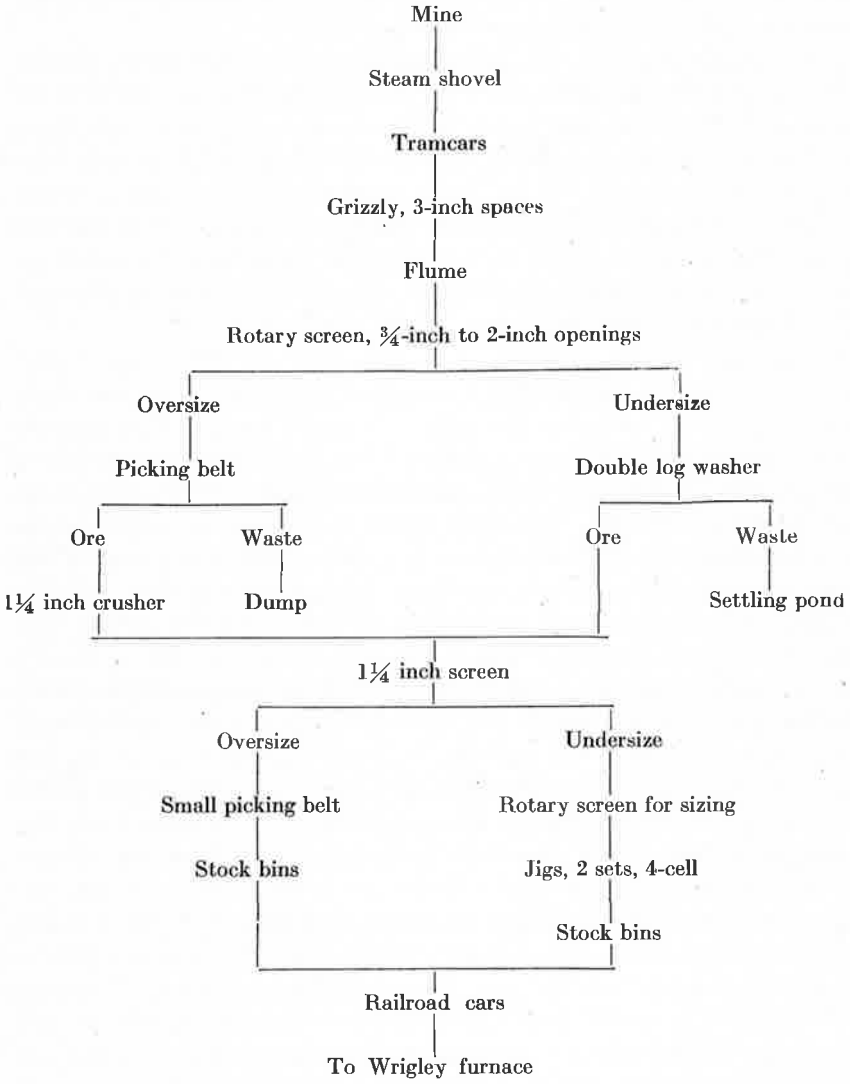
In correspondence Mr. J. H. Walker, Consulting Engineer of the Tennessee Products Corporation, states in regard to this washer that as there is but little stripping of non ore-bearing material, all the dirt goes to the washer. The fine ore all passes through the jigs so as to remove any sand or small stones. The lump ore is all crushed to a uniform size that will pass a 2-inch ring, and this ore can also pass through the jigs, if it contains enough foreign matter to justify that treatment. By working the ore in this way it has been possible to raise the iron content in the washed ore about 2 per cent. Crushing the lump ore gives the water better access to the particles of sand, and should there be any foreign matter clinging to the lumps of ore this is broken loose in crushing and is easily separated by the jigs. The material taken to the washer yields about 33 per cent of ore, which when washed will average about 52 per cent metallic iron, 12 per cent insoluble material, 0.30 per cent phosphorus, and 0.35 per cent manganese. Plans reported to be under way were expected to bring the average metallic iron content up to 55 per cent. Some analyses made at Wrigley furnace early in 1927 are as follows:

Analyses by percentage of brown iron ore from Johnson mines, Tennessee

Iron (Fe)	Insoluble	Phosphorus (P)	Manganese (Mn)
55.00	7.12	0.48	0.12
50.70	14.84	.45	.....
47.10	21.10	.25	.....

A generalized flow sheet of the ore from the mines through the washer is given below:

Flow sheet of the Johnson mines ore washer, operated by Tennessee Products Corporation, 3 miles south of Wrigley, Hickman County, Tenn.



Worley tract.—One and a quarter miles northeast of the Johnson mines is the Worley tract of ore-bearing land. (Locality 13 A). Here a large number of prospects have been made within recent years disclosing a very substantial reserve of good iron ore. These prospects are on the ridge land at the heads of hollows tributary to the Dry Creek drainage and are nearer the

new washer than the Johnson mines. It is understood that the Tennessee Products Corporation is interested in this tract. A pit in the side of one of the ravines indicates that a little ore was formerly mined here.

Slayden-Richardson tract.—About half a mile northwest of the Johnson mines some prospecting has been done for iron ore on the border of the upland around the heads of hollows belonging to the Mill Creek drainage. The prospects that were noted were in wooded or brush-covered country and did not reveal much information as to the occurrence of ore except that chert is abundant at the surface rather than clay.

According to notes by R. W. Smith the Slayden-Richardson tract consists of 918 acres and adjoins the west side of the Johnson mines property. He states that partial prospecting indicates an extension on this property of the ore that is being dug at the adjoining mine and gives two analyses of the ore, made by the State Geological Survey. Analysis No. 1 is of ore from one of the test pits, and No. 2 is of float ore from the top and slopes of the ridge.

Analyses in percentage of brown iron ore from Slayden-Richardson tract, Tennessee

	Iron (Fe)	Insoluble	Phosphorus (P)	Manganese (Mn)
1.	45.40	22.16	0.58	0.85
2.	56.04	4.64	.64	2.22

Deposits near Jerry Branch.—On the ridge west of Jerry Branch and about 1¼ miles north of Tottys Bend of Duck River there are several open cuts and a tunnel (locality 14) on land of J. B. Walker, of Centerville. The workings are around the point and on the west face of the ridge at an altitude of about 750 feet; one of the cuts is about 150 feet long and 40 to 50 feet high, and the tunnel is about 30 feet long. These workings cut into massive chert and gravel more or less replaced by limonite. The tunnel is in chert débris and clay but shows very little ore, as it evidently cuts through and passes below the deposit. The deposit is in the shape of a "blanket" over the face of a steep hill, which is perhaps 500 feet long, 75 feet high, and 200 feet wide. This "blanket" is overlain by gravel, clay, and chert débris of varying thickness due to irregularities in its surface. The limonite is of the chert-replacement type. Some of it is rich but the greater part is sandy, cherty, or light-brown and ocherous. Boulders partly conglomeratic but containing some quartz pebbles, the whole being cemented by limonite, outcrop on the hillside. The general grade of the ore is too siliceous for present use unless crushed and thoroughly picked and cleaned. This deposit is reported to have been opened about 1888 and worked a short time again about 1910, but only a few loads of ore were recovered and hauled to the Goodrich and Warner furnaces. Other prospects are reported to lie beyond the hollows on the west, between Morgan Creek and Jerry Branch, also on the Walker land. There is considerable timber in this locality, and the presence of phosphate rock is

reported, but unless the roads are improved it will be difficult to handle these products.

Deposits near Aetna.—West and north of Aetna, a village on the Nashville, Chattanooga & St. Louis Railway in the southern part of the county, are extensive brown-ore mines of the former Bon Air Coal & Iron Corporation. The principal opening (locality 15) is situated half to three-quarters of a mile north of Aetna on the high land west of the valley of Piney Branch, a tributary of Beaverdam Creek, at an altitude of 820 to 850 feet. (Plates 22, B and 23, A and B). The lower part of the ore bed is about 110 feet above the valley level. The deposit as disclosed by the open cuts underlies 4 or 5 acres and is irregular both in plan and in cross sections. A special map of the Aetna locality (Figure 5) shows the topographic position of the ore deposits, the outlines of the workings, and the relations of the mines, washer, and railroad. The overburden consists of thin soil, loam, red clay, and chert débris 1 to 10 feet thick, grading down into wash-ore dirt, and in places this ore dirt extends almost up to the surface. The materials associated with the ore are red loam and clay, light-colored sandy clay with ferruginous streaks, and light-colored clay and chert débris residual from the Mississippian St. Louis limestone and possibly from the Warsaw beds. The residual chert associated with the ore has caved and warped to a great extent on account of solution of the limestone, with which it was originally interbedded. Bedded limestone exposed in the creek valley 2 or 3 miles down stream from the ore mines lies nearly horizontal. Similar exposures occur in a creek half a mile east of Aetna. The reddish clay-loam is mixed with ore or overlies the brown ore, and the residual "white horse" underlies and borders the ore in the hollows and pinnacles. (See Plates 23, A and B). The ore is limonite of the usual types of this region. It appears to be fairly rich in some places and rather lean and cherty in others. There are good illustrations of cherty conglomerate cemented with more or less limonite of the chert-replacement type of ore, in which the chert fragments are angular and the mass simulates breccia; in other places, chiefly near the upper limit of the deposit, the mass contains rounded pebbles of chert. At one place rounded chert nodules were found cemented by limonite, which had partly replaced the chert. Some ore has the appearance of having been formed by replacement of sandy clay. This material is of a lighter-brown color than the better grade of limonite and contains more or less sand. In places it shows purplish-red colors.

The principal mine cut is connected with an ore washer on the hillside just northwest of Aetna by a tramway about 3,500 feet long. This open cut has been mined by steam shovel, but it was idle at the time of visit. The recovery in 1923 was about 1 ton of ore to 5 tons of dirt mined and washed. In places good massive ore is still exposed in the banks, such as is shown in Plate 23, A. The ore is apparently very pockety, and a more readily movable and more efficient steam shovel was needed for mining this deposit

to the best advantage. At the times of visit in 1921 and 1923 considerable good ore lay about the cuts, but it was mixed with poor ore and consequently was difficult of recovery. When the demand for iron becomes acute, much of the cherty débris might be cleaned up and put through the concentrator in order to recover this ore.

Other brown-ore deposits near the main open cut of the Aetna mine are on the east and west sides of Black Hollow (locality 16), which opens northward into Brushy Creek valley. On the east side of Black Hollow are some old workings and a few old drifts, known as the Ward tunnels, in which ore of fair grade mixed with considerable hard chert was noted. In addition to the cherty ore there is some of the clay-replacement type. The altitude at the surface is about 800 feet, and the ore appears to extend through a vertical distance of about 60 feet on the hill slope. These cuts are about 2,700 feet from the washer tipple. It is reported that they were opened about 1891 and reworked during 1918.

On the west side of Black Hollow about 1,000 feet from the Ward tunnels are some open cuts on the land of Brice Milam. The prospects and hillside outcrops show ore in places over an area of 2 or 3 acres. The ore horizon is at an altitude of 800 to 850 feet, and the hillside pits indicate a vertical range in the ore deposit of about 40 feet. Chert débris and clay are associated with the ore, and the nearest bedded rock is a variety of decomposed siliceous limestone resembling tripoli, which is exposed in thin horizontal beds about 100 feet lower in Black Hollow and may represent the upper part of the Fort Payne chert. Boulders of ferruginous conglomerate containing a few smooth rounded quartz pebbles crop out on the slope. The ore deposit is on a spur running from the ridge on which the Aetna mines are situated northward toward Brushy Creek. Ore of good grade was disclosed around the largest opening, but in general the ore is of the usual type, containing considerable chert and clay. There is also some ore débris on the ridge and slope. Only a little mining was done here in 1891 and 1918, so that the ore is far from being worked out, and the showing on the surface and in the pits may be said to be fairly promising. Haulage from this place to the Aetna ore washer would be over a fairly level surface.

About 1,600 feet west of the washer, at the head of Washer Hollow near the top of the hill, are some underground brown-ore workings known as the Washer Hollow tunnel mine. (Locality 17). The level of the ore here is about 180 feet above Piney Branch near the Aetna station, and the altitude is about 850 feet. The hill rises 25 to 50 feet higher than these tunnels. Limonite of medium grade mixed with chert and clay was obtained here as late as 1918, and earlier mining is said to have been done about 1891. The ore appears to be largely of the clay-replacement type. The old tunnels are badly caved, so that no accurate idea could be obtained as to the richness of the ore-bearing ground, but a number of test pits on the hilltop 150 feet or more back from the face of the hill indicate the presence of ore.

Some of this "clay-replacement" ore analyzed by D. F. Farrar gave the following results:

Analysis of impure brown iron ore from Washer Hollow tunnel

No. 7 Tunnel workings, Washer Hollow, Aetna, Hickman County, Tenn.

	Per cent
Iron (Fe)	31.03
Silica (SiO_2)	44.06
Alumina (Al_2O_3)	2.81
Phosphorus (P)	0.24
Manganese (Mn)	.10
Water expelled at 100° C.	.52
Total loss on ignition	7.40

Near the top of the northwest escarpment of Piney Branch, about half a mile southwest of the ore washer on lands of the former Bon Air Coal & Iron Corporation, are some open cuts extending for a distance of about 600 feet. (Locality 18). These cuts are about 20 feet high and extend back 10 to 40 feet into the hill, and some end in short tunnels. The ore that attracted attention here is chiefly chert gravel cemented by limonite, and there are bands of nearly pure limonite between bands of chert also veins of limonite ramifying through the chert masses. Prominent ledges and boulders of chert and gravel cemented by limonite crop out on the face of the escarpment, some of them 10 to 12 feet thick. (See Plate 24, A). The deposits are apparently about 30 feet thick and are 120 to 150 feet above Piney Branch, at an altitude of about 820 feet. Prospects on top of the hill at an altitude of about 880 feet show ore, and it is possible that this deposit extends back well into the ridge. The average ore disclosed by these prospects contains considerable chert, but a good separation of the chert and the ore may be made by cobbing. The position and character of the deposit seem to suggest that it originated on an old stream terrace, possibly through deposition of limonite by iron-bearing spring waters.

Some ore is reported to have been obtained for the Aetna furnace by hand mining from deposits on the ridge about a quarter of a mile east of Aetna. It is reported that some ore has been left here and that there is a similar deposit on the same ridge about 1 mile southwest of Aetna.

Ore from the Aetna mines was washed in a plant built on the hillside overlooking the village of Aetna. The tramway from the large open-cut mine terminates in a tipple and grizzly, from which the ore is carried into a flume down to the washing plant. The capacity of the washer is reported to be 200 tons of concentrates in 10 hours, but probably this maximum could be produced only under the most favorable conditions. An ample supply of water is available from Piney Branch and from a large spring near the creek level at Aetna. A photograph of the washer plant is shown in Plate 24, B, and the flow sheet is given on page 114.

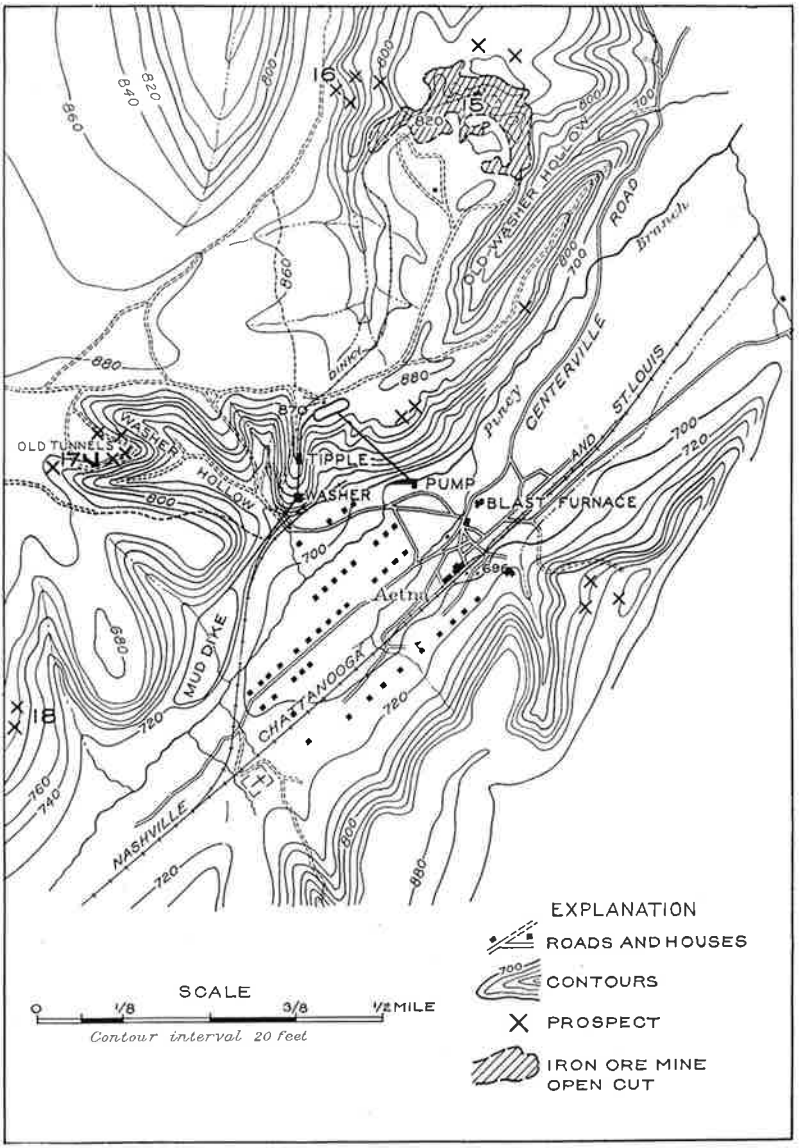


Figure 5.—Map of Aetna and vicinity, showing relations of brown iron ore deposits to topography.

(A) Nunnelly brown iron ore mines, Hickman County, October, 1921. Bank at left is red loam at top with talus below covering "white-horse" clay. Farther to the right "white-horse" clay is shown.

(B) Main cut in Aetna brown iron ore mine, Hickman County, 1921.

(A) Cut in Aetna brown iron ore mine, showing ore overlying white clay.

(B) Cut in Aetna brown iron ore mine, showing deposit of high-grade ore behind J. T. Brown, Superintendent.

(A) Outcrop of cherty limonite on bluff at Piney Creek, one-fourth of a mile northwest of Aetna.

(B) Tipple, ore washer, ore bin, and waste flume at Aetna brown iron ore mine of former Bon Air Coal & Iron Corporation, 1921.

Analyses of ore from the Aetna mines, made by the former Bon Air Coal & Iron Corporation at Wrigley furnace, indicate a general range in metallic iron betwen 36 and 48 per cent, in insoluble material between 18 and 36 per cent, in phosphorus between 0.27 and 0.33 per cent, and in manganese between 0.20 and 0.22 per cent, although a few percentages higher and lower than these ranges have been found.

The following quotation from Killebrew[27] relates to the iron-ore supplies on the Aetna property.

"* * * As to the quantity and quality of its ores they are accessible all over the banks of this property and will stand every test of analysis, as they have stood the test of the best markets. As to quantity only an examination is needed to convince the most skeptical that no man need, with all the possible production of a century, begin at the end of that time to approach the subject of supply."

Evidently in 1881 there could have been no adequate conception of the rate at which the consumption of iron ore would increase in the next 50 years.

Analyses in percentages of brown iron ore from Aetna mines, Tennessee

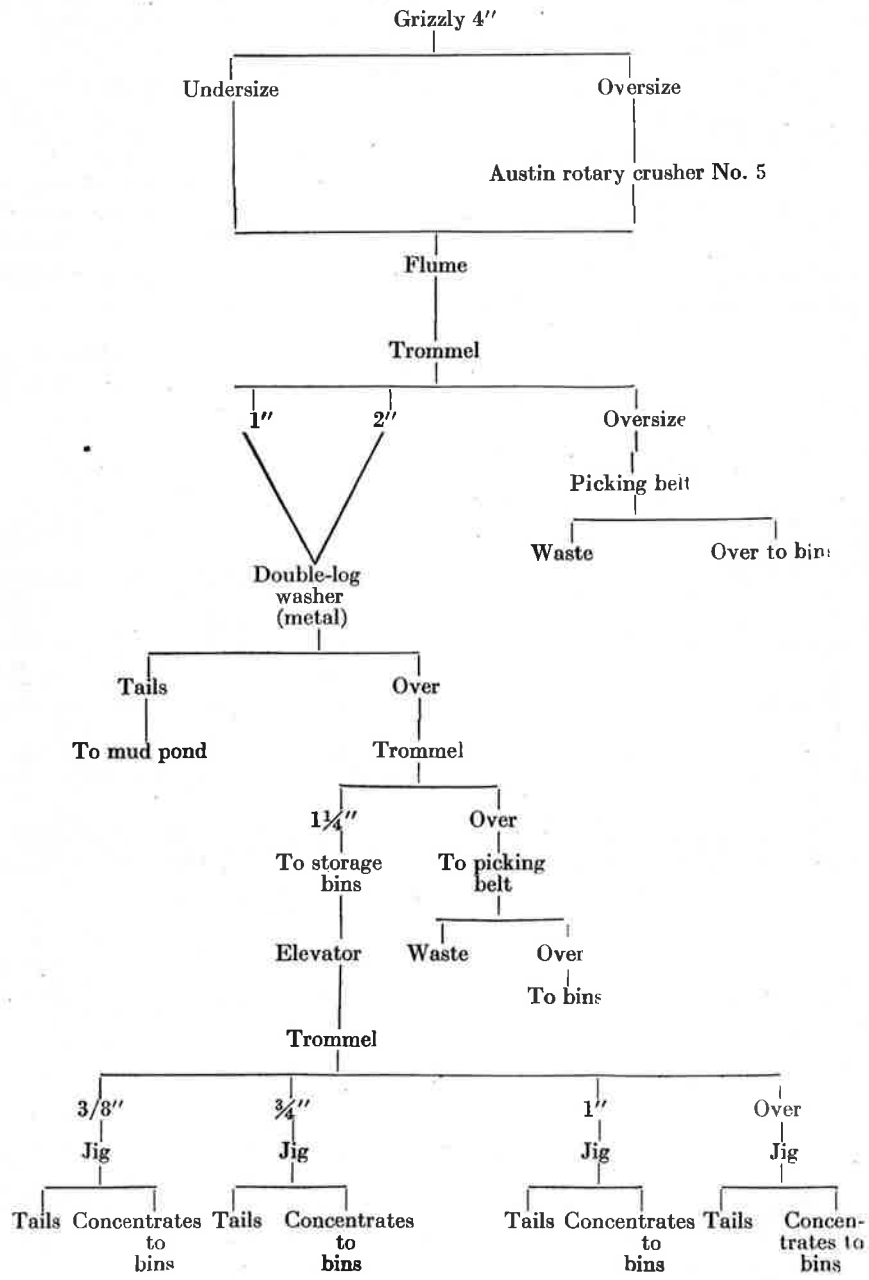
Date	Car loads	Iron (Fe)	Insoluble	Phosphorus (P)	Manganese (Mn)
April 13, 1920	2	40.43	32.36	0.33	0.21
April 17, 1920	2	37.99	36.44	.33	.19
April 18, 1920	1	33.14	46.98	.34	.20
April 26, 1920	6	24.75	31.89	.39	.22
May 3, 1920	5	46.10	24.69	.32	.20
May 14, 1920	2	36.29	36.64		
August 18, (?)	5	42.32	28.99	.30	.22
August 2, (?)	5	46.65	21.62	.29	.22
July 21, (?)	1	48.61	18.47	.27	.22
April 12, 1923	Average from stockpile	43.69	21.64	.176	.49
April 13, 1923	Sample	48.21		.168	.38

The preceding analysis by D. F. Farrar of a specimen of ore thought to have been derived by partial replacement of clay by limonite shows a high content of silica rather than of alumina, and a low content of iron.

[27]Killebrew, J. B., op. cit., p. 115.

Flow sheet of the brown iron ore washer operated by the Bon Air Coal & Iron Corporation at Aetna mine, Hickman County, Tennessee

(By R. W. Smith)



Deposits near Jenkins Hollow.—About 3 miles in an air line southeast of Aetna or 4 miles by wagon road is a brown-ore deposit on lands of the former Bon Air Coal & Iron Corporation, situated on the ridge between Jenkins Hollow and the next hollow south. (Locality 19). The altitude is about 850 feet, and the deposit is about 300 feet higher than Swan Creek, into which Jenkins Branch empties. The deposit is narrow and branching following a narrow ridge 1,500 feet or more lengthwise by 100 to 250 feet in width. The overburden is reddish clay mixed with chert and carries a little surface ore down to a depth of 5 to 8 feet, below which small boulders of ore occur to a depth of 10 to 15 feet farther. The underlying rocks are not exposed and there is not much loam or loose gravel, although a little gravel is cemented by limonite into conglomerate. The ore is of fair to good grade but carries some chert breccia. This deposit is reported to have been worked as a wagon mine about 1891 to 1895 by hand excavation, hand cobbing, and dry screening, and the ore was hauled to Aetna furnace. The cobbed and screened product is reported to have carried 49 to 52 per cent metallic iron. No deeper mining was done here, but deeper prospects, reported to have been made in 1918, do not show much ore. There is probably some ore left between the old workings, but it is doubtful whether there is sufficient to warrant the building of a railroad spur.

Deposits southwest of Coble.—About 2 miles in an air line southwest of Coble is a so-called "nickel and cobalt" prospect. (Locality 20). The distance by wagon road is much greater, however, as it is necessary to go up Cow Hollow about 2 miles, then across the divide to the East Fork of Wolf Creek, north on East Fork half a mile, then about half a mile east up a small branch of East Fork of Wolf Creek. This prospect is on land of W. S. Nunnelly, of Vernon. It consists of a cut about 50 feet long, 6 to 10 feet wide, and 5 to 10 feet deep, driven N. 28° E. into the point of a ridge about 50 feet below the top and at an altitude of about 680 feet, and a smaller pit a few rods east of the principal cut. The horizon is about 160 feet above the black Chattanooga shale, which is exposed in East Fork of Wolf Creek. The cut is in beds of fine-grained sandy chert decomposed to a soft condition like tripoli. The evidence of metallic ore here is an oxide of manganese, which occurs in vertical seams from a thin coating to a thickness of perhaps 2 inches and occurs also in pockets and small geodes, in which the manganese oxide has been deposited on quartz crystals. The discovery was made below a small surface gulley, the erosion of which may have exposed the manganese oxide. The chert is light buff to light yellowish brown but does not show an excessive iron stain, and there is less limonite than manganese oxide present. The beds show a slight dip of 5° to 6° N. 20° E. It is reported that a carload of this manganiferous chert was hauled to the railroad at Centerville and shipped to the laboratories of Thomas A. Edison, at Orange, N. J. It is understood that small percentages of nickel and cobalt were found in this manganese oxide, and it is believed that the material was sought in the hope of finding

an appreciable content of these metals, but the search was abandoned after the shipment was made. There is a little manganese-stained chert scattered about the surface of this locality and in other places; some was observed near Buffalo Switch.

A sample of this manganiferous ore from near Coble was sent to Washington by Wilbur A. Nelson, then State Geologist. The material submitted was largely in the form of black, hard crusts of psilomelane, from which a sample of clean material was picked in the chemical laboratory of the U. S. Geological Survey by E. P. Henderson, who made the following analysis.

Analysis of manganiferous ore from near Coble, Tennessee

	Per cent
Insoluble	6.05
Manganese dioxide (MnO_2)	52.93
Alumina (Al_2O_3)	21.15
Iron oxide—ferric (Fe_2O_3)	0.88
Cobalt oxide (CoO)	.81
Nickel oxide (NiO)	1.48
Barium oxide (BaO)	.11
Water (H_2O)	14.40
Phosphorus pentoxide (P_2O_5)	.20
Copper (Cu)	Trace
Lithium (Li)	Trace
Fluorine (F)	None
Calcium (Ca)	None
Sulphur trioxide (SO_3)	None
Carbon dioxide (CO_2)	None
	98.01

Mr. Henderson makes the following comments concerning the analysis:

"The manganese is reported as MnO_2, but there is probably some present as a lower oxide, which would lower the percentage total somewhat. All determinations reported have been duplicated to make sure the low summation was not due to an error.

"No other determinations were made. However, there is a chance that the remaining 2 per cent might be divided between the alkalies. The fact that there is 6.05 per cent of material insoluble in hydrochloric acid, and its composition unknown, I think the alkali determination would be of little value.

"The analysis is not a good mineralogical analysis, as no good crystals were found on which the analysis could be made. There is present a very small quantity of needle-like crystals, but the quantity is so small and they are so mixed throughout the sample no separation was made. This can hardly be called an assay, for when the samples were first received I picked them over, picking out the black masses in the hope of finding some definite crystals. When this analysis was requested it became necessary to use this more or less selected material."

On other lands of W. S. Nunnelly and on lands of Dr. Lucius P. Brown, of Franklin, Tenn., in the country from 3 to 6 miles southwest and

south of Coble (localities 21, 22, and 23) indications of brown ore are reported, and some prospecting is said to have been done without very satisfactory results. This locality is very remote from railroad transportation and is accessible only by difficult roads with steep grades, crossing the local streams, so that the development of ore deposits, if present, is not likely to occur until some time in the distant future. No examinations were made by the writer during the present survey. Notes by Wilbur A. Nelson, who has visited some of these deposits, indicate that in a prospect pit 64 feet deep ore and chert gravel were encountered to the full depth, and in another place recent spring deposits of limonite were noted. Many of the deposits are on high ground, evidently on the interstream ridges similar to those near Aetna, but the locations of others, as furnished to the writer, show them to be lower down, as those near Morgan and Cave Branches.

LEWIS COUNTY[28]

By Reese F. Rogers

INTRODUCTION AND GENERAL DESCRIPTION OF THE AREA

The material for this report was obtained in a detailed field investigation during the winter months of 1912-13. All the main roads and most of the secondary roads were covered. It is believed that nearly all the known occurrences of iron ore in Lewis County have been located and described. (See Plate 25).

The writer wishes to acknowledge his obligations to companies and individuals for courtesies extended, and for information and assistance freely given throughout the period of field work.

Location and area.—Lewis County is situated in the southwest portion of the geographic division commonly known as Middle Tennessee, and on the southwest side of the physiographic division known as the Highland Rim. It contains approximately 297 square miles or 190,080 acres, the greater portion of which is covered with second-growth timber and classed as unimproved lands. It received its name in honor of Merriwether Lewis, the companion of Clarke in the famous Lewis and Clarke overland expedition to Oregon Territory in the years 1803-6. It may be well to state that near the center of the county, on the line of the old Natchez Trace, while on a journey from the Louisiana Territory, of which he was Governor, Merriwether Lewis, on October 11, 1809, met his death, either by suicide or murder. At this very spot he was buried, aud in 1848, the Legislature of Tennessee had a monument erected to the memory of this renowned explorer and patriot.

Surface features and drainage.—Lewis County lies within the deeply dissected plateau known as the Highland Rim, the highest points of which have an average elevation between 900 and 1,000 feet above mean sea level. In the Lewis County area the elevation of the plateau will probably average higher than that of the counties surrounding it. A study of the topography of this region clearly shows that the present land surface is the result of the dissection of a level or gently undulating plain, which, if restored, would have an altitude of over 1,000 feet.

The surface is composed of high, irregular-shaped ridges with steep slopes to narrow valleys. A mile or more away from the streams the lands become flat and open. There is a belt of such land, averaging about 3 miles in width, running diagonally across the county from northwest to southeast. The crests of the ridges vary from 900 to over 1,000 feet above

[28]The data pertaining to Lewis County are reprinted from Resources of Tennessee, vol. 5, No. 3, 1915, in their original form with a few unimportant omissions, because the report is out of stock. All descriptions and dates are therefore as of the period when the work was prepared. Some additional notes have been supplied by E. F. Burchard, as indicated.

sea level, and are from 250 to 350 feet above the streams. It is on or near the tops of the ridges that the iron ore occurs.

The plateau-like surface of the county is gashed by many streams. Most of these rise in the county, and flow from it to nearly every point of the compass. Buffalo River is the largest stream. It rises in Lewis and Lawrence Counties, flows across the southern portion of Lewis, and empties into Duck River, in Humphreys County. Among the smaller streams may be mentioned Big and Little Swan Creek, Cane Creek, Trace Creek, Rockhouse Creek, Grinders Creek, Chief Creek, Indian Creek, and many others too numerous to mention. For the names and locations of these the reader is referred to the county map accompanying the report.

THE IRON-ORE DEPOSITS

Topographic relations.—The iron-ore deposits have a well defined and striking relation to the topography of the region, being located on or near the crests of the ridges and spurs of the inter-stream divides. They have approximately the same elevation, and any noticeable differences in elevation are apparently due chiefly to the amount of denudation the locality has suffered.

Geologic relations.—The ridges and their spurs are generally covered with a thick blanket of residual clay soil, containing fragments of partly weathered, and often bleached, cherts and siliceous limestones. This soil mass is chiefly derived from the weathering of the underlying limestones and cherts of the St. Louis and Tullahoma [Fort Payne] formations. Water-worn quartz and chert gravels, and what appears to be alluvial sands, sandstones, clays, and shales are frequently intermingled with the residual soil mass. In some exposures layers of cherty limestones overlie the water-worn gravels, but no conglomerate from which the quartz and chert gravels could have been derived has ever been found in this region[28a]. The gravel seems more abundant near the top of the mass, and apparently decreases with depth. It, however, is patchy in its occurrence. More or less occurs, with rare exceptions, in the loose mass containing the ore, but in a few instances, the ore is found in very red clay containing little or no gravel and chert. The apparent abundance of gravel near the top is, in most cases, doubtless due to the clay soil having been removed by erosion, thus leaving the more resistant gravels.

In the mass containing ore deposits there is no clearly defined arrangement of materials. The bedded rocks that sometimes occur do not appear to occupy their original position. The whole mass has a jumbled appearance. Doctor A. H. Purdue[29] has suggested that the bedded material came to its

[28a]The former presence of the Tuscaloosa gravel had not been recognized when this chapter was first published in 1915. E. F. B.

[29]The resources of Tennessee, vol. 2, No. 10, p. 382, 1912.

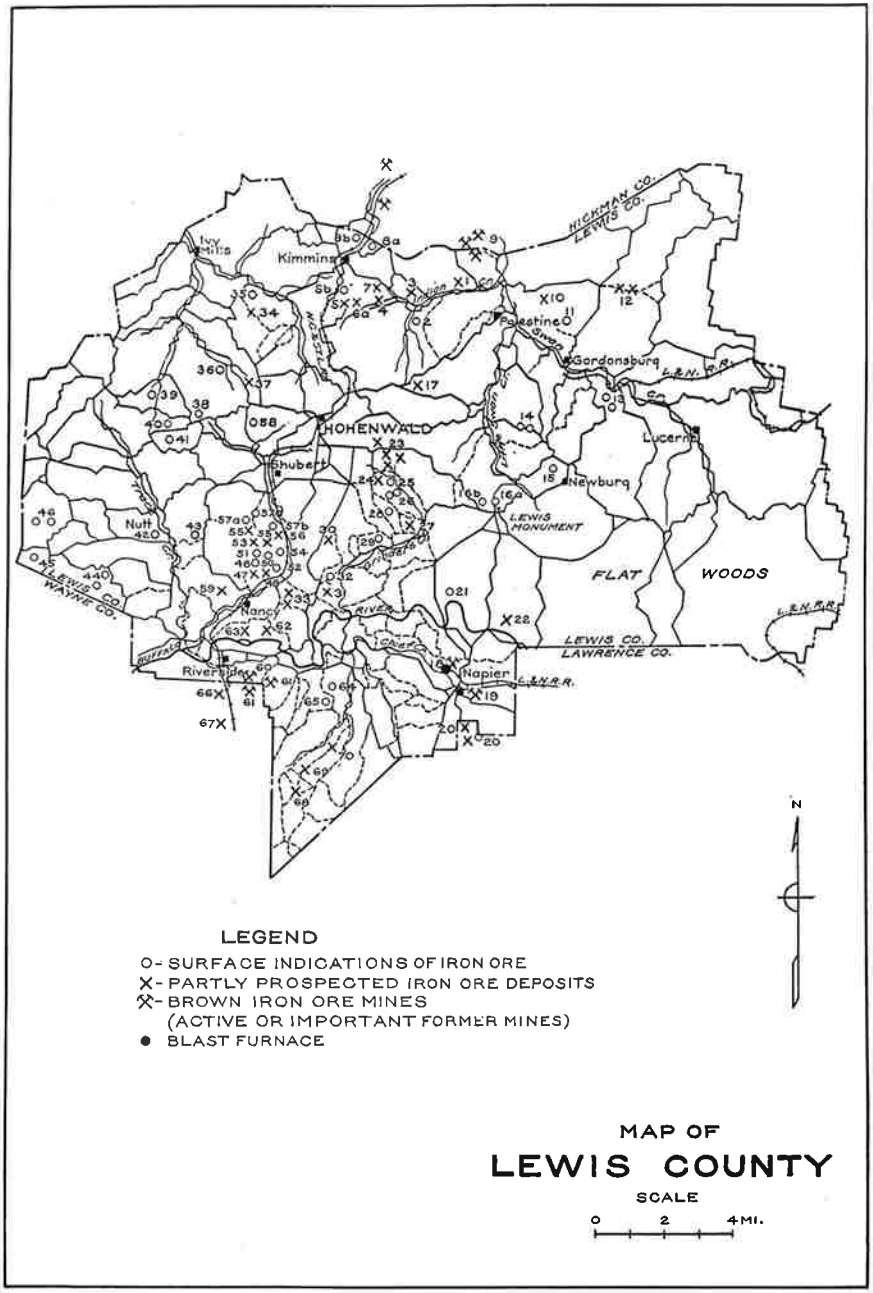
present position by landslides. The loose material overlying the solid rocks varies from a few feet to over 100 feet in thickness, and has, in most cases, a considerable thickness in this area. It is in the loose material, as in a matrix, that the iron-ore deposits of the region occur.

Observations in this area seem to show that probably most of the deposits occur in the loose material at approximately the same geological horizon within the St. Louis limestone. This, however, is rather difficult to determine, on account of the thick covering of soil usually found in this area, and the nature and position of the material in which the ore occurs.

Mode of occurrence.—The ore is found accumulated at certain centers, which are called "banks." The upper portion of the bank is called the "top clay," which varies from nothing to over 15 feet in thickness. The upper part is often of a yellow or grayish color, while the lower portion is always very red, and contains more or less "shot ore." The shot ore is less than an inch in diameter and is of irregular size and shape, but usually somewhat rounded. It is rich in iron, and often occurs in the clay in such abundance as to make it workable. Large fragments of ore more than 10 feet in diameter sometimes occur in the top clay. Some of these are highly siliceous, containing a considerable amount of gravel and angular chert, while others may be very rich with limonite. The shot ore and the clay are formed by the weathering of the larger fragments of ore and the associated rocks.

Beneath the top clay, the ore is found aggregated in irregular bunches or pockets of varying richness, and these are separated by more or less barren material. They are of all dimensions from less than 10 feet up to masses over 40 feet in diameter, and may assume various shapes and positions. Many are tabular and approach the horizontal, but they may be inclined at any angle. The ore sometimes occurs in isolated lumps called "pots." The pots are lenticular shells, which vary from a few inches to more than 25 feet in their longest dimensions. The smaller ones are sometimes hollow, but frequently they are partly or completely filled with water, decomposed chert, a white or yellowish powdery clay, or tough, fat clay. The larger shells may inclose one or more of the following substances: Clay, gravel, sand, and angular chert. The larger pots sometimes have the appearance of irregular veins winding through the banks in different directions. Large chunks of conglomerate and breccia frequently occur cemented with hydrous iron oxide (limonite). These appear to be more abundant near the top of the bank, but may occur elsewhere. An iron-stained, soft sandstone is sometimes met with. Masses of ore frequently surround or partly cover a "white horse" or "yellow horse," which is a putty-like, residual clay that becomes extremely sticky when wet, and can not be easily separated from the ore in the washer.

Size.—Some of the banks of the Western Iron Ore Region occupy an acre or less, while others cover several square miles. The deposits of Lewis County will vary from banks less than an acre in extent to those covering over 500 acres. However, these large banks must be thought of as numerous



Map of Lewis County, showing iron-ore mines, prospects, and ore banks.

(A) Deep cut in Napier brown iron ore mine, Lewis County, showing disintegrated chert in wall.

(B) Blast furnace of Napier Iron Works and stock of pig iron no hand, October, 1924.

deposits or local segregations of varying richness. The worked deposits often supply a large amount of ore before they are exhausted. In the excavations if a mass is struck it is followed until it disappears, when another is sought for.

Depth.—The depth of the ore varies greatly, even within the same bank. Developments have shown that while some deposits may be less than 15 feet deep, others are 60 feet or more. The workings at the Nunnelly mine, in Hickman County, have reached a depth of over 60 feet, and a shaft put down 60 feet further is reported to be in ore-bearing ground. The bottom of the ore in the Napier mine has not been reached at a depth of 45 feet. The lowest limits of the ore bodies at the Bon Air Coal & Iron Co.'s mine, near Allens Creek, and of the adjoining Perry mine, near Riverside, have not been found at a depth of 60 feet. The openings at the Aetna Mine, located at Aetna, Hickman County, have reached a maximum depth of about 40 feet. Here, test pits sunk a few feet deeper in the old workings have not reached the bottom of the ore deposits. The greatest possible depth at which the ore can occur will depend upon the thickness of the loose material overlying the solid rocks, for pay ore has never been found in the bedded rocks.

Outcrop.—Outcrops vary greatly in size and form, and frequently indicate the nature and value of the deposits. Some outcrops will extend over less than a quarter of an acre, while others will occur more or less continuously over several hundred acres. However, in many cases the size and character of the outcrops are insufficient criteria upon which to base a reliable estimate of the size and value of a bank. Valuable deposits have been found to underlie areas showing little or no surface indications. In such cases more or less soil or gravel overlies the ore body. No doubt there are local segregations of ore many acres in extent that do not show at all or appear on the surface. Such deposits doubtless exist in the flat ridge lands where the soils have a considerable thickness, and in other favorable situations where erosion has lagged behind rock weathering.

A promising form of outcrop consists of chunks of ore embedded in the soil with the surface of the ground strewn with either or both large and small fragments of ore, and the subsoil very red and containing a considerable quantity of shot ore. Other things must be taken into consideration, such as the depth of the material overlying the solid rocks, and the elevation and extent of the workable deposit.

A less promising form of outcrop consists of a ledge of highly siliceous and massive conglomerated and brecciated ore protruding from the side of the hill or ridge. These ledges are sometimes 20 feet or more in thickness, and from a few feet to over 150 feet in length. The ore underlying such outcrops is usually of a very inferior quality, and of little or no commercial value at the present time.

Overburden.—The overburden varies in thickness from a few inches to over 30 feet. It usually consists of clay, water-worn quartz and chert

gravels, and angular chert, but may consist only of clay or both clay and chert. The tops of the ore bodies are nearest the surface on the points of the ridges and their spurs, and in other situations where the soil has been largely removed by wash. In the flat lands or so-called "barrens" the ore is well concealed beneath 10 feet or more of clay soil, or soil and gravel.

PROSPECTING

The ore in most places is covered by soil, gravel, and sand, so that outcrops do not occur except in such favorable situations as around the head of hollows and gullies and near drainage ways or streams, where the overburden has been removed by erosion. It thus follows that in the high flatlands there may be local segregations of ore of workable size that do not appear at the surface.

Experience has shown that a search for brown ores in this part of Tennessee should be confined to the highest lands. In the absence of ore outcrops, the intense red color of the soil and the presence of float shot ore are valuable criteria, which often indicate a probable bank. In wooded areas, however, the color of the soil is often hidden by vegetation. In such situations the roads, trails, and other surface features bare of vegetation, the upturned roots of trees and the holes of burrowing animals should be carefully examined for iron ore. Fragments of ore scattered over the surface, and residual ore embedded in the soil, indicate a bank beneath. After all surface indications have been carefully examined, the prospect should be proved by sinking test wells or shafts, for the surface indications of limonite deposits do not afford a true index to the size and commercial importance of the bank. The careful sinking of a requisite number of test wells at proper intervals would determine the lateral and vertical extent of the ore, its quality, and

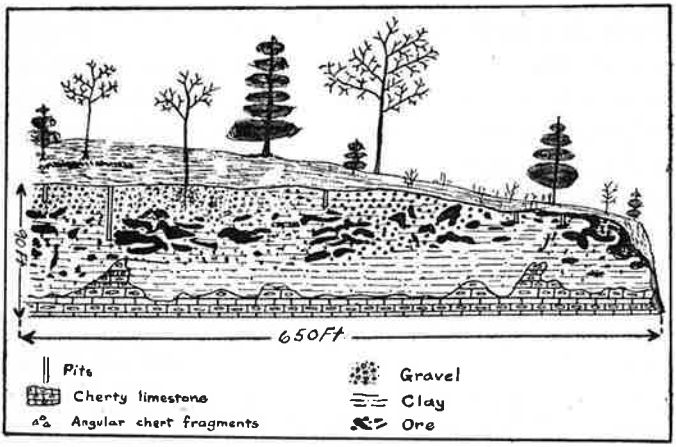


FIGURE 6.—Hypothetical section to illustrate how shallow pits may fail to show ore on the crest of a ridge where the overburden is thick.

the thickness of the overburden. The prevailing method of sinking wells and pits is by hand, in which the windlass, rope, bucket, shovel, and pick are used. The wells should be sunk to a depth of 20 feet or more, depending upon the thickness of the unconsolidated material overlying the solid rocks, for the ore is not known to occur commercially in the stratified rocks. The most economic size of shallow pits is probably 2½ by 2½ feet, and of deep ones, 3 feet in diameter. Very siliceous ore (gravelly, sandy, and cherty) may occur in the upper portion of a bank, while that at lower depths may be of a good quality, so that considerable judgment is necessary in determining the value of a deposit.

A good topographic map is exceedingly valuable in prospecting for brown ores and in development work. Such a map should show the vertical and often the probable lateral range of the deposits and their relation to the drainage. Many other valuable features are brought out in a map having the proper contour interval and scale.[30]

MINING AND CONCENTRATING METHODS

Mining operations are comparatively simple, owing to the shallow nature of the deposits. All the workings are open cuts. The ground is loosened by picking and blasting. Steam shovels are used in the large banks, and the ore is usually transported to the washer on mine cars hauled by a steam locomotive. The small deposits can often be profitably worked by the hand method, and the ore trammed to the washer in wagons, provided the deposit is rich, and the washing plant is near by. However, many of the deposits are too small to support expensive equipment, and these can not be profitably worked unless mining is done in connection with the larger banks. The ratio of the ore to waste varies from about 1 to 3 in the richer deposits to about 1 to 10 or 12 in the poorer deposits. The lowest that can be profitably worked at the present time is about 1 to 10.

The ore is concentrated in modern steel-log washers. It is transported in wagons or mine cars to the tipple, where it is dumped on grate bars. There the large fragments and boulders are broken up so that it can pass into an inclined metal-lined flume, in which a stream of water is constantly flowing. The water forces the ore down the flume into the washer, which automatically removes most of the waste from the ore. Some of the coarser material which is not separated by the washer is removed by hand, as the ore passes along on a belt towards the storage bins. The chief equipment for a modern steel-log washer will consist of two logs, sizing screens, crushers, jigs, receiving bins, distributing trammels, picking belt, and a complete pumping

[30]A detailed description of the methods of prospecting for iron ore is given by E. F. Burchard, in The production of iron ore, pig iron, and steel, advanced chapter from Mineral Resources of the United States, U. S. Geol. Survey, p. 24, 1911.

station. Water is obtained from the numerous creeks found in this section of the State. The residue from the washer passes into settling ponds, from which part of the water may be used over again.[81]

MINES AND PROSPECTS

INDIAN CREEK DEPOSITS

The Indian Creek deposits are located in the vicinity of Indian Creek, in the northeastern part of the county. The location of these is shown on the accompanying topographic sketch map, Figure 7 [and by the numbers on the map of Lewis County].

Peeler and Carroll bank.—(No. 1. Owned by J. M. Peeler, W. A. Carroll and others, Hohenwald, Tenn.). This bank, located 3½ miles S. 80° E. of Kimmins, is situated on the top of a rather narrow ridge and its spurs. This ridge lies on the north side of Indian Creek, and northwest of the fork of the Indian Creek and Aetna roads. Its elevation is between 800 and 850 feet above sea level.

The top of the ridge is about 200 feet above the bed of Indian Creek. Cherty limestones of the Tullahoma [Fort Payne] and the overlying St. Louis formations outcrop on the lower southern slope of the ridge and extend up its side through a vertical distance of approximately 70 feet. The rocks are nearly horizontal. The ridge is capped by residual material, consisting of clay and partly decomposed, angular chert, containing some water-worn gravels. It is in this loose material that the iron ore occurs. The thickness of the loose material overlying the solid rocks is evidently less than 130 feet, though weathering apparently extends to a considerable depth.

More than 16 shallow test pits, covering one area of 10 or 12 acres, have been dug on and near the top of the ridge. The depth of most of the pits is between 3 and 4½ feet, though a few are 8 to 10 feet deep. Six of them are blank, or show a little shot ore in very red clay. Most of the 10 remaining ones show a fair quantity of ore, and 5 of the 10 make an excellent showing. On this ridge is a small, shallow cut from which a few wagon loads of ore were hauled to the old Aetna furnace when it was in blast. The material thrown out of the test pits consists of ore, very red clay, angular chert, and some water-worn gravel. The surface of the ground is in places more or less covered with fragments of ore, and shot ore is especially abundant. Some rather large chunks were seen on the slopes of the ridge and others are embedded in the clay. A few were found 30 feet below the crest of the ridge and apparently in place.

The test pits and outcrops indicate that some good deposits may be found over an area of 20 to 25 acres. Erosion has apparently brought the ore de-

[81]For a complete discussion of the methods of treating brown iron ores, the reader is referred to an article by H. S. Geismer, Am. Inst. Min. Eng., Bull. No. 56, 1911, p. 642.

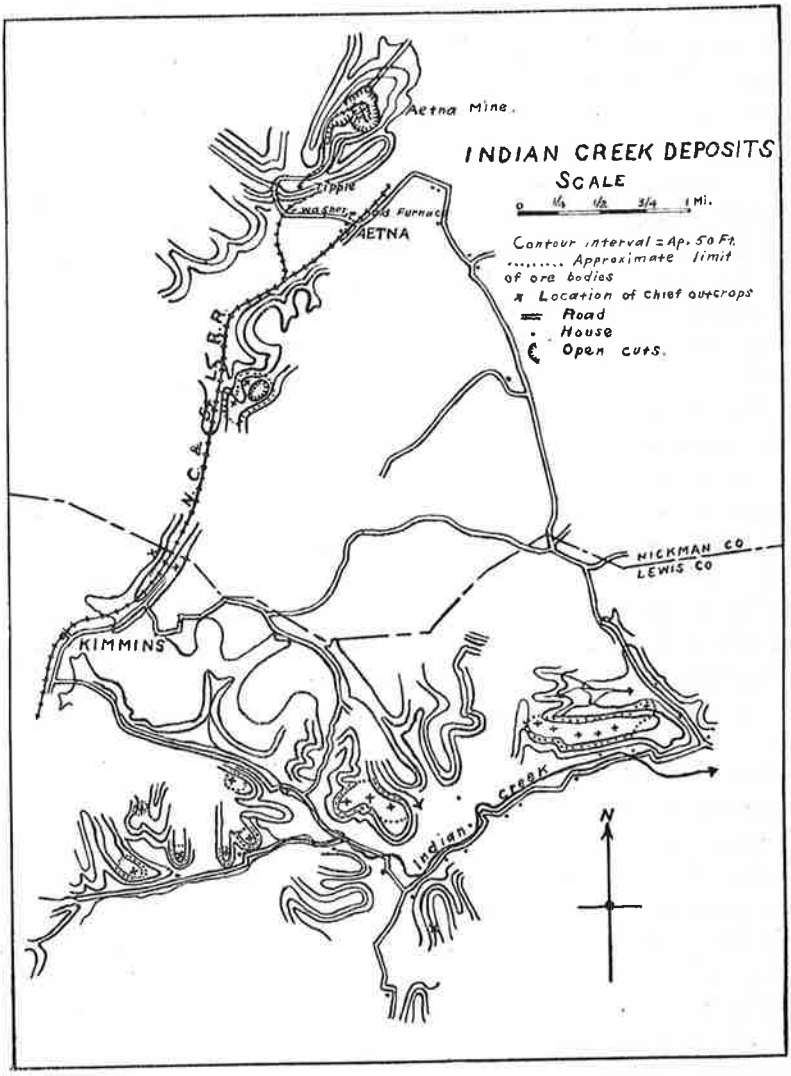


FIGURE 7.—Sketch map showing location of brown iron ore deposits in Indian Creek District.

posits near the surface, so that the overburden should not be excessive. The limonite seems to be of good quality, and is generally free from excess of sand, chert, and gravel. The ore is chiefly in the form of shells ("pots") and solid lumps. An average sample taken from several of the pits analyzed[32] 54.29 per cent iron, 8.62 per cent silica, 0.166 per cent phosphorus, and 0.009 per cent sulphur. A sample taken from several pits on Carroll's land an-

[32]All analyses herein quoted were made by Dr. Paul C. Bowers, Chemist of the State Geological Survey, unless otherwise stated.

alyzed 53.73 per cent iron, 8.59 per cent silica, 0.347 per cent phosphorus, and 0.047 per cent sulphur.

Baker's prospect.—(No. 2. Owned by A. L. Baker, Hohenwald, Tenn.). This prospect is located 2¼ miles S. 45° E. of Kimmins, and on the south side of Indian Creek. It is situated on the west side of a very narrow secondary ridge at approximately 50 feet below its crest. At this place a very shallow excavation was made into the side of the hill, and the material piled up near the place showed a considerable amount of ore for a shallow cut. The ore seems to be of fair quality and comparatively free from foreign material. The top of the ridge is about 150 feet above the bed of Indian Creek, and considerable gravel was observed on its crest. No indications of ore were found, except the one mentioned above. Surface indications have been reported on several ridges a quarter of a mile or more east of this locality.

Langford and Long bank.—(No. 3. Owned by J. R. Langford, Hohenwald, Tenn., and Charles Long, Mt. Pleasant, Tenn.). This bank is located on the north side of Indian Creek, 2 miles S. 60° E. of Kimmins. The ore deposits occur on and near the top of a secondary ridge and its spurs. The top of the ridge is approximately 160 feet above the bed of the creek. A 40-foot section of rocks was observed on the south slope of the ridge, extending down to the creek. It thus appears that the loose material in which the ore occurs might extend to a depth of 120 feet, though such is not probable.

Eight shallow test pits and a shallow cut were found scattered over an area of possibly 25 acres. These pits have been dug on or near the top of the ridge. They vary in depth from 4 to 8 feet, and most of them show a fair quantity of ore. Angular chert fragments and some water-worn gravel occur mixed with the clay and ore from the pits. The clay subsoil exposed in the pits is very red and is frequently rich with shot ore. This ridge contains a shallow cut from which a few wagon loads of ore were hauled to the Aetna furnace when it was in operation. Shot ore is abundant on the top and slopes of the ridge, and larger fragments of ore occur embedded in the soil, and as float. A few large boulders of iron-cemented conglomerate and breccia were observed.

The ore appears to be of good quality and largely free of siliceous impurities. It is mainly in the form of pots and compact varieties. An average analysis from eight samples gave 51.77 per cent iron; 10.60 per cent silica; 0.859 per cent phosphorus; and 0.031 per cent sulphur.

The surface indications and test pits seem to show that the ore occurs in pockets of varying richness over an area of 20 acres or more. The property should be systematically prospected.

Coble property.—(No. 4. Owned by J. D. Coble.). This property is situated on the southwest prong of Indian Creek, 1½ miles S. 40° E. of Kimmins. The iron-ore bank occurs on the southeast point of a narrow sec-

ondary ridge, and there are also surface showings on an adjoining southwest point. No outcrops of stratified rocks were found. The points of the ridge where the ore outcrops occur are about 125 feet above the small stream at their base. Several shallow excavations were found on the edge of the southeast point, and the writer was informed that a few wagon loads of ore were hauled from these cuts to the old Aetna furnace. Here the ground is strewn with residual ore fragments. The clay in the excavations is very red, and contains a large amount of ore, principally shot ore, in its upper part. A few large chunks of residual ore were seen. A considerable quantity of float ore, and also ore embedded in the soil, was found on the edge of the southwest point. The intervening space between the points make a poor showing for much ore. The southeast point shows up better than the southwest one. The indications are favorable on 3 or 4 acres on the southeast point of the ridge and on one or more acres on the southwest point. The ore probably extends to a depth of at least 20 feet. An analysis of the ore gave 53.40 per cent iron; 8.26 per cent silica; 0.952 per cent phosphorus; and 0.044 per cent sulphur.

Smith bank No. 1.—(No. 5. Owned by Frank Smith, Pasadena, Cal.). The deposit is located on a southeast prong of Indian Creek, 1½ miles S. 15° E. of Kimmins.

The bank is situated on and near the top of the point of a long, narrow secondary ridge. The top of the ridge is about 100 feet above the small stream near its base. The ore occurs in the loose material overlying solid rocks, but no rock outcrops were observed. However, chert fragments were abundant near the base of the ridge and these indicated the presence of the St. Louis formation. Water-worn gravel is abundant on the crest of the ridge north of the ore deposits.

Developments consist of two shallow pits on top of the ridge, and these show a fair quantity of good ore in very red clay. The larger pit is 20 by 10 by 8 feet, and the smaller pit is 5½ feet deep. Several wagon loads of ore are reported to have been hauled from these cuts to the old Aetna furnace. Ore fragments are scattered over several acres on the top and upper slopes of the ridge. Massive conglomerate cemented with limonite, outcrops on the south slope, and a large quantity of water-worn gravel was noticed at this place.

Surface showings are good over 3 or 4 acres, and these indicate that the ore pockets extend to a depth of at least 15 feet. An analysis of the ore gave 50.73 per cent iron; 13.79 per cent silica; 0.614 per cent phosphorus; and 0.032 per cent sulphur.

Smith bank No. 2.—(No. 6a. Owned by Frank Smith, Pasadena, Cal.). One-fourth of a mile east of the ridge described above is an excellent prospect for a small bank. This is also a narrow ridge about 100 feet higher than the valley.

The property shows several small, shallow cuts from which ore is said to have been hauled by wagons to the old Aetna furnace. The largest cut is 25 by 20 by 10 feet. The cuts are on the point of the ridge, and all show ore in very red clay. Most of them make an excellent showing. Several shallow excavations on the slope of the ridge, 40 to 50 feet below the top, show a large quantity of ore. Large solid chunks of ore, which appeared to be in place, were seen embedded in the clay soil 30 feet or more below the crest of the ridge. Large boulders, some over 3½ feet in diameter, of limonite-cemented conglomerate and breccia, occur on the slope of the ridge. Some iron-stained blocks of sandstone also occur. The point of the ridge is covered with shot ore and larger fragments of ore. Some of the solid chunks are heavy with iron.

There is probably a good small iron-ore bank in this ridge, and the indications are favorable over at least 4 to 5 acres. Judging from the large chunks of residual ore and ore in the pits below the crest of the ridge, it is likely that the ore pockets extend to a depth of 45 to 50 feet. Most of the ore is in the form of solid chunks and pots. There is also a little honeycomb ore.

(No. 6b.) Two fifths of a mile north 40° west of the above bank, ore outcrops on top of a ridge, near a draw. The outcrop covers an area of several hundred square feet, but no prospecting has yet been done in this locality.

Prospect north of the Coble property.—(No. 7.) This prospect is located on the northwest prong of Indian Creek, 1¼ miles S. 50° E. of Kimmins, and half a mile north of the Coble property. Several very shallow pits have been dug on the crest of a ridge whose elevation is about 125 feet above the bed of the creek. All the holes show some ore, chiefly shot ore, and two of them make a good showing. In places, the surface of the ground is covered with shot ore. No large chunks of ore were found here. The last dirt thrown out of the holes is very red clay containing shot ore in more or less abundance, and some chert fragments.

The test pits are only a few feet apart, but surface indications are fairly good over 3 to 4 acres. More test pits will have to be dug here before any opinion can be formed regarding the depth and areal extent of the deposits.

Outcrops of highly siliceous, low grade conglomerate and breccia ore, were observed on the slope of a ridge about half a mile northwest of the above-described prospect. The outcrops are only a few feet above the bed of the stream. Low-grade float ore also occurs, at intervals, in or near the bed of the stream for a distance of several thousand feet north and south of this locality.

Nicholson's prospects.—(No. 8a.) These prospects are located on the Nashville, Chattanooga & St. Louis Railway, three-fourths of a mile northeast of Kimmins. A shallow excavation has been made into the side of the ridge east of the railroad track. The excavation is about 20 feet above the bed of the nearby stream, and a few feet below the top of the ridge. This

cut is very shallow, but there is a good showing of ore. Small fragments of ore are abundant on the slope of the ridge near the prospect, and a few float boulders were found in a shallow hollow about 800 feet north of the prospect.

(No. 8b.) Several shallow excavations have also been made into the side of the ridge on the west side of the railroad, and one of them shows considerable ore. The soil is red in spots near the top of the hill, and a very little shot ore was found. However, water-worn quartz and chert gravels are abundant, and apparently have a considerable thickness.

On the whole, there seems little chance of finding ore in workable quantity, at this locality, but it may be hidden beneath the thick blankets of soil and gravel of the flat lands. The ore is of fair quality.

SWAN CREEK SECTION

The Swan Creek section is in the northeastern part of Lewis County. All the known occurrences of iron ore in the vicinity of Big and Little Swan Creeks are described under this heading.

Jenkins Branch deposits.—(No. 9. Owned by the former Bon Air Coal & Iron Co., Nashville, Tenn.) These deposits are located 3 miles S. 45° E. of Aetna, Hickman County, and, as shown by the accompanying topographic sketch (Figure 8), are situated upon the crest of a secondary ridge south of Jenkins Hollow. That portion of the ridge where the ore occurs, ranges in elevation from 700 to over 850 feet above sea level. It can thus be seen that the deposits have a vertical range of over 150 feet, but it is not assumed they are of that thickness. Practically all of the Jenkins Branch deposits are in Hickman County near the Lewis County-Hickman County line.

This bank was worked about 20 or 25 years ago, at the time the old Aetna furnace was in blast. The mine was then owned by The Southern Iron Co., of Nashville, Tenn., and was operated by them until about the year 1895, when it was sold to the Buffalo Iron Co., of Nashville. The property was acquired by the Bon Air Coal & Iron Co. in July, 1902. At the time the mine was worked, the ore was hauled by wagons to the Aetna furnace at Aetna, a distance of 5 miles by the road.

The ore deposits occur in the loose material overlying the St. Louis cherty limestone formation. In this case the matrix consists almost entirely of very red clay. No outcrops of rocks were noticed in the immediate vicinity of the ore, though they occur on the lower slopes of the ridge near Swan Creek. The crest of the ridge on which the ore occurs is between 250 and 300 feet above the creek.

Developments consist of more than 40 cuts and test pits. These have various shapes and dimensions, but all have nearly the same depth, which, in most cases, is less than 12 feet. The largest cut is approximately 275 feet long, 30 to 50 feet wide, and 15 to 18 feet deep. There are quite a number

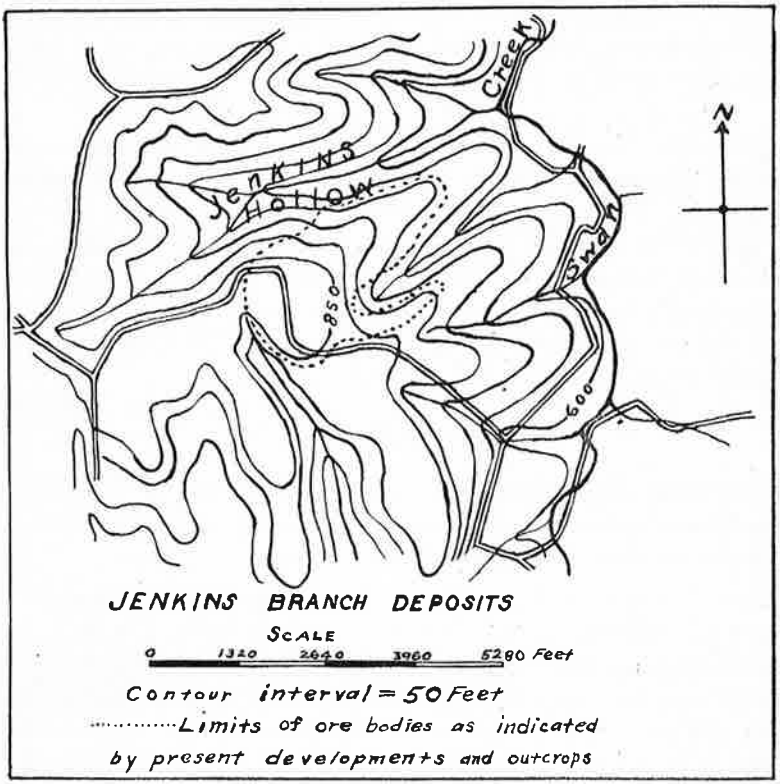


FIGURE 8.—Sketch map showing location of brown iron ore deposits near Jenkins Branch.

of cuts nearly as large as this one, but most of the openings are shallow test pits. The surface of the ground has a red cast and is more or less covered with residual-ore fragments, which vary in size from shot ore up to chunks over 2 feet in diameter. All the pits show very red clay below the top soil. This "blood-red" clay is commonly rich with ore, chiefly shot ore, but ore boulders over 4 feet in diameter occur.

It is evident, judging from the number and size of the openings, that a large amount of ore has been removed from this mine. However, only the richest and easily accessible pockets appear to have been worked. There is abundance of shot ore in the red clay, which can be profitably used under modern methods of mining. Deep shafts should be dug, for further explorations ought to reveal some promising deposits. There is doubtless a large quantity of ore still remaining in this bank. No outcrops of solid rocks were found, and the residuum here appears to be thick, possibly exceeding 100 feet. The outcrops and pits indicate that the deposits extend over an area of 83 acres and to an unknown depth. The overburden should not be great.

The ore is a dark-brown limonite of excellent quality, being free of excessive foreign material. It is in the form of solid lumps, pots and porous honeycomb ore. The property is 4 miles from a railroad and 5 miles from

the washer at Aetna. A representative sample analyzed 54.36 per cent iron; 7.92 per cent silica; 0.486 per cent phosphorus; and 0.041 per cent sulphur.

Low Gap Branch prospect No. 1.—(No. 10. Owned by Dr. A. H. Grigsby, Centerville, Tenn.). This prospect, located 2 1-5 miles N. 20° W. of Gordonsburg, is situated on the ridge north of Low Gap Branch. The prospect occurs on the top of a secondary ridge, and extends over several spurs. The ridge has an elevation of between 850 and 900 feet above sea level, and its crest is over 250 feet above Swan Creek.

All the test pits have been dug in a slight depression on the narrow part of the ridge where the outcrop appears most promising. In this area 5 shallow pits were found, varying in depth from 3 to 3½ feet. All except one make a fair showing of ore. The clay subsoil in the pits is very red and contains shot ore. Fragments of ore are scattered over the surface and extend to the point of a north spur of the ridge. Here some large chunks occur embedded in the soil and also protrude from the surface on the narrow part of the ridge. Surface indications are favorable over about 6 acres.

The ore is limonite and contains some inclusions of sand and chert. Most of the ore is of the honeycomb variety. A sample taken from the pits analyzed 52.53 per cent iron; 12.46 per cent silica; 0.876 per cent phosphorus; and 0.073 per cent sulphur.

Low Gap Branch prospect No. 2.—(No. 11. Owned by The Charles Mining Co., Columbia, Tenn.). This prospect is located 1 1-5 miles N. 3° W. of Gordonsburg on the point of a spur of a secondary ridge between two very small streams, at an elevation of over 850 feet above sea level. At this place masses of siliceous ore, 20 feet thick, have the appearance of a ledge extending several hundred feet around the point, about 25 feet below the top of the hill. Outcrops of limonite, consisting of boulders and fragments, are scattered over an area of 1½ acres. Root-wads from upturned trees contain shot ore in red clay. Some of the ore is of good quality, but the large masses are cherty. Outcrops of ore were observed around the heads of several hollows a short distance north of this place. The locality has never been systematically prospected, and there are probably many other deposits of ore that have not yet been located. A surface sample of the ore analyzed 58.99 per cent iron; 8.17 per cent silica; 0.838 per cent phosphorus; and 0.035 per cent sulphur.

Wilson Branch-Cade Branch bank.—(No. 12. Owned by Dr. A. H. Grigsby, Centerville, Tenn.). This bank is 3 miles N. 40° E. of Gordonsburg, between Wilson and Cade Branches. It is situated on both sides of the road on top of a ridge and its spurs. The ridge is narrow and has an elevation of over 900 feet above sea level, as shown by the accompanying topographic sketch (Figure 9).

Some prospecting has been done here, but it was not thorough, nor sufficient to prove the value of the deposits. Six very shallow test pits were found distributed along the ridge for a distance of about 2,000 feet. None of the

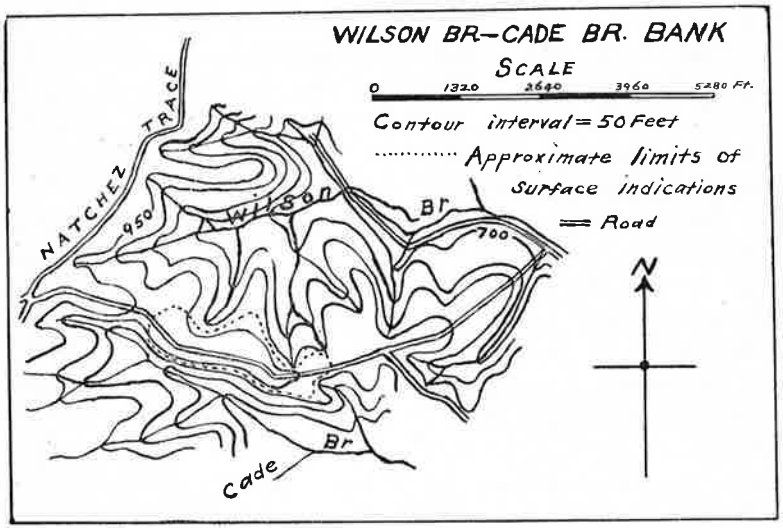


FIGURE 9.—Sketch map showing location of brown iron ore deposits between Wilson Branch and Cade Branch.

pits are over 3½ feet deep, but all except one show a little ore. The ore occurs in red clay, which contains chert fragments and some water-worn gravel. Small fragments of ore are abundant on both sides of the road, for a distance of 1,200 to 1,500 feet, and over this area the ground has a red cast in spots. Chert fragments are abundant on the ridges and on the slopes to the hollows. The talus deposits around the heads of the hollows contain many boulders of chert weighing over a ton. Lumps of ore can be seen in this loose rock, and some of these are more than a foot in diameter. The rock rubble also contains water-worn quartz and chert gravels, and such gravels occur in places on top of the ridge. No exposures of solid rock were observed, but the numerous chert fragments indicate the presence of the St. Louis formation. However, the thickness of the detritus overlying the solid rock is not known, and it may be considerable here. Surface showings, as described above, extend over an area of 25 or 30 acres. The ore seen was of fair quality, but a considerable amount of rotten chert is embedded in the large boulders. A sample of the ore analyzed 54.7 per cent iron; 8.95 per cent silica; 0.566 per cent phosphorus; and 0.006 per cent sulphur.

Stockard prospect.—(No. 13. Owned by S. N. Stockard, Gordonsburg, Tenn., and The Consolidated Phosphate Co., Columbia, Tenn.). This prospect, located 1½ miles S. 50° E. of Gordonsburg, is situated on a narrow ridge between Grinders Branch and Big Swan Creek. Here iron ore outcrops on the crest and near the points of the ridge and its spurs, at an elevation of between 800 and 900 feet above sea level, or 200 feet above Swan Creek.

Boulders, some over 3 feet in diameter, and fragments of limonite outcrop at intervals over an area perhaps 12 or 15 acres. The subsoil, where

exposed by root-wads, etc., is often very red, and in places contains an abundance of shot ore.

Rocks of the Tullahoma formation [Fort Payne chert], Chattanooga shale, and Leipers formation outcrop along the base of the ridge, and extend up its slopes for a vertical distance of 100 feet or more. These solid rocks lie nearly horizontal, and are apparently overlaid by 60 to 70 feet of loose material.

The ore is siliceous and often shows inclusions of chert fragments. Sand and gravel are sometimes mixed with it. Most of the limonite seen was in the cellular or porous form, but solid chunks occur. The ore will probably improve in quality at lower levels. Test pits should be dug at intervals over the ridge, and these should be put down to a depth of at least 20 feet. A surface sample analyzed 50.23 per cent iron; 16.19 per cent silica; 0.766 per cent phosphorus; and 0.069 per cent sulphur.

Hartley Branch prospect.—(No. 14. Owned by The Charleston, S. C., Mining & Manufacturing Co., Mount Pleasant, Tenn.). This prospect is located 2½ miles S. 30° W. of Gordonsburg, on both sides of the ridge road north of Hartley Branch. Surface indications occur on both sides of the road, on the crest of a ridge and its spurs, at an elevation of 950 feet above sea level, or 300 feet above Little Swan Creek. Two shallow test pits about 2,000 feet apart, showing some ore in very red clay, were found. These appear to have been dug several years ago, and are now partly filled up. The clay from the holes contains chert fragments and gravel. Shot ore and a reddish soil occur on both sides of the road, for a distance of about 2,500 feet. Throughout this distance some larger fragments of ore occur embedded in the soil and also as float, but these fragments are not abundant. A low grade, highly siliceous (very cherty and gravelly) ore outcrops around the heads of several hollows.

The ore is limonite, and most of that seen was of the cellular type, though solid lumps occur. No systematic prospecting has ever been done in this locality, and the value of the prospect is, therefore, not definitely known. No outcrops of solid rock occur in the immediate vicinity.

Beach prospect.—(No. 15. Owned by Fred S. Beach, Charlotte, Mich.). This prospect, located two-fifths of a mile N. 68° W. of Newburg, is situated on the point of a spur at an elevation of 950 feet above sea level, and about 50 feet below the crest of the main ridge.

The outcrop is confined to an area of about half an acre, and consists of boulders of limonite embedded in the soil, and smaller fragments of ore scattered over the surface. The ore is siliceous, and occurs in the cellular and other forms.

A considerable amount of shot ore was observed in spots on the ridge in the vicinity of Newburg, where the clay soil often shows up red in the road cuts. In several of the hollows near Newburg, large masses of highly

siliceous conglomerate and breccia ore occur. Fragments of ore are also scattered over several old fields near Newburg.

Lyon tract.—(No. 16a. Owned by M. F. Lyon, Adrian, Mich.). The surface showings occur on the crest of a spur about 1,000 feet north of the Lewis monument at an elevation between 1,000 and 1,050 feet above sea level. Here, the ground is more or less covered with shot ore, and a few chunks of ore were seen embedded in the soil of the road. Several shallow test pits have been dug, most of which show a considerable amount of small fragments of ore. In places the surface of the ground has a red cast. Root-wads from upturned trees frequently show an abundance of shot ore. Such indications extend over 10 acres or more.

Most of the ore seen was cellular limonite, and often contained inclusions of chert. However, not enough ore was found to enable the writer to judge of the quality. A surface sample analyzed 47.09 per cent iron; 4.86 per cent silica; 0.606 per cent phosphorus; and 0.04 per cent sulphur.

(No. 16b.) Surface showings also occur on the crest of another secondary ridge, which is located two-fifths of a mile west of the above-described prospects. The ridge has the same elevation as the one described in the preceding paragraph, and is 300 feet above the head of Little Swan Creek. At this place shot ore is scattered over the surface, and root-wads often show a considerable quantity of these small fragments of ore. The shot ore is especially noticeable in and near an old log and tire road. No large fragments of ore were found, and the top soil is not very red. No prospecting has been done.

Wilkins prospect.—(No. 17. Owned by Ashby Wilkins, Columbia, Tenn.). This prospect is located on the Palestine road 3½ miles N. 60° E. of Hohenwald. It is situated upon the crest of a long ridge and several of its spurs. The ridge has an elevation between 900 and 950 feet above sea level, and is about 350 feet above Indian Creek. It is a continuation of the flat lands that surround Hohenwald.

The soil is very red for a distance of about 800 feet along the road, and shot ore is abundant in spots, or wherever the soil is of a deep red color. The soil is the reddest, and contains the most shot ore at the deepest cuts in the road. Small fragments and large boulders of ore were found on the point of a south spur of the ridge at about 600 feet from the road. The outcrop covers an area 150 feet long by 75 feet wide. In a small ravine on the west side of this place are several wagon loads of highly siliceous, low-grade boulder ore. Only one shallow pit has been dug, but it shows some ore in red clay. Weathering has probably extended to a considerable depth on this ridge, for outcrops of solid rocks were not observed. The value of this prospect con not be estimated from showings of the one shallow pit and surface indications. The ore from the pit analyzed 54.8 per cent iron; 6.92 per cent silica; 0.675 per cent phosphorus; and 0.005 per cent sulphur.

NAPIER MINING DISTRICT

The Napier mining district is located in the southeastern part of Lewis County, near the town of Napier.

Napier mine No. 1.—(No. 18. Owned by the Napier Iron Works, Nashville, Tenn.). This mine is located three-fourths of a mile north of Napier on the crest of a high east and west main ridge and its spurs. The main ridge is really a divide between Buffalo River and Chief Creek, which streams are here only about a mile apart. The ridge has an elevation between 900 and 950 feet above sea level. The crest of the ridge is between 150 and 200 feet above Chief Creek and about 250 feet higher than Buffalo River.

The country rocks are composed chiefly of cherty limestones, the upper portion of which belongs to the St. Louis formation. The ore is found in the detritus overlying the latter formation. Bedded rocks are exposed along the lower slopes of the ridges, and extend up their sides for a vertical distance of 50 feet or more. These rocks have never been encountered in any of the mine openings. It appears, therefore, that the loose material overlying the bedded rocks may be as much as 100 feet thick or possibly more. The bedded rocks lie nearly flat.

Iron-ore crops out around the heads of hollows, on the slopes of ridges, and in other favorable situations where the overburden has been wholly or in part removed by wash. The outcrops occur in patches over an area of at least 200 acres, and consist of boulders, some over 3 feet in diameter, irregular-shaped masses protruding through the clay, lumps, and many small fragments. The ore is embedded in the soil or is scattered over the surface. Within the area of some of the outcrops, the ground is well covered with ore. Many test pits show ore in areas where there are no outcrops. In places the surface showing consists of only a few isolated fragments.

The ore is found irregularly distributed through the matrix in lumps and small fragments, in various shaped masses, and in lenticular and tabular forms. The pockets have various dimensions up to masses 25 or more feet in diameter. These bunches may lie horizontal or nearly so, or again they may be inclined at any angle. Some of the pockets produce only a few tons of ore, while others will supply scores of tons before they run out. The matrix consists principally of very red clay, which contains more or less chert, and frequently water-worn gravel. The overburden, which is composed of the same material as the matrix, varies from zero to more than 15 feet in thickness. The deposits extend to an undetermined depth, and ore in workable quantity has been found below the first workings. One of the openings has reached a depth of 45 feet.

The mine has been developed by several large, and many small openings, as shown on the accompanying topographic sketch (Figure 10). Most of these have been sunk to an average depth of 20 feet. Cut No. 1, one of the first opened, contains an area of 25 acres, and has an average depth of

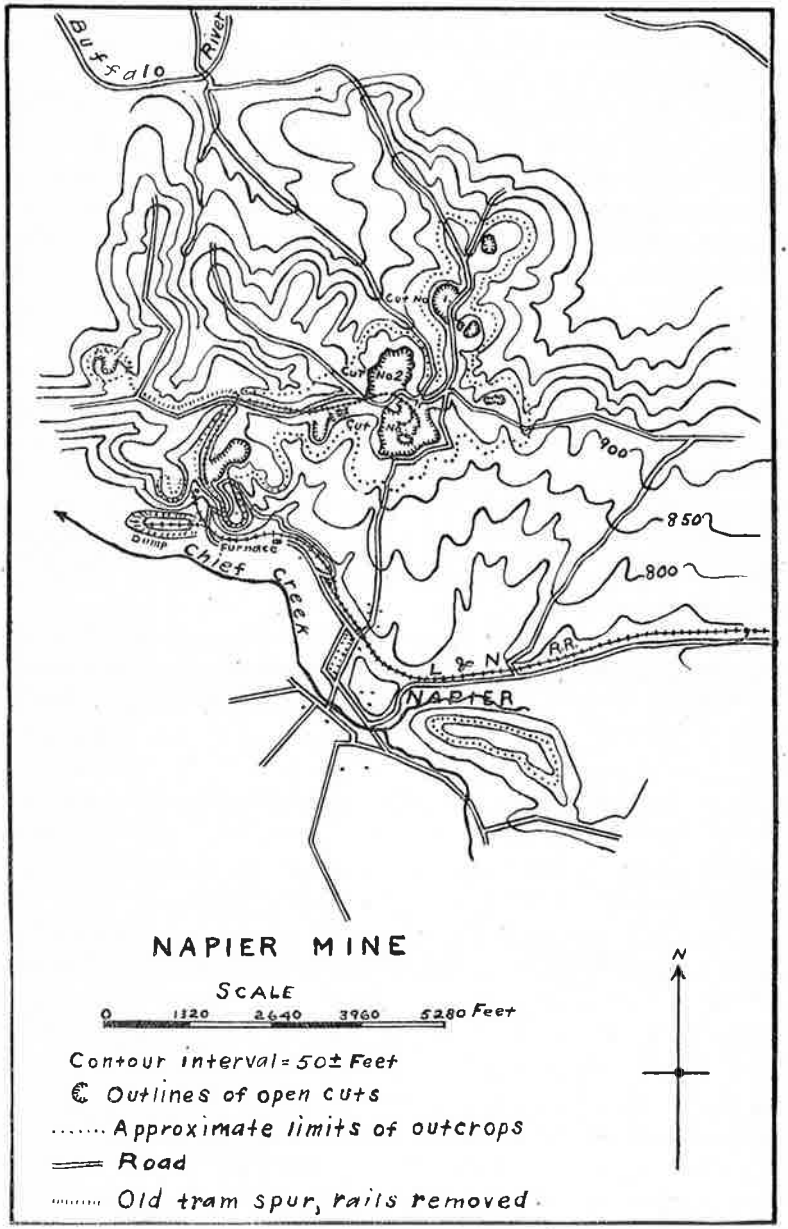


FIGURE 10.—Sketch map showing location of brown iron ore deposits in the Napier District.

between 15 and 20 feet. Cut No. 2 covers an area of 7 acres and has a maximum depth of 20 feet. No work is being done in this cut at present. Cut No. 3 contains an area of 12 acres. It has a maximum depth of 45 feet in its north end, but over most of the pit the average depth is less than 25 feet. A steam shovel is at work in the deepest part of the cut, and here a rich pocket of ore has recently been found below the first workings. The ore at this mine is of excellent quality, being low in phosphorus.

The following extracts relating to the history of the mine and furnace at Napier were taken from an article by Dr. A. H. Purdue,[33] on information furnished by Mr. William H. Lindsey, Vice-President of the Napier Iron Works:

"Prior to the Civil War, when that part of Lewis County in which the Napier Furnace is now located was still a part of Lawrence County, a forge was operated on the property in a small way. Somewhere near 1870 a company was formed for the purpose of taking over this old forge and of carrying on business in a strictly commercial manner, and between that time and the year 1904 there were removed from the mines at Napier from 450,000 to 500,000 tons of ore.

"In 1904 the mining of ore was discontinued by the operating company for the reason that the facilities for handling and cleaning ore had not at that time been perfected to an extent that would warrant the company in continuing the mining of ore at that point. Recently, however, the Napier Iron Works, the present owner of the property, has installed a modern steel-log washer with crushers and jigs of the manufacture of McLanahan & Stone at Hollidaysburg, Pa., and with this new and strictly modern plant it is practicable to recover ore at reasonable cost.

"The quality of ore at this mine is exceedingly fine, being low in phosphorus and high in metallic iron. The average of metallic iron will be over 50 per cent, whereas the phosphorus will run about 0.50 per cent. It is the anticipation of the Napier Iron Works that they will yet recover from this mine under the present operation approximately 200,000 tons of this ore.

"Prior to the Civil War the ore property at Napier was operated in a small way by private individuals in conjunction with a forge at that point. During the early 70's there was built at Napier what is known as a 'hillside' furnace, which was operated with charcoal as fuel, the wood for this purpose coming from nearby forests. The pig iron which was produced was hauled in wagons to Mount Pleasant, Tenn., the nearest shipping point at that time. Some years later the railroad was extended to Carpenters station, and pig iron was hauled to that point until about 1890, when the property was taken over by Major E. C. Lewis, Colonel E. R. Cole, and the late John Hill Eakin, and the organization of the Napier Iron Works was the result. A railroad was then built from Summertown, Tenn., to Napier, Tenn., and a new furnace was constructed. This furnace was operated with charcoal as fuel until 1897, when an additional stove and blowing engine were added to the equipment and the plant changed so as to enable it to substitute coke as a fuel in place of charcoal.

"Since that time the Napier furnace has secured its supply of coke from the Virginia field, and since 1904 the supply of ore for the furnace has come from its Wisdom Ore Mine (Sharp Mine), located near Pinkney, Tenn. These mines are now being abandoned, and the ore in the future will come from its mines at Napier."

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[33]The resources of Tennessee, State Geol. Survey, vol. II, No. 10, October, 1912, p. 375.

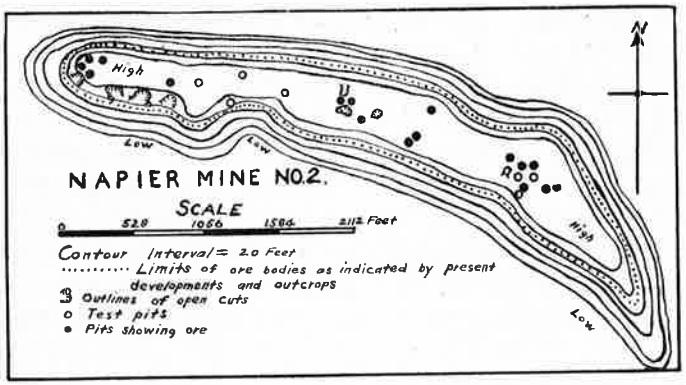


FIGURE 11.—Sketch map showing plan of Napier mine No. 2.

Napier mine No. 2.—(No. 19. Owned by the Napier Iron Works, Nashville, Tenn.). This mine, which lies on the eastern edge of the town of Napier, is 1 mile south of Mine No. 1, and is separated from the latter by the valley of a small stream. It is situated on the top of a long and extremely narrow ridge, which is a divide between Chief Creek and one of its branches. This part of the ridge has an east and west trend, and an elevation apparently considerably less than that of the main ridge on which Mine No. 1 is located. (See Figure 11).

The ridge is approximately 100 feet higher than Chief Creek. A 40-foot section of cherty limestone is exposed on the lower slopes of the ridge near the streams. The thickness of the material overlying solid rocks is not definitely known, but, as indicated by the outcrops of bedded rocks, is probably 60 feet. The ore, which occurs in pockets in the loose material, lies immediately above solid rocks, but no exposures were seen showing it in contact with them. The loose material consists chiefly of very red clay containing some chert.

The mine was worked on a small scale a number of years ago, the ore having been hauled out in wagons. No operations are being carried on at present, and have not been for some time. The work done was confined largely to prospecting. Developments consist of quite a number of test pits, small open cuts, and a few narrow trenches. All of these are shallow, and afford no reliable basis for accurately estimating the amount of ore remaining in the deposits. It is evident, from the size and number of the openings, that only a relatively small percentage of the ore has been removed.

The ore outcrops at intervals over an area of about 40 acres, and is composed of boulders, and smaller fragments. The clay soil in places is very red, and is often quite rich with shot ore. The ore is a good grade of dark-brown to nearly black limonite.

Supplementary notes (By Ernest F. Burchard).—The principal mine workings are three-fourths of a mile to one mile north of the village of

Napier, on the east-west ridge, which forms a divide between Buffalo River and Chief Creek, and there is a small opening about half a mile east of Napier between Chief Creek on the south and the railroad track on the north. The main workings north of Napier were examined by E. F. Burchard and R. W. Smith, October 23, 1924. The relations of the open cuts to the topography are substantially as shown on the maps by Rogers (Figures 10 and 11), although considerable extensions to cut No. 3 have been made since these mines were examined by Rogers in 1913.

The main ore body is well toward the highest part of the ridge, a remnant of the old plateau, which represents the peneplain developed on a surface of cherty limestone in this part of Tennessee. Rogers shows the ridge to be above an altitude of 900 feet and the height of the principal ore deposits above the level of Chief Creek to be a little more than 150 feet, which coincides with barometric observations made during the writer's visit. The deposit east of Napier, according to Rogers's map appears to be about 50 feet lower.

According to a property map made by Robert H. McNeilly, of Vanderbilt University, dated 1921, and evidently having the same base as the Rogers map (Figure 10), which was available at the time of the recent visit, the principal iron-ore deposit occupies an irregular-branching area 6,250 feet in length from southwest to northeast, with a maximum width of about 2,100 feet, and a small outlying deposit is shown about 2,000 feet west of the principal area. According to this map only portions aggregating less than half of this area have been mined out, but the map does not appear to be strictly up to date in this respect. The old mine pits and many new prospect pits, mainly at the north, show that the overburden is clay and chert débris, the latter disintegrated in places to gravel and sand, the thickness ranging from a few feet to 15 feet or more. On steep slopes and in the heads of hollows boulders of ore and ferruginous conglomerate outcrop, and in places lumps of loose ore are found on the surface. Much ore occurs, however, in pockets below heavy cover, where no ore shows at the surface. No bedded rocks are exposed in association with the ore deposits, but flat-lying cherty limestone is exposed in the vicinity of Buffalo River and Chief Creek. The ore is embedded in broken chert, clay, and sand. Where the surface material closely overlies ore it is reddish and ferruginous, but over places barren of ore it appears of lighter shades. In the mines and test pits fine-grained, hard, fossiliferous chert similar to the Fort Payne is common, but there are also large blocks and boulders that are somewhat porous and inclined to weather sandy as does the chert of the Warsaw formation, and the presence of this material suggests a mixture of material residual from these two chert horizons, which is inconsistent with the view taken by Rogers that the upper portions of the underlying cherty limestone beds belong to the St. Louis formation. In places near the top of the bank in cut No. 2 red sandy clay mottled with bluish-green clay was noted.

The cuts numbered 1 and 2 are 10 and 30 feet deep and some ore has been indicated by prospects below their present floors. Cut No. 3 is much deeper, reaching more than 60 feet in places. (Plate 26, A). The ore in this cut evidently was pockety and probably required the moving by steam shovel of considerable barren ground between the pockets of ore.

The old mine openings did not show much ore at the time of the recent visit, as the walls were weathered and much talus has accumulated obscuring the ore deposit and the bottoms of the workings, but from what could be seen there and on the surface in connection with a large number of prospect pits north of the old mines the ore appears to be of fair grade, and does not show much of the chert-breccia type of ore, although there are masses and boulders of this material in places. Many specimens, however, are of a lighter shade of brown than is characteristic of the best grade of ore, and this suggests a higher content of disseminated silica and alumina. In a few places the ore contains manganese above the average for brown ore of this region, and such ore is darker than the average. The content of phosphorus is said to be about 0.50 per cent, which is higher than is desirable for charcoal iron.

The test pits on the ridge between No. 1 and No. 2 cuts and north of No. 2 are from 10 to 20 feet deep. Samples of ore are displayed about these pits, each representing the recovery by washing and screening of 1 cubic foot of dirt from each 5 feet of depth in the pits. The quality of the ore thus recovered generally appeared good, some being dark and slightly manganiferous, and the limonite fragments do not show a large proportion of adherent chert. The proportion of rock and waste in the ore as a whole, however, appears fairly high, judging by the ore recovered in the new test pits, the appearance of the mine openings, and the rock pile at the site of the former washer. It was, however, reported that about 4 cubic yards of the ore-bearing dirt would yield 1 ton of ore.

The latest period of operation of these mines was from August, 1912, to August, 1917, when 208,550 long tons of ore are reported to have been delivered to the blast furnace. This compares closely with the probable recovery of 200,000 tons of ore estimated by this company in 1912, as stated on page 137. According to the blast-furnace records for this period the average yield of metallic iron in the ore consumed was about 50 per cent. The latest period of operation of the blast-furnace was from 1912 to 1923, except for a few periods of inactivity lasting less than a year. The blast-furnace was supplied from 1917 to 1923 in part by ore from mines in the vicinity of Corning, Wayne County, also owned by the Napier Iron Works, and in part by red hematite from the Birmingham district, Ala. The product was No. 2 foundry iron, fracture graded. Upon the closing of the mines at Napier the ore washer was moved to the Corning mines, which were operated at intervals from 1917 to 1923 when they were considered to be worked out. If it is decided to reopen the mines at Napier, it is probable that the ore washer will be moved back to this locality. There seems to be a

fair chance of there being enough ore in the extensions of the ore body disclosed by recent prospecting to warrant reopening the mines in times of strong demand and high prices for pig iron and ferrophosphorous, but as these periods are of erratic occurrence and uncertain duration the undertaking involves an element of speculation.

Revenue from an unusual source was being obtained on this property in October, 1924, through the shipment of chert gravel from the old washer dumps to the blast furnace at Rockdale, Tenn., where ferrophosphorus is manufactured from Tennessee limonite and phosphate rock. The addition of this gravel (which is accompanied by a small percentage of limonite lost in the washing) is for the purpose of introducing a definite proportion of silica into the blast-furnace burden, in order to carry the excess lime of the phosphate rock into the slag. The Napier Furnace and stock of pig iron on hand in October, 1924, is shown in Plate 26, B.

Dubowich bank.—(No. 20. Owned by L. Dubowich, Memphis, Tenn.). This bank, located 1¼ miles south of Napier, is situated on the top and slopes of secondary ridges and their spurs. Most of the bank is in Lawrence County, but it extends east into Lewis County.

Here the elevation of the ridges is apparently the same as the Napier mine. The tops of the ridges are between 200 and 250 feet above Chief Creek, and 50 feet above the bottom of the main hollow located near the center of the deposits. No outcrops of rocks occur in the vicinity of the bank. Erosion seems to have been less active on these ridges than on those of the Napier mine, so that the overburden appears to be thicker.

The developments consist of 18 very shallow test pits distributed in groups over a tract of 80 acres. These pits have been dug on the slopes of the ridges within the areas of the outcrops, and to an average depth of 2¾ feet. Fourteen pits show ore, 7 making an excellent showing, and 4 are blank. Most of the pits are less than 20 feet below the crests of the ridges. The material in which the ore occurs is mainly clay, often of red color, and contains angular chert and some water-worn quartz and chert gravel. The ore outcrops at intervals over an area of 30 acres or more, and consists of small fragments and rather large boulders of limonite embedded in the clay soil, and as float. The distribution and outcrops are indicated on the accompanying topographic sketch (Figure 12).

The surface ore is siliceous, due to inclusions of sand and chert, but a considerable amount of it appears to be of fair quality. The ore occurs in the cellular and compact forms.

These deposits have not been systematically prospected, and such shallow pits as have been dug are of little value in determining the commercial importance of the bank.

Smith prospect.—(No. 21. Owned by Frank Smith, Pasadena, Cal.). This prospect, located 3 miles north of Napier, is situated on the point of a

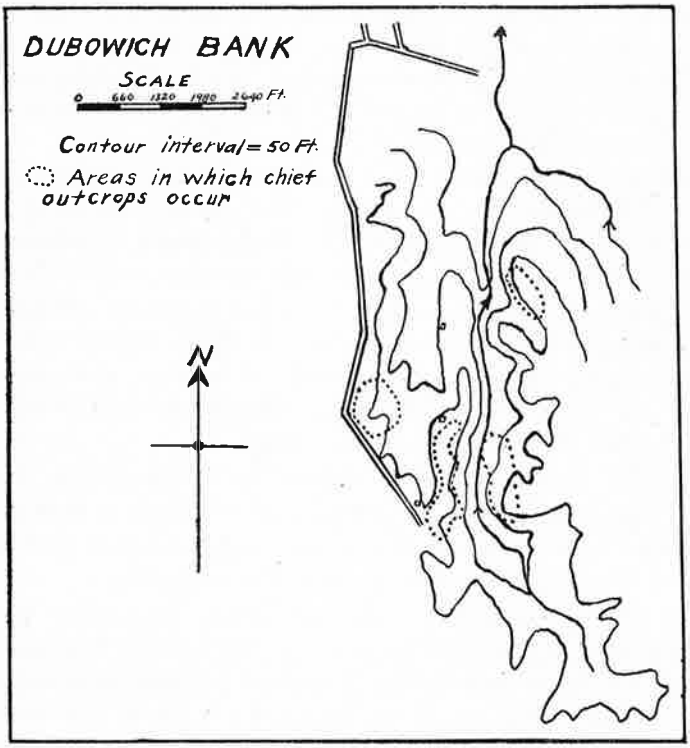


FIGURE 12.—Sketch map showing topographic relations of Dubowich Bank.

secondary ridge north of Buffalo River. Here the crest of the ridge is between 125 and 150 feet above the river.

One very shallow test pit has been dug on the south slope of the ridge, and this showed a little ore in red clay. Near this point masses of conglomerate and some breccia occur projecting from the side of the ridge, at about 35 feet below its crest. The mass is 20 feet thick and consists of chert and gravel with limonite as a cement. Some large boulders occur near the base of the ridge, and these evidently broke off from the large mass above. Shot ore is scattered over an area of 12 to 15 acres, and is especially abundant in the vicinity of the massive-ore outcrops. This prospect probably lies close to the solid rocks, for a 40-foot section of stratified rocks is exposed on the south slope of the ridge near Buffalo River. A surface sample of the ore analyzed 54.58 per cent iron; 9.66 per cent silica; 0.441 per cent phosphorus; and 0.019 per cent sulphur.

Hale bank.—No. 22. Owned by John W. Hale, Napier, Tenn.). This bank, located 2½ miles N. 35° E. of Napier, is situated on and near the top of a secondary ridge and its spurs. This ridge is approximately 250 feet above Buffalo River and on the north side of the river.

Developments consist of 6 test pits varying in depth from 2 to 5½ feet, and all show ore in very red clay. Five of the holes make a good showing

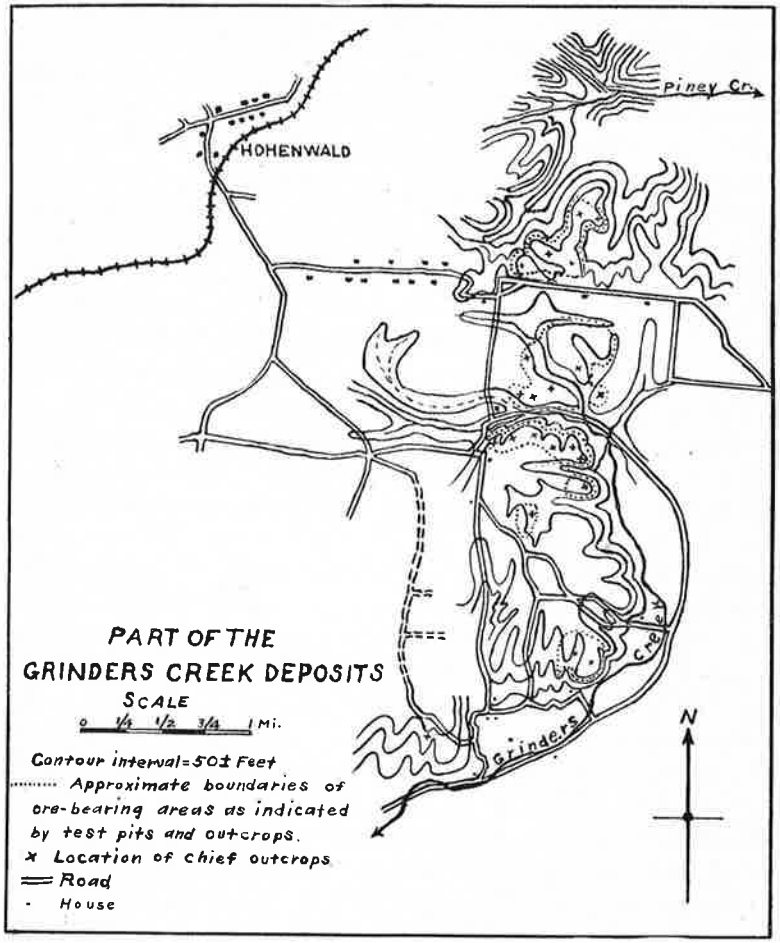


FIGURE 13.—Sketch map showing topographic relations of part of the Grinders Creek deposits.

for shallow pits, but the sixth shows only a little shot ore. Ore outcrops at intervals over an area of about 8 acres, and the pits have been dug within the area of the outcrop. The pits are near and on the top of the ridge and are scattered over an area of 2 acres. Residual ore outcrops 20 feet below the top of the ridge, so that the ore evidently extends to at least that depth. The ore occurs in the cellular and compact forms, and most of it is of good quality.

GRINDERS CREEK DEPOSITS

The Grinders Creek deposits, located in the south and southeast portion of the county, are situated in the vicinity of Grinders Creek and tributary branches. The topographic sketch (Figure 13) shows part of the Grinders Creek deposits.

Loveless and Overbey tract.—(No. 23. Owned by C. D. Loveless and J. Overbey, Hohenwald, Tenn.). This tract is located 2½ miles S. 70° E. of the Hohenwald post office. It is situated on the slopes and crest of a relatively narrow part of the broad ridge that runs through the county from southeast to northwest. The ridge has an elevation between 1,000 and 1,050 feet above sea level. This tract of land contains 625 acres, but probably less than 150 acres are known to be ore-bearing. Additional prospecting will doubtless extend this area, for many test pits show ore where there are no apparent surface indications.

Iron ore is exposed on the slopes and around the heads of the hollows and shallow draws, and in other favorable situations where the soil has been largely removed by wash. The locations of the most conspicuous outcrops are shown on the accompanying topographic sketch. The deposits, like the others of this region, are pockety, and occur in the loose material overlying cherty limestones of the St. Louis formation. No exposures of bedded rocks were found in the immediate vicinity of the bank, but stratified rocks outcrop 150 feet below the crest of the ridges, in the deep canyons to the north. The bedded rocks have apparently a nearly horizontal structure. The material in which the deposits occur is chiefly very red clay which contains more or less partly weathered angular chert, frequently water-worn quartz and chert gravels, and sometimes sand. The percentage of angular chert varies greatly, and often the material is largely very red clay. Some of the pits show considerable angular chert with little or no gravel, or the reverse in a few instances. The loose material seems to be thick, possibly 100 feet or even more.

Between 55 and 60 test pits have been dug on the slopes and crest of the ridge, and these are scattered in groups over an area of 300 acres. The pits are of varying depth, usually shallow, 3½ to 5½ feet, though quite a number are 10 to 18 feet deep. Twenty-seven pits make a very poor showing of ore or are blank, 15 show ore in fair quantity, and 15 make an excellent showing. The shallow pits on the slopes of the ridge sometimes show a large quantity of ore, but those on the top of the ridge do not, as a rule, show much. Some of the deep holes on or near the crest of the ridge show a large amount of ore. A few pits have been dug on the ridge at 40 feet or more below its crest, and some of these make a good showing.

Limonite is known to outcrop at intervals over an area of about 350 acres. Many of these isolated outcrops are small, and frequently consist entirely of only a sprinkling of shot ore; but others of the exposures are large, and extend over an area of several acres. Isolated fragments may occasionally be found over a rather extensive area. The outcrops consist of boulders, lumps, and large and small fragments. These are scattered over the surface or are embedded in the clay soil. Sometimes these are thickly strewn over the ground, and then again only an occasional boulder or fragment occurs. Residual ore was found more than 40 feet below the crest of the ridge. This

tract is covered by a rather thick soil blanket, so that outcrops of ore do not occur except in favorable situations. It appears that the overburden may be great in portions of the bank.

The ore is a brown to dark-brown or nearly black limonite, and much of it is excellent quality, though highly siliceous ore is occasionally met with. The chief siliceous impurity in the ore is chert, which occurs as inclusions, though sand and quartz are sometimes present in small quantities. A considerable amount of the ore is cellular or honeycombed. There is also a large amount of pots and ore in the compact form.

The writer believes, from a careful examination of the property, that the bank will warrant thorough prospecting, and possibly development. The depth to which the ore extends is not known, but the residual outcrops and the depth of the present test pits indicate that the deposits extend to a greater depth than 35 or 40 feet. Surface showings also occur on lands adjoining the Loveless and Overbey tract, and are especially favorable on those south and southeast of this bank. An average sample of the ore taken from several pits analyzed 49.53 per cent iron; 13.43 per cent silica; 0.743 per cent phosphorus; and 0.042 per cent sulphur.

Wapf bank.—(No. 24. Owned by H. Wapf, Hohenwald, Tenn.). This bank is 2¾ miles S. 50° E. of the Hohenwald post office and adjoins the Loveless and Overbey tract on the north. It is situated on the spurs of a ridge, whose elevation is about 1,000 feet above sea level. The crests of the spurs are 60 to 70 feet higher than the west fork of Grinders Creek.

The outcrop covers an area of 10 or 12 acres, and within this area large and small boulders and many small fragments of limonite are more or less thickly strewn over the surface. Most of the large boulders and many of the small fragments are partly buried in the clay soil. Some of the large chunks are over 3½ feet in diameter. Three shallow test pits were dug on one of the spurs, but most of the material removed has now been put back into the holes. The material remaining around these partly filled pits is mostly very red clay containing shot ore and small lumps of ore.

No outcrops of bedded rocks occur, and the loose material overlying stratified rocks probably has a considerable thickness. The top of the ore deposits seems to be near the surface so that the overburden should not be great. The maximum depth of the deposits, as disclosed by the outcrops, is 25 feet, but the actual depth is not known. Surface indications are exceptionally favorable on 8 or 10 acres of the Wapf property. Surface showings also extend over into the adjoining Smith property, which is described elsewhere.

Most of the ore seems of good quality, but many of the boulders, particularly the large ones, contain considerable chert. The ore occurs in the compact and cellular forms. The pot ore and many of the solid chunks seem very pure. A representative surface sample analyzed 47.14 per cent iron; 19.03 per cent silica; 0.338 per cent phosphorus; and 0.017 per cent sulphur.

Smith bank No. 3.—(No. 25. Owned by Frank Smith, Pasadena, Cal.). This bank, located 3 miles S. 53° E. of the post office at Hohenwald, lies just east of the Wapf bank, on spurs of the same ridge, and may be considered as a continuation of those deposits.

Limonite outcrops at intervals over an area of 25 or 30 acres, and is especially abundant around the heads of the draws and on the points and steep slopes of the spurs. The outcrops consist of fragments, both large and small, embedded in the clay and scattered over the surface. Some masses occur protruding through the clay on the slopes to the draws. Portions of the area show little or no ore, but on other parts the ground is pretty well covered with small pieces of ore.

This locality should be thoroughly prospected. The ore appears to be of about the same character as that occurring in the Wapf bank.

Smith and adjoining property.—(No. 26. Owned by Frank Smith and others, Pasadena, Cal.). The property is south of Smith bank No. 3, and is separated from the latter by an east and west hollow, which is about half a mile in length. It is located 3½ miles S. 52° E. of Hohenwald.

Two rather conspicuous outcrops of limonite were found. One of these is situated on the point of a long, narrow ridge, just across the hollow from Smith bank No. 3. The other exposure is two-fifths of a mile S. 64° W. of the first mentioned. This outcrop occurs on the east slope to a shallow draw, and consists principally of boulders embedded in the soil. Both outcrops extend over several acres.

Old Mays place (Hughes bank).—(No. 27. Owned by G. T. Hughes, Jr., Columbia, Tenn.). The bank on the "Old Mays Place," located 4¼ miles S. 45° E. of the post office at Hohenwald, is situated in an old field on a secondary ridge and its spurs. The crest of the ridge is about 140 feet above Grinders Creek, and has an elevation of approximately 950 feet above sea level. The slope is toward the south, and the bank is on this slope. The surface showings consist almost entirely of small fragments of ore, which are very abundant in places. These are scattered over an area of 25 acres or more.

The soil has a red cast, and at certain places the red color is particularly noticeable. The residuum in which the ore occurs is composed largely of very red clay, though a comparatively small amount of angular chert and sometimes a little water-worn gravel is present. No outcrops of bedded rocks were seen, and the indications are that the residuum is thick.

The bank has been developed by 14 test pits distributed over an area of 25 acres. Six that are less than 4 feet deep show a very little ore. Three holes with an average depth of 11 feet, show a fair quantity of ore, and 5, which are 5 to 15 feet deep, show a large amount. The pits have been dug from 30 to 50 feet below the crest of the ridge, and the clay from them is often rich with shot ore. The ore is of excellent quality, and this bank will warrant further prospecting. The ore is a dark-brown limonite and occurs

in the form of pots and the compact types. Very little chert and practically no sand are associated with it. A sample obtained from 5 pits analyzed 55.69 per cent iron; 3.97 per cent silica; 0.380 per cent phosphorus; and 0.03 per cent sulphur.

Overbey prospect.—(No. 28. Owned by J. D. Overbey & Co., Hohenwald, Tenn.). This prospect is located 3¾ miles S. 43° E. of the post office at Hohenwald, and three-fourths of a mile northwest of the bank on the "Old Mays Place," described above. Residual iron ore occurs around the head of a very shallow draw on the west slope of a secondary ridge. The draw opens into a north-south hollow, through which flows a small stream, 50 feet below the outcrop. The outcrop covers one-fourth of an acre, and is composed of rather large chunks and small pieces of limonite. A sprinkling of shot ore occurs over several acres.

Morton's and adjacent property.—(No. 29. Owned by S. D. Morton and others, Hohenwald, Tenn.). This property is located 4¼ miles S. 35° E. of the post office at Hohenwald, and half a mile northwest of Morton's house. The surface showings consist of an occasional boulder and a few fragments of limonite sparingly distributed over the slopes of several spurs of a ridge and around the heads of several hollows. Some of the ore seen was of excellent quality, especially the pot ore. Most of the ore found was in old fields. A sample of float ore analyzed 56.36 per cent iron; 5.42 per cent silica; 0.749 per cent phosphorus; and 0.054 per cent sulphur.

Christian bank No. 1.—(No. 30. Owned by H. T. Christian, Riverside, Tenn.). This deposit, located 3½ miles S. 12° E. of the post office at Hohenwald, is situated on the south slope toward a shallow hollow, on the spur of a ridge near its crest. It is near the head of Rush Branch, and about 2 miles northwest of its mouth.

The outcrop covers an area of nearly an acre. It consists of boulders protruding through the clay soil and of small fragments scattered over the surface. Three shallow pits, ranging from 3 to 4 feet in depth, have been dug within the area of the outcrop. Two pits are on the slope of the spur, and the other one is in the hollow near its base. All the pits show some ore, and one a considerable quantity. The last clay thrown out of the two upper pits is very red. The ore is a fair quality of limonite.

A small outcrop of iron ore was found on Mr. Brown's land, half a mile north of here.

Christian bank No. 2.—(No. 31. Owned by H. T. Christian, Riverside, Tenn.). This bank is 1 mile N. 38° W. of the junction of Grinders Creek and Buffalo River. The deposits are situated on the top and slopes of a high southeast spur of a secondary ridge. The ridge has an elevation of 900 feet above sea level, and its crest is nearly 200 feet above Grinders Creek.

The deposits occur in red clay with which is associated more or less angular chert and sometimes water-worn gravel. Bedded rocks are exposed

on the northeast and east slope of the ridge near its base. A 40-foot section of cherty limestones was observed near the mouth of Rush Branch. As the top of this section is approximately 125 feet below the crest of the ridge, it appears that the detritus overlying solid rock is quite thick.

The outcrop extends over an area of 12 to 15 acres. It is composed of boulders and fragments embedded in the soil and scattered over the surface. On a large part of this area, especially on that south of the road, the ground is thickly strewn with ore. There are boulders over 5 feet in diameter, some of which appear heavy with iron, but others are light and contain a large per cent of chert. A mass of highly siliceous ore extends along the south face of the spur for a distance of 75 feet, about 40 feet below its crest. Twenty shallow test pits have been dug within the area of the outcrop. Eight are located on the north side of the road and 12 on the south side. Six of those on the north side of the road are nearly blank, and the 2 remaining ones make a fair showing. Of the 12 pits on the south side of the road 7 show very little ore, 4 make a fair showing, and one an excellent showing. The last material removed from the pit is generally of a deep-red color, but some of the very shallow ones do not show any very red clay. This material often has a large quantity of shot ore mixed with it, and angular chert is frequently abundant, but comparatively little water-worn gravel was noticed.

Much of the ore is siliceous, silica occurring principally as embedded chert and sometimes in the form of sand; but the percentage of siliceous material varies largely, portions of the ore being almost free from it, while the amount in other portions runs very high. The ore occurs in both the cellular and compact forms. Relatively little pot ore was seen, most of it being of the solid-chunk variety. Some limonite-cemented sandstone was observed. A representative sample taken from the dumps analyzed 46.73 per cent iron; 20.79 per cent silica; 0.476 per cent phosphorus; and 0.094 per cent sulphur.

The test pits and surface showings indicate that deposits of ore occur over an area of at least 10 or 12 acres. The depth to which the ore extends is not known, but the residual outcrops 40 feet below the crest of the spur indicate that ore extends to at least that depth.

Christian-Floyd and adjoining property.—(No. 32. Owned by H. T. Christian, Henry M. Floyd, C. R. Brown and others, Hohenwald, Tenn.). That part of the property showing ore is practically a continuation of the Christian bank No. 2, already described, and is located on a northeast spur of the same ridge.

In the road on the northeast slope of the spur, there are some spots that have a very red clay soil. Shot ore is abundant in the clay, and a few hundred feet north of this place lumps of siliceous ore are distributed over the surface and protrude through the clay of the road. Similar indications occur sparingly around the heads of several draws on this spur.

Christian bank No. 3.—(No. 33. Owned by H. T. Christian, Riverside, Tenn.). This bank is located 3 3-5 miles N. 45° E. of Riverside, or 1½ miles east of Nancy. It is situated on the top of a ridge, at an elevation of 900 feet above sea level. On and near the point of a northeast spur of the ridge 11 test pits have been dug. Their depth varies from 2 to 3½ feet, which is entirely too shallow for test purposes. Only 2 of the 11 holes showed a fair quantity of ore, and most of the others are blank or nearly so. Seven holes were found on the southeast extension of the main ridge, and between this place and the one previously described 5 more pits occur. These pits are also very shallow, for their average depth is only about 3 feet. Six make a fair to excellent showing of ore, and 1 a poor showing. Some of the 5 remaining ones show more or less shot ore, and others are blank. The surface showings at this place extend over 8 to 10 acres.

The outcrops extend over a total area of possibly 10 or 20 acres and at certain places, the surface is thickly strewn with large and small fragments of limonite. Some of these are buried in the clay soil, while others are loosely distributed over the ground. A few of the boulders are more than 2 feet in diameter, but large chunks of ore are rare. The outcrops consist mostly of shot ore. Some of the root-wads show a large quantity of ore. No exposures of stratified rock were found in the vicinity of the bank.

The ore occurs in red clay containing chert fragments, which are often very abundant. The surface showings between the two main outcrops and the few shallow pits, indicate that ore would probably be encountered by sinking deep shafts on the higher lands located on and near the crest of the ridge.

Much of the ore seems free of excessive chert, gravel, and sand, but some is quite siliceous. The ore is found in both the cellular and compact forms. An average sample from 11 shallow pits analyzed 51.94 per cent iron; 12.45 per cent silica; 1.233 per cent phosphorus; and 0.045 per cent sulphur.

CANE CREEK DISTRICT

The Cane Creek district is in the northwestern part of the county. The following is a description of the deposits occurring in it:

Skelton bank.—(No. 34. Owned by John Skelton and others, Hohenwald, Tenn.). This bank, located 4 miles N. 40° W. of Hohenwald, is situated on the spur of a ridge near Cotton Branch, about 125 feet above that stream.

A 15-foot excavation has been made into the south face of the spur, 45 feet below its crest. A large quantity of boulder pipe and needle ore was encountered. Some of the boulders are over 3 feet in diameter and are heavy with iron. Part of the ore in the excavation has the appearance of irregular, thin veins in the clay. Ore outcrops over an area of about 1½ acres. Fragments of leached and porous chert, often stained with iron oxide, are abun-

dant on the top and slopes of the ridge. The ore is of excellent quality, but probably does not occur in workable quantity. The locality has never been thoroughly prospected.

A typical sample of the ore analyzed 48.24 per cent iron; 21.10 per cent silica; 0.702 per cent phosphorus; and 0.083 per cent sulphur.

Prospect northwest of the Skelton bank.—(No. 35.). Three-fourths of a mile N. 25° W. of the Skelton bank, there is an outcrop of low-grade limonite covering an area of about half an acre. The outcrop occurs on a spur of the same ridge on which the Skelton bank is located. Most of the ore is massive and highly siliceous, but some of it is of fair quality. Lumps of compact ore are scattered over the ground. The locality has never been systematically prospected.

Goodmans Prong prospect No. 1.—(No. 36. Owned by West Henson and others, Hohenwald, Tenn.). This prospect is on the south side of Goodmans Prong, a branch of Cane Creek, and 1¼ miles S. 35° E. of its mouth.

Large boulders and many small fragments of siliceous limonite outcrop over an area of 1 acre on the slopes of a very narrow ridge. The ridge is west of the junction of Stillwater Branch with Goodmans Prong, and the top is approximately 125 feet above the latter stream. The outcrops extend to near the base of the ridge. About 1,000 feet east, and on the same ridge, is another small outcrop. The ore at both places is a light-brown limonite, and is very cherty. A number of other outcrops have been reported as existing on the ridges only a short distance south and west of this locality.

Goodmans Prong prospect No. 2.—(No. 37. Owned by Andrew King, Hohenwald, Tenn., and the L. P. Cheatham estate). This prospect is located 2½ miles N. 60° W. of Hohenwald, on the east side of the Goodmans Prong road. It is situated on the top of a ridge, which is a continuation of the broad, flat ridge lands surrounding Hohenwald. The ground is more or less covered with shot ore and a few larger fragments occur. Three very shallow test pits have been dug on the top and slope of the ridge. A large quantity of ore was removed from the pit on the slope of the ridge near the top. The other two are on the top of the ridge. One of these shows some very red clay containing shot ore, and the other mostly angular chert gravel and a light-colored clay. The writer found only three pits, but several more are said to have been dug in this locality.

It thus appears that the prospecting has not been sufficient to prove the value of the deposits. The ore is evidently hidden or masked by what seems to be a thick overburden. That seen was of good quality, considering it is surface ore. At a greater depth a better quality may probably be found. A representative sample of the surface ore analyzed 57.35 per cent iron; 4.67 per cent silica; 0.847 per cent phosphorus; and 0.035 per cent sulphur.

The Skelton place and vicinity.—(No. 38. Owned by J. E. Morrow, Hohenwald, Tenn., William Murphy, and others.). This locality is on the Linden road 3 miles west of Hohenwald, and should be considered as a part

of the so-called "flatwoods" country. The indications for iron ore are a very red soil, shot ore, and residual chunks of low grade, highly siliceous, liver-colored conglomerate ore exposed in the road, and around the heads of adjacent hollows. The red-clay soil shows up for a distance of 1,500 feet long the road and contains shot ore and occasionally larger fragments. A few test pits were dug a number of years ago, but these are partly filled up. North of the road shot ore is abundant at intervals over an area of several hundred acres, especially on the slopes to the hollows. Root-wads frequently show shot ore. If there is much ore in this vicinity, it is overlaid by a considerable thickness of water-worn quartz and chert gravels, which appear to be over 25 feet thick in places.

Fain bank.—(No. 39. Owned by J. B. Fain, Hohenwald, Tenn.). This bank is located 4¾ miles N. 80° W. of the post office at Hohenwald. It is situated on the crest of several secondary ridges and their spurs, near the head of Fain Prong, which is a branch of Cane Creek. The tops of the ridges are between 125 and 150 feet above Fain Prong. The ridges are very narrow, their crests being in most cases, less than 250 feet wide.

Large and small fragments of ore occur on the top and slopes of the ridges. Some of these are embedded in the clay soil, while others are scattered over the surface. These fragments are most abundant on the points and depressions of the ridges where the soil has been largely removed by wash. Root-wads frequently show shot ore and water-worn gravels. Angular chert and gravel are abundant at many places on these ridges. No outcrops of solid rocks were observed on or near the ridges, but such rocks outcrop in the bed of the streams east and west of here. Surface indications occur at intervals over an area of at least 40 acres and to near the base of some of the ridges. Iron ore outcrops on ridges north of the Fain property, and is reported as occurring at a number of other localities in this neighborhood.

The ore is a light-brown limonite, associated with a considerable amount of chert. An average surface sample of the ore analyzed 39.81 per cent iron; 26.93 per cent silica; 0.668 per cent phosphorus; and 0.110 per cent sulphur.

THE TRACE CREEK DEPOSITS

The Trace Creek deposits, located in the southwest part of the county, are situated in the vicinity of Trace Creek and its tributary streams.

Odom and Cheatham lands No. 1.—(No. 40. Owned by Odom Brothers, Hohenwald, Tenn., and L. P. Cheatham estate.). This prospect is located 4¾ miles S. 80° W. of the Hohenwald post office. On a secondary ridge and its spurs shot ore was found in root-wads and also strewn over the surface. Sometimes these small pieces of ore are very abundant, but usually there is only a sprinkling of such. These surface indications extend over an area of 30 acres or more. A short distance northeast of Odom's

house, large and small fragments of ore are abundant on the south slope of the ridge, strewn over the surface and protruding through the clay soil. The outcrop extends along the hill for a distance of 150 feet. A shallow excavation was found in the area of the outcrop, and the material removed showed a large quantity of siliceous ore. A surface sample of this ore analyzed 54.9 per cent iron; 6.97 per cent silica; 1.189 per cent phosphorus; and 0.21 per cent sulphur.

Odom and Cheatham lands No. 2.—(No. 41. Owned by Odom Brothers, Hohenwald, Tenn., and the L. P. Cheatham estate.). This prospect is 4½ miles S. 75° W. of Hohenwald. It is on a ridge about half a mile southeast from the prospect described in No. 1. Iron ore outcrops around the heads and side slopes to several shallow V-shaped ravines, small fragments of ore are scattered over the points of several spurs of the main ridge, and root-wads frequently show red-clay subsoil and some shot ore. Iron ore is reported to outcrop in several other localities in this vicinity, but these were not visited.

The Odom and Cheatham lands have never been systematically prospected, and nothing is known regarding the possibilities of finding ore in paying quantities. Not enough was found to enable the writer to judge of its character, but most of that seen was rather siliceous.

Charlotte Lumber Co. tract No. 1.—(No. 42. Owned by the Charlotte Lumber Co., Charlotte, Mich.). This prospect is located three-fifths of a mile northwest of the junction of Sweetwater Branch with Trace Creek. At this place compact boulders of limonite occur in the bottom of a draw between two spurs of a ridge, and on the slopes to the hollow. The ore protruding from the slopes is 15 feet above the bed of a small stream, and is evidently in place. It appears that the stream has cut through an ore pocket. The outcrop is small, but the ridges were covered with leaves at the time the prospect was visited, so that other outcrops could not have been easily seen even if present. There are doubtless other occurrences of ore in this vicinity. The region has never been prospected.

Charlotte Lumber Co. tract No. 2.—(No. 43. Owned by the Charlotte Lumber Co., Charlotte, Mich.). This prospect is 4 miles N. 15° W. of Riverside, and three-fourths of a mile east of the junction of Sweetwater Branch with Trace Creek. It is situated on the southwest slope and the point of a high secondary ridge. The crest of the ridge is over 250 feet above Trace Creek and has an elevation between 950 and 1,000 feet above sea level.

The principal outcrop consists of compact boulder ore, embedded in the soil on the southwest slope of the ridge at approximately 30 to 35 feet below the top. This outcrop covers an area of 1 acre. Besides the main outcrop, there are isolated boulders and small lumps distributed over an area of 6 or 7 acres on and near the point of the ridge. The clay adhering to the roots of several fallen trees contains shot ore and sometimes larger fragments. This ridge seems to be covered by a rather thick soil mantle. The north

slope has a deeper soil than the southwest one. Comparatively little angular chert and gravel was noticed on the ridge or in its vicinity.

The surface showings are fair over about 4 acres, and there are at least 4 to 6 acres more on which the surface indications are more or less favorable, thus making a total of 8 or 10 acres over which pockets of ore may be expected to occur. The ore extends to a depth of at least 30 feet, for it is exposed at that distance below the crest of the ridge. Deep pits are necessary to test the property. Most of the ore is of fair quality, but some of it is very siliceous, due chiefly to chert inclusions. An average sample taken from the outcrop analyzed 50.9 per cent iron; 10.50 per cent silica; 1.422 per cent phosphorus; and 0.032 per cent sulphur.

Charlotte Lumber Co. tract No. 3.—(No. 44. Owned by the Charlotte Lumber Co., Charlotte, Mich.). This prospect, located 4¼ miles N. 53° W. of Riverside, is situated on and very near the crest of a high, chert-covered, secondary ridge, with an elevation of 900 feet above sea level, and about 250 feet higher than Sweetwater Branch. Large boulders and many small fragments of iron ore outcrop over an area of several acres around the head of a hollow, near the crest of the ridge. About 1,000 feet southwest of this place and on the opposite or south slope of the ridge, near its point, is another small outcrop of the same character of ore. Both outcrops consist of ore embedded in the clay soil and also strewn over the surface. Lumps of ore and shot ore occur sparingly between the two principal exposures. The slopes and top of the ridge are strewn with angular chert fragments, some of which have a fresh appearance. These suggest that bedded rocks of the St. Louis formation are comparatively near the surface, though no outcrops were observed on any of these ridges.

The ore is a light-brown limonite and is often quite siliceous. Many of the boulders contain decomposed chert and some gravel, while others are nearly free of foreign material. This locality has never been systematically prospected, and there are probably other iron-ore outcrops in this vicinity. A representative sample taken from the outcrop analyzed 54.11 per cent iron; 8.99 per cent silica; 0.732 per cent phosphorus; and 0.044 per cent sulphur.

Charlotte Lumber Co. tract No. 4.—(No. 45. Owned by the Charlotte Lumber Co., Charlotte, Mich.). This outcrop of ore is in the extreme southwest corner of Lewis County, 6½ miles N. 60° W. of Riverside. The ore exposure is on the point of a spur of a secondary ridge, and covers an area of about 300 square yards. It consists of large and small chunks embedded in the soil, and float ore. Most of it is very cherty. A surface sample taken from the outcrop analyzed 34.64 per cent iron; 35.02 per cent silica; 0.688 per cent phosphorus; and 0.048 per cent sulphur.

Charlotte Lumber Co. tract No. 5.—(No. 46. Owned by the Charlotte Lumber Co., Charlotte, Mich.). These iron-ore outcrops are located 4 miles N. 80° W. of the junction of Sweetwater Branch with Trace Creek.

They are situated on the spurs of ridges at less than 100 feet below their crests.

The outcrops consist of boulders and large and small fragments protruding through the clay soil on the slopes of the spurs and also scattered over the surface. The outcrops are distributed over an area of 80 acres. Much of the ore is cherty, but some of good quality was seen. The siliceous outcrops may give place to ore of better quality with depth. An average sample taken from the outcrop analyzed 40.44 per cent iron; 26.97 per cent silica; 0.278 per cent phosphorus; and 0.009 per cent sulphur.

JACKS BRANCH—ROCKHOUSE CREEK GROUP

The Jacks Branch-Rockhouse Creek group, located in the southern portion of the county, is situated on a high ridge and its spurs, between Jacks Branch and Rockhouse Creek. It has a north and south trend and an elevation ranging between 900 and 1,000 feet above sea level, the crest being 200 to 250 feet higher than Jacks Branch.

The ore is found in pockets in the clay, gravel, chert, and other loose material overlying the St. Louis formation. No outcrops of bedded rocks were seen in the immediate vicinity of the banks, but such rocks are exposed on the lower slopes of the ridge. The loose material is probably thick. Water-worn quartz and chert gravels are more or less abundant on the top

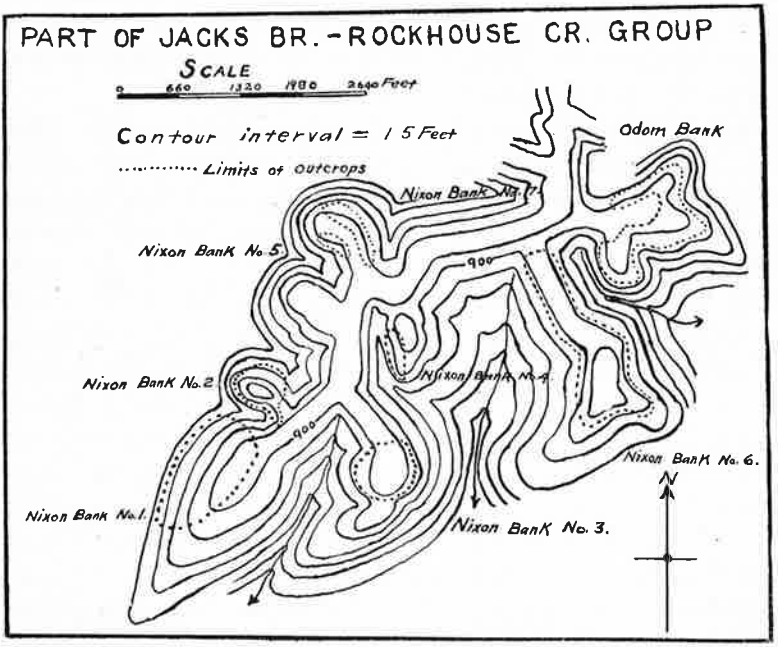


FIGURE 14.—Sketch map showing topographic relations of part of Jacks Branch-Rockhouse Creek group of brown iron ore deposits.

of the main ridge and its spurs, especially on the main ridge, where these gravels in places, appear to have a thickness of over 15 feet. Most of the outcrops occur on the spurs. Nearly all the test pits are very shallow, and afford little knowledge regarding the size and depth of the deposits.

Nixon bank No. 1.—(No. 47. Owned by the Henry Nixon heirs, Centerville, Tenn.). This bank is on the southwest spur of the ridge, near Jacks Branch, and four-fifths of a mile N. 8° E. of McLean. Residual ore occurs over an area of 8 to 10 acres. Massive ore and boulders protrude through the clay on the west slope of the ridge, and some of these occur more than 30 feet below the top.

Fifteen pits have been sunk on the top and slopes of the spurs, and these are distributed over an area of about 5 acres. Some have been dug where there are apparently little or no surface showings. The pits range from 2 to 30 feet in depth. About 25 per cent of them make an excellent showing of ore, 50 per cent a poor to fair showing, and 25 per cent are blank. The clay in most of the pits is very red and is sometimes rich with shot ore. The material from the pits is composed mainly of clay which contains some angular chert and frequently water-worn gravel.

The test pits and outcrops indicate that at least 10 acres are ore-bearing, and that the ore extends to a depth of 30 feet or more. It often shows particles of chert and frequently grains of sand, but much of the limonite is of good quality. The ore occurs in the compact forms and as pots. A representative sample analyzed 47.07 per cent iron; 18.42 per cent silica; 0.640 per cent phosphorus; and 0.042 per cent sulphur.

Nixon bank No. 2.—(No. 48. Owned by the Henry Nixon heirs, Centerville, Tenn.). This outcrop is situated on a spur a short distance north of and adjoining the Nixon Bank No. 1 The outcrop consists of a few fragments and small boulders scattered over perhaps 2 acres, and the ore seems to be of about the same character as that occurring in the Nixon Bank No. 1.

Nixon bank No. 3.—(No. 49. Owned by the Henry Nixon heirs, Centerville, Tenn.). This bank, located 1 mile N. 30° E. of McLean, is situated on a south spur of the main ridge. The outcrop consist of small fragments, and an occasional boulder of brown ore over a nearly circular area of 4 or 5 acres. It has been prospected by 4 pits ranging from 2 to 10 feet in depth. The pits are about 140 feet apart, and occur at different elevations on the spur. All show more or less ore in red clay. Three others have been sunk on a narrow part of the spur, northwest of this outcrop, near the main ridge. These are shallow, and show chiefly water-worn gravel and angular chert.

The ore is a light to dark brown limonite and frequently contains some fine sand and small, irregular flakes of decomposed chert, but on the whole seems free of excessive siliceous impurities. It is of both the cellular and compact types. A typical sample analyzed 50.41 per cent iron; 13.49 per cent silica; 0.320 per cent phosphorus; and 0.049 per cent sulphur.

Nixon bank No. 4.—(No. 50. Owned by the Henry Nixon heirs, Centerville, Tenn.). The outcrop is situated on a south spur of the ridge about 1,000 feet north of the Nixon bank No. 2. At this place residual limonite is exposed at intervals over an area of 2 acres.

Nixon bank No. 5.—(No. 51. Owned by the Henry Nixon heirs, Centerville, Tenn.). The outcrop is about 900 feet northwest of Nixon bank No. 4, and is situated on a north spur of the ridge opposite the latter bank. At this location residual brown ore occurs sparingly over an area of 5 acres.

Nixon bank No. 6.—(No. 52. Owned by the Henry Nixon heirs, Centerville, Tenn.). This bank is 1 1-5 miles N. 35° E. of McLean and is on the southeast spur of the main ridge. Outcrops extend over an area of approximately 17 acres, parts of which are thickly covered with fragments of brown ore, but in most places, the showing consists of only a few scattered fragments. Some boulders 2 feet in diameter were found on the point of the spur. Many of the large fragments and most of the boulders are embedded in the soil.

The ore is light to dark brown in color and varies in texture from compact to cellular. Silica is present chiefly in the form of small particles, and these inclusions frequently have a flaky aspect. A surface sample analyzed 53.69 per cent iron, 9.10 per cent silica; 0.352 per cent phosphorus; and 0.002 per cent sulphur.

Nixon bank No. 7.—(No. 53.). On the main ridge northwest of the above described outcrop about 25 very shallow test pits were found. They occur at different elevations on the ridge, but most of them are on the slopes less than 30 feet below the crest. These pits vary from 2 to 4 feet in depth, and only a few showed any ore, but this is to be expected from the shallowness of the pits. The material taken out is mainly clay, which contains an abundance of water-worn quartz and chert gravels and more or less angular chert fragments. It thus appears that there is a considerable thickness of gravel on top of the ridge at this place. This locality is west of and between the spurs where the outcrops of previously described banks occur, but here the exposures consist of only an occasional fragment, and some shot ore. The pits are scattered over an area of 25 acres, and have been dug where there are little or no surface indications. The ore seen was a light-brown or liver-colored limonite and generally highly siliceous, though the quality might improve with depth.

On the main ridge, about three-fifths of a mile north of this place, 20 or more pits were found on both sides of the road. This locality is between the Grinder and Odom banks. These pits are also very shallow. A few showed a little ore, but most of them are blank, as would be expected from their small depth. They have been dug where there are little or no surface showings, but residual ore outcrops around the heads of several hollows in the immediate vicinity. The pits usually show a large amount of water-worn

gravel and some angular chert in the clay. A part of this locality is described under the Nixon bank No. 7, which adjoins it.

From the preceding statements it is quite evident that if ore in quantity exists at either of these localities, deep shafts will have to be sunk to find it. The detritus overlying solid rocks is probably thick, and outcrops of bedded rocks do not occur in the immediate vicinity.

Odom bank.—(No. 54. Owned by Dempse Odom, Hohenwald. Tenn.). This bank, located 1 2-5 miles N. 28° E. of McLean, is situated on an east spur of the main ridge, * * * . The bank is marked by an outcrop of limonite in the form of a few boulders, lumps, and small fragments occurring here and there over an area of 8 to 10 acres. Some of the ore is embedded in the clay, but most of the exposures are loose residual fragments. The ore is quite abundant on portions of the south and southeast slopes of the spur, near its point.

A mining company is reported to have offered to prospect the bank, but as yet no test pits have been dug. The value of the property can not even be approximately determined from the surface showings alone, which extend west into the Nixon property.

The ore is a light to dark brown limonite, which has a texture varying from closely compact to coarsely cellular. The ore is frequently somewhat siliceous, which is chiefly due to embedded chert, for very little sand and quartz were visible in any of the specimens examined. An average surface sample of the ore analyzed 48 50 per cent iron; 14.38 per cent silica 1.071 per cent phosphorus; and 0.029 per cent sulphur.

Nixon bank No. 8.—(No. 55. Owned by the Henry Nixon heirs, Centerville, Tenn.). This bank is located 1¾ miles north of McLean and 1¼ miles northwest of Grinders mill. It is on and near the crests of the main ridge and several of its secondary ridges and their spurs.

Iron ore, in the form of boulders and fragments embedded in the clay soil and scattered over the surface, is exposed at intervals over an area of 450 acres, within which the test pits have been dug. The outcrops cover an area varying from a few square yards to several acres, and are most abundant on the points and slopes of the ridges and spurs where the soil has been largely removed by wash. Residual ore was found in the bottoms of several of the shallow hollows, on the lower slopes of some of the ridges and in shallow pits, more than 60 feet below the crest of the main ridge. An occasional lump of ore and shot ore can be found over nearly the entire tract.

Developments consist of more than 66 test pits scattered in groups over the area. These range from 2 to 7 feet in depth. As a rule, the holes have been dug where the surface showings are most abundant. Thirty-eight pits show more or less ore and 28 are blank or show only a little shot ore. Nine of the 38 show a large amount of ore, 21 fair quantity, and 8 make a poor showing. The blank holes are on or very near the top of the ridges, and the material removed from these is mainly water-worn and a light-colored clay

often containing angular chert fragments. The material is frequently nearly all gravel, thus suggesting that, at least on the crest of the ridges, a rather thick blanket of gravel overlies the ore deposits. The last material removed from those pits that show ore consists of red clay, angular chert, and sometimes water-worn gravel.

The ore has a dense to coarsely cellular texture, but usually occurs in the compact form. The color of the limonite varies from light-brown or liver-colored to dark-brown or nearly black on fresh surfaces. It is siliceous, and some of it highly so. The chief siliceous impurity is decomposed white chert, which occurs in the form of small fragments and flaky particles incorporated with the ore. Small grains of sand are sometimes present, but large amounts of sand and quartz were not often noticed in any of the ore examined. Some of the dark-brown ore is nearly free of silica, and this is evidently of excellent quality. The quality may improve with depth. A representative sample taken off the dumps of the 38 pits analyzed 43.84 per cent iron; 20.42 per cent silica; 0.822 per cent phosphorus; and 0.05 per cent sulphur.

A close examination of this bank warrants the conclusion that many deep shafts will have to be sunk before any opinion can be formed regarding the value of the property. The prospecting already done is superficial and of little value. However, the test pits and outcrops indicate that deposits of ore doubtless exist over a large portion of the area and to a depth of perhaps 60 feet. No outcrops of bedded rocks were seen, and the residuum may be quite thick.

Grinders bank.—(No. 56. Owned by J. C. Grinder, Hohenwald, Tenn.). This bank is located 1 4-5 miles N. 25° E. of McLean and is on an east spur of the main ridge. The elevation of the spur ranges from 950 to nearly 1,000 feet above sea level, and its crest is over 200 feet higher than Grinders Creek.

Rocks are exposed in the bed of a small stream on the south slope of the spur, near its base, and about 150 feet below its crest. The loose material evidently extends to a considerable depth on the crest of the spur. Residual iron ore occurs on portions of 10 or 12 acres. The showing consists of boulders, lumps, and small fragments, the best ones being on the point and south and east slopes of the spur.

The bank has been prospected by nearly 40 test pits, which are scattered over an area of 8 acres. Most of the pits range from 3 to 12 feet in depth, and a few are 15 feet deep. The pits occur at different elevations, 30 feet below the top. One deep shaft (partly filled with water at the time visited) is reported to show ore at the bottom and to have encountered some ore throughout the greater portion of its depth of 47 feet. About 40 per cent of the pits show a fair to large quantity of ore, 35 per cent make a poor showing, and 25 per cent are blank or nearly so. The pits that are nearly blank

show only a little shot ore. The ore occurs in very red clay. Angular chert and sometimes water-worn gravels occur in the clay.

Much of the ore is dark-brown limonite of apparently good quality, for excessive amounts of siliceous matter are not visible in most of this ore. However, some of it is siliceous, which is due chiefly to embedded chert, although sand and small chert pebbles occur. The ore occurs mostly in the compact forms, but pots and other types are met with.

This bank deserves systematic prospecting and possibly development. It extends over into the adjoining Nixon property, but nearly all the pits have been put down on that part of the spur owned by J. C. Grinder. More and deeper pits should be dug, and these should be more evenly distributed. Other portions of the spur should be thoroughly prospected. An average sample taken from several pits analyzed 50.46 per cent iron; 12.39 per cent silica; 0.841 per cent phosphorus; and 0.221 per cent sulphur.

Barker tract.—(No. 57. Owned by J. M. Barker, Bristol, Tenn.). The part of the tract showing iron lies 1½ miles S. 10° W. of Shubert. Here small outcrops of iron ore occur around the heads of several hollows, and a few fragments of high grade ore were found on the points of several spurs of the main ridge. Such surface showings occur sparingly over several hundred acres of the Barker land south and southwest of the above-described locations. Some of the ore seen was highly siliceous. There is a sprinkling of shot ore over a rather extensive territory.

(No. 57a.). On the point of a long, narrow spur north of the Grinder bank, there is a small outcrop of limonite covering several square yards. The top of the spur is covered by a water-worn gravel deposit of considerable thickness, and no other exposures were found. Brown ore is reported to outcrop on other spurs north of this place. This tract has not been prospected.

ROCKHOUSE CREEK DEPOSITS

The Rockhouse Creek deposits are located in the southern part of the county. Only a few isolated deposits of iron ore situated in the vicinity of Rockhouse Creek and its branches will be described under this heading, for most of the banks have already been described under the Jacks Branch-Rockhouse Creek group.

Carter's land.—(No. 58. Owned by J. C. Carter, Hohenwald, Tenn.). This property is 1½ miles west of Hohenwald. A small stream runs through the center of the property from northwest to southeast. The crest of the ridges on both sides of the stream are 60 to 70 feet above the bed of the stream. The surface showings occur on several spurs of the broad ridge on which Hohenwald is located. Small compact chunks of ore were found, which seemed heavy with iron. On top of the spur there is an outcrop of residual ore over an area of one-fifth of an acre. Shot ore and a few larger

fragments occur on several spurs a short distance southeast and west of here, and are particularly abundant on the spur located 500 feet southeast.

Nixon and Craig bank.—(No. 59. Owned by the Henry Nixon heirs, Centerville, Tenn., and Mrs. H. Craig, Riverside, Tenn.). This bank, located three-fifths of a mile N. 30° W. of Nancy, is situated on and near the top of a southeast spur of a main ridge. The spur has an elevation of between 900 and 950 feet above sea level, and its crest is nearly 250 feet higher than Rockhouse Creek. The main ridge has a north and south trend, and its elevation ranges from 900 to 1,000 feet above sea level. No exposures of bedded rock occur, and the detritus overlying solid rock is probably thick on the crest of the spur and the main ridge.

The outcrop consists of small fragments and a few boulders of brown ore scattered in patches over an area of about 8 acres. These are very abundant on a portion of the Craig property and occur around the head of a draw. Ten shallow test pits have been dug on the crest of the spur, distributed over an area of 5 or 6 acres. The pits vary in depth from 2 to 6 feet. Six of the 10 pits show a poor to fair quantity of ore, and the 4 remaining holes are blank. The ore occurs in cherty clay, some of which is of a very red color and frequently is rich with shot ore.

The ore is a light to dark brown limonite, which generally occurs in the compact form. Some of it is cherty, but some is of good quality. The prospecting has not been thorough, and the acreage of ore-bearing property is not known. An average sample taken from several pits analyzed 51.63 per cent iron; 10.87 per cent silica; 1.113 per cent phosphorus; and 0.036 per cent sulphur.

ALLENS CREEK—RIVERSIDE MINING DISTRICT

Percy mine.—(No. 60.). This mine, located four-fifths of a mile S. 60° E. of Riverside, is situated on and near the crests of a high ridge and its spurs, at an elevation between 950 and 1,000 feet above sea level. The top of the ridge is 250 feet higher than Allens Creek. The topographic relations are indicated in Figure 15, which shows by means of the dotted line the probable limits of the ore-bearing area. [The latest description of this mine, prepared by H. D. Miser, is given on page 170 of this bulletin.]

A double steel-log washer of the McClanahan & Stone type is used at this mine, which has a capacity of 350 tons per day. The mining is done with steam shovel, and tram haulage is used to transport the ore to the tipple. The total average number of employes is about 55.

Allens Creek mine.—(No. 61.). This is one of the largest iron-ore mines in the southern portion of the Western Iron Ore Region. It is located in the extreme northeast corner of Wayne County, about three-fifths of a mile northeast of Allens Creek, and adjoins on the north the Percy mine of the Warner Iron Co. Nearly all the worked portion of the mine lies in Wayne

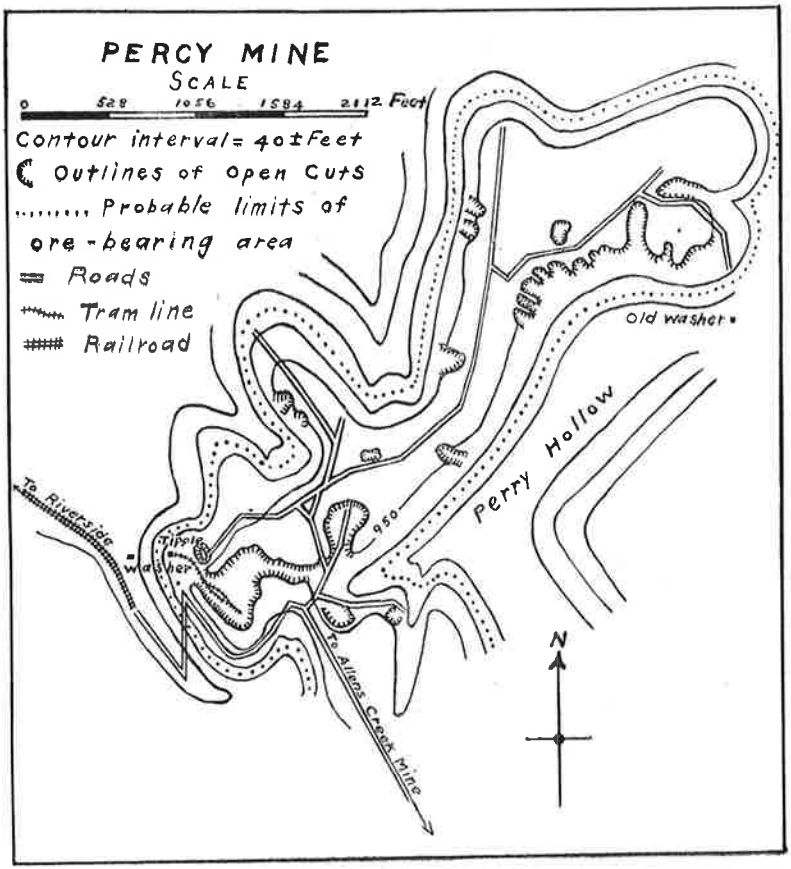


FIGURE 15.—Sketch map showing topographic relations of brown iron ore deposits at Percy mine.

County, and for that reason the bank will be only briefly described here. However, the local segregations of ore composing the Allens Creek deposits extend into Lewis County, and this forms one immense bank. [The latest description of this mine will be found on pages 166-170 of this bulletin.]

Christian bank No. 4.—(No. 62. Owned by H. T. Christian, Riverside, Tenn.). This deposit, located 1 3-5 miles N. 50° E. of Riverside, is situated on the top of a secondary ridge, which is on the east side of Piney Hollow. That part of the ridge where the ore occurs has an elevation between 850 and 900 feet above sea level and is about 250 feet higher than Buffalo River.

Boulders and fragments of limonite occur over an area of 5 or 6 acres. Some of the ore is embedded in the soil, but most of it is loosely distributed over the surface. Chert fragments are abundant on the top and slopes of the ridge. Boulders of cherty ore and lumps of good ore were found on the of which show some ore in red clay. The ore from one of the pits is very side of the ridge 20 feet below the top. Two shallow pits have been dug, both

cherty, but a fair quality was removed from the other. Most of the ore seen at this bank was rather siliceous, chiefly due to embedded chert.

Rochell and Slayton bank.—(No. 63. Owned by M. R. Rochell, Hohenwald, Tenn., and T. J. Slayton, Clarksville, Tenn.). This bank, located 1 1-5 miles N. 35° E. of Riverside, is situated on a secondary ridge on the west side of Piney Hollow. The bank lies about 75 feet below the crest of the main ridge, and the elevation is about 825 feet above sea level, or between 200 and 250 feet above Buffalo River. The outcrop extends over an area of possibly 5 acres, and consists of an occasional boulder embedded in the soil and of smaller pieces of ore scattered over the surface. Within this area 6 test pits have been dug, ranging from 2½ to 4½ feet in depth. Only one of the pits shows any marked amount of ore, but most of the holes show considerable shot ore in very red clay. Some of the ore is very cherty, but that of good quality also occurs. Surface indications were noticed at several points north of here, near the crest of the main ridge.

Brown prospect.—(No. 64. Owned by C. M. Brown, Napier, Tenn.). This prospect is located 3 2-5 miles S. 80° E. of Riverside, and 1 1-5 miles S. 11° E. of the junction of Chief Creek with Buffalo River. It is situated on the crests of a high secondary ridge and its spurs, west of Brush Creek. The ridge and its spurs have an elevation of 950 feet, and their crests are nearly 300 feet higher than Buffalo River.

Surface indications consists largely of a few fragments of loose ore, but chunks and lumps occasionally occur, embedded in the clay soil. Root-wads frequently show shot ore. These exposures sparingly occur over an area of several acres. The surface ore is a light-brown siliceous limonite, which analyzed 36.3 per cent iron; 34.22 per cent silica; 0.232 per cent phosphorus; and 0.086 per cent sulphur.

Water-worn quartz and chert gravel is abundant on the tops of the ridge and its spurs, and if ore exists here in quantity it is evidently covered by these deposits. Surface showings extend over into lands owned by the Davidson, Hicks & Greene Co.

Davidson, Hicks & Greene Co. tract (Smith tract).—(No. 65. Owned by the Davidson, Hicks & Greene Co., Nashville, Tenn.). This tract is located 3 miles southeast of Riverside, but the outcrop of brown ore here described is located two-fifths of a mile S. 10° W. of the Brown prospect and on the same secondary ridge as the latter. At this place limonite is exposed around the head of a hollow near the crest of the ridge, and only a few feet west of, and near the crook in the ridge road. The outcrop covers an area of several hundred square yards and consists chiefly of boulders and fragments embedded in the soil. A few thousand feet west of this place, near the ridge road leading to Allens Creek, several very shallow test pits were found. Some of these showed a little shot ore in red clay, but the pits are entirely too shallow for test purposes. The only chance of finding much ore on the crest of the ridge is by sinking deep shafts.

Limonite is reported to outcrop at a number of places between this locality and Perry Hollow, which is 1 2-5 miles southeast of Riverside. The writer did not go over this area in detail, but had seen enough to convince him that the section will warrant systematic prospecting.

MID-BRUSH CREEK DEPOSITS

These deposits are located 4 miles southeast of Riverside, between Little and Big Brush Creeks. They are situated on a high ridge and its spurs at an elevation ranging from 900 to nearly 1,000 feet above sea level. The deposits consist of 3 distinct banks situated only a short distance apart, but separated by apparently barren ground. The topographic relations of the banks and the approximate limits of the outcrops are shown on the accompanying sketch map, Figure 16.

Estimates regarding the quantity of ore present in these banks have varied widely among those making them. As no systematic prospecting has been done, the value of the banks can not be determined from the outcrops and the few shallow test pits. The three banks are described below.

Brush Creek bank No. 1.—(No. 68.[33a] Owned by the Napier Iron Works, Nashville, Tenn.). This bank is located 4 miles S. 40° E. of Riverside. The topographic relations and exact situation are mentioned above. Boulders and fragments of brown ore are exposed over an area of 48 acres. Within portions of this area the surface is thickly strewn with ore. It has been prospected by ten shallow pits, most of which are 10 to 12 feet long, 4 to 6 feet wide, and 3½ to 4½ feet deep. All but 3 pits show more or less ore, and 2 make a good showing. The ore occurs in very red clay which contains variable amounts of water-worn gravel and angular chert.

Rocks outcrop on the east slope of the ridge at approximately 60 feet below the top. Residual ore is exposed 30 feet or more below the crest of the ridge. It is apparent, therefore, that the ore extends to a depth of at least 30 feet.

Brush Creek bank No. 2.—(No. 69. Owned by the Napier Iron Works, Nashville, Tenn.). This bank is located 3 3-5 miles S. 45° E. of Riverside, and about three-fifths of a mile northeast of bank No. 1.

The outcrop consists of boulders and fragments of ore scattered over an area of about 35 acres. Two shallow test pits were found in this area, and these show some ore in very red clay, which contains chert fragments.

Brush Creek bank No. 3.—(No. 70. Owned by the Napier Iron Works, Nashville, Tenn.). This bank is located 4 miles S. 55° E. of Riverside, and half a mile northeast of bank No. 2.

The outcrop consists of boulders and fragments of brown ore scattered in patches over an area of approximately 50 acres, within parts of which the surface is thickly covered.

[33a]Prospects numbered 66 and 67 on the map of Lewis County, were incorrectly located. As those are not in Lewis County, their descriptions are omitted.

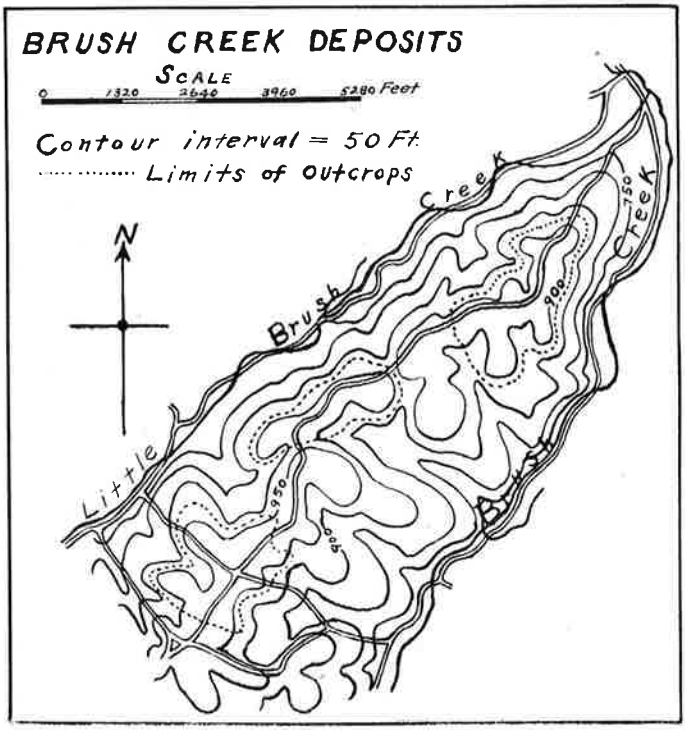


FIGURE 16.—Sketch map showing topographic relations of brown iron ore deposits in Brush Creek District.

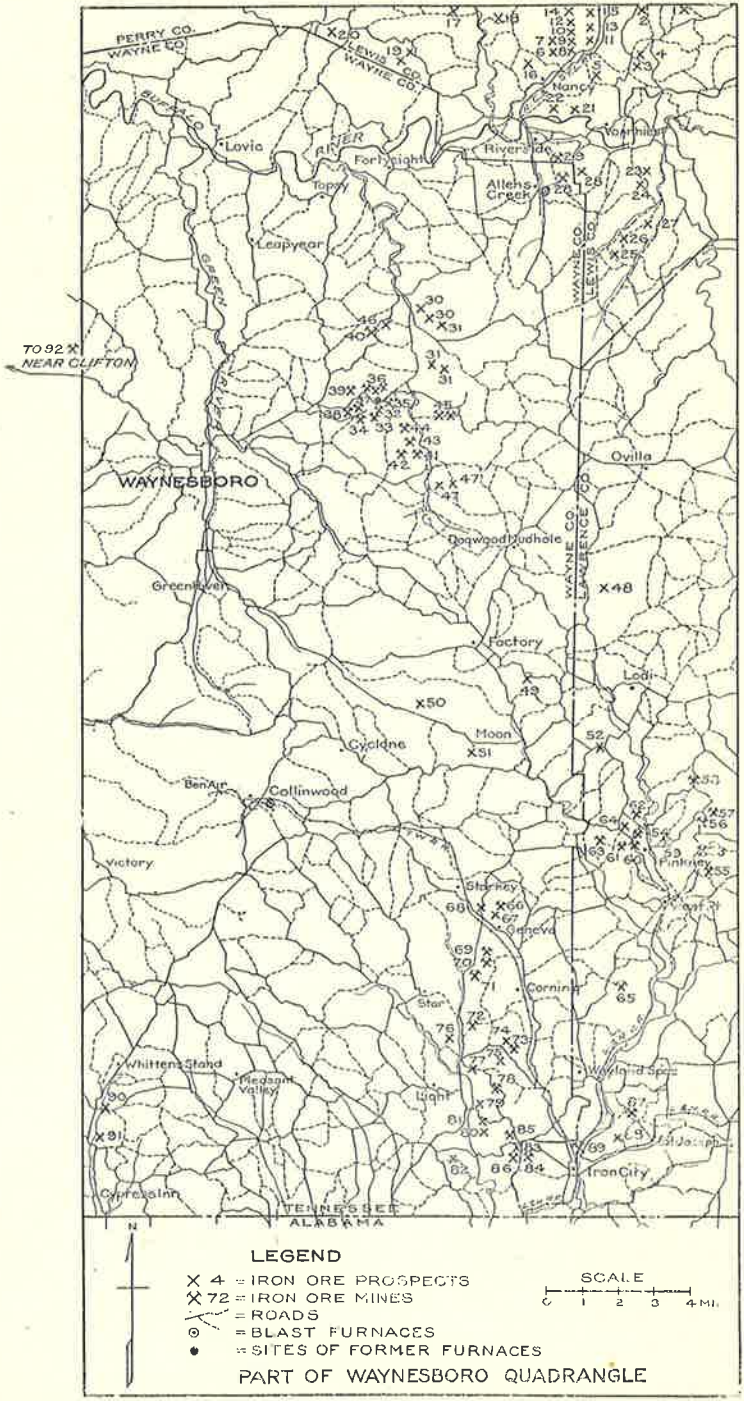
The bank has been prospected by 6 shallow pits, 2 of which are blank, the remainder showing some ore, principally shot ore. The material in which the ore occurs is chiefly very red clay. The bank should be thoroughly prospected.

The ore is a dark-brown limonite of good quality. It has a texture varying from compact to cellular, but the compact variety is the most abundant. A sample analyzed 54.08 per cent iron; 5.79 per cent silica; 1.916 per cent phosphorus; and 0.056 per cent sulphur.

WAYNE AND LAWRENCE COUNTIES

The brown iron ore deposits of Wayne and Lawrence Counties are mainly comprised within the Waynesboro quadrangle, an area of 974 square miles, which lies between latitudes 35° and 35° 30′ N. and longitudes 87° 30′ and 88 ° W. The greater part of Wayne County and the western 5 miles of Lawrence County are within the quadrangle.

Practically all the deposits of brown ore in these two counties have been described by Hugh D. Miser in "Mineral resources of the Waynesboro quadrangle," Bulletin 26 of the Tennessee State Geological Survey, published in 1921. As Bulletin 26, with its geologic map and other data of scientific and economic interest, is available for distribution at the time when



Map of portion of Waynesboro quadrangle, showing location of brown iron ore deposits and mines.

the present paper is being prepared, only abstracts of Miser's descriptions of these deposits will be published here, but the location of the prospects and mines are shown on both the general and local maps, Plates 1 and 27. Certain of the more important deposits, such as those at Allens Creek, Wayne furnace, Pinkney, West Point, and Iron City, were visited by E. F. Burchard in order to note later developments, and supplementary notes are therefore included regarding some of them.

Most of the deposits in Wayne County are grouped near Allens Creek and the Wayne furnace site, in the northeastern part of the county, and in the southeastern part near Iron City, and those of Lawrence County are in the southwestern part of the county near Pinkney and Iron City. The Allens Creek iron-ore area is reported to have been transferred to Lewis County through change of the county boundary. Mining was active in 1923 and 1924 at Allens Creek and as late as 1927 at the Van Leer mine 1½ miles northwest of Iron City. Of the prospects and mines shown on the map of Waynesboro quadrangle, 46 are in Wayne County and 22 in Lawrence County. Two of the deposits, one of them at the Cedar Point mine, half a mile north of Iron City (locality 89, Waynesboro quadrangle map, Plate 27), the other near Clifton, which is beyond the western boundary of the map, are of a definitely bedded type instead of the type of brown ore common to this locality, which occurs in residual clay. The bedded type of ore is not of consequence as regards future ore supply in this region, as apparently it consists of ferruginous limestone, in which there has been a little more than usual deposition of iron in the sediments, and the extent of such deposits is small. The deposit near Cedar Point is described under ferruginous limestone, page 210 of this bulletin. The following descriptions, Nos. 28 to 91, are mainly abstracted from the report by H. D. Miser.

Allens Creek mines (28).—The Allens Creek mines, also known as the Mannie mines, are on the crests of the ridges just east of the village of Allens Creek, the terminus of the Centerville Branch of the Nashville, Chattanooga & St. Louis Railway. The mines were opened in 1891 and worked until 1892. They then remained idle until October, 1895, and from that time operations were continued until April, 1913. In January, 1916, mining was resumed and was still going on at the time of last visit by H. D. Miser (April, 1920).

The production of iron ore before October 1, 1895, was probably 75,000 tons, and the production from that date until December 31, 1920, was 1,255,693 tons. The total production was therefore 1,330,693 tons to the close of 1920.

The workings are open cuts and cover an area of about 40 acres. Some are as much as 60 or 65 feet deep, and they will average 50 feet deep. [The deposits of ore are on the upland ridge 1 mile or less south of Buffalo River, at an altitude of about 900 feet, and they extend out half a mile or more toward the north on the crests of several spurs of the ridge.]

The iron ores occur in the residual chert and clay of the St. Louis limestone and at places in pockets and lenses of sand and gravel that are present in or above the clay. The total depth of these surficial materials is not known, but it probably everywhere exceeds 60 or 65 feet, the maximum depth of the workings. No rock ledges, either limestone or chert, have been found in the workings, though at places there are layers of chert 3 to 6 inches thick, which are fractured and bent. The bending and fracturing of the chert layers was caused by slumping during the removal of the limestone through solution. Most of the chert fragments, however, are irregularly distributed through the clay. A great deal of the chert is hard; the rest is soft and when struck by a hammer falls to a fine powder resembling tripoli.

Over much of the ore-bearing area the soil and subsoil have been leached to a light-yellowish color for a depth of 1 to 2 feet; a bright-red loam 1 to 4 feet thick occurs beneath this material; and below this loam the clays are usually yellow but at places are red and at others are white.

The pockets and lenses of gravel and sand differ greatly in size and shape; they are numerous, and some of them are found below layers of chert. (See Figure 17). The sand contains considerable mica in small flakes. The pebbles in the pockets of gravel are hard, subangular to well-rounded, most of them half an inch to 2 inches in diameter though some are as much as 5 inches in diameter. They are mostly chert but are partly quartz. A few fragments of chert in the pockets are angular and appear as if they had not been water-worn at all. The chert pebbles, as is indicated by fossils in them, were derived from beds in the St. Louis limestone. They have, however, been water-worn, except the few angular fragments that have just been mentioned, and they were apparently deposited by streams before the removal of the calcium carbonate of the limestone. The source of the quartz pebbles is unknown. The streams deposited not only gravel but sand and probably some clay. That the stream-laid materials were deposited before the removal of the limestone is shown by the occurrence of pockets of sand and gravel below clay that contains nearly horizontal layers of fractured chert. This means that some of the materials were deposited in limestone sinks or other surface irregularities.

The ore occurs mostly in irregular masses both large and small. Many of the masses are solid but others are reticulated, being composed of a network of veins. The larger masses occur here and there and are generally 10 feet or more below the surface but become fewer below a depth of 30 feet. The ore at and near the surface consists of small fragments, ranging in size from shotlike pieces to those 2 to 3 inches in diameter. Experience in mining is said to show that most of the ore is in the centers of the ridges. Parts of the ore contain much quartz sand and parts inclose clay and fragments and pebbles of chert so that the silica content of such parts is high. The top

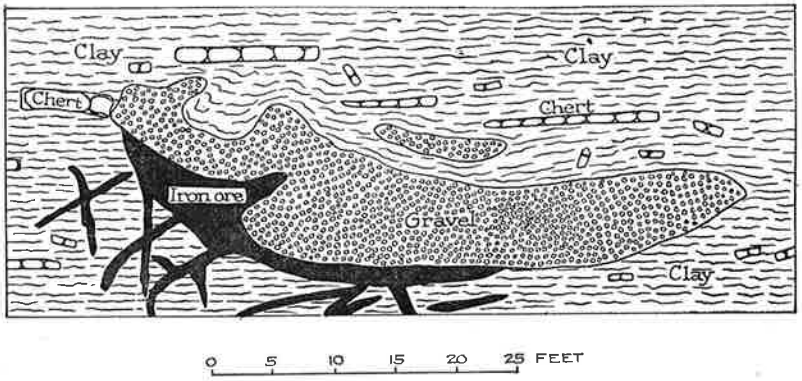


FIGURE 17.—Sketch of side of a cut at the Allens Creek mines, illustrating the occurrence of pockets of gravel in the residual cherty clay of the St. Louis limestone also an occurrence of the brown iron ore.

fragmentary ore is better than the lower, more-massive ores, the latter being subject to high percentages of silica.

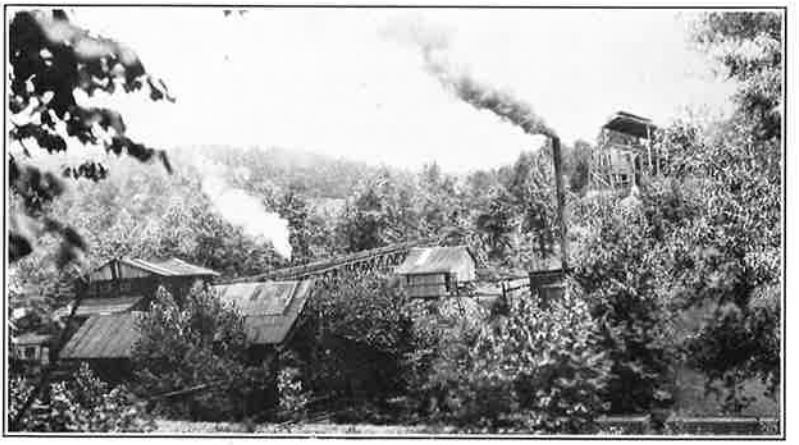
Supplementary notes.—The Allens Creek mines, which rank among the largest in the Western Highland Rim area, were visited by E. F. Burchard and C. C. Anderson in July, 1923. The mines were then being operated by the Bon Air Coal & Iron Corporation, now a part of the Tennessee Products Corporation, and continued active until very recently. Four steam shovels were then utilized in mining ore, and a new deep level, the bottom of which was 50 or 60 feet below the former surface, was being opened. The ore at this deep level was reported as of good grade. This cut was worked by drilling holes by hand or gasoline churn drill on the bottom of the next higher level 8 or 10 feet back from the face and blasting loose the ore-bearing material, then loading it by steam shovel into tramcars, which were drawn by dinky locomotives to the ore washer. (See Plate 28, A).

Considerable systematic prospecting had been done between, beyond, and below the old mine cuts with the result, according to Superintendent Deaver in 1923, that a supply of ore sufficient for 10 years at the current rate of production had been disclosed.

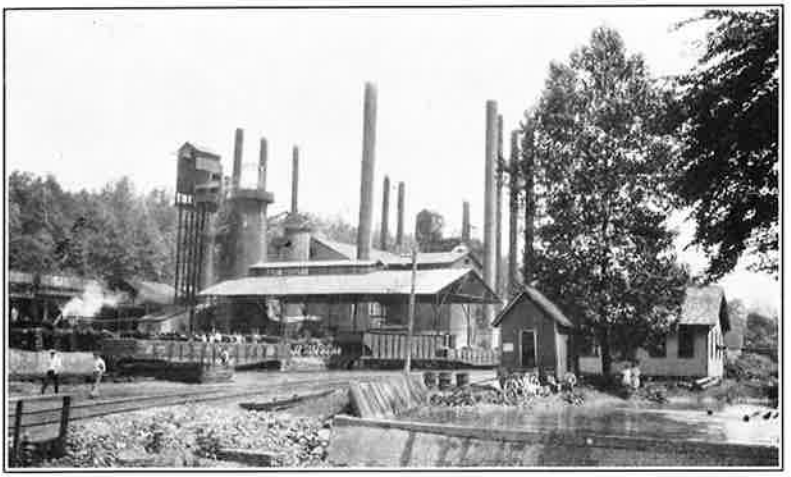
In noting the geologic relations described by Miser it was found in one place that the layers of chert that lie below the ore form a distinct ridge where the ore had been stripped off in mining. This chert shows partial replacement by limonite along joint and bedding planes, but generally not to such an extent as to form a commercial grade of ore.

In one of the lower mine cuts warped layers of chert are underlain by a pocket or lens of yellowish sand. Near here this sand was encountered at a depth of 60 feet in a test drill hole. The sand may fill an old solution channel or cave, but possibly it may represent a sandstone layer formerly within the cherty limestone. The thickness of the ore-bearing material, which consists of clay and disintegrated chert in association with limonite, is 40 to 60 feet as indicated by the open cuts, and there may be ore at greater

(A) Brown iron ore mine of the former Bon Air Coal & Iron Corporation, at Allens Creek, 1923.



(B) Brown iron ore washer at mines of the former Bon Air Coal & Iron Corporation, at Allens Creek, 1923.



(A) Mannie blast furnaces of the former Bon Air Coal & Iron Corporation, at Allens Creek, 1923.

(B) Waste pile of chert and limonite discharged from washers at Pinkney brown iron ore mine, Lawrence County, 1923.

(A) One of the main cuts at the Percy mine, 1 mile southeast of Riverside, Lewis County. (After H. D. Miser.)

(B) Side of a cut at Hessemer No. 2 mine one-fourth of a mile southwest of Pinkney, showing small mases of iron ore near the surface and large masses at greater depth. (After H. D. Miser.)

depths, as indicated by drilling below some of the pits. The limonite occurs in lumps, which may be nearly solid or else geodal, and in irregular masses and ramifying streaks. In places the ore is exceptionally rich, but the tenor of the product depends, of course, upon the character of the bank in which the steam shovel is excavating. The limonite is largely of the chert-replacement type, and some is apparently of the clay-replacement type. Some of the chert-replacement ore is cavernous and honeycombed and suggests that the replacement of silica by limonite has been accompanied by a loss of volume, but this is not universally true as lumps of nearly solid limonite are found, which indicate that the latter mineral has almost entirely replaced loose lumps of chert. The geodal lumps may represent partial replacement and partial removal of silica. A specimen of the "clay replacement" ore from below a surface gully, represented by the following analysis by D. F. Farrar, of the State Division of Geology, shows both alumina and silica present in considerable quantities.

Analyses of impure brown iron ore of "clay-replacement" (?) type from mine near Allens Creek

	Per cent
Iron (Fe)	32.11
Silica (SiO_2)	32.76
Alumina (Al_2O_3)	9.28
Phosphorus (P)	0.84

It was stated at the mine that the ore-bearing material might range in proportion from 12 yards of dirt to 1 ton of ore all the way to 4 yards to 1 ton. The washed ore ranges in iron from 42 to 53 per cent and in insolubles from 25 to 10 per cent, but generally from 42 to 45 per cent iron. Phosphorus is high, ranging from 0.80 to 1.25 per cent, but is said to be least in the lowest levels. Manganese ranges from 0.10 to 0.50 per cent, and sulphur is practically negligible, generally below 0.01 per cent.

Analyses in percentage of brown iron ore from Allens Creek mines[34]

	Iron (Fe)	Insoluble	Phosphorus (P)	Manganese (Mn)	Sulphur (S)
November, 1922	45.12	17.80	General range 0.86 to 1.25	General range 0.10 to 0.50	Generally below 0.01
	48.20	14.60			
	49.46	15.40			
	50.22	12.00			
	52.50	10.80			
December, 1922	42.47	25.60			
	47.22	18.60			
	49.22	15.20			

The ore washer, on the east side of Allens Creek above the blast furnace, consists of a tipple and grizzly high on the valley side, a long flume down which the ore is carried by water and separated from part of the adhering clay, a coarse rotary screen, 2 steel logs, a picking belt, sand screen,

[34]By the former Bon Air Coal & Iron Corporation.

and a set of 4-cell jigs. The output was reported to be from 150 to 300 tons of ore a day, all used at the local blast furnace. The arrangement of the washer is shown in the photograph, Plate 28, B.

The blast furnace (Plate 29, A), known as the Mannie furnace, formerly consisted of two stacks, although only one of them was operated for several years and the other has been dismantled recently. The daily output of this stack was reported to range from 80 to 100 tons of pig iron, depending to some extent upon the grade of ore available. Limestone for flux was brought from the quarry of the company at Wrigley, for the stone obtainable at Allens Creek is less suitable. Foundry pig iron, containing 2.25 to 6 per cent silicon, is the staple product of the furnace.

Percy mine (29).—The Percy mine consists of a number of cuts at different places on the crests of a ridge and its spurs almost 1 mile southeast of Riverside. The aggregate area of the cuts is about 20 acres and the maximum depth between 60 and 70 feet. The ridge is between 950 and 1,000 feet above sea level and between 250 and 300 feet above Allens Creek, which flows north past the west base of the ridge. (See Plate 30, A).

The Warner Iron Co. opened the mine in 1899 and operated it and a washing plant more or less continuously until January 27, 1919. The property was then sold to the Bon Air Coal & Iron Corporation, which was mining and washing ore at the time of last visit of H. D. Miser, April, 1920. The production of iron ore by the Warner Iron Co. was 404,821 tons, which was shipped to Cumberland furnace; the Bon Air Coal & Iron Corporation from January 27, 1919, to December 31, 1920, produced 64,660 tons, which was shipped to the Cumberland and Goodrich furnaces. The total production before December 31, 1920, was therefore 469,481 tons.

The iron ore is irregularly distributed through loose material composed largely of red clay but partly of chert fragments, sand, and gravel, and the ore-bearing material had not been passed through in the workings in 1920. The clay and chert fragments, as at other mines in the Waynesboro quadrangle, have been derived from the St. Louis limestone, whereas the sand and gravel, which occur in lenses and pockets, are probably stream deposits of Upper Cretaceous age. The iron ore is generally free from quartz sand. It reaches the surface at some places, but at others good pockets of high-grade ore are concealed by as much as 15 feet or more of barren material. The pebbles in some of the gravel lenses are cemented together by iron oxide, forming a hard conglomerate, and large masses of this conglomerate are avoided as much as possible in mining. The ratio of washed ore to ore-bearing material for several years averaged 1 ton of washed ore for every 3 cubic yards of loose ore-bearing material.

In composition the iron ore is very similar to the ore from the Allens Creek mines, except that it contains more phosphorus. The accompanying analyses represent the composition of samples of ore collected by N. F. Drake and analyzed by Paul C. Bowers.

Analyses of iron ore from the Percy mine

	Per cent	Per cent
Iron (Fe)	51.01	49.85
Phosphorus (P)	1.247	1.417
Sulphur (S)	0.002	0.004
Silica (SiO_2)	6.27	12.52

Sufficient prospecting has not been done to determine the total area of ore-bearing material nor to determine the full thickness of the deposit.

Churchwell prospects (30).—Two Churchwell prospects east of Forty-eight Creek and between Duggar Branch on the north and Little Forty-eight Creek on the south cover 167½ acres. At one prospect all of the many pits except three show shot ore and lump ore in clay, in which there is at places considerable chert, the clay and chert having been derived from the lower part of the St. Louis limestone. At the second prospect nine of the twelve pits showed ore in considerable quantity occurring as "shot," "lump," and "bomb shell" ore, much of it in red clay but some in chert derived from the lower part of the St. Louis limestone. The deepest pit revealed ore in St. Louis chert and below this it penetrated the yellow Fort Payne chert, which contains no ore. Both prospects contain ore of good quality and apparently in minable quantity.

Robinett prospects (31).—The Robinett prospects comprise 1,250 acres on and near the lower course of Little Fortyeight Creek. Prospecting has been done on three ore-bearing tracts. In Prospect No. 1 thirty-eight pits reveal shot ore and some lump ore in red clay in which there is a small quantity of chert. The ratio of concentration appears to be 3 or 4 parts (by weight) of ore-bearing clay to 1 part of ore. The brown iron oxide is compact and hard and free from sand. The deposit apparently contains ore in minable quantity. In Prospect No. 2 two pits reveal ore-bearing clay. Further prospecting will probably prove a workable ore body of considerable size. In Prospect No. 3 one pit, 12 to 15 feet deep, revealed ore from surface to bottom. The ore-bearing area is perhaps 4 or 5 acres in extent. The ore, which is compact and hard, occurs in clay and chert derived from lowermost beds of the St. Louis limestone; Fort Payne chert (next lower formation) is exposed on the hill slopes just below the outcrops of the deposit.

Wayne furnace locality.—The Wayne furnace mines (Nos. 32 to 45, inclusive) are near Wayne furnace site, which is on Furnace Branch 5 miles northeast of Waynesboro.

Chert and clay, 50 to 100 feet thick, derived from the lower part of the St. Louis limestone, cap the ridges on which the ore-bearing tracts lie. No undecomposed limestone is exposed on the surface or has been encountered in the openings. If none is present in the ridges on which the mines have been opened, its residual chert and clay rest directly upon the Fort Payne chert, which is exposed on the lower slopes of the ridges and along the streams. The Fort Payne is generally concealed by débris derived mostly from the St.

Louis limestone. The iron ore, chiefly brown oxide with a small amount of red oxide, is hard and generally free from sand and occurs as branching or reticulated veins, both wide and narrow, in the clay, chert, and gravel. The veins include these materials at places.

Analyses in per cent of iron ore from the Wayne furnace mines, Tennessee

	1	2	3	4	5
Iron (Fe)	52.28	50.86	52.91	53.55	54.52
Manganese (Mn)	.....	1.49	.....	.....	.....
Phosphorus (P)	0.88	0.985	1.561	0.744	0.874
Sulphur (S)	.....	.....	0.015	.021	.01
Silica (SiO_2)	9.41	11.25	7.30	11.90	9.11

1. Sample composed of 462 pieces, taken from 5 different shafts. Analysis furnished by W. C. Collin. Wuth & Safford, analysts.
2. Sample composed of 9 pieces. Analysis furnished by W. W. Collin, Pittsburgh Testing Laboratory, analyst.
3, 4, and 5. Samples collected by N. F. Drake. Paul C. Bowers, analyst.

The ore was mined by hand from open cuts and short drifts at many places in such a way as to get the greatest possible quantity per day without regard to future production. Future mining will be done mostly in open cuts, but the great thickness of the overburden in places will probably necessitate some underground mining. A complete washing plant will be required.

East Furnace Ridge mine (32).—The East Furnace Ridge mine is on the crest of a ridge 750 to 920 feet in altitude, extending southward from the ruins of Wayne furnace. Sixty or more pits, cuts, shafts, and short tunnels have been made over more than 30 acres, most of them on and near the crest of the ridge, but a few are 80 feet below it. (See Figure 18). Many of the openings represent recent prospecting and most of them reached iron ore. They range in depth from a few feet to 48 feet, but more than half exceed 20 feet. The ore lies in an irregular, noncontinuous bedlike body, ranging in thickness from a few inches to about 30 feet and probably averaging not less than 10 feet. The ore is massive, hard, and fairly free from impurities except for some clay and angular chert. The mine-run ore will probably yield 1 ton of marketable ore to 1 ton of waste. The overburden of chert, clay, and gravel varies from nothing to about 30 feet thick.

West Furnace Ridge mine (33).—The West Furnace Ridge mine is on a ridge south of Furnace Branch and west of East Furnace Ridge. About 20 openings, consisting of cuts, not exceeding 12 feet in depth, and shafts, ranging from 22 to 50 feet in depth, have been made, but only about half revealed from a few feet to more than 30 feet of ore-bearing chert and clay. This will yield at least 1 ton of marketable ore to 1 ton of waste. Sufficient work has been done to show that ore is present in workable quantity.

Nigger Ridge mine (34).—The Nigger Ridge mine on Nigger Ridge west of West Furnace Ridge and between Lathen Hollow and Nigger Hollow was operated when Wayne furnace was in blast. Between 15 and 20 openings, including old open cuts, an old tunnel, and a number of recently

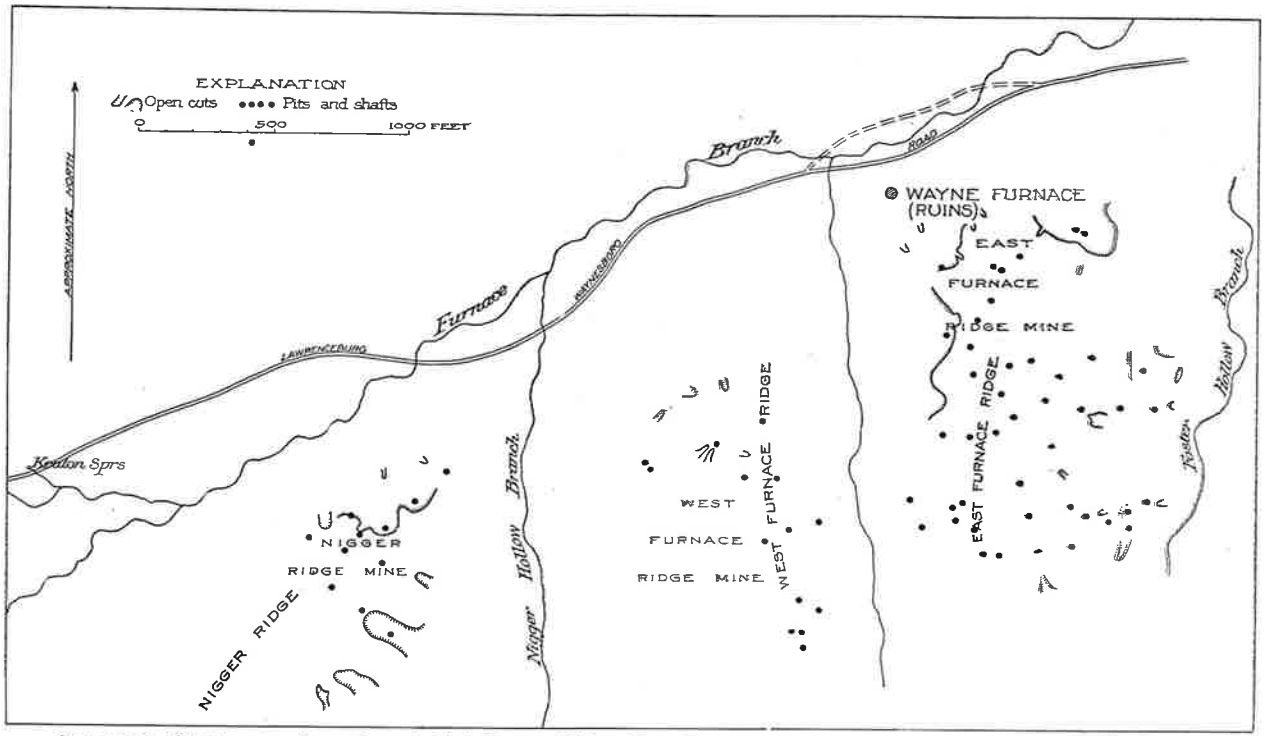


FIGURE 18.—Sketch map of openings at East Furnace Ridge, West Furnace Ridge, and Nigger Ridge mines near site of Wayne furnace.

made shafts as much as 38 feet deep, have been made over about 10 acres at and near its northeast end. (See Figure 18). They are situated from the crest of the ridge down to about 75 feet below it; probably more than half revealed iron ore in clay and chert. Ore-bearing material will probably average more than 10 feet thick and probably yield one part of marketable ore to one part of waste. The overburden is from nothing to about 20 feet thick.

Supplementary notes.—The deposits near the site of the former Wayne furnace were visited briefly by E. F. Burchard and C. C. Anderson on the way from Collinwood to Allens Creek in July, 1923. The old pits of East Furnace Ridge mine and Nigger Ridge mine (localities 32 and 34, Waynesboro quadrangle, Plate 27) were inspected. The openings are on the slopes and tops of the ridges at altitudes of 785 to more than 900 feet and indicate a vertical range in ore-bearing ground of nearly 150 feet, beginning about 75 feet above Fortyeight Creek. The ore is of the chert-replacement type and occurs in masses and débris in cherty clay along a fairly definite horizon. Some of the workings had been driven underground a short distance, but most of these underground openings had caved in to such an extent as to prevent a study of the ore-bearing formation. Mr. D. C. Clark, who lives opposite the old furnace, reported that extensive prospecting by pits and drills was done here in 1921 under the direction of a professional mining geologist, and that this work indicated that much ore is still available in this locality. This, it appears, was the belief of the owner, the Tennessee Valley Charcoal Iron Co., which during the World War undertook the construction of a railroad from the company's blast furnace and chemical plant at Collinwood to the Wayne furnace locality, in order to transport iron ore to the blast furnace. This road was graded a few miles from Collinwood, and some ties were laid, but the furnace did not get into active operation during the war, and the project to mine the ore was abandoned. The remoteness of this locality from railroads will retard developments here, for under present conditions mining and transportation costs would prove prohibitive.

Foster Hollow prospect (35).—The Foster Hollow prospect is on the northwest point of the hill east of the mouth of Foster Hollow. Four shallow pits at about 75 feet above the base of the hill were dug in yellow clay, in which there are chert fragments, but only one of them revealed considerable iron ore of good quality.

Lee Ridge mines (36).—The Lee Ridge mines are on the crest of Lee Ridge, between Louse Hollow and Furnace Branch. There are on the crest of this ridge and its spurs and on the slopes as much as 50 feet below the crest about 70 openings, comprising cuts as much as 150 feet long, 100 feet wide, and 15 feet deep, pits 10 feet or less deep, and a few short drifts. The iron ore, available in practically all the openings, occurs as fragments at and near the surface and as large and small irregular branching veins at greater depths. It is hard, compact, and free from sand, but much contains

fragments of chert. The overburden, consisting of chert fragments and pebbles, ranges from nothing to 10 feet or more thick and will probably average not more than a few feet. The ore appears to occur in minable quantity over 60 acres or more, but mining should not be begun without further prospecting.

Broach mine (37).—The Broach mine is on the south point of a hill northwest of Furnace Branch and is opposite Nigger Ridge. The workings consist of two cuts about 60 feet above Furnace Branch and two or more very small pits. The cuts were badly caved, and the ore as indicated by material on the old dumps consists of large and small fragments of hard iron oxide, some, especially the larger ones, containing chert fragments. Shallow pits east of the cuts reveal only a small quantity of iron oxide, but a pit and an outcrop 75 feet northwest of the cuts reveal massive ore containing many chert fragments and pebbles.

Keaton Springs mine (38).—The Keaton Springs mine is on the southeast points of the two spurs west of the Broach mine. Several shallow pits within an area 100 feet square on the westernmost spur, 80 feet above Furnace Branch, yielded massive ore containing chert fragments. The small pits on the other spur reveal ore of the same character. Further prospecting will be necessary to determine whether there is sufficient iron ore at this bank and at the Broach to warrant mining under present conditions.

Perigo mine (39).—The Perigo mine is on a hill on the southeast side of Louse Hollow, three-fourths of a mile northwest of Wayne furnace. There are three cuts, the largest of which, on the northwest slope of the hill 35 feet below the crest, is 30 feet wide and 50 feet long and before it caved had a face 15 feet or more high. It reveals a large amount of ore in irregular veins and masses in clay having many chert fragments and some chert pebbles. The other cuts, 10 to 15 feet deep, are on the east slope and show considerable iron ore in clay comparatively free from chert.

Spurs north of Louse Hollow.—Iron ore is reported to show on the surface on the south points of 12 short ridge spurs on the north side of Louse Hollow from its head to its mouth, a distance of about 1½ miles. No prospecting has been done except at one place where a small amount of ore was mined for Wayne furnace.

Irontop mine (40).—The Irontop mine is 6 miles northeast of Waynesboro on the crest of the ridge followed by the wagon road from Waynesboro to Allens Creek. Two recent pits on the crest, one 15 feet deep and the other 20 to 25 feet deep, reveal chert and clay and considerable iron oxide. Shot and lump ore occur on the surface near several small, old pits on the west and north slopes of the ridge and along the wagon road for about one-fourth of a mile. The prospecting has not been sufficient to determine the magnitude of the ore body. Iron ore is said to occur on the surface on the northwest points of all the short spurs between the Irontop mine and the head of Bowstring Branch.

Murphy mine (41).—The Murphy mine, on the east point of a ridge just west of Fortyeight Creek, 1¾ miles southeast of Wayne furnace, consists of three shallow, badly caved trenches 60 to 80 feet long and four pits as much as 20 feet deep. The trenches and one pit revealed much iron ore in chert and clay on the east slope of the ridge, but the other three pits on and near the crest failed to discover ore in paying quantities, which indicates that the ore-bearing area probably does not exceed a few acres in extent and is confined to the east end of the ridge. The ore, brown iron oxide, is hard and free from sand.

Crews mine (42).—The Crews mine is half a mile west of Fortyeight Creek and 1½ miles southeast of Wayne furnace. The openings consist of two badly caved cuts, one 10 to 15 feet wide, 70 feet long, and 15 feet or more deep before it was caved and the other, just west of the first, 50 to 60 feet wide, 60 feet long, and originally 25 feet or more deep. The ore was not visible in the cuts, but the old dumps show it to be a hard brown iron oxide free from sand, associated with clay, chert, and pebbles. A very small pit on the north side of the wet-weather branch that runs east past the cuts reveals brown iron oxide associated with chert.

Sapling mine (43).—The Sapling mine is on a ridge about one-fourth of a mile west of Fortyeight Creek and 1½ miles southeast of Wayne furnace. Fifteen to 20 pits and cuts, which do not appear to exceed 10 feet in depth, were dug over 3 or 4 acres on the crest and south slope of the ridge. Most of them revealed brown iron oxide of good quality in clay containing a comparatively small amount of chert and with little or no overburden. A blank pit higher on the ridge, west of the openings, suggests that the iron-ore deposit is confined to the east end of the ridge, but systematic prospecting may reveal an ore body workable by steam shovel.

West mine (44).—The West mine is on the east end of a ridge one-fourth of a mile west of Fortyeight Creek and 1¼ miles southeast of Wayne furnace. The main opening, a cut 100 feet square and 15 feet or more deep, on the north slope of the ridge, was made in brown clay containing chert fragments and pebbles and considerable brown iron ore. Another cut, 30 feet long, 12 feet wide, and 10 feet or more deep, and a few pits as much as 25 feet deep on the east end of the ridge also revealed considerable iron ore. Additional prospecting is necessary to determine whether or not the ore body is large enough for profitable mining.

Lee Hollow mines (45).—The Lee Hollow mines are just south of Lee Hollow, a southeastward-trending hollow followed by the Waynesboro-Lawrenceburg road just east of Fortyeight Creek. The old and new pits range in depth from a few feet to 42 feet, and the old drifts are as much as 50 feet long. These openings cover 100 to 150 acres on the ridge south of Lee Hollow and two adjoining ridges or spurs that extend southwestward from the first ridge and occupy the crests and the slopes as much as 50 feet lower.

A bed of well-rounded chert gravel from a few feet to 10 feet or more thick caps the ridges at most places and rests upon clay and chert derived from the St. Louis limestone. The chert predominates over the clay at most places.

The ore, brown iron oxide, occurs in large irregular masses, branching veins, and bomb shells (see Plate 3, B) in the clay and chert and in places occurs in the overlying gravel as a cementing material. The minable ore, at places 25 feet or more thick, is mostly massive, compact, and hard, and generally free from sand but contains much chert and clay. The ore bodies of minable size extend about 50 feet below the crests of the ridges but would comprise less than 100 acres. Mining in open cuts can probably be carried on to a great extent, but the overburden on the crests of the ridges may make underground mining necessary.

Tract north of Lee Hollow.—Iron ore is said to show on the surface on the crest of the ridges between Lee Hollow and the Robinett property, but no prospecting has been done.

Nutt prospect (46).—The Nutt prospect is on the crest of a ridge 6 miles northeast of Waynesboro, adjoining on the east the Irontop mine. Shot and lump ore was observed on the surface, in one or two old pits, and in tree mats for about 100 yards east of the Irontop tract.

Buchanan prospects (47).—The Buchanan prospects, on the headwaters of Fortyeight Creek, 7 miles east of Waynesboro, comprise 1,107 acres. Ten pits, ranging in depth from a few feet to 15 feet or more, were dug on the crest and as far as 40 feet below the crest of a north-south ridge about three-fourths of a mile south of Fortyeight Creek. Five pits revealed brown iron oxide and five revealed none. The deepest pit is said to have shown 26 feet of ore from the surface to the bottom and not to have passed entirely through it.

More than a dozen pits, ranging in depth up to 20 feet or more, on a north-south ridge just east of a northward-trending hollow that separates this ridge from the above-described ridge have been dug over a considerable area on the crest and west slope. Some penetrated clay, others clay and chert, and the rest clay, chert, and gravel. Eight revealed brown iron oxide in considerable quantity but the others little or none.

The iron ore on these two ridges is of good quality, but further prospecting would be necessary to determine whether workable ore bodies are present.

Hughes prospect (48).—The Hughes prospect is on the crest of a ridge on the east side of Chisholm Creek, about 1½ miles north of the mouth of Reed Patch Creek and 7 miles north of Pinkney. The ridge trends northeast and is capped with clay and chert residual from the St. Louis limestone, the clay predominating, and with small pebbles of chert and quartz.

Possibly 50 prospect pits 10 feet or more in depth, scattered along the ridge for a quarter of a mile, penetrated the clay and other surficial materials,

About half of the pits revealed iron ore; some were not sunk deep enough to reach the ore horizon. Shot ore is revealed on the surface on the crest of the ridge and in the pits on the crest, whereas lump ore is revealed in the pits on the slopes. The ore, brown oxide of iron, is hard and generally free from sand, but the lump ore in places contains fragments of chert, these being soft and easily separable from the ore.

Flippo, Bruton, Kidd, and Biggs tracts.—Iron ore is said to occur on the Flippo, Bruton, Kidd, and Biggs tracts, which are within close proximity to each other and lie on the west side of Chisholm Creek northwest of the Hughes tract. A small amount of prospecting has been done on the first three of these tracts.

Prospect of Sheffield Iron Corporation (49).—Shot ore is revealed in red clay at places in a wagon road for about half a mile along the crest of a westward-trending spur 2½ miles west of Lodi, and in a few small pits also on the crest. Further prospecting is necessary to determine the size of the ore body.

Prospect on Double Branch (50).—An iron-ore prospect on the crest of a ridge on the north side of Double Branch, 3 miles west-northwest of the mouth of this stream, reveals brown iron ore in red clay containing fragments and pebbles of chert. More prospecting is necessary to determine the size of the ore deposit.

Prospect of Wayne County Land Co. (51).—Prospecting for iron ore on the crest of the ridge about half a mile south of Moon post office revealed brown oxide of iron occurring in the residual clay and chert of the St. Louis limestone and in gravel. It is exposed on the crest and slopes of the ridge and along streams in hollows that dissect the ridge. The ore consists of small particles and large masses and is of good quality. The ore-bearing area probably covers half a square mile, and systematic prospecting may reveal one or more ore bodies of workable size.

McDonald-Robinson prospect (52).—Shot ore in red clay occurs in gullies by the roadside and on the surface of the crest of a ridge 3 miles north-northwest of Pinkney. A well on top of the ridge showed 10 feet of clay, containing some chert fragments and pebbles, underlain by chert. Fragments of good quality lump ore were removed from the well. The ore-bearing tract apparently extends over several acres, but further prospecting is necessary to determine whether iron ore occurs in minable quantity.

Wright mine (53).—The Wright mine, 1½ miles east of Pinkney, consists of irregular cuts on crooked ridge crests, the cuts aggregating 40 acres and their average depth being 15 feet. The openings reveal a gray loam 1 to 2 feet thick at the surface, then 20 to 25 feet of red clay, and below this yellow clay containing pebbles, fragments, and boulders of chert. Large pockets of yellow and red sand are present in the clay. Ore in the form of shot, lumps, and boulders of brown iron oxide occurs in the sand and clay near the surface and as branching veins and large masses at greater depth.

Most of the ore is hard and compact and free from sand and chert fragments and pebbles. The ore-bearing clay was mined with four steam shovels and hauled on tramroads to two washing plants, 506,000 tons of ore having been produced in 1897 to 1900. Estimates of minable ore still present range from 500,000 to 4,000,000 tons, but an estimate reported to have been based on systematic prospecting was 750,000 tons. The ore that was mined here was used in furnaces at Sheffield, Ala., and South Pittsburg, Tenn.

Supplementary notes.—No further work had been done at this mine when visited by E. F. Burchard in 1923. The chert associated with the ore contains bryozoans and crinoid stems similar to those of the Fort Payne, and as Fort Payne chert in place, overlying Ridgetop shale, is exposed near by at a slightly lower level than the mine, it appears that the ore-bearing horizon at this place can be established fairly definitely.

Pinkney mine (54).—The Pinkney mine, on the ridge just west of Pinkney, consists of open cuts along the crest of a north-south ridge for about half a mile, though one small cut of half an acre was made on the east hill slope between 150 and 200 feet below the crest of the ridge. The aggregate area of the cuts is about 25 acres, their depth ranging from several feet to 50 feet. [The altitude of these ore deposits is between 850 and 900 feet.]

North of the washing plant on Boarding House Hill the cuts reached a depth of 20 to 25 feet, and those on the ridge west and southwest of the washer average between 40 and 50 feet. The ore-bearing material is mainly red clay, that near the surface containing a small quantity of chert fragments and pebbles, but deeper in the cuts the chert predominates over the clay. The clay contains many lenses or pockets of cross-bedded sand as much as 35 feet thick.

The ore, brown iron oxide, occurs as shot and disconnected fragments of different sizes at and near the surface and as veins and large irregular masses in the lower parts of the cuts, much of it containing clay and many chert fragments and pebbles. Some iron oxide occurs in the lenses of sand but is not mined, as it is too siliceous to be of value. Ore marketed by the Pinkney Mining Co. is said to have averaged 47 per cent iron, 0.70 per cent phosphorus, and 17.50 per cent insolubles.

The mine was operated at times with two or three steam shovels, and the crude ore was treated in a washing plant. A large pile of waste from the washer is reported to contain so much iron oxide that at some future time it may be worth while to reconcentrate it in a new washer.

The Pinkney mine has been one of the large ore producers in this region, 962,500 tons having been the reported output from an area of 37 acres. The ore was supplied to Cumberland, Clarksville, Cowan, Chattanooga, and Sheffield furnaces. The minable ore remaining in the old workings and unworked areas, which aggregate 4 or 5 acres, is estimated as between 400,000 and 500,000 tons.

Supplementary notes.—The magnitude of the pile of waste from the old washer is shown in the photograph by E. F. Burchard, in July, 1923, (Plate 29, B), which indicates a height of more than 60 feet. The material of this dump consists chiefly of rounded and subangular chert gravel, but there is an appreciable quantity of limonite present in the form of small lumps and sand due to lack of thoroughness in the former washing operations. At times this material has been picked and screened by hand, thus yielding a marketable ore carrying 42 to 44 per cent of iron, and it is believed that a higher percentage of iron could be recovered by reconcentration in a modern plant. Some of the material as found in the waste pile has been shipped to the blast furnace at Rockdale, where is was added to the other raw materials used in making ferrophosphorus in order to supply silica for slagging off the excess lime in the phosphate rock.

Ironsides mine (55).—The Ironsides mine, also known as the West Point mine, on the crest of a hill 1½ miles northeast of West Point, is a cut covering 16 acres and averaging 30 feet or more in depth. The upper parts of the sides of the cut reveal red clay, whereas their lower parts reveal yellow clay. The clay is comparatively free from chert fragments and pebbles but contains them at many places in the lower part of the cut. Pockets of yellow to red sand 25 feet or more thick and 100 feet or less long and wide are fairly numerous. The ore, brown iron oxide, which is generally hard and compact and once formed veins and reticulated masses in the clay and sand, has largely been broken up in weathering and occurs as lump and shot ore near the surface and as boulder ore in the lower parts of the cut. Many boulders of sandy and pebbly ore were left in the cut.

The ore deposit proved to be very rich. During the first year that it was worked the ratio of concentration averaged 1 ton of washed ore for every 2 yards of loose ore-bearing material and during the second year 1 ton of washed ore for every 2½ yards. The marketed ore is said to have averaged more than 50 per cent of iron, much of it averaging 52.50 per cent, 0.83 per cent of phosphorus, and 10.10 per cent of insolubles. The ore was mined by steam shovel and was hauled in tramcars to the washing plant just north of the mine, where it was beneficiated. The production is reported as 650,000 tons.

Neal property.—The P. A. Neal property, adjoining the properties of the Ironsides and Wright mines, is reported to show iron ore on the surface, but no prospecting has been done.

Sharp (56), *Wisdom* (58), *Drake* (59), *and Burkett* (57) *mines.*—The Sharp, Wisdom, Drake, and Burkett mines, which are on a large tract of land half a mile to 2 miles east and northeast of Pinkney, have produced about 400,00 tons of iron ore, of which the Sharp mine yielded between 135,000 and 140,000 tons and the other mines between 260,000 and 265,000 tons.

The Sharp mine is an irregular cut of 8 to 10 acres and as much as 35 feet deep on the crest of a ridge. The Burkett mine, which is a cut 250 feet long by about 100 feet wide on the crest of a ridge half a mile northeast of the Sharp mine, probably has not produced more than 5,000 tons of iron ore. The depth was not determined, as the cut was filled with water to within 10 feet from the top. The Wisdom mine consists of several irregular cuts on the crest of a ridge 1¼ miles north of the Sharp mine and 2 miles northeast of Pinkney. The cuts cover between 15 and 20 acres and range from several feet to 25 or 30 feet deep. The Drake mine is a cut of 2½ to 3 acres and as much as 25 feet deep, on the west point of a southwestward-trending ridge half a mile east of Pinkney.

The deposits of iron ore at these mines are similar. The cuts reveal a gray surficial loam 1 to 2 feet thick, then 20 to 25 feet of red clay, and below this yellow clay. Pebbles, fragments, and boulders of chert are generally absent in the red clay but abundant at places in the yellow clay. Pockets of yellow and red sand measuring many feet in their three dimensions are common. The brown iron oxide, occurring as shot, lump, and boulder ore, is irregularly distributed through the clay and sand. The ore is hard and most of it is compact, but the large masses are more or less porous and contain clay and chert fragments and pebbles. The ore in the pockets of sand is very siliceous and was not mined. Apparently only about one-third of the original available ore has been left in the deposits at these mines, and it was considered that the deposits had been pretty well worked out under the conditions that existed when the mines were active. These mines, besides the Gresham, Elting, J. B. Powell, Corning, Robinson, Littrell-White, and others supplied ore to the Napier Iron Works a few years ago.

Hessemer mines No. 1 (61) and No. 2 (60).—The Hessemer No. 2 mine is on the crest of a north-south ridge one-fourth of a mile southwest of Pinkney and joins the south side of the Pinkney mine. The Hessemer No. 1 mine is on the crest of the first north-south ridge west of Hessemer No. 2. The production of ore from Hessemer No. 1 mine was 170,000 tons and from No. 2 mine 130,000 tons.

Hessemer No. 2 consists of several cuts occupying 10 to 12 acres and ranging in depth from about 10 to 35 feet, which extend along the crest of the ridge from a quarter to half a mile. The character of the ore and ore-bearing material is similar to that at the Pinkney and Ironsides mines. The brown iron oxide occurs as shot, lump, and boulder ore, all of it compact and hard and generally free from clay, chert, sand, and gravel, except the large masses, which are porous and contain some of these impurities. (See Plate 30, B). The ore occurs in red sand and clay, but in the deeper parts of the cuts there are many fragments, boulders, and pebbles of chert. The ore occurring in the sand contains much sand, and parts that have not been mined rise as pinnacles above the floors of the cuts. Mining was done with a steam shovel, but the area has not been worked over entirely and apparently much available ore remains.

Hessemer No. 1 mine consists of several irregular cuts, some as much as 30 feet deep, extending along the crest of the ridge for about 1,500 feet and comprises 7 or 8 acres. The ore and ore-bearing materials are the same as those at Hessemer No. 2 mine. The minable ore is said to be exhausted. The washing plants for these mines have been dismantled and the railroads torn up.

Little Hill mine (62).—The Little Hill mine is on the crest of a hill half a mile northwest of Pinkney. The mine is an open cut covering 4 or 5 acres and from a few feet to 40 feet deep.

Brown iron oxide in the form of shot and lump ore is irregularly distributed through yellow and red clay and chert débris. It is generally compact and hard, only the larger masses being porous and containing clay and some chert and pebbles. Horizontal lenses of yellowish-red sand as much as 15 feet or more thick are common, and the parts containing much sand or little ore have not been mined, making the cut very irregular. When mining was discontinued in 1911 the minable ore was considered to have been exhausted.

Dodd mine (63).—The Dodd mine, also known as the Gray mine, is 1¼ miles west of Pinkney. The mine is an irregular cut of 3 or 4 acres, ranging in depth from 10 to 20 feet, on the south slope and west point of a ridge, its lowest point being about 100 feet below the crest of the ridge.

The brown iron oxide, which is compact and hard and comparatively free from sand, is mostly in the form of lump and shot ore with some boulder ore. It occurs in red clay containing much chert, some pockets of gravel and a few of sand. When mining was discontinued in 1913 or 1914 the minable ore was considered to have been exhausted.

From 1907 until 1913 or 1914 the production from this and the Little Hill mine is reported to have been 150,000 tons of iron ore. The ore in these two mines was taken out by steam shovel and hauled on a tramcar to a washing plant at Pinkney. The washer has been dismantled and the railroad torn up.

Hopkins prospect (64).—The Hopkins prospect is on the crest of a ridge north of Hessemer No. 1 mine and west of the Pinkney mine. Test pits made here are said to have revealed much iron ore.

Couch mine (65).—The Couch mine, which is on the crest of a ridge 1 mile west of Rhodes Hill station, produced 196,000 tons of iron ore from 1909 to 1912, with an average iron content of 48.87 per cent.

The mine consists of a cut covering 7 acres, in most parts between 20 and 25 feet deep. Brown iron oxide occurs in clay as shot, lump, and boulder ores and at places there is bombshell ore. The clay also contains some pockets of sand and gravel and many chert fragments and boulders. At some places sand and gravel are so abundant that they could not be separated from the ore commercially. Much available ore remains in the deposit and may perhaps be mined profitably in the future.

Gresham mine (66).—The Gresham mine, on the crest of a ridge 1 mile north of Geneva station produced from 1913 to 1915, 65,138 tons of iron ore. The mine consists of an irregular cut covering 10 to 12 acres and from a few feet to 18 feet deep. Brown iron oxide as shot and lump ore, also some as boulder ore, is contained in red clay, in which at places there are sand and chert fragments and pebbles. These impurities occur in some of the ore itself. A specimen of ore from the Gresham mine, analyzed by Paul C. Bowers, contained 56.39 per cent of iron, 0.788 per cent of phosphorus, 0.014 per cent of sulphur, and 3.83 per cent of silica.

Much ore remains and may possibly be mined profitably in the future. Pits and shot ore on the surface indicate that the deposit extends along the crest of the ridge for about one-fourth of a mile southeast of the cut. The ore was mined with two steam shovels and was hauled on a tramroad 7 miles long to the washing plant near Rhodes Hill station.

Gambrel prospect (67).—The Gambrel prospect, just west of the Gresham mine, revealed small fragments of brown iron oxide at places on the surface and in one small pit on the crest of a ridge. Future prospecting will doubtless reveal conditions similar to that at the Gresham mine.

Hollis prospect (68).—The Hollis prospect is one-fourth of a mile west of the Gresham mine and half a mile north-northwest of Geneva. A few pits at widely separated localities on and near the crests of the hills revealed a small amount of brown iron oxide in red clay, but one pit on the south point of a hill by the roadside revealed considerable ore. Hard, compact brown iron oxide and some clay and chert were removed from the pit to a depth of 10 feet, and it is said that the ore was not passed through. Large and small fragments of ore cover the surface near the pit and are reported to occur on the surface along the crest of the hill for half a mile north of the pit.

Elting mine (69).—The Elting mine, on the crest of a ridge three-fourths of a mile south of Geneva and 1½ miles northwest of Corning, produced 25,651 tons of iron ore in 1917-18.

The mine is a north-south cut 500 feet long covering about 3 acres, and averaging between 10 and 15 feet deep. It was made in red clay in much of which there are boulders and small fragments of soft to hard chert, also a few pockets of chert pebbles and pockets of fine sand. The brown iron oxide occurs as lump and shot ore and in veins disseminated through the clay, chert, and gravel, and most of it is confined to the lower part of the cut. The ore is said to average between 45 and 48 per cent iron. All the ore that could be mined by steam shovel was considered to have been exhausted in 1918, but some ore apparently remains in the deposit. The ore was hauled on a tramroad 1.4 miles to the washer about 1 mile west of Corning.

J. B. Powell mine (70).—The J. B. Powell mine, on the crest of a ridge and adjoining the south side of the Elting mine, produced 28,618 tons of iron ore in 1917-18.

Four irregular cuts, 10 to 20 feet deep, cover about 5 acres. The ore in its character and occurrence is similar to that at the Elting mine. Apparently much ore remains but none that can be mined under present conditions. The deposit was worked by a steam shovel, and the ore was hauled over a tramroad to a washing plant about 1 mile west of Corning. It is said to have averaged between 45 and 48 per cent of iron, and phosphorus in specimens analyzed before mining was begun ran 0.80 to 1.02 per cent.

Mine of Tennessee Charcoal Iron Co. (71).—This mine, which is on the crest of a ridge half a mile southwest of the J. B. Powell mine and 1½ miles west-northwest of Corning, produced between January and March, 1918, 7,000 tons of iron ore. The mine consists of 2 cuts, 700 feet apart, their area being 1½ to 2 acres and their depth from a few feet to 15 feet. The ore, apparently of good quality, occurs as shot and lump ore in red clay containing some chert. The ore body has not been worked out, but all of it that was available for mining by steam shovel under conditions that prevailed in 1918 has been mined.

The ore was hauled on a tramroad about 2 miles long to the washing plant 1 mile west of Corning.

Robinson mine (72).—The Robinson mine, also known as the White-Littrell mine, 2 miles southwest of Corning, is an irregular cut about 1,700 feet long trending S. 70° W. along the crest of a ridge. It covers 10 acres and ranges in depth from 10 to 35 feet. The production of iron ore, 1918-20, was 134,610 tons.

The brown iron oxide occurs as shot and lump ore, in a network of thin veins, and as single veins in clay and greatly fractured chert, also as fragments in clay at and near the surface. It is generally compact and hard, but some is porous (see Plate 3, A), and some contains chert fragments. The ore is said to have averaged 45 to 48 per cent iron. The clay and chert are intermixed, but more chert occurs in the lower part of the cut than in the upper part. The clay is dark red near the surface and yellowish red in the lower part of the cut. Pockets composed of well-rounded chert pebbles, also pockets of wad, are encountered in mining, especially in the lower part of the cut. Prospect pits in adjoining areas indicate much ore still available.

The ore was mined with two steam shovels and hauled on a tramroad 1¼ miles long to the washer about 1 mile west of Corning.

Hardwick mine (73).—The Hardwick mine is on the crest of a spur three-fourths of a mile west of Hardwick station on the Tennessee Western Railroad and is 200 feet above Hardwick. The property was extensively prospected by pits, and a washing plant capable of handling 2,500 tons of ore a month was erected just north of the mine. The production of ore during 1920 was 6,500 tons. The principal cut, 150 feet long, 30 feet wide, and 20 feet deep at the deepest place, which was made by steam shovel, started on the north slope of the spur and trends S. 15° W. The north part of the cut passed through red clay with chert pebbles and fragments and with very little

ore, but the south end showed lump and shot ore in large quantity in red clay containing some chert. A smaller cut was made in ore-bearing clay 150 feet west of the one just described. Other prospect pits penetrated red clay containing chert fragments to a depth of as much as 30 feet and most of them reveal ore in minable quantity. The ore, consisting mostly of brown and some red oxides of iron, occurs in large masses and small particles and is generally free from sand. A hill just south of the mine reveals ore in the clay, but no prospecting has been done there.

Two ore-bearing tracts—one of 1½ acres, and the other of half an acre —are on the crest of a ridge about one-fourth of a mile southeast of the washing plant. The ore-bearing clay probably averages 5 feet thick over the 2 acres in these tracts and contains a fair quantity of iron ore.

J. B. Powell prospect No. 1 (74).—The J. B. Powell prospect No. 1 is on the crest of a ridge 1 mile west-northwest of Hardwick and is a westward continuation of the deposit at the Hardwick mine. Both shot and lump ore are revealed throughout the entire depth of two pits, one being 7 and the other 25 feet deep, also on the surface over about 3 acres. The ore is hard and free from sand, is apparently of good quality, and occurs in red clay containing chert fragments and pebbles.

J. B. Powell prospect No. 2 (75).—The J. B. Powell prospect No. 2 is on the crest of a northwest-southeast ridge, 1 mile west-southwest of Hardwick. Brown iron oxide occurs as lump and shot ore in considerable quantity on the surface over several acres in an old field, and was revealed in red clay in a gully and in the two small pits. It is compact and hard and mostly free from sand and gravel. The presence of chert fragments on the surface suggests that they occur in the clay. Further prospecting will be necessary to determine the size of the ore body.

Littrell-White prospect (76).—The Littrell-White prospect is on the crest of a north-south ridge on the west side of Swannigein Creek 1 mile north of its mouth. The brown iron oxide, which is generally compact and hard and consists of both lump and shot ore, occurs in red clays containing some soft chert and sand, though most of the deposit is free from these impurities. The proportion of ore in the clay, quality of the ore, and size of the deposit, which probably covers 4 or 5 acres, will apparently justify mining.

Napier Iron Works prospect (77).—The Napier Iron Works prospect is on the crest of a hill one-fourth of a mile east of the mouth of Swannigein Creek. Prospecting by pits 10 feet or less deep was done in 1910, disclosing shot ore of good quality disseminated through red clay over about 12 acres and apparently in minable quantity.

Berlin prospect (78).—The Berlin prospect is 3 miles northwest of Iron City, and although little work has been done on it, there are indications that shot ore in red clay underlies about 25 acres on the crest of a northwest-southeast ridge. Thorough prospecting, however, will probably show ore in minable quantity in only a fraction of this area.

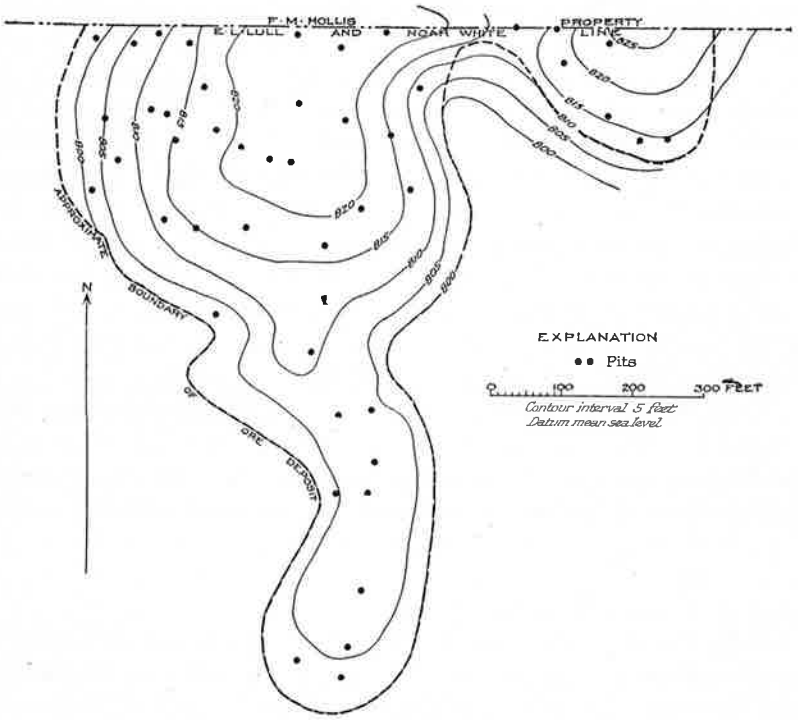


FIGURE 19.—Sketch map of pits at Lull-White prospect; approximate boundary of iron-ore deposit shown by dashed line.

Unnamed prospect (79).—A tract of prospected land is on the crest of a hill half a mile northeast of the mouth of Stults Branch, 2 miles southwest of Hardwick. Prospecting by pits over 30 or more acres, it was reported, showed an ore-bearing area of 5 or 6 acres, but showed that the iron ore, which is brown iron oxide occurring in red clay, contains too much sand to be salable under present conditions.

Lull-White prospect (80).—The Lull-White prospect is on the crest and west point of a spur, half a mile east of Butler Creek and 2½ miles west-northwest of Iron City. Figure 19 shows the location of the pits, most of which were less than 6 feet deep but some as much as 20 feet. The ore-bearing area covers about 9 acres. Most of the pits reveal ore in minable quantity, only a few of the shallow ones failing to do so. The brown iron oxide, which consists of lump and shot ore, occurs in red clay containing at places much chert, and is free from sand except in one pit near the south edge of the deposit. The excellent quality of the ore and the size of the deposit mean that the deposit can be worked successfully at some future time.

Stults prospect (82).—The Stults property, on the crest of a ridge 1 mile northwest of the Lull flint mine on Butler Creek, and 3½ miles west of Iron City, has been prospected to a small extent, and is reported to show iron ore.

Van Leer mine (83).—The Van Leer mine, also known as the Gray mine, is on the crest of the ridge between Holly and Butler Creeks, 1½ miles west-northwest of Iron City. It is on one of several adjoining tracts from which about 40,000 tons of iron ore was mined by Sam Van Leer between 1832 and 1837, most of which came from the Van Leer mine. The lump ore was separated from the clay by hand picking then placed on stacks of wood, which were burned, and was next hauled in wagons to the Van Leer furnace, a charcoal furnace operated by water power, 1½ miles southwest of the mine. (See Plate 2, B). The mine was owned for a number of years by the Sheffield Coal & Iron Co. and was sold in 1918 to J. J. Gray, Jr., of Rockdale, Tenn., for whom the property has been operated by Dr. L. J. Gray, beginning in November, 1919. It was being operated at the time of visit (April 6, 1920) by means of a steam shovel, and the area of the cut at that time was 2½ acres and the depth was 12 to 18 feet. The cut and the old and new prospect holes adjoining the cut show that the ore-bearing area comprises about 17 acres and that the ore extends at places to a depth of as much as 40 feet. Also pits in the floor of the cut show the ore to extend 8 or 9 feet deeper.

The production of the Van Leer mine from December, 1919, to March, 1920, was 8,445 tons of washed ore, and to yield this 21,870 cubic yards of ore-bearing clay were treated. This means about 0.4 ton of washed ore for every cubic yard of ore-bearing clay.

The iron ore is brown iron oxide in small and large masses, which are disseminated through red clay from the surface down to the depths just indicated. The clay at places is barren of ore and such clay is dumped by the track and is not taken to the washing plant. The ore-bearing clay contains chert fragments and boulders, particularly in the deeper parts of the openings, but much of it near the surface is free from chert so that it is left for later and deeper mining when chert will be encountered. The reason for this is that the chert-free clay will not disintegrate readily in the washing plant. The ore that was observed on the northeast side of the property is very sandy in places, and some of it is porous. Chert fragments at some places are cemented together with iron oxide. The largest of these masses and the largest chert boulders are discarded in the cut. The presence of a pink mineral in one of these discarded masses was called to the writer's attention by Dr. Gray, and specimens of rock containing it were collected and submitted to W. T. Schaller of the U. S. Geological Survey, who reports that the pink mineral is strengite, an iron phosphate. He also discovered beraunite, a reddish-brown iron phosphate, and cacoxenite, a fibrous canary-colored iron phosphate. This locality is one of the four occurrences of strengite in the United States known to the writer.

Supplementary notes.—The area occupied by the large deposits of brown iron ore on the ridge 1½ miles northwest of Iron City, as outlined by Miser on the map, Plate I, Bulletin 26, is about ¾ of a mile in length from south-

east to northwest and about half a mile in maximum width. The altitude of this tract ranges from 800 feet to 864 feet, approximately the maximum upland level in this vicinity, and is typical of the occurrence of many brown iron ore deposits in the Waynesboro quadrangle.

The Van Leer was the only mine in the vicinity of Iron City that was active from 1921 to 1927 (locality 83, Plate 27). At the time of visit by E. F. Burchard in 1923 it was operated by Dr. L. J. Gray for J. J. Gray, Jr., who has since sold it to the Tennessee Products Corporation. Ore rarely outcrops at the surface. The overburden, generally 3 to 15 feet thick, is composed of red clay and chert débris with some sand and gravel in places. The ore-bearing ground varies in thickness from a few feet to 30 or 40 feet and comprises red clay, chert débris, gravel, a little sand and light-colored clay, and limonite. The excavations have disclosed no limestone immediately underlying the ore, but limestones of Laurel, Lego, and Ridgetop ages are exposed extensively in the valleys of Shoal Creek and its tributaries near Iron City, 250 to 300 feet lower than the ore horizon.

The iron ore is limonite of the chert-replacement and conglomerate types. Most of the available limonite is in fragments in the clay and chert débris, and the quality of these limonite fragments appears generally good. Some of the limonite cements angular or rounded chert débris into large masses, and it is probable that the loose limonite found in the deposit has been derived largely from the breaking down of such masses of rock. In addition to the uncommon iron minerals, beraunite, cacoxenite, and strengite, found by Doctor Gray in this deposit and mentioned above by H. D. Miser, a mineral occurring in radiated fibrous masses similar to those of the cacoxenite, but of a dull, olive to dark-green color, was identified by C. S. Ross, E. P Henderson, and the writer as dufrenite. These hydrous phosphates of iron have been formed on the lining of cavities within limonite; they appear to be later than the iron oxide with which they are associated and show alterations from one form to another. The occurrence of iron phosphate here in definite minerals is of interest. The deposit in general carries a little more than the normal percentage of phosphorus for brown ores of the region. The Mississippian rocks immediately associated with the iron ore are not high in phosphorus, but some of the Ordovician limestones, lower in the geologic section, are distinctly phosphatic, and they may have contributed phosphate material to ascending waters, which have deposited it in the brown ores.

An interesting lens of limonite gravel overlying yellow sand was noted in the side of one of the old mine cuts. (Plate 31, A). This gravel is rounded and water-worn like ordinary creek gravel and apparently possesses the characteristics of a small placer deposit of limonite fragments reworked from a pre-existing mass of ore. This gravel is associated with deposits that may be reworked Tuscaloosa (Upper Cretaceous) material or else material of more recent derivation.

The Van Leer mine consisted, in 1923, of several open cuts, 15 to 20 feet deep and about 1,000 feet long. Stripping and removal of barren ground as well as mining ore is done by steam shovel. Prospecting was done by hand drills to a depth of 10 or 12 feet. The ore was loaded into 4-yard cars and drawn to the washer by a dinky locomotive. The washing plant was equipped with steel logs and jigs. At the time of visit preparations were being made to mine ore from levels beneath the first mine cuts, as prospecting was reported to have indicated ore at still lower levels. By selective mining and careful washing ore carrying 45 to 48 per cent iron, 10 per cent silica, and 0.5 to 2 per cent phosphorus is produced, which is shipped to the blast furnace at Rockdale. The proportions of ore, chert, and clay vary greatly from place to place. Disregarding the waste material that is too lean to go through the washer there was being produced at the time of visit, it was stated, 0.22 ton of ore from each yard of dirt washed, but at times the proportion of ore was twice as great. The ore is used in the manufacture of ferrophosphorus, and for this purpose it may carry higher percentages of silica and phosphorus than for charcoal pig iron. The ferrophosphorus is reported to carry 18 to 22 per cent phosphorus. In 1923, when the Rockdale blast furnace was under repair, ferrophosphorus was made temporarily at the former Red River Iron Co. blast furnace at Clarksville. The burden of the furnace at Clarksville is reported to have consisted of 80 tons lump phosphate rock and 55 tons brown iron ore, in addition to small quantities of iron borings, mill cinder, etc. The furnace at Clarksville has since been dismantled.

The manufacture of ferrophosphorus in the blast furnace at Rockdale, Maury County, is of so much interest and importance to the iron industry of Tennessee, that a description by Mr. James A. Barr, Mining Engineer of the International Agricultural Corporation, a large producer of phosphate rock, is quoted on pages 211-214.[35] A view of the Rockdale furnace is shown in Plate 31, B. Along with the Van Leer brown iron ore mine the blast furnace at Rockdale was acquired by the Tennessee Products Corporation.

Seavy-Lull mine (84).—The Seavy-Lull mine is on the crest of the ridge between Butler and Holly Creeks, 1½ miles west-northwest of Iron City and just south of the Van Leer or Gray mine. It is one of several adjoining tracts that were worked by Sam Van Leer between 1832 and 1837. The ore, which consisted entirely of lump or boulder ore, was hauled in wagons to Van Leer furnace 1½ miles southwest of the mine. The tract was extensively prospected by pits several years ago, and mining was begun late in 1919 by a steam shovel but later discontinued because of bad weather, 714 tons of washed ore having been produced.

The small steam-shovel cut, about 200 feet long, 8 feet deep, and less than 100 feet wide, and many pits and ore outcrops show the ore-bearing

[35]The furnace at Rockdale is described also in the Iron Trade Review, Dec. 24, 1925, pp. 1595-1596.

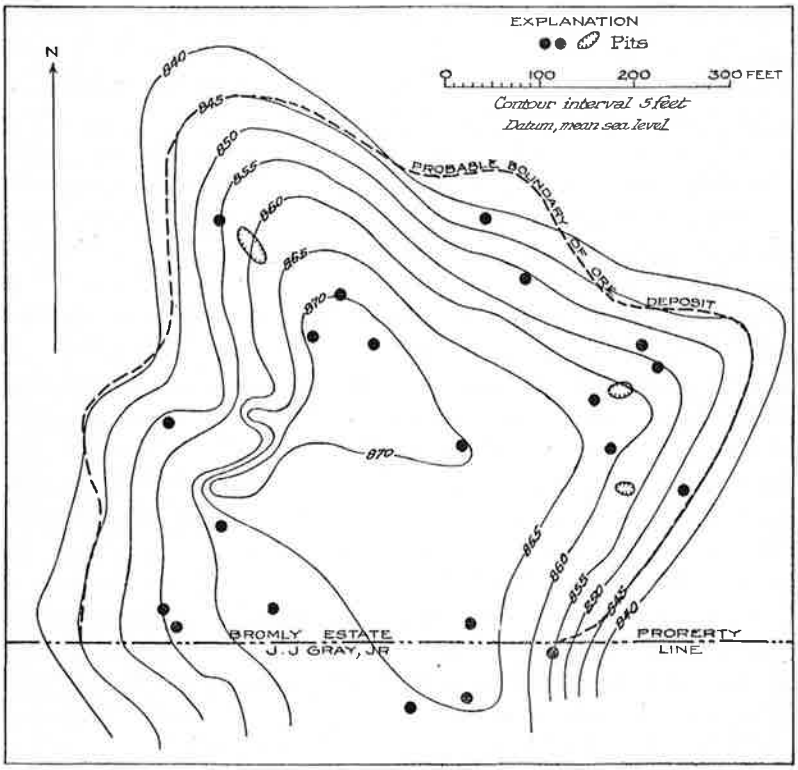


FIGURE 20.—Sketch map of probable boundary of iron-ore deposit at Bromly mine.

area to comprise approximately 20 acres, some of the deeper pits showing ore to a depth of 30 feet. (See Figure 21). The brown iron oxide, which is comparatively free from sand, consists of massive, lump, and shot ore, the finer particles occurring in red clay on the crest of the ridge to a depth of 6 to 10 feet. The more-massive ores, occurring in cherty clay in which the amount of chert increases with the depth, extend from a depth of 6 or 10 feet to as much as 30 feet below the crest of the ridge. The following are analyses of samples from recent prospect pits:

Analyses by percentage of iron ore from the Seavy-Lull mine, Tennessee

	1	2	3	4	5
Iron (Fe)	49.76	54.35	54.22	54.55	54.02
Manganese (Mn)	.....	0.48	1.08	0.51	.....
Phosphorus (P)	0.74	.98	0.92	.64	1.07
Sulphur (S)	.....	.....	.....	.....	0.014
Insoluble residue	10.00	6.30	4.90	7.25	.....
Silica (SiO_2)	.....	.....	.....	.....	6.98
Magnesium carb. ($MgCO_3$)	.41	.....	.....	.....	.....

1-4. From Purdue, A. H., The iron industry of Lawrence and Wayne Counties: The Resources of Tennessee, vol. 10, p. 384, 1912. Samples collected by Paul Seavy of Iron City; analyses by the Sloss-Sheffield Steel & Iron Co.
5. Samples collected by N. F. Drake; analysis by Paul C. Bowers.

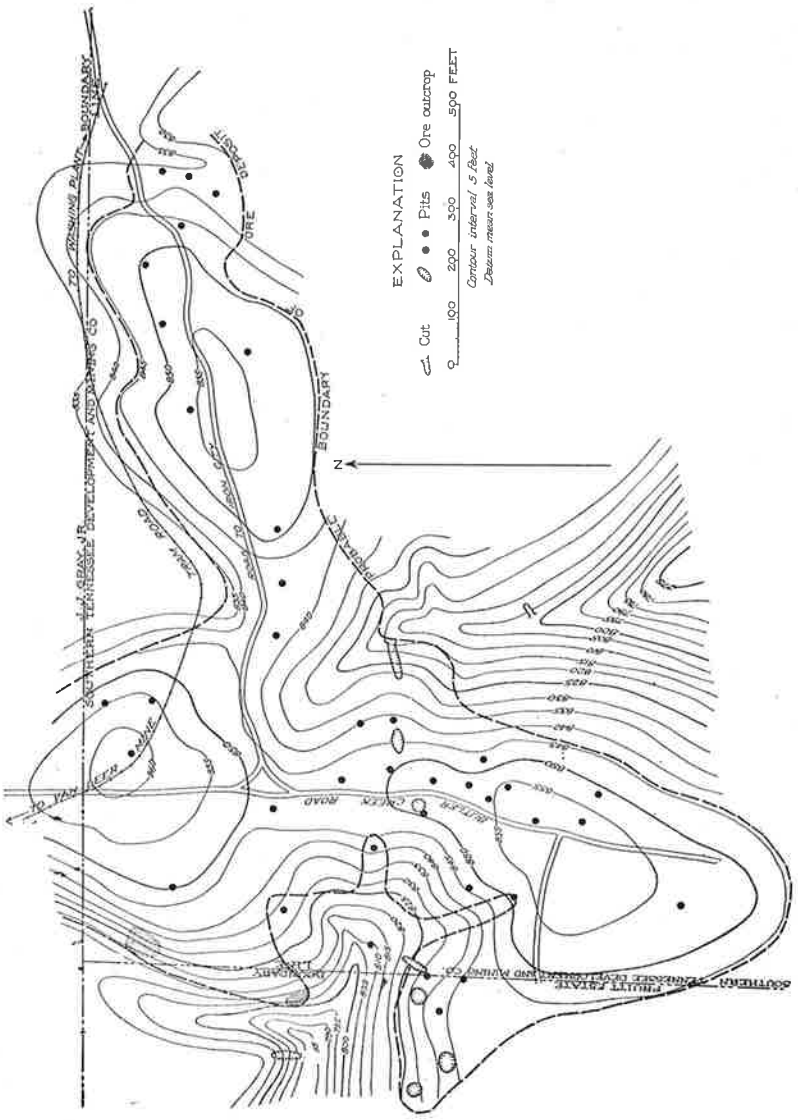


FIGURE 21.—Sketch map of probable boundary of iron-ore deposits at Seavy-Lull and Pruitt mines.

Bromly mine (85).—The Bromly mine is on the crest of the ridge between Butler and Holly Creeks, 1½ miles west-northwest of Iron City and just north of the Van Leer mine. The ore body adjoins that of the Van Leer mine and is on part of the tract worked by Sam Van Leer from 1832 to 1837. The old and new openings and surface showings indicate that the ore-bearing area probably comprises 6 to 7 acres extending to a depth of as much as 22 feet and is apparently of workable size. (See Figure 20). The ore is brown iron oxide, similar to that at the Van Leer mine.

Pruitt mine (86).—Pruitt mine adjoins the Van Leer mine on the north and Seavy-Lull mine on the east. Iron ore was mined here between 1832 and 1837 for use at the Van Leer furnace. The ore is brown iron oxide consisting of wash, lump, and massive forms like those at the adjoining mines. Although the ore is of good quality the ore-bearing area does not exceed a few acres and probably could not be mined profitably except in connection with the adjoining deposits. (See Figure 21).

Powell mine (87).—The Powell mine is on the crest of a hill 1½ miles southeast of Wayland Springs and 2½ miles northeast of Iron City. It was operated many years ago by pick and shovel and the ore was conveyed by a tramline to a small washing plant. The workings consist of two cuts: The larger, comprising 6 or 7 acres, follows the crest of a ridge with a south-eastward trend and is 15 feet deep at the deepest place; the other, comprising about 1 acre, just west of the northwest end of the large cut, does not exceed a few feet in depth.

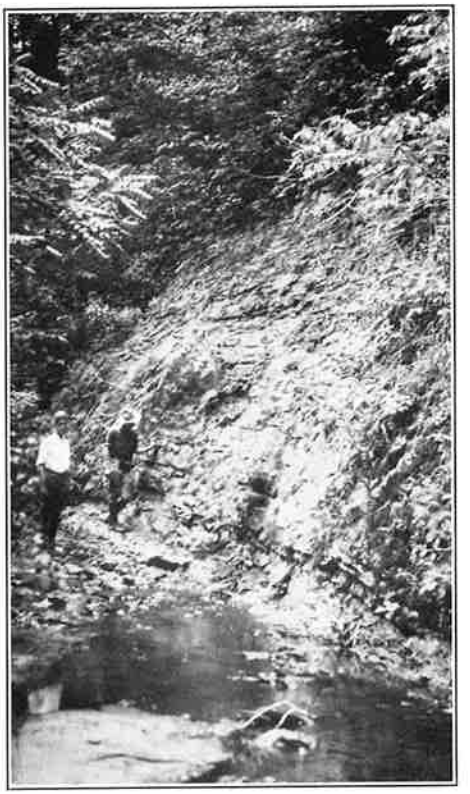
The brown iron oxide consists mostly of shot and lump ore and at places some massive ore. It is free from sand and chert fragments and is hard and compact, though the massive ore and some of the lumps are porous. Many fragments contain large cavities surrounded by a shell of iron oxide as much as 1 inch thick and are called bombshell ore. The ore is disseminated through red clay containing at places a small quantity of chert. Occurrence of ore in the bottoms and sides of the cuts and on the surface on the crest of the ridge for 350 feet southeast of the larger cut indicate that much ore remains. Deeper mining will encounter a larger amount of chert associated with the clay and ore.

Allen prospect (88).—The Allen prospect is on the crest of a hill 1½ miles northeast of Iron City and about a half a mile north of the Columbia, Florence, Sheffield Branch of the Louisville & Nashville Railroad. Several years ago 30 pits were made in the ore-bearing clay, which covers between 2 and 3 acres probably averaging 4 feet thick. Brown iron oxide consists of compact hard shot and lump ore free from sand. Although the deposit is small it can probably be worked because of its nearness to the railroad and the apparent good quality of the ore.

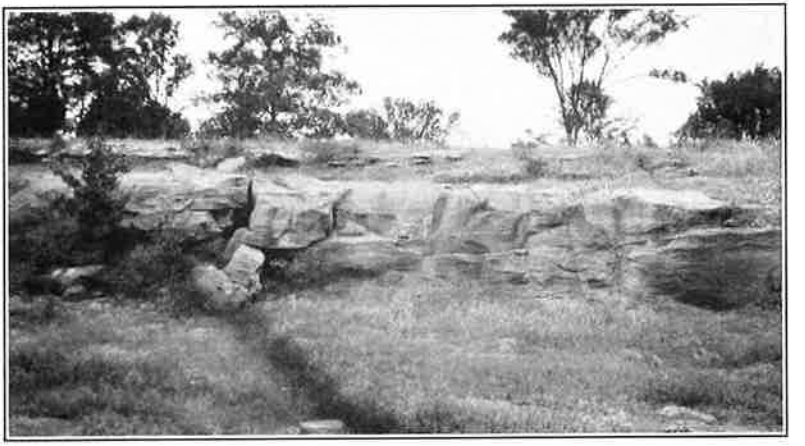
Holt prospect (90).—The Holt prospect is on the east side of Cypress Creek 2½ miles north of Cypress Inn. Several pits as much as 30 feet deep have been made in a nearly level field in the valley of a small stream running west into Cypress Creek, and others have been made on a bench south of the field and 50 to 75 feet above it.

Brown iron ore apparently of good quality, occurring as pockets and veins in clay and chert derived from the St. Louis limestone, was found in all the openings. Probably half of the ore-bearing material is ore. Most of it contains chert fragments, many of which have been largely replaced by iron oxide. An analysis of a sample collected by N. F. Drake showed 55.44

Map of Hardin County, showing localities where iron ore has been noted.



(A) Exposure of ferruginous beds in the Bear Branch limestone member, on Bear Branch, 1.7 miles east-southeast of Olive Hill, Hardin County.



(B) Quarry in ferruginous limestone in the Fernvale formation, near Baker Station, Davidson County.

per cent iron, 0.987 per cent phosphorus, 0.005 per cent sulphur, and 6.11 per cent silica.

The deposit occurs over several acres and may be worked successfully at some time in the future, if a railroad is built near it. Cypress Creek would furnish sufficient water for a washing plant.

Prospect near Cypress Inn (91).—A prospect on the east side of Cypress Creek 1½ miles north of Cypress Inn revealed iron ore in a few small pits at the base of the hill and east of the road, and ore crops out naturally for 500 feet along the hill slope in masses as much as 15 feet thick. It is hard and compact and free from sand, but some contains chert fragments and pebbles. The deposit is in clay and chert residual from the St. Louis limestone, and these are overlain by more than 50 feet of Tuscaloosa gravel. An analysis of a sample collected by N. F. Drake showed 55.44 per cent iron, 0.508 per cent phosphorus, 0.012 per cent sulphur, and 6.17 per cent silica.

Further prospecting may prove the ore body to be of considerable size and to extend into the hill underneath the Tuscaloosa gravel so that extensive operations would require underground mining. The deposit may be of value if a railroad is ever constructed to pass near it.

Other occurrences near Cypress Inn.—Brown iron oxide is exposed at the south base of a hill by the side of the road, half a mile south of Cypress Inn and just north of the Alabama-Tennessee line. The oxide exposed is small in quantity, but apparently of good quality, being hard, compact, and free from sand. It occurs in clay and chert derived from the St. Louis limestone, and some of it cements chert fragments together. Tuscaloosa gravel 50 feet or more thick caps the hill. Any prospecting should be confined to the clay and chert at and near the base of the hill, because minable iron ore is nowhere known to occur in the Tuscaloosa gravel [in Tennessee]. If a workable ore body is revealed, underground mining would probably be necessary because of the thickness of the overlying gravel. Iron oxide occurs in the bed of a small stream southeast of the above-described locality also on the hill slopes southeast of the stream, where it forms the cementing material of a gravel conglomerate.

Other occurrences in the Waynesboro Quadrangle.—Iron oxide is exposed along the wagon road from Flatwoods eastward for about 1 mile. It cements together chert fragments and occurs as loose masses on the surface and as veins and pockets in the Fort Payne chert and in chert derived from the St. Louis limestone. Veins of such iron oxide, 1½ inches thick, occur in the lower part of the Fort Payne chert near Bells Ford on Buffalo River.

The Tuscaloosa gravel, at many places cemented together by the iron oxide, forms masses on hard conglomerate, which are especially abundant at or near the base of the gravel. They are very resistant and form projecting ledges, one of which near Stout in the southwest corner of Waynesboro quadrangle forms a bluff 30 feet high.

Very small particles of iron oxides occurring on the surface of the crests of the ridges in the east half of the quadrangle are sufficiently abundant at some places, as at the head of Couch Branch and near Dogwood Mudhole, to give a brown color to the soil. They are generally associated with gravel present on most of the ridges but are not thick enough or widespread enough to be represented on the map, Plate 27.

Production of iron ore.—The production of iron ore in the Waynesboro quadrangle from 1832 to 1920, inclusive, is given by H. D. Miser as aggregating about 5,405,000 tons. The production by mines is summarized in the following table, the figures having been taken in part from articles by A. H. Purdue[36] and E. L. Lull[37], but most of them were obtained by Miser from the mine operators.

There is an apparent inconsistency between the total of 5,405,000 tons given in the following table for the years, 1832 to 1920, and the total of 5,301,599 tons given on page 221 for Wayne and Lawrence Counties for the years 1797 to 1930. This is due, in part, to the fact that the production of the Percy mine, in Lewis county, is included in the larger total in the following table, whereas in the general table on page 221 it is included in the total given for Lewis County. Many of the figures obtained by Miser from the mine operators are well-rounded totals, which are likely to be larger rather than smaller than the actual production. On the other hand, the statistics collected by Government and State agencies from 1896 to 1927 are almost certain to be below the actual production, on account of failure to obtain reports from every producer every year.

Production of iron ore in the Waynesboro quadrangle, Tennessee, 1832 to 1920 inclusive

	Tons
Allens Creek mines (28)*a*	1,255,693
Percy mine (29)	469,481
Wayne furnace mines (East Furnace Ridge mine (32); West Furnace Ridge mine (33); Nigger Ridge mine (34); Lee Ridge mine (36); Broach mine (37); Keaton Springs mine (38); Perigo mine (39); Irontop mine (40); Murphy mine (41); Crews mine (42); Sapling mine (43); West mine (44); Lee Hollow mines (45))	145,000
Wright mine (53)	506,000
Pinkney mine (54)	962,500
Ironsides mine (55)	650,000
Sharp mine (56), Burkett mine (57), Wisdom mine (58), Drake mine (59)	400,000

[36]Purdue, A. H., The iron industry of Lawrence and Wayne Counties: Resources of Tennessee, vol. 2, No. 10, pp. 370-388, Oct., 1912.

[37]Lull, E. L., An important southern ore field: Iron Age, vol. 90, No. 25, p. 1423, Dec. 19, 1912.

Hessemer No. 1 mine (61)	170,000
Hessemer No. 2 mine (60)	130,000
Little Hill mine (62) / Dodd mine (63)	150,000
Couch mine (65)	196,000
Gresham mine (66)	65,138
Elting mine (69)	25,651
J. B. Powell mine (70)	28,618
Mine of Tennessee Charcoal Iron Co. (71)	7,000
Robinson (White-Littrell) mine (72)	134,610
Hardwick mine (73)	150*b*
Van Leer mine (83) / Seavy-Lull mine (84) / Bromley mine (85) / Pruitt mine (86)	40,000*c*
Van Leer mine (83)	8,445*d*
Seavy-Lull mine (84)	714*e*
Powell mine (87)	50,000*f*
Cedar Point mine (89)	10,000
Sanders mine (92)	(*g*)
	5,405,000

*a*Numbers refer to location on map, Plate I.
*b*Production before April, 1920.
*c*Production, 1832-1837.
*d*Production, from Dec., 1919, to March, 1920, inclusive.
*e*Production in 1919 and 1920 prior to April, 1920.
*f*Production not known, but estimated by H. D. Miser.
*g*Production not known.

HARDIN COUNTY

It is a question whether or not Hardin County should be considered as actually within the Western Highland Rim. The altitude of the higher points in the county is lower than that of the Highland Rim in general, because of their proximity to Tennessee River, but the most important criterion in this connection is the distribution of geologic formations within the county. The rocks associated with the typical brown iron ore deposits of the Western Highland Rim are cherty limestones of Mississippian age or their weathered residues, and in Hardin County these rocks occupy only small areas. The rocks that form the upland surface of the county are principally Cretaceous sands, gravels, and clays, and in the lower lands there are terrace deposits and stream alluvium of Quaternary age. Devonian, Silurian, and Mississippian rocks, consisting of limestone, chert, sandstone, and shale, outcrop chiefly in narrow areas in the valleys of creeks on the east side of Tennessee River. The geologic map of Hardin County shows the distribution of the rocks in Hardin County, and a detailed although generalized section of these rocks by Dr. Willard B. Jewell is given below:

Preliminary generalized section of the rocks in Hardin County, Tennessee

System	Serie	Formation	Member	Thickness (feet)	Lithologic Character
Quaternary	Recent	Alluvium		0–40	Sands, silts, clays, and gravels
	Pleistocene	Terrace gravels	Unconformity	0–80	Chert and quartz gravels with sands and clays
Cretaceous	Upper Cretaceous	Selma clay		100+	Light-gray to nearly white, sandy micaceous, calcareous clay with some greensand
		Eutaw formation	Coffee sand	200+	Micaceous, cross-bedded, variegated sands with carbonaceous clays and some greensand
			Tombigbee sand	60+–300+	Red and purplish, micaceous, cross-bedded sands and light-gray clays with some gravel lenses and variegated sands
		Tuscaloosa formation	Unconformity	0–100+	Chert gravel and sand with some clay
Carboniferous	Mississippian	Warsaw formation		0–55+	Deeply weathered fossiliferous white chert, tripoli, and clay with some limonite
		Fort Payne chert[a]		0–125+	Light-gray slightly calcareous chert. Usually deeply weathered to white and yellowish porous chert, tripoli and clay with some limonite
		Ridgetop shale[a]	Unconformity	0–110+	Dark fissile shale and dense, tough dark-gray limestone with black flint nodules
			Maury glauconitic	6	Green phosphatic sandstone and shale
Devonian or Carboniferous		Chattanooga shale	Unconformity	0–25	Black carbonaceous shale with some thin, dark, cross-bedded sandstone layers and lenses
			Hardin sandstone	0–16	Light to dark gray cross-bedded marcasitic, phosphatic, fine-grained sandstone
Devonian	Lower Devonian	Harriman chert	Unconformity	0–40+	Thin-bedded brittle, buff to gray chert or novaculite
		Quall limestone	Unconformity	0–10+	Heavy-bedded, dense, cherty, gray limestone
		Decaturville chert	Unconformity	0–2	Porous, gray, fossiliferous chert
		Birdsong shale	Unconformity	0–8+	Deeply weathered light-gray clay and thin chert beds
		Olive Hill formation	Unconformity—Flat Gap limestone	0–53	Massive, crystalline, stylolitic, light to pinkish gray limestone
			Bear Branch limestone to north; Pyburn limestone to south	0–45+	Bear Branch limestone is a massive, cross-bedded, ferruginous, reddish limestone. Pyburn limestone is impure, cherty, massive to thin-bedded, dark-gray limestone, cross-bedded in places; 0–40 ± feet thick
			Ross limestone	0–60+	Dense, tough, cherty massive to thin-bedded, dark-blue siliceous limestone
		Rockhouse shale		0–26	Gray shale and shaly limestone

[a]The Fort Payne chert of Charles Butts, Geology of Alabama: Alabama Geol. Survey Special Rept. No. 14, 1926, probably corresponds in age to Fort Payne and Ridgetop of Hardin County, Tenn.

		Decatur limestone	Unconformity	0–60	Massive to thin-bedded, stylolitic, dense to crystalline, light-gray to pinkish limestone
		Brownsport formation	Lobelville shaly limestone	0–40	Thin-bedded, cherty, brownish to gray dense limestone, shaly or crystalline or pyritic in places
			Bob crystalline limestone	0–20	Massive, crystalline, stylolitic, light-gray to white limestone. Rarely somewhat cherty
			Beech River shaly limestone	0–45+ —	Thin-bedded, brownish-gray, shaly limestone and gray and greenish shale. Limestone occasionally glauconitic, pyritic, or cherty
		Wayne formation	Dixon earthy limestone	0–40+ —	Thin-bedded, red, earthy limestone (in places mottled and blotched with greenish limestone) and red and greenish shale
			Lego limestone	0–36+ —	Heavy-bedded, stylolitic, dense, tough, light-gray to pinkish-gray limestone. Occasionally pyritic
Silurian			Unconformity[b] Waldron clay	0–1½	Gray clay and shaly nodular limestone
			Laurel limestone	0–35+ —	Heavy-bedded, stylolitic, dense, tough, light-gray to pinkish-gray limestone
			Osgood (?) earthy limestone	0–9+ —	Pinkish limestone and gray shale
		Brassfield limestone	Unconformity	0–25½	Thin to heavy-bedded, dense, greenish-gray, glauconitic limestone in upper part. Massive, glauconitic, ferruginous, brown limestone in lower part
	Upper Ordovician	Fernvale limestone	Unconformity	0–10+ —	Thin-bedded, crystalline, brownish-gray limestone and gray shale.
Ordovician	Middle Ordovician	Hermitage formation		60+	Dense, tough, blue limestone and interbedded dark fissile shale

[b]Unconformity local in the vicinity of Savannah, where the Lego limestone rests unconformably upon the Hermitage.

In the summer of 1927 an economic survey of Hardin County was made by Dr. Willard B. Jewell[38], of the Department of Geology, Vanderbilt University, assisted by Mr. T. G. Andrews. This survey was carried on through the co-operation of the State Geological Survey and the County Court. The State Geologist, W. F. Pond, and E. F. Burchard visited Hardin County in August, 1927, and examined certain showings of iron ore and other ferruginous rocks. In the course of the economic survey Doctor Jewell examined practically every outcrop or other surface showing of iron-bearing material that he found or that was brought to his attention. The localities at which indications of iron occur are shown on the map of Hardin County, Plate 32. Their numerical order is geographic, beginning in the northwest part of the county, in order to facilitate finding the localities on the map. Doctor Jewell's notes concerning the surficial character of each ore

[38]Jewell, W. B., The geology and mineral resources of Hardin County, Tennessee: Tennessee Div. Geol. Bul. 37, 1931, 117 pp.

showing are given below, as edited and arranged by E. F. Burchard to suit the requirements of this bulletin.

POSSIBLE IRON-ORE LOCALITIES

(Doctor Jewell considers localities 19, 23, 24, 28, 33, 35, 39, 40, and 44 the most promising for further prospecting.)

1. Small amounts of sandy float rock of low iron content were noted in the Selma clay in roadside gullies six-tenths of a mile[39] north of Old Hurricane Church and two-tenths of a mile south of the Hardin-Henderson county line.
2. On Squire Newman's land bombs of sandy limonite 1 to 2 inches in diameter occur in the Coffee sand. They appear most thickly scattered along the sides and bottoms of rain gullies one-tenth of a mile west of Newman Cemetery and 5.2 miles north-northwest of Saltillo.
3. Some sandy shot limonite occurs in the Selma clay one-tenth of a mile directly west of Morris Chapel, along the north side of the road.
4. Sandy shot limonite from the Selma clay was noted on both sides of the road 2.2 miles south of Morris Chapel.
5. On east side of a small hill on both sides of the road, 3.3 miles west of the intersection of highways 45 and 69, a small patch of fair-grade float limonite has been derived from the Selma clay. Some of the float is massive, some porous, and some sandy. None of the fragments are more than 8 or 9 inches in greatest diameter. The Selma Clay is weathered here to a brownish-yellow loam.
6. One hundred yards southeast of Goodman's filling station in Shiloh Park, low-grade siliceous float limonite from the Eutaw sand (Tombigbee) was noted in the rain gullies on the slope south of the road.
7. Considerable low-grade sandy float limonite and shot ore derived from the Eutaw sand (Tombigbee) occur by the roadside on the east side of a hill 2.1 miles east-northeast of Pine Rest Hotel, in Shiloh Park.
8. Considerable sandy float and shot limonite have weathered out of the Eutaw sand (Tombigbee) in the vicinity of Mount View School. The float occurs on the hill slopes and in the bottom of the stream gullies as well as on top of the flat ridges.
9. Small amounts of float limonite formed by replacement of the Fort Payne chert was noted in the head of a small stream on the north side of the ridge road, 1.1 miles north of highway 15, and 1.7 miles east-southeast of Bethlehem.
10. Good-looking float limonite was noted down the road from Cross Roads Chapel to Smith Fork, which has evidently been washed down from the overlying Tombigbee sand.

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[39]Distances are measured in an air line on the map.

11. Small limonite bombshells washed out of the Eutaw sand were noted on the hillsides 1.3 miles east of Whitlow.

sand were noted on the top of the hills and ridges 2.1 miles north of

12. Shot ore and very low grade sandy float limonite from the Tombigbee highway 15, and approximately 1 mile southwest of Smith Fork.
13. Oolitic hematite is present in the Bear Branch limestone member of the Olive Hill formation. A good exposure of this phase of the formation was found on the left side of Bear Branch about 1.7 miles east-southeast of Olive Hill. (See Plate 33, A). At this place 35 feet of beds are exposed just above low-water level, displaying the following section. The beds dip about 3°-4° W-NW. The analyses that follow the section indicate the composition of the exposed lower portion of the beds:

Section of rocks exposed on Bear Branch, 1.7 miles east-southeast of Olive Hill.

Formation	Member	Thickness (feet)	Lithology
Chattanooga shale		15+	Top not exposed. Black fissile shale.
	Hardin sandstone	12	Very dark, marcasitic, phosphatic, cross-bedded sandstone.
—Unconformity			
	Bear Branch limestone	10	Distinctly bedded, slightly ferruginous, gray limestone.
		25	Massive, ferruginous, reddish-brown limestone
Olive Hill formation			
	Ross limestone	2+	Base not exposed. Thin-bedded, cherty, dense, bluish-gray, siliceous limestone.

Analyses of Bear Branch limestone, locality 13, Hardin County.[a]

No. of sample and height above Ross limestone	Silica (SiO_2)	Ferric oxide (Fe_2O_3)	Alumina (Al_2O_3)	Calcium carbonate ($CaCO_3$)	Magnesium carbonate ($MgCO_3$)	Iron (Fe) (calculated)[b]
21) 25 feet 3 inches	3.86	33.22	2.62	59.42	0.60	23.25
20) 24 feet						
19) 23 feet 5 inches	1.88			92.80	.62	4.76[c]
18) 22 feet 2 inches						
17) 21 feet 3 inches	4.90	44.97	4.17	44.05	1.76	31.48
16) 19 feet 11 inches	4.46	33.88	2.84	56.11	2.82	23.72
15) 18 feet 3 inches						
14) 17 feet 3 inches	4.88	38.16	3.42	51.35	1.87	26.71
13) 14 feet 8 inches						
12) 13 feet 3 inches	3.72	28.30	2.96	62.66	2.45	19.81
11) 12 feet 5 inches	5.64	18.80	3.28	70.36	1.78	13.16
10) 11 feet 4 inches	1.46	8.09	3.87	84.69	2.01	5.66
(9) 10 feet 8 inches	4.88	37.18	2.46	53.41	1.90	26.03
(8) 9 feet 6 inches	4.80	37.23	2.37	53.57	1.94	26.06
(7) 8 feet 7 inches	5.38	35.82	2.54	53.69	2.42	25.07
(6) 7 feet	2.88	20.77	3.15	71.08	2.18	14.54
(5) 6 feet 1 inch	3.02	6.88	2.92	85.55	1.50	4.82
(4) 5 feet	4.60	29.74	3.12	60.41	2.02	20.82
(3) 4 feet	4.42	17.43	0.85	75.31	2.04	12.20
(2) 2 feet 11½ inches	7.24	30.74	3.04	57.14	1.96	21.52
(1) 1 foot	2.84			90.98	2.04	3.96[d]

[a] D. F. Farrar, analyst. Samples obtained by Doctor Jewell.

[b] Phosphorus was determined from a composite sample made by mixing equal portions of every other sample and ran 0.08 per cent.

14. Small pieces of float and shot limonite occur near the base of the Tombigbee sand by the roadside 1.5 miles northeast of Mount Herman Chapel.
15. Andrew Abel's place. Very low grade float limonite from the Tombigbee sand also from the Tuscaloosa gravel occurs scattered over the hillside west of Mr. Abel's barn, about 1.5 miles north of highway 15 and 1 mile east of Steel Creek.
16. On the west side of Smith Fork about 1 mile south-southeast of Union Chapel and School small shot ore and small float limonite were observed in the Tombigbee sand on the east slope of the ridge that divides Smith Fork from Boone Creek.
17. Along the road 1.7 miles south of Thompson's store, on the east side of Smith Fork, occurs a thickness of 45 feet of Fort Payne chert. The float shows that a portion of the chert has been partly replaced by limonite, forming a breccia. The small amount of float limonite would not indicate a large deposit. The material (if ore) is also of very low grade, as it contains a large amount of unreplaced chert.
18. On Judge Watson's land 3 miles south of Thompson's store a very little low-grade float limonite replacement of the Fort Payne chert was found in the bed of a stream. The valley of this stream is called "Baugus Hollow" by the local residents.
19. There is a pocket of limonite 1.1 miles southeast of Old Town on M. L. Hosey's land, just across the road from Mr. Hosey's barn. The pocket is in the base of the Tombigbee sand just above its contact with the Silurian limestone. It is about 7 feet long and 20 inches wide and is very irregular in outline. Small bombs of limonite up to 14 inches long also occur as float in the washes close by.
20. Shot ore and fair-looking float limonite from the Tombigbee sand was noted along the north side of the road at Covey Chapel.
21. On the hill that rises directly behind Burnt Church and School limonite float, principally of the bombshell type, occurs near the top of the hill, which is capped by Tombigbee sand. None was seen in place and the amount of float is small.
22. At A. K. Irwin's place, on the west side of Choate Creek, float limonite along the hillside evidently has been washed down from the Tombigbee sand, which caps the hills and ridges in this vicinity. This is approximately 1 mile north-northeast of the Seaton prospect (23), and three-tenths of a mile up the creek from the Pinhook road.
23. On the west side of Choate Creek about 1.2 miles south-southwest of Burnt Church is the former Nunley Crotts place, now owned by R. D. Seaton. At a point 250 feet southeast of Seaton's saw mill, at the base of the hill, in the lower part of the Tombigbee sand just above

its contact with the Silurian limestone is an occurrence of limonite, apparently as a pocket in the Tombigbee. Some of it was deposited in shells around limestone boulders. There is a little black material (wad, or impure manganese oxide) associated with the ore. The ore outcrop shows a thickness of five feet and about the same length and is apparently in place, although this is not certain as no prospecting has been done. Float limonite is thick around the base of the hill on either side. Fragments of white chert lying around may indicate the presence of a little Fort Payne chert, though none is exposed. There is a possibility that the ore may be a pocket in the latter formation, though from the appearance of the ore this is considered unlikely.

24. Bombs of limonite occur on Herbert Reynold's place, on the south side of Turkey Creek about eight-tenths of a mile southeast of Burnt Church. The bombs are scattered over the lower slope of the hill a few hundred yards south of the Reynold house and are rather abundant in the first ravine southeast of the spring back of the house. They apparently come from the Tombigbee member of the Eutaw sand near the base. They are generally hollow but some contain clay or sandy clay around which the limonite has been deposited in a thin shell up to 1 or 1¼ inches thick. Most of the bombs are rather small, but several were noted that had a maximum diameter of 20 inches. No ore was seen in place.

25. On the south side of Little Turkey Creek 1.3 miles east of Burnt Church considerable float limonite occurs in the gullies and along the slopes, evidently having been washed down from the Tombigbee sand, which caps the divide between Turkey and Little Turkey creeks.

26. On the north side of Turkey Creek one-fourth of a mile west of the road between Gillis Mills and Thompson's store, 25 feet of Tuscaloosa gravel overlies the Fort Payne chert. The lower portion of the gravel is firmly cemented by limonite into a very hard, coarse conglomerate, though some seams are more firmly cemented than others. There is not enough limonite here to make ore, unless there be richer pockets that are covered.

27. On the east side of Choate Creek, a little less than a mile north of Tom Irwin's place and about 1.6 miles south of Burnt Church, there is a very little limonite float on the hillside, apparently washed down from the Tombigbee sand.

28. At the northeast side of the road, on Tom Irwin's place 2.1 miles south of Burnt Church, there is a large showing of float limonite, much of which is of good quality. This float extends southeastward down the hill slope but becomes scarcer and finally disappears above the level of the creek. The limonite occurs near the base of the Tombigbee sand.

29. Float limonite from the Fort Payne chert and the Tombigbee sand appears along the south side of the valley and in the creek bed for four-tenths of a mile east of the middle Savannah road, on Tom Irwin's place. This locality is about 2.4 miles south of Burnt Church.
30. About 1 mile southeast of Ross Mill on the Ross farm, on the east side of Horse Creek 5½ miles southeast of Savannah, shot ore and small pieces of float limonite occur scattered over the surface about the middle of the Tombigbee sand. None was seen in place.
31. Shot ore and small pieces of float limonite were noted on the hill slopes about one-tenth of a mile east of the middle Savannah road, approximately 1.2 miles north-northwest of Lowryville. This material has evidently been derived from the red Tombigbee sand.
32. Low-grade siliceous limonite float from Tombigbee sand was noted on the hillside west of W. J. Frank's residence two-tenths of a mile east of Gillis Mills.
33. Half a mile north of Abram Chapel, on the north side of Horse Creek on land belonging to W. J. Franks, the hill slope is thickly scattered with float limonite. This material has replaced chert of the St. Louis limestone. Some of the fragments are 2 to 3 feet across and several inches thick, though most of the pieces are much smaller. No ore was seen in place, but the large quantity of float would possibly warrant prospecting.
34. Three-quarters of a mile up Perry Branch from Horse Creek and 1.3 miles south of Gillis Mills there is considerable sandy low-grade limonite float from the Tombigbee sand scattered over the hill slopes.
35. Along the hillside on W. J. Frank's place, at the southwest side of Horse Creek, one-quarter of a mile west of the Wayne County line, there is apparently the outcrop of a pocket of brown ore in place. No prospecting has been done, and the rock may be merely a boulder. It is 3 feet thick where exposed and is uncovered laterally for 4½ feet. The material represents a replacement of the chert in the St. Louis limestone. There are small seams and pockets of limonite exposed by the roadside a few hundred feet east. There is also considerable limonite in the overlying Tuscaloosa gravel at this point. This area might also be worth prospecting.
36. On the north side of Left Fork of Whites Creek, 3.5 miles southeast of Gillis Mills, low-grade float limonite was observed, probably derived from the Tuscaloosa gravel.
37. A little shot ore and limonite float from the Tombigbee sand occur on the side of the hill half a mile south-southwest from Lowryville.
38. A few hundred feet east of Arthur Stansel's house, at the "Burnt Stand" in the gully at the side of the road, a 6-inch layer of brown limonite occurs in the base of the Fort Payne chert at its contact with the

Ridgetop shale. The upper 2 to 3 feet of the Ridgetop is slightly leached to a dirty-white clay. The limonite bed is an incomplete replacement of the Fort Payne chert.

39. At the top of the bluff along the Tennessee River between How and Bluff Branches and along the lower slopes on land belonging to Arthur Stansel, there are large quantities of low-grade sandy limonite float washed down from the Tombigbee sand, which caps the hills and ridges here. Some of the boulders are 3 feet in diameter, though most of them are much smaller. A very large percentage contains too much sand to be of value as an iron ore. This area north of Pyburn bluff might bear prospecting for richer pockets.
40. One-tenth of a mile west of the main road from Walnut Grove to Savannah and about 2 miles north of Duncan's landing, on the northeast side of a small branch tributary to Bruton Branch, there is a bluff 10 feet high composed of deeply weathered porous Fort Payne chert. A small portion of the chert here has been partly replaced by limonite, forming a breccia. It may be that concentrated pockets of ore could be found by prospecting in this vicinity.
41. On the hillside west of Holland Creek, eight-tenths of a mile south of the Lowryville-Savannah road there is a very little float from the Fort Payne chert, which has been partly replaced by limonite.
42. Shot ore and small pieces of float limonite as large as a man's fist occur along the ridge north of Pompey Branch, about eight-tenths of a mile east of the Walnut Grove-Savannah road, and are residual from the Tombigbee sand, which caps the divide north of Pompey Branch. Most of the float is very sandy.
43. On the north side of Pompey Branch a little over a mile from the main river road there is a very little limonite deposited in the Hardin sandstone, in the vicinity of a slightly crushed zone on the east side of a fault having 50 feet to 70 feet throw. There is not enough ore to be of any importance. The Hardin sandstone butts up against the Fort Payne chert on the west side of the fault, the Ridgetop shale being cut out. Float limonite (replacement of Fort Payne chert) is scattered sparsely over the hillside on the west side of the fault.
44. On the north side of Pompey Branch 1.5 miles from the main river road a woods road leads off to the north up a small branch tributary to Pompey Creek. One-tenth of a mile up this woods road, on the east side of the small branch, a bluff of deeply weathered porous Fort Payne chert is exposed for a thickness of 6 feet, 20 feet above the bottom of the small branch. The rock in place contains a considerable quantity of limonite as a complete or partial replacement of the chert, but its distribution is very irregular. On the small talus below the bluff and in the bed of the stream very striking blocks of solid limonite

occur, 2 to 3 feet in length and up to 1 foot thick. Some of them show a mammilary surface. One or two of the partly covered blocks in the stream bed look as if they might be in place. If so, there would be 20 feet or more of ore-bearing rock here. Most of the chunks have undoubtedly broken off from the bluff above. Many of the float blocks contain considerable incompletely replaced chert fragments. One-tenth of a mile farther up the branch the Fort Payne chert contains practically no limonite, so that the pocket is only a local concentration. No prospecting has been done. This showing is considered as indicating one of the most promising points to prospect that has been noted anywhere in the county. The land belongs to Bill Williams.

45. Much sandstone cemented with iron oxide residual from the Tombigbee sand was observed on the hill slopes north of the Dry Creek road 4 miles east of Paulk's store, and some of the float passes into low-grade sandy limonite.

46. A very little limonite in the deeply weathered porous Mississippian cherts, probably Fort Payne, was noted along the roadside southeast of the Florence-Walnut Grove road, approximately 4.5 miles south-southeast of Lowryville.

47. On the east side of Bumpus Creek and about six-tenths of a mile north of the Alabama line there is some low-grade limonite float from the Tuscaloosa gravel, which is 28 feet thick here. The overlying Tombigbee sand also contains some sandy limonite float. Nothing was seen here to indicate ore of value. This is probably on land comprised within an area on which timber cutting was begun on a large scale a few years ago.

48. One mile southeast of Duncan's Chapel and School 90 feet of Tuscaloosa gravel overlies St. Louis limestone. There is some limonite in both formations. In the Tuscaloosa the limonite is of very low grade, occurring as a ferruginous cement of the gravel, and in the St. Louis it consists of small pockets and seams a few inches thick as a replacement of the chert. No sign of prospecting was seen anywhere in this southeast section of Hardin County, although the narrow-gage timbering railroad, which has been torn up, ran all around this vicinity. It was reported that the rails were torn up and timbering activities discontinued by Hubert F. Young in 1924.

The southern part of the Young timber property was examined in April, 1923, by R. W. Smith, who made a trip of one day in a Ford car accompanied by Mr. Young. Mr. Smith states that at a number of places there were surface evidences of iron ore, such as very red soil, and "shot" ore. One outcrop near the south edge of the property, near the head of a fork of Bumpus Creek, showed 8 to

10 feet of fragments of chert cemented together and partly replaced by limonite. No good-grade iron ore was found in the outcrop. No other good outcrops were seen, but a number of pieces of iron ore were found at various places, all of them of the same character as the outcrop mentioned above or else "peanut-candy" ore, composed of rounded pebbles of chert cemented together by iron oxide.

McNAIRY COUNTY

McNairy County is in the Coastal Plain area of West Tennessee well beyond the western border of the Western Highland Rim. The county does not contain deposits of iron ore of the same geologic associations as those of the latter area, but the presence of certain iron-bearing materials was called to the attention of the State Geologist and the writer in the summer of 1927, and a visit was made by them to one locality on August 10, 1927.

The iron-bearing material examined is in the vicinity of Oxford School and Prospect Churches, on the lands of William Hockaday, W. H. Wolf, and others, in District 6, 4 to 5 miles east-southeast of Selmer. The iron-bearing material is impure limonite, occurring as a cementing material in gravel and in ledges in place, and in lumps, slabs, concretions, and a variety of forms usually exhibited by limonite found in the sediments of the Coastal Plain. The material occurs at a fairly definite horizon in the Ripley formation, of Upper Creataceous age, which is composed of calcareous and glauconitic sands, clays, and marls, of marine origin. The limonite possesses characteristies similar to deposits of this material in Mississippi, Louisiana, and Texas that have been altered from siderite. Its association with glauconitic beds is also similar to that of the material in these States, and lends support to the belief that glauconite has played an important part in contributing iron toward the concentrations that now exist. The general dip of the beds is low toward the west-southwest, so that the lower beds of the Ripley formation pass below the McNairy sand member a short distance west of this locality.

In its natural state the limonite probably contains too much silica to yield iron ore in commercial quantity and grade. Small quantities could be obtained by selective mining, but operations on a commercial scale would require crushing and washing of the material in order to reduce the silica and alumina. Mr. J. H. Walker, of the Tennessee Products Corporation, at Nashville, reports that samples of the crude ore from several deposits have been found to carry about 42 per cent iron, 20 per cent insoluble material, phosphorus 0.08 per cent (generally below the Bessemer limit of 0.10 per cent), and manganese 0.17 per cent. It was planned to ship a few carloads of average iron-bearing material from this locality to the ore washer at the Johnson mines near Wrigley, Hickman County, for experimental washing. If washing the material succeeds in bringing it up to satisfactory grade, say, 48 per cent iron, and if a sufficient quantity can be obtained at reasonable

cost, the material would appear to have possibilities as a source of low-phosphorus ore, which is highly desirable for use in making charcoal pig iron at the Wrigley blast furnace.

These deposits of limonite are from a few feet to 25 feet below the tops of the ridges and the flat inter-stream areas, generally 50 feet or more above the neighboring ravines, and at a greater height above Oxford, Crooked, and other creeks, between which they lie. Their general altitude is probably nearly 500 feet above sea level; that of the Mobile & Ohio Railway at Selmer is 441 feet. The outcrops of the ledges are confined to places where erosion has been active, at the brows of the hills, but there is much float in places on slopes and in ravines, which can be traced back to the ledges of limonite. Some of the float is of very high quality ore. The overburden consists of soil, sand, and clay, 1 foot to 12 or 15 feet thick.

The deposits range in area from a few square yards to several acres, and in thickness from a foot to 2½ feet where noted. A considerable number of test pits have been dug, and the continuance of the ore-bearing ledge from one side of a ridge to another has been demonstrated, but in some of the wider interstream areas it seems doubtful whether the ore occupies more than a belt bordering the crest of the hills. The visit of inspection was so brief that not all the prospects in the vicinity could be examined, nor could areas south of Oxford Creek, reported to be ore-bearing, be seen, consequently no attempt can be made to estimate the reserves of iron-bearing material.

The mineral rights on about 5,000 acres of land in this vicinity are said to be under option to persons in Florence, Ala., but local parties consider that only about one-sixth of this acreage probably contains limonite. It is obvious that the area of the limonite is limited by its geologic and topographic relations to the higher portions of a rather narrow belt of country, the surface of which is underlain by the Ripley formation. This formation appears to attain its widest area of outcrop in this part of McNairy County, but extends toward the north-northeast into Chester and Henderson Counties, as shown by the geologic map of Tennessee, published by the State Geological Survey in 1923.

FERRUGINOUS LIMESTONE

As has been indicated earlier in this bulletin in the discussion of the general geology and of the industrial developments there is an abundance of good limestone available for blast-furnace flux (see pages 19-22). There remains to be mentioned the occurrence of ferruginous limestone, which if used as a flux may contribute an appreciable percentage of iron to the blast-furnace charge. Areas of limestone of this description in Hardin, Davidson, and Lawrence Counties have come to the attention of the writer, and others may exist.

HARDIN COUNTY

In the notes on Hardin County, page 199, is given a description of beds of oolitic hematite in the Bear Branch limestone member of the Olive Hill formation, at locality 13 about 1.7 miles east-southeast of Olive Hill. The most ferruginous portion has a thickness of about 25 feet. These beds were sampled every foot or two, and the ferric oxide (Fe_2O_3) was found to range from about 3 per cent to 44.97 per cent, corresponding to 2.1 per cent and 31.5 per cent, respectively, of metallic iron (Fe). Only four of the samples contained less than 17 per cent of ferric oxide, and the average was probably in the neighborhood of 25 per cent, or 17.5 per cent of metallic iron. This, of course, is too low in iron to constitute an ore of that metal, but as the analyses show the rock to be fairly high in carbonates of calcium and magnesium, fairly low in silica and alumina, and very low in the objectionable element, phosphorus (only 0.08 per cent), it becomes evident that the composition of the rock is desirable, and that it contains more than enough of the carbonates to flux its own impurities from the iron content and to contribute surplus fluxing values to the charges of iron ore and fuel in the blast furnace.

At present the deposit is too remote from transportation facilities to be utilized, but in view of the possible future extension of a railroad through Hardin County it is thought worth while to call attention to the potentialities as well as to the limitations of this material, for at the time of the writer's visit there seemed to be a belief locally that the material might prove to be a valuable iron ore.

DAVIDSON COUNTY

The ferruginous limestone in Davidson County to which it is desired to call attention is included within the Fernvale formation of Upper Ordovician age. The deposits occur at six or more localities in the hills of the Western Highland Rim surrounding Nashville from the northeast around to the west and southwest. Only one of these localities, that near the Louisville & Nashville Railroad between Goodlettsville and Bakers, was visited by the writer to familiarize himself with the general character of the material, because all the deposits have been described in detail by Wilbur A. Nelson.[40]

It will therefore serve best to give excerpts and summaries from Mr. Nelson's report in order to describe this material.

Location.—All the hematitic limestone is situated within a 12 to 19-mile radius of Nashville, outcropping on the sides of the hills that skirt the Highland Rim and in places extend out into the Central Basin.

"On these hills the ore occurs in pockets, the location of which is always indicated by the deep-red color of the soil on the lower slopes.

[40]Nelson, Wilbur A., The Fernvale iron ore of Davidson County: Tennessee State Geol. Survey, Resources of Tennessee, vol. 1, No. 2, pp. 44-57, August, 1911.

"The elevation of the ore varies: At Vaughan's Gap it is about 750 feet above sea level, while around Goodletts it lies between 550 and 600 feet. On most of the hills it outcrops about half way up and forms a small bench running back about 50 or 100 feet, but in places it lies on top of the hill with practically no overburden, or at the base of the hill, where it forms the bottom of the streams.

"There are six distinct fields into which the whole area can be divided, as follows:

"1. Vaughan's Gap and vicinity, where the ore has a thickness of about 5 feet and occurs on the hillsides on both sides of the track. The hillsides are steep, and the ore occurs as a ledge about 75 feet from the top. An estimate of about 50 acres of ore land is made for this section, containing about 1,000,000 tons of ore.

"2. Along Indian Creek, which is 10 miles west of Nashville, and about 2 miles from the river a bed of ore averaging 8 feet at the outcrop occurs on the hills on both sides of the creek. The ore is covered by a heavy overburden. An estimate of about 60 acres of ore land is made for this section, containing about 1,920,000 tons of ore.

"3. Along Little Creek, which is about 8 miles north of Nashville, and just east of White's Creek, are some very thick deposits of hematite, which vary from 6 to 13 feet in thickness, and occur about halfway up the hillside in most of the places, but in one place it occurs at an altitude of 500 feet in the bed of a small creek; elsewhere, the altitude is about 625 feet. Most of the ore in this locality is 10 feet thick and of good quality. An estimate of about 100 acres of ore land is made for this section, containing about 4,000,000 tons of ore.

"4. Along the Louisville & Nashville, from Bakers to Goodlettsville, the ore is about 6 feet thick, and has been mined in two places. In this locality the most of the outcrop is covered by soil. The altitude of the ore bed varies around 530 feet. An estimate of about 40 acres of ore land is made for this section, containing about 960,000 tons of ore.

"5. Along Willis Branch, about 3 miles northeast of Goodlettsville, there are several hills, which show an outcrop of the ore of about 6 feet, occurring near the top of the hill at an altitude of 530 feet. An estimate of about 15 acres of ore land is made for this section, containing about 360,000 tons of ore.

"6. North and south of Shackle Island, in the hills on the east of Drake Creek, are several outcrops of iron ore, occurring at an altitude of about 600 feet. This ore is very thin, having a thickness of only 2 feet where visited; and as no indications of ore were found east of here this would seem to be the eastern limit of the hematite.

"Adding up the estimated acreage of the hematite ore, gives a total of 265 acres, with an approximate tonnage of 10,000,000 tons of ore."

Geologic relations.—The ferruginous limestone is in the lower part of the Fernvale formation, so named from its fine outcrop at Fernvale, Williamson County. The formation consists mostly of soft chocolate-colored and green shale with here and there a band of coarsely crystalline, flesh-colored limestone containing greenish specks. Not many feet above the Fernvale is found the persistent black Chattanooga shale, of Devonian or Carboniferous age, which serves as a guide to finding the horizon of the ferruginous limestone. The rocks lie nearly horizontal, but the general dip is at a low angle toward the northwest, so that the Fernvale horizon passes below the Highland Rim within a short distance.

Character and occurrence.—The rock here considered is a strongly ferruginous, fossiliferous, crystalline limestone. It occurs in lenses in the lowest part of the formation, but there are many places at the same horizon where no iron is present but where there is highly phosphatic material instead. The ferruginous rock is interbedded between shale and in places contains films of greenish-blue shale up to an inch or more in thickness. Much of the calcium carbonate of the fossils appears to have been replaced by ferric oxide. There is very little oolitic material and thus the rock differs from certain beds of iron ore in the Clinton formation. Many of the beds outcrop only on one side of a hill, which would indicate that they extend back into the hill as wedges or lenses and thin out entirely within. No prospect drilling has been done, and the deposit has been mined on the outcrop in only a few places, and so it is impossible to determine the extent or thickness of the lenses below the surface.

Chemical composition.—Three analyses were made of the ferruginous limestone, showing iron, lime, sulphur, and phosphorus, and the iron content of samples from nine additional localities was determined. The material ranged in major constituents as follows: Metallic iron, 10.99 to 44.7 per cent; calcium oxide, 35 to 22.53 per cent; phosphorus, 0.51 to 1.30 per cent, and sulphur from 0.085 to 0.143 per cent. The results of these analyses show the rock to contain an average of about 17 per cent metallic iron and about 55 per cent calcium carbonate, or fluxing material, indicating that it would be suitable for mixing with the brown ores of the region, except for the high phosphorus content. If the high phosphorus content is characteristic of all the ferruginous limestone at this horizon it would be a serious obstacle to the use of the rock, but if there are areas of lower phosphorus they might be exploited separately. Possibly also means may yet be devised for eliminating excess phosphorus in the furnace.

Whether a ferruginous deposit may be considered an ore or not is determined by conditions of blast-furnace practice. One of these conditions is that a lower content of metallic iron and a higher content of impurities may be permitted in a limy material than in one that contains but little lime. Thus in places where brown iron ores (which contain no lime) are available

for mixing with a ferruginous limestone such as the Fernvale, the latter, being also a flux, can be used. It could not be used alone or classed as an ore where no brown ores are available for mixing with it. This material contains enough lime to flux itself together with one or two times its weight of brown ore or limonite, and the small quantity of iron in it can thus be considered as so much gain in the output of a furnace.

Economic considerations.—The ferruginous limestone was mined prior to 1910 at two places in the vicinity of Goodlettsville (see Plate 33, B), and rock was shipped to furnaces at Clarksville and Cumberland Furnace. It is understood that the rock was then found to be too expensive to use, as the gain in iron value did not equal the excess in cost, including freight charges, of this material over the price of limestone flux obtained near the furnaces.

Mr. Nelson pointed out in 1911 that Nashville then appeared to afford a splendid site for a by-product coke iron furnace, which could utilize the limy iron ore found in the vicinity in connection with the brown ore from the Western Highland Rim. This would involve carrying the bulk of the ore greater distances than it is now carried, but the coal or coke and the ferruginous limestone less distances than would now be involved, but the feature of greatest economic significance in such a plan at present is the utilization of the gases from the by-product ovens, which can be done most advantageously at a city of the size of Nashville, where domestic and industrial consumption of gas could be depended upon to be large and steady. This suggestion of Mr. Nelson is well worth serious study today.

LAWRENCE COUNTY

The ferruginous limestone most worthy of note in Lawrence County is a deposit in the Brassfield limestone, of Silurian age, that occurs at Cedar Point, a quarter of a mile north of Iron City. Here is a bed 2½ to 4 feet thick, containing about 17 per cent of metallic iron has been mined, and the product shipped to Florence, Ala., where it was used in the blast furnace as a flux with brown iron ore from Pinkney, Tenn. This iron-bearing limestone, locally called "spathite," has been described by Miser.[41] It resembles very closely the ferruginous limestone of the Bear Branch and Fernvale limestones, described above. The only analysis cited by Miser shows 0.456 per cent of phosphorus in the Brassfield ore, which is between that of the material from the other two formations.

[41]Miser, H. D., Mineral resources of the Waynesboro quadrangle: Tennessee State Geol. Survey Bull. 26, pp. 118-120, 1921.

MANUFACTURE OF FERROPHOSPHORUS AT ROCKDALE, MAURY COUNTY TENN.[42]

By James A. Barr

The process of manufacturing ferrophosphorous lies not alone in smelting a mixture of phosphates, silica, iron ore, with coke as fuel, but upon smelting this mixture with coke and air as chemical agents as well as heat producers and in conjunction with extraordinary procedures and manipulations making the process continuous and profitable. For best results there must be cool top, limited fusion zone, hot bottom, good mechanical condition of stock and perfect distribution of gases; also minimum air supply, high heats and excess of coke or carbon.

Ferrophosphorus, an alloy of phosphorus and iron or perhaps a physical mixture of definite compounds of iron and phosphorus, has become of increasing importance as the use of the basic open hearth has extended. Commercial ferrophosphorus is a porous, brittle metal of crystalline structure and often with a bluish metallic luster. A typical analysis is as follows:

	Per cent	
Phosphorus	18.0 to	22.0
Iron	80.0	76.0
Oxygen	0.2	
Sulphur	.3	
Silicon	.1	
Carbon	.1	
Manganese	.2	

This alloy was first made in an electric furnace, as it was thought that the high heat of the electric arc together with the reductive effect of carbon was necessary.

About 1898, J. J. Gray, Jr., was producing a high-phosphorus pig iron in his furnace at Rockdale, Tenn., by using high-phosphorus, local iron ores. As these high-phosphorus ores were difficult to obtain, he conceived the idea of increasing the phosphorus content of the pig iron by the addition of phosphate rock to the furnace burden. When the phosphorus content of the pig was kept low and only small amounts of phosphate rock were added to the burden, no particular troubles were encountered, but when he increased the amount of phosphate rock to produce an 18 per cent alloy, his furnace troubles rapidly multiplied. After many failures and freeze-ups, he was partly successful in making short campaigns on 18 to 20 per cent "ferro."

At first, when the furnace got in bad shape on ferro, he would switch to a regular pig-iron burden until the furnace was brought around sufficiently to start on ferro again. About this time, Mr. Gray applied for and obtained his first patent.

[42]Am. Inst. Min. and Met. Eng. Trans., vol. LXXI, pp. 507, 511, 1925.

As he grew more skilled in the furnace operations, he was enabled to extend the furnace campaigns and produce ferrophosphorus continuously for the life of the furnace lining. These improvements were made the subject of another patent issued in 1916.

Essentially, ferrophosphorus is the result of smelting a mixture of iron ore, phosphatic rock, siliceous flux and coke, under intensely reducing furnace conditions, with heated blast, above a bath of molten slag and ferrophosphorus.

The iron ore, a limonite, is obtained from Mr. Gray's mine, 50 miles south on the Louisville & Nashville Railroad, at Iron City. The ore is a nodular variety occurring in a clay matrix. The beds are stripped and mined by steam shovels, the ore hauled by side-dump cars and locomotives to washers, where the clay is washed out in log washers and trommels, followed by McClanahan-Stone jigs for the separation of flint. The concentrated ore runs about as follows: Iron 45 per cent, silica 10 per cent, phosphorous 2 per cent. Silica flux is obtained form jig tailings, which run quite high in iron as well as silica. Sometimes small amounts of washed sand and gravel, from Spruce Pine, Ala., are used.

Phosphate rock, in the lump form, is obtained from the Mt. Pleasant field about 6 miles to the north; a large firm lump being preferred, running high in BPL ($Ca_3P_2O_8$) and low in free lime. A typical analysis is

	Per cent
$Ca_3P_2O_8$	76.0 to 78.0
equivalent to P	15.2 to 15.6
SiO_2	4.5
Free lime, $CaCO_3$	5.0

Other materials may be used in the furnace burden, such as mill cinder, running high in iron and silica, iron turnings, scrap pig, and shot ferrophosphorus from the magnetic separating plant.

A good firm grade of coke is used and the braize is screened out in the usual manner. The presence of too much fines in the burden tends to form scaffolds and make the furnace slip.

All the incoming materials are brought in on a high line from Louisville & Nashville Railroad connections and dumped from a trestle into a concrete tunnel, in which a charge car, with a multiple-scale beam, operates to collect the furnace charge. The charges are dumped into a skip, hoisted on an incline track, and end-dumped through a single-bell top into the furnace. The furnace has the following dimensions: Height 40 feet, inside hearth diameter 8 feet, bosh diameter 12 feet, bosh angle 80°.

The hearth and bosh are water-cooled, as the molten charge is very corrosive and would soon cut its way through an uncooled jacket and lining. Six water-cooled bronze tuyeres are connected through the usual penstocks and nozzles to a brick-lined bustle pipe, which distributes the blast.

The furnace gases are handled at about 450° to 500° in a brick-lined downcomer through two dust catchers into a cast-iron balloon gas washer; the flue dust is wasted.

A battery of four checker-filled single-pass stoves use part of the furnace gas to heat the blast to around 1,000° F.

The remainder of the gas, and there is a large excess over the usual iron blast furnace quantities, is burned under a battery of Rust water-tube boilers, which supply steam for blowing engines, pumps, and general purposes.

Blast is furnished by a McClanahan-Stone, horizontal, poppet-valve engine of very early manufacture, but still giving excellent service. It is equipped with leather flap valves, a forerunner of the modern plate valve; the cylinder is 6 by 6 feet and when run at the usual 24 to 28 r. p. m. furnishes 7,200 cu. ft. free air per minute at 5 to 12 lb. pressure. A smaller vertical Weimer blowing engine is kept in reserve. The proper manipulation of blast volume is very important. Too much air causes the melting line to rise, tends to form scaffolds, and burns coke needed for the reduction of phosphorus.

The usual operating procedure is to add five regular charges consisting of phosphate rock, iron ore or mill cinder, high-silica tailing, shot ferrophosphorus, coke—about twice the amount used in pig-iron practice.

Every fifth time, a regular pig-iron charge is added to help keep the furnace working freely and consists of iron ore, limestone and coke. Sometimes a blank coke charge is added in addition to the above, according to the needs of the furnace.

Slag is tapped every 3 hours into a water-filled granulating pit. The following analysis is typical.

	Per cent
Al_2O_3	5.18
SiO_2	38 to 42.00
CaO	35 to 38.00
FeO	4.96
P_2O_5	7.33
S	1.07
MnO	0.54

The ferrophosphorus is tapped every 6 hours and run on to a floor paved with cast-iron bricks, where it cools in thin slabs and can be easily broken and handled. At the end of the cast, when the iron notch is blown free of slag by blast pressure, the presence of lumps of incandescent coke is very noticeable and shows that it is present in the tuyere zone to effect the reduction of the phosphorus.

The capacity of the furnace is 35 tons of ferro per 24 hours or about half that of usual pig-iron production.

Some phosphorus oozes out of the cracks in the jacket and collects under water. During the war this was scraped up and sold. Occasionally white

fumes of phosphorus burning to P_2O_5 can be seen. Some of the phosphorus is lost in the stack gases and the remainder in the slag. The problem of saving P_2O_5 from blast-furnace gases is complicated by the large volume, i. e., about five times that from an electric furnace.

As the slag contains considerable shot ferrophosphorus, provisions are made for its recovery. The slag is dipped from the granulating pit by a bucket-operating locomotive crane and dumped on to a drainage pile and finally fed by the same crane into a hopper located over the feed of a 5 by 40 foot direct-heat, countercurrent, rotary dryer. The dried slag is elevated and discharged on to a Dings belt-type magnetic separator. The reclaimed slag is fed back with the furnace burden as previously described. The rejected slag is chuted directly into railroad cars for use as ballast.

Ferrophosphorus is mainly used for increasing the phosphorus content of steel and is added directly to the ladle. The writer observed one steel company adding 650 lbs. to the 100-ton ladle. As is well known, the basic open hearth removes practically all of the phosphorus from the steel. When rolling thin sheets it has been found that a small percentage of phosphorus is necessary in the steel to make the sheets strip readily. Certain other classes of steel also require small amounts of phosphorus in exact quantities. Ferrophosphorus may also be added to a cupola charge where the pig is too low in phosphorus for the casting requirements. [In 1925 the furnace was enlarged by taking out the old stack and replacing it with a larger modern stack having a revolving feeder; larger blowing engines and boilers were installed and the entire plant modernized for low-cost production, according to communication from James A. Barr, March 24, 1925, in which slight revisions were made in the original edition of the paper.]

BENEFICIATION OF IRON ORE

An iron ore is said to be beneficiated if its quality is in any way improved by physical or chemical treatment. Thus the elimination of more or less of the foreign accessories, such as sand, clay, and water, with the result of increasing proportionately the percentage of iron, not only beneficiates the ore directly but, if done at the mine, lowers the cost of transporting the ore to the furnace. Merely changing the physical character or the chemical composition of the ore without eliminating any of the impurities may so improve its quality that it is more suitable for use in the blast furnace; therefore processes that produce such results may also properly be said to beneficiate the ore. There are many methods of improving the quality of iron ores, some of them very simple and even primitive and others rather complex and depending for their efficiency on large and expensive mechanical equipment, with all manner of gradations between the extremes. The methods and equipment employed depend, of course, largely upon the character of the ore and the nature of the problem to be solved.

A thorough discussion of beneficiation of Lake Superior iron ores as developed up to 1916 was published by the U. S. Geological Survey in that year, [43] and more recent information published by the University of Minnesota s referred to on page 217-218 of this bulletin. It is of interest to know that when information was sought in 1901 as to whether the sandy iron ores of the western part of the Mesabi Range, Minn., were amenable to concentration, a carload of that ore was sent to Cedartown, Ga., where it was successfully washed on the ordinary log washer used for brown ores in that district. This early demonstration of washing methods brought to Southern ore producers as a return much benefit from the experience of the larger-scale operations in the Lake Superior district.

A summary of the forms of beneficiation usually practiced in the various ore fields of the United States is as follows:[44]

"1.—Hand-picking or cobbing, to separate that portion of the ore that is visibly of high grade from the poorer material.

2.—Drying, to remove excess moisture.

3.—Roasting, to remove moisture from hydrated ore and sometimes water combined mineralogically; to drive off carbonic acid from carbonate ores; to reduce the percentage of sulphur in some ores; to facilitate the removal of clay, rock, and sand by making a non-magnetic iron magnetic; and to improve the physical features of the ore.

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[43] Newton, Edmund, and Bradt, Harlan H., Beneficiation of Lake Superior iron ores: Mineral Resources of the United States, 1915, vol. 1, pp. 303-314, October, 1916.

[44] Birkinbine, J. L. W., Beneficiating iron ores; The A B C of iron and steel, Fifth Ed., p. 22, Cleveland, Ohio, Penton Pub. Co., 1925.

4.—Washing, to reduce excessive amounts of clay, sand, and rock.
5.—Jigging, to accomplish the same results as washing, but with finer material.
6.—Magnetic separation, to separate the strongly magnetic particles from those that are nonmagnetic.
7.—Agglomeration, to form finely divided material into lumps, either by briquetting, nodulizing, or sintering."

The first five of the above processes have been employed in the treatment of the brown iron ores of the Western Highland Rim, Tenn., except that roasting has not been used for desulphurization or carried to the extent of making the ore magnetic. An early method of treating the brown ore was to pile it on "ricks" of wood and set the wood on fire; the resultant roasting loosened the clay, drove off some moisture, and through decrepitation loosened considerable of the chert so that it could be more easily separated by hand. The early mechanical means of treating the ores was a log washer, or inclined trough, in which was rotated a log 10 to 20 feet in length having metal paddles attached to its sides at such an angle that the iron ore was churned and gradually moved up the trough against a flow of water that washed away the sand and clay. The ore then went on a picking belt from which the coarse rocks and lumps of clay were picked by hand. Steel posts have now to some extent replaced the wooden logs. As the art of washing the ores progressed, other devices were introduced both before and after the log washer, such as the grizzly, a coarse grating usually of railroad rails on which the ore is dumped, broken by sledges to pass the openings, below which it is washed in a flume and sized in trommel screens. Rotary or jaw crushers are also used after the grizzly. As the log washer is an inefficient apparatus, which saves coarse impurities and wastes fine ore, pulsating jigs have been introduced toward the end of the process that take advantage of the difference in specific gravity of the brown ore and the chert and sand. The jigs require close sizing of the material and are usually built in a series of cells, in which material of one size is treated in each cell.

As now developed the ore washer, as it is called, has become a fairly complicated plant involving crushing, sizing, washing, picking, and jigging of the ore. The most graphic representation of the apparatus used, its arrangement, and the course followed by the ore is possible in the "flow sheet," such as have been shown for the washers at the Louise, Stokes, Aetna and other mines. Some of these washers are illustrated by means of photographs.

A good supply of water is necessary to a successful ore-washing plant also a large area of lowland below the plant site for settling ponds and dumps for the finely divided waste that is carried away from the washers. The plant should be built if possible on a hillside lower than the ore deposit so as to have the advantage of gravity in the movement of ore from the mine and through the plant. (See Plate 21B).

The ratio of crude ore, or "dirt," exclusive of stripping and barren ground, that must be treated to the ore recovered varies considerably in the practice in the Western Highland Rim area. Good ground will yield 1 gross ton of ore for 2 or 3 cubic yards of dirt, and as much as 16 cubic yards of dirt has been reported as being washed in order to recover 1 ton of ore, but probably this ratio was not maintained as an average. Just what the limiting ratio may be can not be stated, as it would depend on many diverse factors not all of which are operative at any one place. For instance, where an area of lean ground must be removed in order that better ore may be reached, it may pay to run the lean material through the washer rather than to throw away the ore contained therein.

The problem of beneficiation of the brown iron ores in the Western Highland Rim is of prime importance. One hundred and twenty-five years of mining has necessarily exhausted much ore of the highest grade, and future mining will involve handling ores with increasing proportions of clay, chert, sand, and gravel, and in places the reworking of ground that has been carelessly mined and even of old gravel dumps. The writer is not technically trained in the art of ore dressing, but in his judgment it would seem that the present local methods of ore treatment have been developed nearly as far as practicable, and that radical departures from present practice may be required in order to treat successfully cherty brown iron ore of grades lower than those at present acceptable. It is his belief that wherever there is lean hematite or limonite in large quantity convenient to transportation and markets, the next logical step in beneficiation practice should be to endeavor to develop a commercially successful process for reducing the hematite or limonite to a magnetic condition, in which the magnetic ore may be separated from the nonmetallic impurities by electromagnetic action. Magnetic separation has been employed successfully on a large scale for many years on moderately low grade magnetite ore at Mineville, N. Y. In the eastern part of the Mesabi Range, Minn., there are enormous quantities of metamorphosed rock containing 15 to 30 per cent of magnetite. For some years the Minnesota School of Mines experiment station studied the possibility of recovering the magnetite in this rock by means of wet magnetic separation and met with sufficient encouragement so that the Mesabi Iron Co. erected at Babbitt, Minn., in 1922, a plant large enough to make shipments of a very high grade sintered ore. The success of this process seems to depend to a considerable extent on large-quantity operations. During the World War brown iron ore from a deposit at Waukon, Allamakee County, Iowa, was concentrated by means of the Goltra process. At the Waukon deposit there is much clay, chert, and limestone intimately mixed with the ore as mined—in fact this ore strongly resembles that of the Western Highland Rim area of Tennessee in its general character and associations. Log washing and hand picking did not succeed in making an economical separation of this ore from

its impurities, and the Goltra process was developed with special reference to the Waukon ore. In this process the washing of the ore with water is dispensed with, and instead the ore is subjected to drying, crushing, screening, air separation, picking, roasting, further screening, partial reduction to magnetic iron oxide in sealed chambers in the presence of hydrocarbon reducing agents, and finally electromagnetic separation. Descriptions and discussion of this process are published elsewhere.[45] It is not known whether this process would be applicable to Tennessee brown ore, but it illustrates the direction taken by an effort to handle a similar ore, and may involve a principle that might be of service, perhaps in connection with existing methods, to effect greater recovery of iron oxide.

Some official experimental work has been done on magnetic concentration of nonmagnetic iron ore by the Minnesota School of Mines Experiment Station in connection with its development of concentration of magnetic ore. The nonmagnetic ore was hematite, not limonite, and therefore the studies do not bear directly on the present problem, but they are suggestive and may be of interest to Tennessee iron-ore producers. In his description of the experiments, Mr. Davis [46] points out that the cost of the plant is necessarily large, and its operation may be expensive, therefore a large supply of ore must be available at a low mining cost and must command a ready market. The concentrates are usually of a high grade, which in part compensates for the expense of preparing them.

A study of beneficiation of the low-grade iron ores of the Southern States, has been undertaken by the United States Bureau of Mines at its Southern experiment station at Tuscaloosa, Ala. Thus far most attention has been paid to the high-silica hematite, or red ore, but it was hoped that the brown iron ores would receive their share of attention, as it was reported that shipments of brown ore from certain mines of the Western Highland Rim of Tennessee had been made to the laboratories.

Prior to 1927 only a little laboratory work was done on this material, and that work was done on *washed* brown ore instead of beginning with the *crude* ore and making a fundamental study of the problem, including field study of local washers and washing methods by the metallurgist. The results as summarized in a letter from B. W. Gandrud, Junior Metallurgist of

[45]Phillips, W. B. Concentration by the Goltra process: Iron Age, Nov. 12, 1914. pp. 1148-1150.

Burchard, E. F., Iron ore in Cass, Marion, Morris, and Cherokee Counties, Tex.: U. S. Geol. Survey Bull. 620, pp. 103-106, 1915.

Howell, J. V., The iron-ore deposits near Waukon, Iowa: Iowa Geol. Survey Ann. Rept., 1914, vol. 25, pp. 33-100, 1916.

[46]Davis, E. W., Magnetic concentration of iron ore: Minnesota Univ. School of Mines Exper. Sta. Bull. 9, Dec., 1921, pp. 112-117: Magnetic roasting of iron ores: Iron Trade Review, April 6, 1922, pp. 968-972.

the Bureau of Mines to Mr. R. Lee Collins, Acting State Geologist of Tennessee, dated August 14, 1926, are as follows:

"The work consisted principally of making jig tests on a shipment of washed brown ore from the district you refer to. The ore was obtained in the vicinity of Allen's Creek. Table tests were also made, but the results from table tests were not very satisfactory. The following is a screen analysis of the ore as received:

Screen analysis of washed ore

Screen size	DRY WEIGHT		Iron (Fe) per cent	Insoluble per cent	Phosphorus (P) per cent
	Per cent	Cumulated per cent			
Plus 3"	15.00	15.00	42.6	26.2	0.88
Plus 2"	13.80	28.80	42.0	27.7	.84
Plus 1"	17.60	46.40	43.1	25.2	.90
Plus ½"	22.10	68.50	48.8	14.7	1.17
4 mesh	17.40	85.90	48.5	13.7	1.22
8 mesh	8.70	94.60	48.3	13.0	1.21
10 mesh	1.23	95.83	46.7	13.8	1.22
14 mesh	1.92	97.75	46.0	14.6	1.22
20 mesh	0.83	98.58	44.3	16.1	1.21
28 mesh	.55	99.13	43.0	17.5	1.20
35 mesh	.42	99.55	41.7	18.1	1.20
48 mesh	.19	99.74	40.8	19.8	1.12
65 mesh	.07	99.81	40.0	20.1	1.11
100 mesh	.04	99.85	39.5	20.3	1.08
—100 mesh	.15	0.15	37.8	24.4	.98
	100.00	100.00	45.6	19.8	1.05

"The ore before drying contained 6.3 per cent moisture. There is no lime in the ore.

"Jig runs were made on this ore with a semicommercial size, three-cell jig after the ore had been crushed to three-fourths of an inch. The combined concentrates from the three cells assayed as follows: 51.5 per cent iron, 11.3 per cent insolubles, and 1.17 per cent phosphorus. The combined hutch products assayed as follows: 47.9 per cent iron, 16.6 per cent insolubles, and 1.19 per cent phosphorus. By combining all the concentrates and hutch products a final concentrate was obtained which assayed 50.9 per cent iron, 12.3 per cent insolubles, and 1.17 per cent phosphorus. In this final concentrate, 92.17 per cent of the iron in the original ore was recovered.

"The table test was made on the ore after it had been crushed to 10 mesh. The table was operated so as to give only two products, concentrates and tailings. The concentrates assayed 53.0 per cent iron, 10.0 per cent insolubles, and 1.20 per cent phosphorus. In the concentrates, 65.3 per cent of the iron in the original ore was recovered."

PRODUCTION OF IRON ORE

Statistics of mineral production in the United States were collected by the United States Geological Survey from 1882 to 1924, and since that period they have been collected by the Bureau of Mines. In the earlier years the records were not kept in a form sufficiently detailed to permit the separation of iron ore produced by counties in the Western Highland Rim area of Tennessee from those of iron ore produced by the whole State. Beginning with 1896, however, the reports of the State mine inspector of Tennessee contain production by counties, and beginning in 1906 those of the Federal Survey are fairly detailed and complete, but those of the State mine inspector show a hiatus for the years 1915 to 1919, and so in order to arrive at the most complete detailed record, beginning with 1896 both these official sources of information have been drawn upon. H. D. Miser has recorded the production of the mines in the Waynesboro quadrangle from 1832 to 1920, as ascertained mainly from the owners of the mines (see pages 194-195), and from these figures the totals for 1832 to 1895 for Wayne and Lawrence Counties and part of Lewis County are derived. The figures used for the years prior to 1896 for the counties north of Wayne are necessarily rough estimates and are subject to revision.

Statistics collected by official agencies are very likely to fail to obtain the full records of production of ore from year to year, and so the compilations by the Federal and State agencies doubtless represent less than the actual production. In 1923, for instance, reports to the U. S. Geological Survey indicated no production of iron ore from Montgomery County, although the writer examined one mine that was active there then, and he believes that the recorded production from Dickson County in 1923 is less than it should have been. Furthermore, there is no recorded production at any time from Benton, Houston, Humphreys, Perry, Decatur, and Hardin Counties, from all of which there were probably small tonnages of ore shipped via the Tennessee River or else consumed locally. For these reasons the grand totals must be regarded as being under rather than over the correct figures.

The Tenth Census of the United States gives the production of limonite in 1880 in Stewart County as 1,043 tons, in Dickson as 10,773 tons, and in Lawrence County as 641 tons. These figures are probably not complete. Safford has given the production of pig metal and castings made in 1854, as shown in the table on page 222, from which it is deduced that the quantities of brown iron ore produced in that year were about as follows: Stewart County, 32,000 gross tons; Montgomery County, 18,500 tons; Dickson County, 13,700 tons; Hickman County, 4,300 tons, and Wayne County, 5,500 tons, with an additional 10,250 tons from some of these counties consumed in furnaces in Perry, Decatur, and Hardin Counties, or a total of approximately 84,250 tons.

The detailed figures by counties from 1896 to 1930, inclusive, together with estimates of the production from the earliest years to 1895 are given in the following table. The earliest production was in Dickson County in 1797, in Montgomery County it was about 1802, in Stewart County, in 1830, and in Wayne County, in 1832. These figures are of interest as showing a total production of 8,559,881 gross tons of brown iron ore from the area. Possibly 50,000 tons might be added as a rough estimate of the unrecorded production, but there is no reliable basis for an estimate of this unknown quantity. This would bring the probable total production up to a little more than 8,600,000 gross tons. The four southern counties have been the greatest producers, with the three northern counties contributing in more moderate degree, and all of them probably roughly according to the relative rank of their ore reserves.

Production of iron ore in Western Highland Rim area, Tennessee, by counties, 1797 to 1930, in gross tons

Year	Stewart	Montgomery	Dickson	Hickman	Lewis	Wayne	Lawrence	Total
1797–1895[a]	95,000	42,000	113,800	376,000	550,000	1,441,300		2,618,100
1896	13,000	5,000	.....	.....	17,755	30,395	137,616	203,766
1897	10,854	.....	.....	.....	.....	30,539	191,737	233,130
1898	10,950	.....	.....	.....	.....	32,141	144,367	187,458
1899	4,500	.....	16,000	16,000	506	8,000	79,828	124,834
1900	8,709	.....	31,106	29,288	26,500	50,949	86,460	233,012
1901	.....	.....	.....	24,177	.....	67,306	102,000	193,483
1902	.....	.....	.....	34,425	16,662	43,955	65,193	160,235
1903	18,000	.....	.....	21,865	71,110	34,242	104,949	250,166
1904	6,000	.....	.....	32,000	21,755	74,934	52,275	186,964
1905	8,000	26,300	4,000	32,534	27,042	71,510	187,197	356,583
1906	2,000	10,000	15,000	38,500	36,309	80,194	232,842	414,845
1907	8,610	9,000	10,000	47,534	28,784	81,528	167,336	352,792
1908	8,198	4,255	5,099	34,954	29,864	44,294	134,321	260,985
1909	6,071	5,704	.....	39,597	23,008	65,119	161,059	300,558
1910	10,271	1,922	.....	42,603	30,388	71,905	221,684	378,773
1911	11,965	.....	.....	66,003	3,175	59,285	78,217	218,645
1912	11,419	.....	.....	42,171	13,953	47,475	55,013	170,031
1913	10,325	.....	.....	5,168	49,863	14,745	44,655	124,756
1914	4,052	.....	.....	9,177	73,237	.....	37,418	123,884
1915	1,500	.....	.....	1,156	60,634	19,200	17,400	99,890
1916	5,000	3,781	12,341	31,257	93,695	50,374	.....	196,448
1917	5,556	.....	29,320	43,644	68,805	107,936	.....	255,261
1918	4,245	.....	21,458	34,216	17,902	99,493	4,791	182,105
1919	.....	4,195	11,943	6,797	.....	75,847	716	99,498
1920	3,140	5,809	12,397	38,246	31,950	72,385	32,424	196,351
1921	.....	.....	.....	.....	.....	.....	12,293	12,293
1922	.....	.....	5,254	13,944	.....	48,757	17,290	85,245
1923	.....	.....	2,473	30,781	.....	55,118	13,273	101,645
1924	.....	1,622	6,977	.....	.....	.....	.....	8,599
1925	.....	.....	22,634	25,398	.....	.....	10,128	58,160
1926	.....	.....	8,302	13,608	.....	.....	8,869	30,779
1927	.....	.....	8,552	22,047	.....	.....	3,942	34,541
1928	.....	.....	8 8 8	23,095	.....	.....	13,273	45,266
1929	.....	.....	8,880	24,536	.....	.....	.....	33,416
1930	.....	.....	.....	23,277	.....	.....	4,107	27,384
Total 1896–1930	172,365	77,588	240,634	847,998	742,897	1,437,626	2,422,673	5,941,781
GRAND TOTAL	267,365	119,588	354,434	1,223,998	1,292,897	5,301,599		8,559,881

[a]Estimated.

able from year to year, and the Western Highland Rim area of Tennessee is no exception to this rule. Troost believed that the pig iron production of this area in 1835 should be about 27,000 tons from 27 furnaces. Safford shows that in 1854, 31 furnaces produced 37,283 tons of pig metal, including castings, but undoubtedly between these years there were fluctuations of output.

The figures for the 21 years 1910 to 1930 show a total production of 1,351,595 gross tons of pig iron. During this period 1910 was the year of largest recorded production, 135,523 gross tons. During these years there were from 2 to 9 furnaces in blast. A comparison of the pig iron produced in this area from 1910 to 1930 with the quantity of iron ore produced in the same period, 2,482,970 gross tons, would indicate a yield of metallic iron of about 54.4 per cent, which is higher than the actual yield because during this period there was a steadily increasing quantity of scrap iron melted in the furnaces, and some ore from the Birmingham and other outside districts was used here. A more nearly accurate factor probably would be 2.25 tons of iron ore for each ton of pig iron produced from the ore, and if this factor be used in connection with the estimated total of ore mined from 1797 to 1909 or 6,076,911 gross tons, it would indicate a total production of 2,700,850 gross tons of pig iron in the area of the Western Highland Rim from 1797 to 1909. Adding the recorded production of 1910 to 1930 inclusive, or 1,351,595 gross tons gives a grand total of 4,052,445 gross tons of pig iron produced from 1797 to 1930. On the basis of these figures there is indicateed an average yield of 47.34 per cent of metallic iron from the ore over the whole period since production began. Although this is higher than the present yield it is not inconsistent when it is considered that in the early days the ore was hand-picked and, as mentioned above, scrap iron and some ore from other districts have been added to the furnace burdens. It is a question, however, whether so high an average yield will be maintained in the future, because of the increasing quantity of siliceous ore that will have to be mined.

The diminishing output of pig iron in the Western Highland Rim area has become a matter of concern to those actively interested in the iron industry as well as to general business interests in this part of the State. It should be pointed out, however, that the experience of the iron region of West-Middle Tennessee is not unique in this regard. Small merchant pig-iron furnaces throughout Pennsylvania, Virginia, and other States have almost all been forced out of business by economic conditions during the last 8 to 10 years. Some of these adverse conditions, not necessarily in order of their importance, are: Competition from larger manufacturers of merchant pig iron and from manufacturers of steel who sell their surplus pig iron; diminishing markets for high silicon and foundry grades of iron; high freight rates on raw materials and finished products; increased cost of production due to decrease of easily available supplies of iron ore and increased cost of labor. When it is

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transpose the text matter.

PRODUCTION OF PIG IRON

The records of the United States Geological Survey and the Bureau of Mines show the production of pig iron, including ferrosilicon and ferrophosphorus, in the counties of the Western Highland Rim by years from 1910 to 1930, and Safford's report, issued in 1855, gives a table of blast furnaces and their products in 1854. The report of the Tenth Census, vol. II, 1883, gives for the year 1880 a production in Stewart County of 1,800 tons of pig iron, valued at $47,000; in Dickson County, 2,400 tons, valued at $70,000, and in Lawrence County, 236 tons, valued at $4,720. The table by Safford follows:

Blast furnaces and products, 1854[a]

County	Name of furnace	Pig metal and castings produced (tons of 2,268 pounds)	Months in blast
Stewart	Saline	1,200	.....
	Iron Mountain	1,015	4
	Peytona	1,220	7
	Bellwood	2,006	.....
	Cross Creek	1,905	11.5
	Rough and Ready	1,050	11.5
	Bear Spring	885	.....
	Union	550	.....
	Ashland	1,200	.....
	La Grange	1,910	.....
	Eclipse	641	4
	Clark	585	4
		14,167	
Montgomery	Louise	2,154	.....
	Sailors Rest	600	7
	Yellow Creek	600	.....
	O. K.	1,160	.....
	Phoenix	1,500	11.5
	Montgomery	1,000	.....
	Poplar Spring	1,175	.....
		8,189	
Dickson	Worley	950	.....
	Jackson	50	.....
	Piney	1,731	.....
	Laurel	357	4.5
	Cumberland	1,926	.....
	Carroll	1,050	9
		6,064	
Hickman	Aetna	1,509	9
	Oakland	385	3
		1,894	
Perry	Cedar Grove	1,500	.....
Wayne	Forty-eight	2,445	12
Decatur	Brownsport	2,109	11.5
Hardin	Marion	915	6
		37,283	

[a]Safford, J. M., A geological reconnaissance of the State of Tennessee, pp. 52-53, 1855.

The production of pig iron throughout the United States, and in fact throughout all countries of the world that produce this commodity, is vari-

borne in mind that the scale of local mining and manufacturing operations is modest in comparison with those of iron and steel companies that have plants comprising from one to half a dozen blast furnaces each with a capacity of 600 to 1,250 tons of pig iron a day, the advantage in cost of production enjoyed by such plants is obvious. The stabilizing of the manufacture of high-grade charcoal iron and blast-furnace ferrophosphorus through recent consolidations will go far toward maintaining the recognized place of these products among the industries of Tennessee.

The following table gives the details of the output of pig iron for such years as may be published:

Production of pig iron, including ferrosilicon and ferrophosphorus, in Western Highland Rim area, Tennessee, 1797 *to* 1930.

Year	Furnaces in blast	Gross tons
1797–1909[a]		2,700,850
1910	7	135,523
1911	6	92,503
1912	6	102,520
1913	7	57,046
1914	5	58,429
1915	3	42,214
1916	7	112,347
1917	7	134,916
1918	7	126,859
1919	6	65,147
1920	9	113,652
1921–22	6	61,044
1923–30	2 to 6	249,395
Total, 191 -1930		1,351,595
Grand otal		4,052,445

[a] Estimated.

RESERVES OF IRON ORE

The Western Highland Rim area contains a valuable reserve of brown iron ore, notwithstanding the fact, which must be apparent to any one who is acquainted with local conditions, that a large proportion of the easily accessible and rich ore has already been mined. The ore that remains must, therefore, be won at greater expense and with greater capital outlay and consequently at greater risk to capital than was involved in the earlier days of mining. The principal factors affecting the availability of a bank of ore are its situation with regard to mining and washing, its accessibility and location with respect to transportation facilities and markets, the demand for and prices of iron ore and pig iron, and the possibility of successfully beneficiating the ore. The process of beneficiation is susceptible of improvement and upon its improvement the future of this brown iron ore field probably depends to a greater extent than on any other single factor today.

In attempting a rough estimate of ore reserves in the areas examined the present processes of recovery have necessarily been taken for granted, but the possibility of better demand and prices have had to be assumed, otherwise it is not likely that the incentive for greater effort and expenditure for the recovery of ore would be forthcoming. The difficulties in making satisfactory estimates of ore tonnages are obvious. Few deposits have been prospected sufficiently to enable their owners to make close tonnage estimates, and no such data were available to the writer. The data used in estimating the ore that might possibly remain in a partly mined-out deposit are the average ratio of ore-bearing dirt in cubic yards to 1 ton of iron ore recovered; the average thickness of the deposit exclusive of overburden; and the area of probable ore-bearing ground corresponding to the above factors that remains. For deposits that had not been mined the best information as to these factors that could be obtained was used, or assumptions were made based upon comparisons with other deposits in the locality that appeared to be of similar character.

The writer attempted detailed estimates based on personal study only for Stewart, Montgomery, Dickson, and Hickman Counties, but made a very general estimate for Houston, Humphreys, Benton, Decatur, Hardin, and McNairy Counties in connection with an estimate of iron-ore reserves in the Tennessee River Basin for the U. S. Engineer Office of the War Department, and has incorporated that estimate into this report. For Lewis County north of the Allens Creek area a general estimate was made from the descriptions in Rogers's report (pages 118-164 of this bulletin) and for Wayne and Lawerence Counties, including the area near Allens Creek recently transferred from Wayne to Lewis County, the estimate by Miser[47] has been used.

[47]Miser, H. D., Mineral Resources of the Waynesboro quadrangle: Tennessee State Geol. Survey Bull. 26, p. 57, 1921.

In computing the reserves in Stewart, Montgomery, Dickson, and Hickman Counties the writer made estimates for each individual deposit examined by him, but as he probably did not see all the ore-bearing territory additions have been included in the estimates for each county in order to compensate for areas not considered, and an additional quantity of ore has been more or less arbitrarily assigned to each county bearing a rough relationship to its probably available ore reserves, as ore which, on account of its remoteness, depth, or inferior quality can not be considered available except in the very distant future. It is possible that the quantities in the two columns would be more nearly accurate if their positions were reversed, or if some ore were shifted from the "available" to the "nonavailable" column; only time or thorough prospecting can supply adequate information on this question.

The totals for the various counties are as follows:

Estimated reserves of brown iron ore in Western Highland Rim area, Tennessee

COUNTY		Probably available now or in near future (gross tons)	Not available except in very distant future (gross tons)
Stewart		450,000	300,000
Montgomery		400,000	200,000
Dickson		600,000	250,000
Hickman		750,000	500,000
wis (north of Allens Creek area)		700,000	550,000
Wayne and Lawrence, (including area near Allens Creek recently transferred to Lewis County)		6,000,000	3,000,000
Houston, Humphreys, Benton, Hardin, and McNairy		500,000	300,000
Grand Total	14,500,000	9,400,000	5,100,000

In an earlier rough estimate, prepared in part by the writer for Dr. C. W. Hayes, of the Tonnage of brown iron ore in the Western Tennessee River Valley embracing the deposits in northern Alabama, West-Middle Tennessee, and western Kentucky, 10,000,000 tons was assigned to the avaliable supply and 15,000,000 tons to the nonavailable supply of ore.[48] Of the available ore 5,300,000 tons was credited to the Russellville district, Ala. An estimate made in 1927 for the U. S. Engineer Office takes account of larger tonnages that have been discovered in the Russellville district since 1909.[49]

Comparison of the figures by counties may raise questions as to their consistency and also as to whether they are conservative or liberal. The writer has no doubt that there are inconsistencies in these totals that can not well be eliminated without giving the field much more study, but he has endeavored to make the estimates as fair and consistent as possible.

[48]Hayes, C. W., Iron ores of the United States, in Papers, on the conservation of mineral resources: U. S. Geol. Survey Bull. 394, p. 96, 1909.

[49]Burchard, Ernest F., Iron ore reserves and production in Tennessee River Basin; Report from Chief of Engineers on Partial Survey of Tennessee River and its Tributaries: 70th Cong. 1st session, H. Doc. 185, pp. 118-119, 1928.

Some property owners doubtless feel that there are in single properties greater quantities of ore than have been estimated for the whole of certain counties. When it is considered, however, that the estimated total production of brown iron ore from this area since the beginning of mining only slightly exceeds 8,600,00 tons and that the estimated total reserve of ore yet unmined amounts to 14,500,000 tons, the latter estimate may even be suspected of being too liberal. If the quantities already mined and yet to be mined stand in relation to each other as indicated in these estimates, it means that practically every mine will have to yield more ore in the future than it has yielded in the past, for there are not many large areas that have not already been developed to some extent. It will be difficult to obtain from some of the old and abandoned mines as much ore as they have produced, or to open new mines on a scale more extensive than that already in effect at the larger existing mines, but old mines will have to be extended and some new mines will have to be opened. There are still large supplies of ore that are just a little too siliceous and much of it contains a little too much phosphorus to be ideal for making charcoal pig iron. There is thus indicated the need for research on the problems of beneficiating the cherty ore and of reducing the phosphorus or of treating it metallurgically. If advances can be made in such problems, large reserves of ore will become available for the special irons for which this region is famous. It seems probable that future production will be maintained steadily in a few stable lines, and whenever a general improvement occurs in economic conditions in the iron industry, there is reason to believe that the Western Highland Rim area of Tennessee will resume its place as an important producer of brown iron ore and high quality pig iron.

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