# IRON AND MANGANESE.

## PRELIMINARY REPORT ON THE RED IRON ORES OF EAST TENNESSEE, NORTHEAST ALABAMA, AND NORTHWEST GEORGIA.

By Ernest F. Burchard.

### INTRODUCTION.

#### PURPOSE OF INVESTIGATION.

The attention of the iron makers of the United States has been turning toward the southern iron-ore fields to a considerable extent during the last decade, but more particularly since it has been proved possible to make basic open-hearth steel from southern iron ore. In response to many inquiries for information concerning the ore fields and the utilization of the ores the State geological surveys of Alabama and Georgia have already issued special reports on these subjects, and the United States Geological Survey has issued Bulletin 400, giving a detailed description of the Birmingham district, Alabama, and several short papers in which inter-State areas are considered, as in the present paper. (See footnote, p. 281.) The Tennessee Geological Survey is about to publish a detailed bulletin by the writer on the red iron ores of east Tennessee. This Tennessee material will, it is expected, be combined with details concerning the ore-bearing area in northeast Alabama and northwest Georgia, extending from the Birmingham district to the Tennessee border, and the whole published as a bulletin by the United States Geological Survey. The completion of this proposed bulletin is awaiting the results of field work that is planned to be done in Alabama between the Birmingham district and Attalla and along Tennessee River northeast of Guntersville. When the proposed bulletin is published reports will be available on the red iron ores of the southern Appalachians from southwest Virginia to north-central Alabama, where the Appalachian ridges become buried by the Mesozoic and Cenozoic deposits of the Coastal Plain.

Most of the field work on which this report is based was done in the autumn of 1911, although the writer has drawn freely on notes made by him during visits to certain mines in 1906 and 1908. The greater part of the expense was borne jointly by the United States Geological Survey and the State Geological Survey of Tennessee. The Chattanooga Chamber of Commerce made a contribution which was used to defray part of the expenses of prospecting.

The work of prospecting was in charge of Mr. J. R. Ryan, a mining superintendent and contractor of Chattanooga. Mr. Ryan measured many of the sections described in this paper and in many other ways rendered valuable assistance. It is largely due to the thorough knowledge of the Chattanooga district possessed by Mr. Ryan and to the loyal and generous spirit in which he served the State that the field work on which this report is based was accomplished within the funds allotted for the purpose.

The city of Chattanooga lies within 4 miles of the southern boundary of Tennessee, and as there are more important reserves of red iron ore within 30 to 40 miles to the south of the city than within an equal distance to the north it was the desire of the Chattanooga Chamber of Commerce that part of the funds allotted for prospecting should be used in Alabama and Georgia, in order to demonstrate the value of the ores tributary to the city. The prospecting was accordingly done without reference to State boundaries.

## PROSPECTING THE ORE BEDS.

As a rule the author of a report on the bedded iron ores of an area in the southern Appalachians has been obliged to depend entirely upon natural exposures of the ore beds or upon exposures made by mining operations, roads, tunnels, etc. The soft, shaly nature of much of the rock overlying the red ore causes the shale above a fresh ore prospect to "slump" down within a few months and practically to cover up a showing of ore. The result is, therefore, that except where mining is actually in progress there are very few exposures of ore beds, even though many fresh prospects may have been made within a year. The geologist who attempts to prepare a report on a bedded ore field must either accept much hearsay evidence concerning the thickness and character of the ore beds, or else he or a member of his party must see and measure every section on which the report is based. The latter plan was consistently carried out in the field work of the present investigation. In order that no very long gaps should occur between measured sections the ore beds were prospected on the outcrop at points where measurements were of most importance. In many places it was necessary only to clean out old prospect pits, but in others fresh pits were dug. Wherever practicable the bed was cut back to firm ore, in order to ascertain the true thickness of the ore. At many of these prospects samples of ore were taken for analysis by the Survey.

## SCOPE OF THIS PAPER.

This paper summarizes the results of the writer's recent investigations of the red iron ore beds in east Tennessee, northeast Alabama, and northwest Georgia, and includes quotations from a paper by C. H. Gordon and R. P. Jarvis on a special area in east Tennessee and from a paper by S. W. McCallie on an area in Georgia. The geology of the region has received so much attention in other publications of the Federal Survey and in State Survey publications that no space will be devoted here to that phase of the subject.[1] Two general maps are presented herewith (Pls. V and VI) to illustrate the relations of the outcropping ore beds to the coal-bearing areas and to transportation routes and other commercial features. One map and one structure section (figs. 29 and 30) have been introduced to show the topographic relations of a body of residual ore near Sweetwater, Tenn. On the general maps areas of outcrop of ore beds generally 2 feet or more in thickness and areas where the beds are generally less than 2 feet thick are differentiated by means of special symbols. As the ores associated with the Tellico sandstone and the Grainger shale have not previously been described, they will be given more attention here than would perhaps be warranted by their importance, compared with the ore of the "Rockwood" formation.

## ORE-BEARING FORMATIONS.

Although many of the formations in the southern Appalachians contain small quantities of iron oxide scattered through the beds, only three formations have been found to contain quantities sufficiently concentrated to warrant their classification as red ore bearing formations. Beginning with the lowest these formations are the Tellico sandstone, of Ordovician age; the "Rockwood" formation, of Silurian age; and the upper or Mississippian part of the Grainger shale.

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[1] See Folios 2, 4, 6, 8, 16, 19, 20, 21, 33, 35, and 75, Geol. Atlas U. S., also the following papers:

Burchard, E. F., The iron ores of the Brookwood district, Alabama: Bull. U. S. Geol. Survey No. 260, 1905, pp. 321-334; The Clinton or red ores of the Birmingham district, Alabama: Bull. U. S. Geol. Survey No. 315, 1907, pp. 130-151; The brown iron ores of the Russellville district, Alabama: Bull. U. S. Geol. Survey No. 315, 1907, pp. 152-160; The Clinton iron ore deposits in Alabama: Trans. Am. Inst. Min. Eng., vol. 39, 1908, pp. 997-1055; Tonnage estimates of Clinton iron ore in the Chattanooga district of Tennessee, Georgia, and Alabama: Bull. U. S. Geol. Survey No. 380, pp. 169-187.

Burchard, E. F., Butts, Charles, and Eckel, E. C., Iron ores, fuels, and fluxes of the Birmingham district, Alabama: Bull. U. S. Geol. Survey No. 400, 1909.

Butts, Charles, Iron ores in the Montevallo-Columbiana region, Alabama: Bull. U. S. Geol. Survey No. 470, 1911, pp. 215-230.

Eckel, E. C., The Clinton or red ores of northern Alabama: Bull. U. S. Geol. Survey No. 285, 1906, pp. 172-179.

McCalley, Henry, Report on the valley regions of Alabama, pt. 2, Alabama Geol. Survey, 1897; Report on the fossil iron ores of Georgia: Bull. Georgia Geol. Survey No. 17, 1908.

Harder, E. C., The iron ores of the Appalachian region in Virginia: Bull. U. S. Geol. Survey No. 380, 1909, pp. 215-254.

In southern Tennessee south of Chattanooga and in northwestern Georgia the lower part of the "Rockwood," which contains in places thin seams of oolitic iron ore, is, according to E. O. Ulrich, of Ordovician age. None of the ore seams that have been noted in these beds are thick enough to be mined except in a small way along the outcrop.

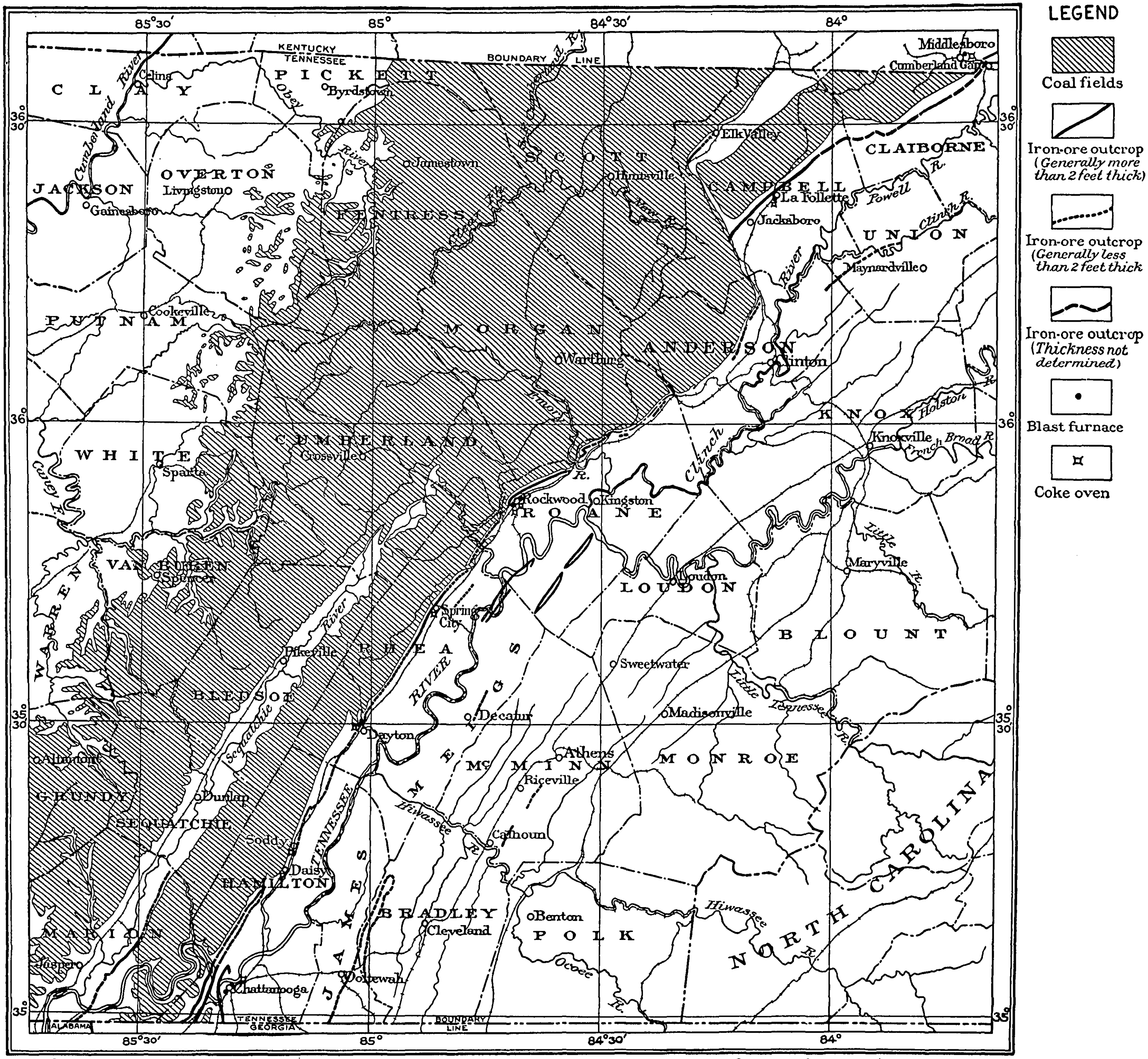
## THE RED IRON ORES.

### GENERAL FEATURES.

By the term "ore" in this report is meant such ferruginous material as may have a value either at present or in the near future as a source of iron, whether or not it occurs in quantities sufficient to warrant mining. At present no ores carrying less than 25 per cent of metallic iron are intentionally charged alone into blast furnaces, and ores as lean as this can not be used economically unless they carry more than enough lime to flux them and are also used in connection with richer ore. As there are in the southern Appalachians enormous reserves of ore carrying 25 per cent or more of iron, it seems hardly necessary in this report to consider as an ore anything leaner than the 25 per cent grade. It is, however, difficult to draw a rigid line. For instance, other things being equivalent, it would be more desirable to use as a flux a limestone carrying 15 to 20 per cent of ferric oxide (10.5 to 14 per cent of metallic iron) than one containing only 3 to 5 per cent of ferric oxide, on account of its higher iron yield. Nevertheless, such a ferruginous limestone would not commercially be styled an ore, while a bed carrying 25 per cent of metallic iron (35.5 per cent of ferric oxide), although in itself hardly rich enough to be used alone for the manufacture of iron, would be conceded to be an "ore." In view of this commercial distinction material carrying less than 20 per cent of metallic iron will not be considered as an iron ore in this report.

The type of iron ore commonly known as red ore is composed essentially of red hematite, or anhydrous ferric oxide ($Fe_2O_3$), together with a variety of impurities, such as silica ($SiO_2$), alumina ($Al_2O_3$), carbonate of calcium ($CaCO_3$), carbonate of magnesium ($MgCO_3$), sulphur (S), phosphorus (P), and manganese (Mn). Here and there a little hydrous iron oxide (brown ore) is mixed with the hematite, but it has resulted from the hydration of the hematite—that is, the chemical combination of water with the ferric oxide—and does not occur in sufficient quantities to affect the composition of the ore greatly.

The distinguishing characteristic of the red ore is its occurrence in beds or thin lenticular masses of great linear extent, analogous to strata of shale, limestone, and sandstone, and it is interbedded with




Base from U.S. Post Route map of Tennessee

Coal areas from geologic folios of U.S. Geological Survey; iron-ore outcrops mapped by E. F. Burchard

MAP SHOWING RELATION OF RED IRON ORES TO COAL FIELDS, TRANSPORTATION ROUTES, AND INDUSTRIAL CENTERS IN EAST TENNESSEE.

such rocks. One notable deposit is described in this report which is due to the concentration of residual fragments and powder of red iron ore derived from bedded deposits.

## IRON ORE IN THE TELLICO SANDSTONE.

### CHARACTER.

Interbedded with the shale in the Tellico sandstone there are in a few localities in east Tennessee and northwest Georgia thin seams or lenses of hematite of moderate extent. Such ore as was noted during the present study varies from a ferruginous calcareous sandstone to a rich, compact material composed mainly of iron oxide and having a relatively high specific gravity. Some of the ore is calcareous and contains many fossil remains. The richest beds range in thickness from a few inches to 18 inches, and much greater thicknesses of lean material have been measured. Where the Tellico sandstone has been disintegrated by weathering and the fragments of residual ore have been concentrated in basins on the surface of harder rocks, deposits of economic importance may be formed. Such deposits occur near Sweetwater and east of Knoxville, Tenn.

### DISTRIBUTION IN TENNESSEE.

Although attention has been directed to the iron ore in the Tellico sandstone only in a few places in Tennessee, namely, east of Knoxville, between Holston and French Broad rivers, near Sweetwater, Monroe County, and near Riceville, McMinn County, there are probably other areas in which this formation carries ore of similar character.

### DEPOSITS NEAR RICEVILLE.

#### LOCATION.

The ore noted near Riceville is included in the Tellico sandstone belt that extends northeast and southwest nearly parallel to and 1¾ to 2¼ miles east of the Southern Railway north of Hiwassee River.

#### TOPOGRAPHIC AND GEOLOGIC RELATIONS.

The Tellico sandstone occupies a dissected ridge that rises 300 feet above Oostanaula Creek. This creek cuts through the ridge near Athens and flows along the east side of the ridge to a point nearly opposite Riceville, where it crosses to the west side and follows the base of the ridge nearly to Hiwassee River. The Tellico here consists of shale, sandstone, and thin beds of limestone, the shale predominating. The formation outcrops on the west limb of a syncline, and the dips are generally about 20° S. 75°–80° E.

#### ORE BEDS.

There are at least two ferruginous beds in the Tellico in this vicinity. The lower of the two observed lies apparently in the lower third of the formation and the upper bed lies, as nearly as could be determined in driving across the formation, in the upper third. The lower ore bed is exposed at a point about 2½ miles southeast of Riceville, where it consists of hard, compact dark-red ore, with a metallic luster. The thickness averages about 9 inches and the range in thickness, measured along a trench 100 feet or more in length, is 6 to 14 inches. The ore is laminated parallel to the bedding and splits easily. It is also jointed perpendicular to the bedding. The material is fossiliferous and overlies a bed of fossiliferous crystalline limestone, gray to chocolate in color. The dip of the bed is 20° S. 75° E.

At this point the ore had been opened many years ago by trenching along the outcrop and stripping to a depth of 10 feet. Three carloads of ore thus obtained are said to have been shipped in 1888 or 1889 to the Citico blast furnace at Chattanooga. It is stated that at that time it cost 75 cents a ton to mine the ore, 75 cents to haul it to the railroad at Riceville, and 66⅔ cents for freight charges to Citico, and that the ore sold for $2.50 a ton, delivered. Judged by the appearance of samples and the analyses, given below, this ore is of excellent quality, but where it was observed it is too thin to be worked except by further stripping, and there is not much ore available for stripping. If the ore should be found to be of workable thickness underground toward the southeast, it might be advantageously worked by means of tunnels driven into the east slope of the ridge at a lower altitude. Considerable prospecting by drilling or tunneling would be necessary in order to determine the thickness, however.

The lower seam of ore was noted also about 4 miles northeast of Calhoun, on the hillside north of Meadow Fork. At this point the ore is only about 6 inches thick, and in places its color is dark, suggesting the presence of manganese oxide. The dip here is 20° S. 80° E.

The upper bed of ferruginous sediments noted in this vicinity displays great variation in character. At a point on the southeast slope of the ridge, about 2¾ miles east-southeast of Riceville (Pl. V), a prospect pit disclosed about 3 feet of ore, but the full thickness could not be determined because the bed was not fully exposed. The position of the mass suggested that it might be a bowlder that had become separated from its original bed. The ore is hard, compact, and dark red, apparently contains much silica, and breaks into prismatic fragments that show slickensides. The dip of the beds here is 20° S. 80° E. The upper ore bed was also noted near Meadow Fork about 4 miles northeast of Calhoun. At this point there is

10 to 12 feet, and possibly more, of ferruginous sandstone. This sandstone is decomposed and rather soft where observed in a road cut. It lies in thin to medium-thick beds, dipping 20° S. 80° E. The color is dark red to brown, but the rock here is apparently too low in iron oxide to be of value as an ore of iron at present. It is reported that several openings have been made on this seam at other places and that where the ore is hard and not decomposed it is of much better quality.

#### ANALYSES.

The following analyses show the character of the ore near Riceville:

*Analyses of soft iron ore from vicinity of Riceville, Tenn.*

[Authority, W. M. Bowron.]

| Locality. | Fe. | $SiO_2$. | P. | S. | $H_2O$. |
|---|---|---|---|---|---|
| McMinn-Thomas bank | 56.65 | 9.67 | 0.52 | 0.09 | 7.85 |
| McCamey | 60.21 | 13.82 | .72 | .09 | 1.02 |
| Dodson Ridge | 60.03 | 13.34 | .13 | .12 | 1.32 |
| Carruths Place | 56.58 | 18.05 | .65 | .......... | 1.10 |
| Meadow Park and Dodsons | 43.32 | 32.18 | .......... | .......... | .......... |

### DEPOSITS NEAR SWEETWATER.

#### LOCATION.

The iron ore 1½ to 3½ miles northeast of Sweetwater extends in a northeast-southwest direction and throughout its extent is from one-half to three-fourths of a mile southeast of the Chattanooga & Knoxville division of the Southern Railway. (See fig. 29, p. 286.)

#### TOPOGRAPHIC AND GEOLOGIC RELATIONS.

The ore lies on the southeast side of the Sweetwater Valley within 1 mile of the creek. It occupies a position not quite halfway to the summit of the divide and is between 75 and 150 feet above the level of Sweetwater Creek. The surface of the deposit is irregular, owing to erosion. In one place, where thickest, the deposit forms a gently rounded hill, and in another it is entirely cut through by a small branch that flows northwestward into Sweetwater Creek.

The deposit overlies the Chickamauga limestone and occupies a depression of irregular depth on the surface of that formation. The prevailing dip of the rocks is about 15° SE. Southeastward from Sweetwater Creek occur the following formations in an ascending scale: Knox dolomite, Chickamauga limestone (including the Holston marble lentil), and Tellico sandstone. The Tellico is partly buried beneath the Knox dolomite along an overthrust fault on the southeast. These relations are shown in the structure section (fig. 30, p. 287).

The upper portion of the Knox dolomite is exposed between Sweetwater Creek and the overlying Chickamauga limestone to the southeast. The residual clay from the Knox contains considerable chert, but where the rock beds are exposed they are generally grayish magnesian limestone. The Chickamauga is a mottled blue and buff dense to partly crystalline fossiliferous limestone. In places films of limonite appear on weathered ledges, but they do not extend far into the rock. The Holston marble in this area is a chocolate-colored to reddish-brown, medium coarsely crystalline stone, containing in some layers considerable ferric oxide. The Chickamauga limestone, including the Holston marble lentil, is 500 to 700 feet thick.

The Tellico sandstone, more appropriately termed shale in this locality, is principally a yellowish sandy shale, with two or more seams of iron ore locally developed.

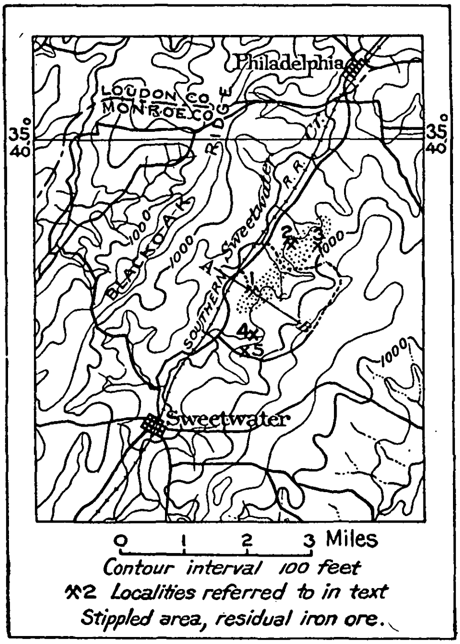



FIGURE 29.—Map showing geographic and commercial relations of residual hematite deposit near Sweetwater, Tenn. Topography from map of Loudon quadrangle, U. S. Geol. Survey. *A-B*, Line of section, figure 30.

### CHARACTER OF THE ORE DEPOSIT.

If scattered lumps of iron and manganese oxides had not been plowed up by farmers in tilling the bright-red soil of this locality, the possibility of the existence of ore in commercial quantity might never have been suspected. The abundance of these fragments in the fields and in gullies where they had been washed out of the soil led to the opening of some pits for the production of manganese ore a dozen years ago. After a few hundred tons of manganese ore (psilomelane) in lump form had been shipped work was abandoned, but several years later a number of pits were sunk in the hope of finding more abundant supplies of manganese, and in these pits a peculiar dark-reddish to bluish-black soft claylike substance was found which proved on analysis to be rich in ferric oxide. One of these pits, about 20 feet deep, showed the following succession from the top downward: Residual soil, red sandy clay, smooth fine-grained dark bluish-red clay, manganese oxide gravel, lumps of red iron oxide, black banded clay, and at the bottom fossiliferous ferruginous limestone dipping 8° to 10° SE. The manganese ore carried 43 to 46 per cent of metallic manganese and a little iron. Another pit showed at the top 3 to 5 feet of ferruginous soil with tough hard slickensided angular fragments of iron ore, from half an inch to 12 or 15 inches long, mixed with nodular lumps of manganese ore. Below this a bed of bluish-red granular clay, 4 to 6 feet thick, lies like a blanket, following the contour of the hill. This material gives a bluish-red graphitic smut when rubbed between the fingers. The bed next below is about 6 feet thick. It is darker, but is of a lower specific gravity than the bluish material. In other pits this horizon is occupied by yellowish and black clay mixed. No rock was struck in several pits, but ferruginous limestone was noted at a lower level on the hillside toward the west. One pit which was started in on the limestone disclosed a very irregular rock surface with gravel iron ore lying in depressions in the limestone and covered by clay. Here and there in the ore gravel and more abundantly among the surface ore fragments are found waterworn pebbles of white sand-

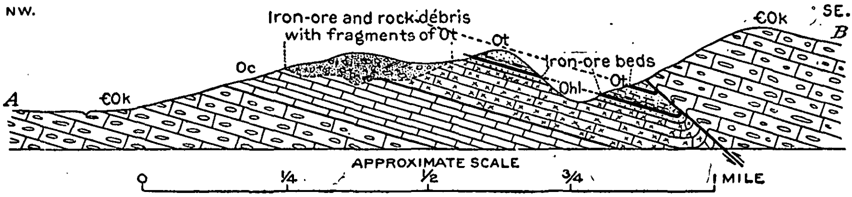



FIGURE 30.—Northwest-southwest structure section near Sweetwater, Tenn., along line *A-B*, figure 29, showing position of residual iron ore deposit and relation of Tellico iron ore beds and ferruginous Holston marble to the ore beds. €Ok, Knox dolomite; Oc, Chickamauga limestone; Ohl, Holston marble lentil of Chickamauga limestone; Ot, Tellico sandstone.

stone and quartzite. When moist all the clay is darker and shows less red color than when dry.

The unique feature of this deposit, so far as this region is concerned, is that the dark bluish-red and steel-colored clay and some of the reddish surface clay really constitute an earthy iron ore. The dark variety is usually manganiferous, but some of the earthy material, though high in iron, contains only a little manganese. This locality was first visited by the writer in 1906. At that time mining was in progress and about 150 carloads of iron ore (more than 5,000 long tons) had been shipped, principally to blast furnaces in Chattanooga. The deposit was again visited in 1911, after considerable more mining had been done. The largest pit from which the material had been mined is near the top of the hill (No. 1, fig. 29) and had a face of about 25 feet and a diameter of about 100 feet. At the bottom of the pit a shaft had been sunk 40 feet, all in soft ore without reaching rock, but a well dug near the power house, beginning at a level about 10 feet below the base of the pit, reached gray limestone within a depth of 40 feet, showing that the thickness of the loose sedimentary material at that place is nearly 75 feet. Near the entrance to the pit, which is reached by a passageway cut from the hillside, the soft ore and ore débris appear to occur in masses having rounded tops. Layers of manganese gravel follow the contour of the rounded masses. Some of the ore is sandy and shows limonite specks. Streaks of greasy pink hematite, with a graphitic feel, are found; such material is called "iron fat" by miners.

The fragments of hard ore embedded in the soft ore appear to have been broken from a bed in the Tellico sandstone which formerly extended over the area but which has been cut back eastward by erosion and disintegration. Many fragments show slickensides parallel to the bedding and on joint planes. Pieces of ore 8 to 10 inches thick were noted, and masses 3 feet thick are reported to have been found. The fragments of hard ore strongly resemble the red ore occurring near Riceville, which is considered by E. O. Ulrich to be in the Tellico sandstone. These fragments have not yielded many fossils, although one brachiopod and numerous crinoid stems were noted. The ore is also oolitic or granular in places. The hard fragments appear to have been derived from two or more beds, one rich in iron and the other lean and sandy—this also being a point of resemblance to the ore near Riceville. In the ferruginous earth forming the walls of a pit formerly worked for manganese ore (No. 2, fig. 29) about three-fourths of a mile northeast of the pit first described, masses of yellow sandy shale, waterworn pebbles of white quartz sandstone, and angular pieces of buff fine-grained sandstone were found. Similar sandy shale occurs in place on the hillside about a quarter of a mile east of the old manganese pit, in the area mapped as Tellico sandstone in the Loudon geologic folio.[1] It overlies crystalline limestone belonging to the Holston marble lentil of the Chickamauga limestone. Two pits in which an ore seam had been cut were noted in this shale. One pit (No. 3, fig. 29) is in the lower part of the formation, 15 to 25 feet above the highest observed outcrop of Holston marble, and about half a mile northeast of the "soft ore" mine. The other pit (No. 4, fig. 29) is about three-fourths of a mile south of the ore mine. A bed about 4 inches thick, dipping about 15° SE., appears in the pit at point No. 3. This bedded ore is rich in iron, fossiliferous, and granular but has been leached so as to be spongy in places. In the pit at point No. 4 the ore is evidently much thicker, although the pit was covered and the thickness could not be measured. Several tons of ore lie on the dump. The ore from this pit is very rich in iron. It is mostly hard, compact, and brittle, breaking into blocks with bright slickensided faces. It is reported that this bed ranged from 18 inches to 3 feet in thickness but pinched out to almost nothing within a few yards, and

[1] Loudon folio (No. 25), Geol. Atlas U. S., U. S. Geol. Survey, 1896.

prospecting was therefore discontinued. This pit is south of the limit given by Keith in the Loudon folio for the Tellico sandstone in this vicinity, but the shale shows plainly in the wagon road half a mile farther south, where the ore also outcrops with a thickness of about 30 inches (No. 5, fig. 29). The beds dip about 15° SE., and if projected northwestward would lie above the present surface of the soft ore.

#### ORIGIN OF THE ORE DEPOSIT.

The fragments of hard ore appear to have been derived from the ore beds in the Tellico sandstone, but another important source of ferruginous material in this locality is the Holston marble. Some beds of this rock contain 15 to 20 per cent of ferric oxide. When the calcite is leached out a large iron oxide residue is left. This is well shown on the weathered edges of some beds of the marble and by fragments from which the lime has been dissolved. In the Chickamauga limestone below the Holston marble lentil there are streaks of limonite ranging in thickness from a knife edge to three-fourths of an inch running irregularly through some beds. Both the topographic and the geologic relations of these three iron-bearing formations suggest that the deposit is residual from (*a*) the hematite beds in the Tellico sandstone that once extended over the area, (*b*) the ferric oxide in the Holston marble lentil of the Chickamauga limestone, and (*c*) the limonite streaks in the other limestones of the Chickamauga. Surface water has assisted in the concentration, as is indicated by the rounded, waterworn pebbles of sandstone that have been carried into the deposit and by the distribution of the nodules of manganese oxide in strata and pockets near the top of the mass of soft ore.

The most notable characteristic of the deposit is the large proportion of hematite present. Throughout the Appalachian Valley occur scattered deposits of limonite, most of which are residual from the limestone beds that have been removed by solution, but nowhere else in the South has the writer seen a deposit of residual iron ore that is composed so largely of hematite. In this respect it resembles, on a small scale, some of the deposits of residual ore in the iron ranges in Minnesota. It is not improbable that similar deposits may be found at other places in east Tennessee where the topographic and geologic conditions resemble those at Sweetwater.

#### MINING.

Prior to 1907 mining was at first accomplished here by cutting down the bank with picks, carting away the stripping, and moving the raw ore in wagons to the siding on the Southern Railway, about three-fourths of a mile distant, where it was dumped into cars and shipped to Chattanooga. Attempts were later made to briquet the ore, and a stiff-mud brick-molding machine was erected. The soft ore was trammed from the pit on small cars, mixed with a little water, made up into about 100,000 bricks, built up in kilns, and burned just hard enough to enable them to stand handling and transportation, most of the moisture being driven off by the process. The ore so treated is reported to have cost $1.26 a ton to mine and briquet and to have been successfully used in the briquetted form by certain blast furnaces. It was not possible to maintain a sufficiently large output from this plant and its use was discontinued. but the results of the briquetting demonstrated that the quality and physical condition of the ore could be much improved through some method of concentration and conversion to a more solid state. Consequently preparations were made first to develop a large output of the ore, and next to install an ore-sintering plant.

In October, 1912, a 20-ton steam shovel was started stripping cover and digging ore. The ore was loaded into mine-dump cars that carried the ore about 900 feet toward the railroad and dumped it into wagons, in which it was carried the remaining five-eighths of a mile to the railroad. Nearly 8,000 long tons of ore is reported to have been shipped to blast furnaces in 1912. Average analyses are said to have shown a little more than 40 per cent of metallic iron and between 2 and 3 per cent of manganese. It is stated that another steam shovel is soon to be installed and that the construction of 1,200 feet of new siding from the Southern Railway to the site of the sintering plant is under way (January, 1913). It is reported that the sintering plant is to be built by the American Ore Reclamation Co. and will comprise four Dwight-Lloyd sintering machines. This plant is planned to produce 400 tons of sintered ore daily, and it is considered that this sinter, which is cellular in structure, should require much less coke than is required to reduce natural iron ores.

It is said that prior to installing the steam shovel 200 acres of this ore land was surveyed and platted, 40 test holes 15 to 80 feet deep were sunk 100 to 200 feet apart, cross sections were drawn, and analyses were made of samples of the ore taken every 5 feet from the test holes, but none of the results of this work could be obtained for inspection by the Survey.

According to reports of recent operations the costs for mining by steam shovel, hauling, and loading the ore on railroad cars were reduced to a very much lower average than before the steam shovel was installed, and it is expected that these costs will be still further lowered when a tramway entirely supplants hauling by team.

A good market is assured for several times the proposed daily output of this mine and sintering plant, so that if the ore exists in sufficient quantity and the beneficiation proves successful the future exploitation of this deposit should be very promising.

### ANALYSES.

The following analyses show the character of the ore near Sweetwater:

*Analyses of iron ore from vicinity of Sweetwater, Tenn.*

| | Authority.[a] | Fe. | $SiO_2$. | $Al_2O_3$. | CaO. | Mn. | P | S | $H_2O$. |
|---|---|---|---|---|---|---|---|---|---|
| Unconsolidated ore | O | 46.90 | [b]20.16 | | ........ | 2.12 | ........ | ........ | ........ |
| | | ........ | ........ | 7.41 | ........ | ........ | ........ | ........ | ........ |
| | | 32.30 | 44.92 | 5.61 | ........ | ........ | ........ | ........ | ........ |
| | | 45.18 | 16.27 | ........ | ........ | ........ | ........ | ........ | ........ |
| | | 43.91 | 23.30 | ........ | ........ | ........ | ........ | ........ | ........ |
| Do | E | 52.32 | 8.52 | 7.73 | ........ | 2.50 | 1.71 | ........ | ........ |
| Do | Ch | 47.84 | [b]16.22 | 11.41 | ........ | 2.78 | .51 | ........ | ........ |
| Do | Ch | 50.75 | [b]17.20 | 10.16 | ........ | ........ | ........ | ........ | ........ |
| Do | Ch | 59.20 | 5.30 | ........ | ........ | ........ | .22 | ........ | ........ |
| Do | Ch | 33.86 | [b]43.80 | 6.10 | ........ | 2.43 | .435 | ........ | ........ |
| Do | L | 29.90 | [b]37.52 | | ........ | ........ | ........ | ........ | ........ |
| Do | L | 41.30 | [b]22.78 | | ........ | ........ | ........ | ........ | ........ |
| Do | L | 46.90 | | 7.41 | ........ | 2.12 | ........ | ........ | ........ |
| Heiskell tract | L | 40.90 | [b]23.98 | | ........ | ........ | .22 | ........ | ........ |
| Do | L | 35.90 | [b]30.36 | | ........ | ........ | ........ | ........ | ........ |
| Do | L | 53.20 | [b]7.32 | | ........ | ........ | .46 | ........ | ........ |
| Prospect sample | L | 46.50 | [b]22.56 | | ........ | 1.18 | ........ | ........ | ........ |
| Do | L | 11.10 | [b]68.56 | | ........ | ........ | ........ | ........ | ........ |
| Do | L | 39.90 | [b]28.44 | | ........ | ........ | ........ | ........ | ........ |
| Do | L | 15.50 | [b]61.94 | | ........ | ........ | ........ | ........ | ........ |
| Do | U. S. | 46.80 | 15.22 | 10.02 | ........ | 1.75 | .12 | .05 | 3.57 |
| "Iron fat" ore | U. S. | 47.85 | ........ | ........ | ........ | ........ | ........ | ........ | 2.82 |
| Ferruginous limestone | Ch | 8.71 | [b]4.10 | | 76.90 | ........ | ........ | ........ | ........ |
| Do | C | 12.11 | [b]6.68 | | ........ | ........ | ........ | ........ | ........ |

[a] Authorities: C, Citico Blast Furnace Co.; Ch, Chattanooga Iron & Coal Co.; E, Embree Iron Co.; L, La Follette Iron & Coal Co.; O, owners; U. S., U. S. Geological Survey.
[b] Insoluble.

## TUCKAHOE DISTRICT.

### SOURCE OF DATA.

In view of the interest that is at present being taken in the deposits of iron ore which lie between Holston and French Broad rivers in Knox and Jefferson counties east of Knoxville, Tenn., and which are somewhat similar in origin and geologic relations to the deposit near Sweetwater, described above, it has been decided to present here certain essential data recently published by C. H. Gordon and R. P. Jarvis, of the University of Tennessee, on the iron-ore deposits of the Tuckahoe district. The complete paper was published in the issue of "Resources of Tennessee" for December, 1912, pages 457–478. According to that description, the ore consists of both limonite and hematite, like the ore near Sweetwater, although in the Sweetwater locality hematite predominates. In the Tuckahoe district the limonite has probably been formed, for the most part, through the hydration of hematite, and a similar process has produced much limonite in the soft "Rockwood" ore near Chamberlain. As brown ore of this type is derived directly from bedded deposits of the normal red-ore type, the brown ore is much more closely allied to the bedded red ore than it is to the typical Appalachian Valley brown ores, and it should logically be grouped with the bedded red ores.

The following quotations on this subject are taken from the report by Gordon and Jarvis mentioned above.

### THE ORES.

The iron ores of the Tuckahoe district are comprised within a belt approximately 14 miles long and 4 miles wide lying between the Holston and French Broad rivers. The southern extremity of the belt lies approximately 4 miles northeast of the junction of the two rivers and extends in a general northeast direction to McCampbells Knob, situated 7 miles southeast of Straw Plains. The southwest extremity of the belt is about 9 miles northeast of Knoxville. The iron-bearing zone as thus defined is included within the three counties of Knox, Sevier, and Jefferson.

The district is readily accessible by good pike roads from the station of Straw Plains, 16 miles northeast of Knoxville on the Bristol & Knoxville division of the Southern Railway. The southwest extremity can be reached from Knoxville over the Dandridge pike, and with the completion of the branch line of the Southern Railway to the marble quarries between the forks of the Holston and French Broad rivers the deposits in part are brought within a distance of 4 to 5 miles of rail transportation. Owing to the close proximity of the rivers to the entire belt, water transportation is within easy reach.

The formation carrying the iron-bearing beds in this district is known as the Tellico sandstone, a gray and bluish-gray calcareous and ferruginous sandstone ranging from 100 to 300 feet thick, of Ordovician age. The formation derives its name from Tellico Plains, in Monroe County, where it is extensively developed. The outcrop of this formation is usually defined by a well-marked chain of knobs. The iron-bearing member within this formation consists of a ferruginous limestone, but often siliceous in part, which has been thrown into multiple folds, giving rise to a series of parallel veins of beds. All members of the Tellico formation weather rapidly, and owing to this fact and the relatively high iron content in certain beds these have formed, under favorable conditions, considerable accumulations of a very good grade of iron ore.

The analogy between the iron ores in the Tellico and those found in the "Rockford" formation (the "Rockford" iron-ore horizon in Tennessee) is remarkable. This similarity holds not only in the association of the iron beds with the inclosing rocks, shales, and limestones in both cases, but also with reference to the chemical composition of the ores and their physical condition. But the analogy apparently no longer holds when we trace the iron-ore beds of the Tellico beneath the surface. In the case of the Tellico formation it has been found that the concentration of the iron due to the action of surface agencies in leaching the more soluble lime carbonate of the iron-bearing limestone and converting the primary iron carbonate into iron oxide, has not progressed to any great depth. Practically all the openings and prospects made on these veins have either been near the crests of the ridges or knobs or on the steep slopes of narrow hollows and ravines, and usually upon the side of the hill having a southern exposure.

* * * There are three roughly parallel belts of Tellico sandstone, of which the central belt is the longest and the most extensively exploited. This repetition of belts is due, of course, to sharp folding and faulting, and, as explained above, the occurrence of three or more parallel beds or veins is doubtless the result of multiple folds. The multiple-fold structure is very prettily shown at

Moores Knob. Generally the iron veins have a steep dip to the southeast, with the strike conformable with the outcrop of the Tellico formation.

Four localities were examined, viz:

1. Johnsons Knob. Prospects on the farm belonging to G. W. S. Johnson.
2. Maurer's place, or farm now owned by Samuel Vance.
3. Moores Knob, situated close to a farm owned by Jesse Campbell, and on a farm owned by J. R. Moore.
4. McCampbells Knob. Prospects situated on a farm belonging to the McCampbell heirs, and also on other contiguous farms owned by Joshua Cates, Charles Snyder, et al.

From the principal prospects at each of these localities samples were taken, and, where accessible, measurements of the ore bodies were made.

The ore bodies consist of beds of extremely variable thickness, the range being from 1½ to 25 feet or more, as shown in the subjoined table, which is adapted from the paper by Gordon and Jarvis. Some of the beds where unweathered are hardly more than ferruginous limestone, but where weathering has taken place and the lime is leached out the residual material is fairly rich in iron. The beds generally dip at high angles and are exposed high above drainage level, thus affording conditions favorable for deep weathering.

*Analyses and other data regarding iron ore in the Tuckahoe district, Tennessee.*[a]

| No. | Locality. | Prospect or vein No. | Character. | Width sampled. | Fe. | $SiO_2$. | CaO. | P. | S. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Ft. in. | | | | | |
| 1 | Johnsons Knob | 1 | | 1 6 | 48.1 | 20.16 | 1.00 | 0.426 | 0.06 |
| 2 | do | 2 | Unweathered | 10 | 28.0 | 35.12 | .40 | | |
| 3 | do | 3 | | 4 | 43.3 | 20.68 | .60 | .295 | .76 |
| 4 | Johnsons Knob, cellar of Johnson's house. | | | 13 | 50.0 | 13.32 | .40 | .498 | .27 |
| 5 | Johnsons Knob | 4 | | 12 | 33.0 | 36.3 | .65 | | |
| 6 | Johnson's dump vein | 2 | | | 36.7 | 24.92 | .50 | .453 | .68 |
| 7 | Vance farm, select ore | | Weathered | 5 | 51.3 | 9.78 | 2.00 | 1.001 | .42 |
| 8 | Vance farm, average ore | | Mixed ore | 7 6 | 41.2 | 21.4 | 1.50 | .831 | .12 |
| 9 | Moores Knob | 1 | Weathered | 13 | 43.6 | 16.88 | .70 | .73 | .65 |
| 10 | do | 2 | Unweathered | 4 6 | 22.0 | 5.20 | 27.20 | | |
| 11 | do | 3 | Weathered | 7 | 34.2 | 15.2 | 9.60 | | |
| 12 | do | 5 | Unweathered | 6 | 19.8 | 8.88 | 26.60 | | |
| 13 | Moores Knob, northeast | 1 | | 20 | 23.1 | 34.10 | 11.30 | | |
| 14 | do | 2 | | 25 | 29.2 | 40.00 | 1.20 | | |
| 15 | do | 3 | Partly weathered. | 9 | 32.4 | 36.6 | 1.80 | | |
| 16 | do | 4 | Weathered | 18 | 41.7 | 19.00 | 4.0 | 1.023 | .45 |
| 17 | McCampbells Knob | 1 | do | 10 | 30.5 | 34.80 | 1.15 | | |
| 18 | McCampbells Knob (southwest prospect). | | do | 10 | 41.4 | 19.6 | 2.25 | .836 | .49 |
| 19 | McCampbells Knob (dump, Joshua Cates). | | Unweathered | | 11.4 | 45.00 | 14.80 | | |
| 20 | McCampbells Knob (dump) | | Weathered | | 40.6 | 17.20 | 6.00 | .958 | .55 |
| 21 | McCampbells Knob | 2 | do | 6 6 | 41.0 | 23.12 | .60 | .648 | .28 |
| 22 | McCampbells Knob tunnel | 2 | | 5 | 32.0 | 29.2 | 1.40 | | |
| 23 | do | 2 | Mixed ore | 5 | 34.2 | 13.20 | 10.80 | | |
| 24 | McCampbells Knob | 3 | | 5 | 42.6 | 22.0 | .40 | .669 | .55 |
| 25 | do | 4 | Weathered | 23 | 42.5 | 19.0 | 1.20 | 1.082 | .60 |
| 26 | do | 5 | do | 6 | 44.7 | 13.92 | 1.75 | .616 | .52 |
| 27 | McCampbells Knob (Snyder farm). | | do | 7 6 | 49.2 | 14.28 | .90 | .959 | .46 |
| 28 | do | | do | 15 | 46.0 | 14.6 | 2.40 | .479 | .52 |
| 29 | do | | Unweathered | 15 | 26.6 | 6.70 | 22.5 | | |
| 30 | Sample taken from Tellico formation near Charleston, Tenn. | | | | 14.0 | 22.6 | 26.70 | | |

[a] Analyses 1 to 30, inclusive, were made on moisture-free samples; R. P. Jarvis, analyst.

*Analyses and other data regarding iron ore in the Tuckahoe district, Tennessee* [a]—Continued.

| No. | Locality. | Iron. | Insoluble. | Mn. | P. | Moisture. |
|---|---|---|---|---|---|---|
| 31 | Johnson's prospect | 35.00 | 31.20 | 0.44 | 0.44 | 3.10 |
| 32 | Johnson's cellar | 53.20 | 9.50 | .97 | .25 | 3.40 |
| 33 | Vance's prospect | 50.40 | 2.25 | Tr. | 1.10 | 1.39 |

[a] Analyses 31 to 33 by Childress & Hunter.

## ORIGIN OF THE ORES.

The evidence that the richness of the iron ores of the Tuckahoe district is due to the leaching out by surface agencies of the more soluble lime carbonate of the iron-bearing limestones of the Tellico formation and the concentration of the iron in the surficial portions is ample and conclusive. As already noted, the exposures are in practically all cases at the tops of knobs and ridges or in narrow hollows and ravines, where erosion has not been sufficient to remove all the products of decomposition. The extent of the deposits is therefore proportional to the depth to which the work of the weather has progressed and the amount of erosion. According to locality, the leaching and the consequent concentration of the iron constituents extends to depths of from 1 or 2 to 40 or 50 feet. In the tunnel on McCampbell property the limestone was encountered 25 feet from the entrance. On making an offset to the right soft ore was found, which extended to the end of the tunnel, a distance of about 50 feet. The more extensive alteration in this portion of the tunnel doubtless finds its explanation in the presence of fractures, permitting the access of water and the consequent leaching of the ferruginous rock. An excellent illustration of this effect of weathering agencies is seen in an outcrop in the north face of the ridge 200 yards southwest of the house on Mr. Snyder's land, in the McCampbell area. Here erosion has removed the products of weathering about as fast as formed. An opening shows the abrupt transition from soft ore to the hard unaltered limestone below. Leaching has progressed irregularily into the rock, following along fractures and crevices, which permitted the easy access of surface waters.

Many other instances may be cited where the indications of the concentration of the iron ores through the leaching of the iron limestone are equally clear and convincing. The prospect shaft put down on Joshua Cates's land west of the McCampbell Knob met with the dark bluish-gray calcareous sandstone (see analysis No. 19) at a depth of about 30 feet, as indicated by the excavated material. The highly ferruginous character of the calcareous beds of the Tellico is shown also by the analyses given (p. 293). It will be readily seen, therefore, that with the removal of the lime by leaching the iron constituents will be concentrated and the deposition thus formed will be confined to the surficial or weathered portions of the formation.

## MINING CONDITIONS.

Considerable excitement in the Tuckahoe district was aroused about two years ago, resulting in most of the above prospecting work being done. Estimates of tonnage based upon the results of this prospecting work have been made, but in view of the foregoing facts and an examination of the prospects the writer is of the opinion that even in small and restricted areas, not to mention the entire district, no estimates worthy of the name are possible.

In general, with reference to the character of the ores, analyses have shown that good commercial grades occur in parts of the weathered zone. All the ores are relatively high in phosphorus and therefore non-Bessemer. After passing through the variable but relatively thin weathered zone of enriched ore the veins show a rapid decrease in iron content with increase of depth. This diminution of iron with depth may be expected to continue until the unaltered ferruginous limestone is reached, after which the iron values will ordinarily vary from 10 to 16 per cent. Under present conditions this material can not be considered an iron ore, though in many places in east Tennessee there are literally mountains of it. Possible other uses may be found for it.

Having thus presented the facts in the case so far as present developments have shown, the question as to whether, under present conditions, these deposits can supply a regular and large tonnage answers itself. If it is possible to mine a deposit that occurs in widths and depths varying between 7 to 20 feet and 1 to 12 feet, respectively, where the values are spotted and irregular, where all the work of removing the materials would have to be done by hand, where the iron ore would have to be delivered by cart, wagon, or tramway to some point to be loaded on railway cars, where the topography is that of knobs and ridges, therefore not easily accessible, all at a cost of 75 cents to $1 per ton, then mining may pay. Up to the present time no one has essayed the task. Therefore, until someone has demonstrated that these deposits can be worked at a profit, we must put them into the class of possible future reserves rather than consider them as an immediate source of supply.

## DISTRIBUTION IN GEORGIA.

In his chapter on the local distribution of fossil ores in Georgia McCallie [1] writes as follows concerning certain ore deposits of Ordovician age which perhaps should be correlated with the Tellico ore of east Tennessee:

Besides the above exposures, there are also limited outcroppings of red ores farther east, which are often confounded with the fossil ores. One of the best exposures of these ores is to be seen on the Hoskins farm near the Georgia-Tennessee line, in Whitfield County, about 1 mile east of Red Clay (Dalton quadrangle). The ores here occur along a series of red hills which extend as far south as Varnell's station. Another exposure of these ores may be seen in the northern part of Murray County, along the margin of the metamorphic slates. This series of iron-bearing rocks, which always weathers into a deep-red soil and occasionally carries a limited amount of workable hematite ore, has been described by Hayes under the name of the Tellico sandstone. The formation seems to be of a more recent origin than the fossil ores; nevertheless the similarity of the two ores is often quite marked. Still other iron ores somewhat resembling the fossil ores but probably belonging to the Tellico sandstone occur in Polk County, a short distance north of Rockmart. These ores, which have been rather extensively worked at two or three points along the Seaboard Air Line Railroad, are the weathered outcroppings of a highly ferruginous thin-bedded limestone. Microscopic sections of the unweathered rock show that the ore is present in the form of magnetite. In some parts of the beds where the ores have apparently undergone only partial metamorphism an oolitic structure still remains, thus showing one of the most common characteristic structures of the fossil ores.

[1] McCallie, S. W., op. cit., p. 39.

To this interesting statement it might be added that the writer visited the deposit 2 miles north of Rockmart, in the Rome quadrangle, finding conditions as described by McCallie and also a slight error in the economic-geology map of the Rome folio. The former iron-ore workings were situated about half a mile east of the railroad station designated " Red Ore " on the map, and not at the point about three-fourths of a mile northeast of the station, where a symbol indicates an iron mine. There was, however, at this point formerly a slate quarry. The available iron ore appears to have been practically all mined out, and there is no longer any railroad station designated " Red Ore." On the map referred to the iron ore is mapped as occurring in the area of Rockmart slate.

## IRON ORE IN THE "ROCKWOOD" FORMATION.

### GENERAL DISTRIBUTION.

The " Rockwood " iron ore in Tennessee, Alabama, and Georgia is nearly but not quite coextensive with the " Rockwood " formation in these States. The exceptions are a few areas where the formation carries little more than a few streaks of ferruginous sandstone or ferruginous limestone. The ore-bearing formation underlies the great plateau areas such as the Cumberland Plateau, Walden Ridge, Sand Mountain, Lookout Mountain, and Pigeon Mountain, which are all broad synclinal areas, and it outcrops in the valleys bordering these plateaus. There are also certain areas of less extent within the valley of east Tennessee and in northwest Georgia, where the iron ore underlies narrow synclinal basins whose continuity has been broken by erosion. The relation of these several areas is shown on the maps (Pls. V and VI).

### EAST TENNESSEE.

The " Rockwood " ore in east Tennessee outcrops along the foot of the Cumberland escarpment from the southern border of the State near Chattanooga to the northern border of the State at Cumberland Gap and in several separate areas in the Tennessee Valley. The Cumberland outcrop is not continuous because a number of thrust faults have buried the formation below older rocks. There are, however, strips of outcrop that extend continuously distances of 15 to 20 miles. The normal dip of the rocks along the escarpment is toward the northwest, but in many places the ore beds dip to the southeast, or away from the mountain. This reversed dip is due to the overturning of the strata during the folding of the earth's crust, and it extends from a few feet to hundreds of feet below the surface.

The iron-ore beds extend under the Cumberland Plateau for unknown distances. In the northeastern part of the State the bed is probably continuous between Powell Valley and Elk Valley, the outcrop in Elk Valley being due to faulting and erosion. Near Caryville the southwestward extension of the ore is cut off by a cross fault, which extends northwestward as far as Elk Valley and here again cuts off the ore that is exposed in that valley, thus forming a block of strata bounded on the southeast by Powell Valley, on the southwest by Coal Creek, on the northwest by Elk Creek, and on the northeast by a fault which passes through Cumberland Gap. Along the escarpment between Coal Creek and Harriman the ore is cut out locally by several thrust faults, so that only three small areas of outcrop remain. From Emory Gap southwestward to a point near Glen Alice the ore outcrop is more or less continuous and in the part of this area extending from Cardiff to Rockwood occurs one of the thickest and most valuable portions of the ore bed that has been opened in the State. Between Glen Alice and Spring City there is one considerable break due to faulting, but from Spring City southwestward to Retro the ore outcrop is practically continuous. Between Retro and Rathburn there is a break followed by a strip of ore outcrop about 2½ miles in length, beyond which no ore is found until the valley of Falling Waters Creek is reached. From this creek southwestward to the State line the ore outcrop is practically continuous and is duplicated on both sides of a narrow anticlinal arch. This arched structure is also seen from Hill City southward to the State line in a second outcrop which lies 1 to 2 miles east of the main outcrop at the foot of the Cumberland escarpment and passes through the city of Chattanooga.

In the Tennessee Valley the several areas of "Rockwood" ore are formed by beds that have been folded in among older strata. The largest of these areas are situated near Chamberlain, a few miles south of Tennessee River, in Roane County, and along Tennessee River near Euchee, in Meigs County. These outcrops are mostly in the form of synclinal basins of the "Rockwood" formation modified by more or less folding and faulting. Just northeast of Decatur lies a small area which is bounded on the east by a fault, and farther south Whiteoak Mountain forms the west limb of a syncline in which ore occurs, extending from the State line northward several miles from Ooltewah. Soft ore has been stripped from the outcrop along nearly the whole extent of outcrop in the State, the only exceptions being in localities so remote from railroads or navigable streams as to make mining unprofitable. The ore has been mined underground at La Follette, to a very small extent near Elk Valley, extensively between Emory Gap and Rockwood, and in a few small drifts or tunnels near Glen Alice. Considerable underground work has been done in the vicinity of Chamberlain and Euchee, and a little near Ooltewah. The possibility of underground mining has of course depended on the thickness of the ore bed and the quality of the hard ore below the limit of weathering, as well as on transportation facilities. (See Pls. V and VI.)

An attempt has been made to distinguish on the maps (Pls. V and VI) between ore that is available or probably available and ore that is not available under present conditions. In the latter class are included ore seams that are so thin as to give no promise of future value and others that probably will not become workable until some time in the remote future when the reserves of more readily available iron ore in the country have become more nearly exhausted and the price has reached a point which will permit exploitation of such ores. Topographic maps have been prepared by the United States Geological Survey covering this whole region, and all of it except two small areas in the southern portions of the Williamsburg and Cumberland Gap quadrangles has been covered by geologic folio maps. The geologic folios that cover the remainder of the region are as follows, named in order from north to south: Briceville (No. 33), Maynardville (No. 75), Knoxville (No. 16*), Loudon (No. 25), Kingston (No. 4*), Pikeville (No. 21*), Sewanee (No. 8*), Chattanooga (No. 6*), and Cleveland (No. 20). A strip about 1 mile wide at the north edge of the Stevenson (No. 19*) and Ringgold (No. 2*) quadrangles completes the area within the State of Tennessee to the south of the Sewanee and Chattanooga quadrangles. The folios marked with an asterisk (*) are out of print; the others may be obtained from the Director of the United States Geological Survey.[1] In the geologic folios the general geology and structure have been described by means of maps, structure sections, and discussions in the text. In certain of the folios the distribution of the "Rockwood" formation has been shown to be more extensive than it is now believed to be. At the time the folio surveys were made data were obtained with regard to the ore beds, and it was assumed that the ore did not extend much below water level. The continuity of the beds to depths far below water level has been proved by recent mining work. In the northern part of Sequatchie Valley, in the Pikeville and Chattanooga quadrangles, recent work has shown, according to E. O. Ulrich, that much of the formation formerly mapped as "Rockwood" is not of Clinton age but is older, and that it does not carry ore beds of importance. In the lower part of Sequatchie Valley, near Inman, the

[1] Owing to damage done by a recent fire in the basement of the Geological Survey building the price of these folios has been reduced to 5 cents a copy.

beds of ore have been mined extensively both on the outcrop and underground a number of years ago, but northward from the vicinity of Inman the ore thins abruptly and in a short distance becomes so lean that it is unfit for consideration.

If placed end to end the outcrops of "Rockwood" ore along the base of the Cumberland escarpment, but a single seam being considered, would aggregate 160 linear miles. If the valley outcrops are similarly considered it brings the total linear outcrop of "Rockwood" ore beds in the State up to 245 miles. Out of this total probably 60 miles of outcrop may be considered as workable for hard ore, so far as quality and thickness are concerned, to whatever distances below the outcrop may be permitted by mining conditions. These distances were determined by scaling off the outcrops as shown in the geologic folios. By measurement on the ground the distance might be appreciably greater, because the scale of the maps is too small to show many sinuosities of the outcrop.

For convenience of description the whole of the east Tennessee red-ore area may be divided into three parts—southeast Tennessee, central east Tennessee, and northeast Tennessee. The first division includes the Tennessee Valley from the south boundary of the State to Evensville and also the Sequatchie Valley and the Whiteoak Mountain area. Central east Tennessee comprises the area from Sheffield northeastward to and beyond Coal Creek, and northeast Tennessee the area from Careyville northeastward to Cumberland Gap, including the Elk Valley.

## SOUTHEAST TENNESSEE.

The leading facts with regard to the "Rockwood" iron-ore beds outcropping in southeast Tennessee may be briefly summarized here. Perhaps the most important question with regard to a bed of such ore at a given place relates to its thickness. Next, provided the bed is of a workable thickness, is the question of quality, and third is the question of extent of the beds. With reference to the third question it may be said that "Rockwood" ore outcrops all the way along the foot of the Cumberland escarpment, with the exception of about 6 miles in the vicinity of Daisy, almost continuously from the Georgia line to a point northeast of Evensville, a distance of about 45 miles. In addition to this length of outcrop 25 miles of ore measures are brought to the surface by anticlinal and synclinal folds near Chattanooga. In places two to four thin seams of ore occur. The thickness of the ore in some areas is less than 2 feet, as indicated on the map (Pl. VI), but at certain places there is more than 2 feet of ore in the section, as is also shown on the map. In the cut of the

Nashville, Chattanooga & St. Louis Railway 2 miles west of Wauhatchie there is a total of 3 feet 7½ inches of ore in a section of ore and shale aggregating 5 feet 2 inches in thickness. Most of this ore is little more than ferruginous limestone, but to the southwest, in Georgia, the ore bed is richer. A quarter of a mile east of Williams Island the bed showed 2 feet 4 inches of hard calcareous ore. Near Falling Waters a section of 27 feet 6 inches contains 5 feet 3 inches of lean ore, no single bed of which is thicker than 1 foot 1 inch. The outcrops at Hill City showed 2½ feet to more than 3 feet of ore, with one shale parting 2 to 7 inches thick near the middle. The hard ore is lean and calcareous, but there is still some soft and semihard ore here. The "Rockwood" formation at Hill City has a very irregular structure. The beds are considerably faulted and so closely folded as to make deep or extensive mining very difficult. Near Daisy a section showed 2 feet 7 inches of ore within 8 feet 2 inches of shale and ore.

In the Sequatchie Valley, near Inman, there is a strip of indefinite length, probably not exceeding 5 miles, in which a limy ore bed outcrops with a thickness of 2½ to 3½ feet. About 2 miles east of Ooltewah ore-bearing strata of the "Rockwood" formation outcrop on both sides of a narrow syncline whose edges are exposed in Whiteoak Mountain and in a smaller ridge about 2 miles east of it. The ore seams are thin here, ranging from 3 inches to 1 foot 6 inches in thickness, including a few shale streaks. On the east slope of Whiteoak Mountain the ore bed dips generally 22° to 25° SE., but there are many minor crumplings in the strata that vary the dip considerably and make mining uncertain and difficult. In the ridge on the east limb of the syncline red ore occurs north of the Southern Railway, apparently in two beds, but geologic examination has shown that a single bed of ore has been repeated by a close, overturned fold. Locally the same bed is displaced and repeated by an overthrust fault, and 1 mile south of the railroad the "Rockwood" formation is buried in a fault. Shallow workings are operated by hand in this area for the purpose of obtaining ore for the manufacture of metallic paint.

Soft ore was mined extensively at Hill City, at Inman, and near Ooltewah many years ago. Whether mining activities are ever renewed in these localities or elsewhere in Tennessee near Chattanooga will depend on future conditions in the iron industry. For the present ore to supply furnaces at Chattanooga will probably have to be obtained from areas farther north in Tennessee and from fields in northeastern Alabama and northwestern Georgia.

In the following table are given a few representative chemical analyses of iron ore from several localities in southeast Tennessee:

*Analyses of "Rockwood" iron ore in southeast Tennessee.*[a]

| Locality. | Authority.[b] | Fe. | $SiO_2$. | $Al_2O_3$. | CaO. | MgO. | Mn. | P. | S. | $H_2O$. |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 miles north of Wauhatchie | U. S. | 15.62 | | | | | | | | |
| Hill City, upper bench | U. S. | 27.30 | 6.21 | 3.20 | 26.53 | | 0.056 | 0.52 ($P_2O_5$) | 0.068 | |
| Hill City, lower bench | U. S. | 17.27 | | | | | | | | |
| Hill City | R. | 25.00 | [c]11.+ | | | | | | | |
| Hill City, near Workhouse | U. S. | 29.92 | [c]3.30 | | 26.94 | | .10 | .35 | .04 | |
| Hill City (soft ore) | R. | 45.+ | [c]24.+ | | | | | | | |
| Do | R. | 37.86 | [c]22.23 | | | | | | | |
| Do | O. | 57.5 | 10.26 | 1.61 | .50 | | .46 | .432 | | 3.45 |
| Falling Waters Creek, middle bed 13 inches thick | U. S. | 12.53 | | | | | | | | |
| 2½ miles northwest of Hickson | U. S. | 18.85 | | | | | | | | |
| 1 mile north of Retro | U. S. | 19.92 | [c]9.45 | | 32.66 | | | | | |
| Ooltewah (soft ore) | B. | 56.00 | 16.45 | | | | | .28 | .10 | |
| Do | B. | 48.36 | 14.78 | | | | | .63 | | |
| Inman | B. | 27.93 | 7.07 | | 18.11 | | | 2.82 | | |

[a] Analyses represent hard ore unless otherwise indicated.
[b] Authorities: U. S., U. S. Geol. Survey; R., Roane Iron Co.; O., owners; B., W. M. Bowron.
[c] Insoluble.

## CENTRAL EAST TENNESSEE.

Central east Tennessee contains large areas of iron ore and is at present the most productive portion of the State. Along the Cumberland escarpment between Sheffield and Glen Alice there are generally two thin seams of ore, the thicker of which measures less than 2 feet in some places and more than 2 feet in others, but in the vicinity of Glen Alice its thickness increases, and thence northeastward past Rockwood and Cardiff to Emory Gap the bed is normally from 2½ to 4 feet thick and in places reaches a maximum of 8 feet. The "Rockwood" formation received its name from the exposures at the town of Rockwood. The ore here is of comparatively high grade, the hard ore commonly carrying 35 to 42 per cent of metallic iron, 6 to 12 per cent of silica, 4 to 8 per cent of alumina, 10 to 15 per cent of lime, 1.5 to 4 per cent of magnesia, 0.5 to 0.6 per cent of phosphorus, and from a trace to 1 per cent of sulphur. The largest underground iron mines in the State are in the Rockwood-Cardiff area. Near Emory Gap the continuity of the bed is broken by a fault, but near Harriman a measurement showed 2 feet 4 inches of soft ore. From a point near Harriman northeastward to Coal Creek the outcrops of "Rockwood" ore are broken by several faults, and the thickness of the bed is from a few inches to about 2 feet.

Certain of the valley areas of central east Tennessee contain important reserves of "Rockwood" iron ore. In the Euchee area the bed is more than 5 feet thick, but the ore is lean. In the Chamberlain-Barnardsville area are two synclinal basins of ore that will furnish a supply to the Roane furnaces for many years. From 5 to 8 feet of hard ore of fair grade occurs here in two benches separated by a shale parting, and there is still available considerable rich soft ore.

The accompanying chemical analyses will afford a fairly definite idea of the quality of the ore available in central east Tennessee.

*Analyses of "Rockwood" ore in central east Tennessee.*

| Locality. | Authority.[b] | Fe. | $SiO_2$. | $Al_2O_3$. | CaO. | MgO. | Mn. | P. | S. | $H_2O$. |
|---|---|---|---|---|---|---|---|---|---|---|
| Rockwood-Cardiff: | | | | | | | | | | |
| Baker slope | R. | 39.25 | 6.46 | 4.28 | 11.60 | 3.16 | ...... | ...... | 0.08 | ...... |
| Do | R. | 35.19 | 7.81 | 5.38 | 13.69 | 3.19 | ...... | ...... | .220 | ...... |
| Warner slope | R. | 38.00 | 7.51 | 5.95 | 10.85 | 4.23 | ...... | ...... | .124 | ...... |
| Dyke slope | R. | 37.00 | 8.92 | 8.11 | 9.76 | 3.42 | ...... | ...... | .226 | ...... |
| Do | R. | 42.63 | 3.85 | 6.74 | 8.74 | 2.70 | ...... | ...... | .160 | ...... |
| Cardiff slope | R. | 35.60 | 10.46 | 5.70 | 10.90 | ...... | 0.15 | 0.59 | .08 | ...... |
| Do | R. | 42.90 | 6.00 | 5.56 | 9.39 | 2.66 | ...... | ...... | Trace. | ...... |
| Wright slope | R. | 26.10 | 6.11 | 6.51 | 20.43 | ...... | ...... | ...... | ...... | ...... |
| Do | R. | 35.10 | 8.08 | 5.27 | 14.00 | 2.59 | .15 | .60 | .84 | ...... |
| Howard slope | R. | 33.35 | 15.35 | 8.60 | 6.88 | ...... | .15 | .60 | .15 | 3.92 |
| Do | R. | 41.30 | 9.55 | 5.60 | 9.24 | ...... | ...... | | .127 | ...... |
| Suddath slope | R. | 34.65 | 6.85 | 4.01 | 17.11 | 2.80 | .36 | | .07 | ...... |
| Do | R. | 36.13 | 5.81 | 3.83 | 16.66 | 2.57 | ...... | | .083 | ...... |
| Patton slope | R. | 41.82 | 8.05 | 3.30 | 9.47 | 3.39 | ...... | | .020 | ...... |
| Do | R. | 38.16 | 8.45 | 6.45 | 10.90 | 4.07 | ...... | | .030 | ...... |
| Durel slope (soft ore) | R. | 47.27 | 13.10 | 6.70 | ...... | ...... | ...... | ...... | ...... | ...... |
| Do | R. | 48.30 | 9.75 | 6.20 | ...... | ...... | ...... | ...... | ...... | ...... |
| Ironton | C. | 26.97 | 7.52 | 4:50 | 23.92 | 1.73 | .35 | ...... | .042 | ...... |
| Do | C. | 24.25 | 10.65 | 6.63 | 22.50 | 1.65 | ...... | ...... | ...... | ...... |
| Do | C. | 30.14 | 4.30 | 3.50 | 23.68 | ...... | ...... | ...... | ...... | ...... |
| Glen Alice (soft ore, surface) | R. | 50.19 | 12.58 | 9.82 | 1.15 | ...... | .92 | ...... | Trace. | ...... |
| Euchee: | | | | | | | | | | |
| Crescent slope | D. | 26.50 | 9.10 | 6.28 | 22.25 | 1.43 | ...... | .416 | ...... | ...... |
| Do | D. | 32.00 | 7.69 | 5.58 | 18.45 | 1.48 | ...... | .446 | ...... | ...... |
| River mines (soft ore) | D. | 45.80 | 11.72 | 7.10 | ...... | ...... | ...... | ...... | ...... | ...... |
| Do | D. | 47.40 | 14.76 | 8.70 | ...... | ...... | ...... | ...... | ...... | ...... |
| Chamberlain | R. | 25.20 | 3.48 | 3.25 | 25.15 | 1.84 | ...... | ...... | ...... | ...... |
| Do | U.S. | 36.30 | 7.92 | 3.07 | 13.77 | 1.71 | .25 | .57 | .05 | 6.11 |
| Do | U.S. | 28.20 | 5.00 | 2.82 | 24.84 | 1.63 | .23 | .431 | .05 | 5.61 |
| Chamberlain (soft ore) | U.S. | 52.45 | 7.62 | 4.31 | .40 | .47 | .23 | .532 | .02 | 10.01 |
| Do | U.S. | 49.76 | 7.63 | 3.64 | 1.68 | .50 | .44 | .736 | .07 | 8.99 |

[a] Analyses represent hard ore unless otherwise marked.
[b] Authorities: C, Citico Blast Furnace Co.; D, Dayton Coal & Iron Co.; R, Roane Iron Co.; U. S., U. S. Geological Survey.

## NORTHEAST TENNESSEE.

The "Rockwood" iron ore outcrops in one continuous strip at the foot of the Cumberland escarpment in northeast Tennessee from Caryville northeastward to Cumberland Gap, a distance of about 37 miles. The iron mines at La Follette and near Arthur are in this strip. The "Rockwood" ore outcrops also in the valley of Elk Creek for a distance of about 5 miles southwestward from the town of Elk Valley and probably extends from one valley to the other below the Cumberland Plateau.

The ore bed near Caryville measures 2 feet 10 inches in thickness, at La Follette it ranges from 3 feet 10 inches to 5 feet, and at the Watts mine near Arthur, 6 miles southwest of Cumberland Gap, the thickness is between 4 and 5 feet. There is a considerable strip northeast and southwest of the Watts mine with regard to which no data were obtainable during this survey. Southwest of the Watts mine, in the northwestern part of the Maynardville quadrangle, the outcrop of the "Rockwood" formation is so far from a railroad that little prospecting has been done. Southwest of the town of Elk Valley the ore bed reaches a maximum thickness of 4 feet. The outcrop in Elk Valley is badly broken by faults. It is possible that there is a basin of ore 1,500 feet to 3,000 feet below the Cumberland Plateau extending from La Follette to Elk Valley; if so, there is a vast reserve of hard ore in this area, aggregating 1,250,000,000 long tons, but this can hardly be considered as available under present conditions on account of its depth. Mining is at present active at La Follette, on the "vertical" ore bed.

The following chemical analyses indicate the quality of the "Rockwood" iron ore in northeast Tennessee:

*Analyses of "Rockwood" iron ores in northeast Tennessee.*[a]

| Locality. | Authority.[b] | Fe. | $SiO_2$. | $Al_2O_3$. | CaO. | Mn. | P. | S. | $H_2O$. |
|---|---|---|---|---|---|---|---|---|---|
| La Follette: | | | | | | | | | |
| Seneca mine | L | 26.3 | 10.24 | 8.30 | 15.89 | 0.60 | 0.61 | 0.0 | 5.0 |
| Do | L | 31.90 | 4.54 | 2.57 | 15.25 | . . . | . . . | . . . | . . . |
| Do | L | [c] 36.40 | [d] 7.82 | | 13.30 | . . . | .48 | . . . | . . . |
| Soft ore | L | [c] 44.65 | 12.48 | . . . | . . . | . . . | . . . | . . . | 15.32 |
| Do | L | [e] 38.89 | 12.39 | 6.54 | 3.10 | . . . | .684 | . . . | . . . |
| Near Loyston (soft ore) | O | 48.2 | 8.9 | 11.0 | . . . | .36 | . . . | . . . | . . . |
| Near Millers Ferry (soft ore) | O | 50.4 | 5.6 | . . . | . . . | . . . | .04 | . . . | .5 |

[a] Analyses represent hard ore unless otherwise indicated.
[b] Authorities: L, La Follette Coal, Iron & Railway Co. and La Follette Iron Co.; O, owners of property.
[c] Dry basis.
[d] Insoluble.
[e] Wet basis.

## NORTHEAST ALABAMA.

### GENERAL DISTRIBUTION OF ORE OUTCROPS.

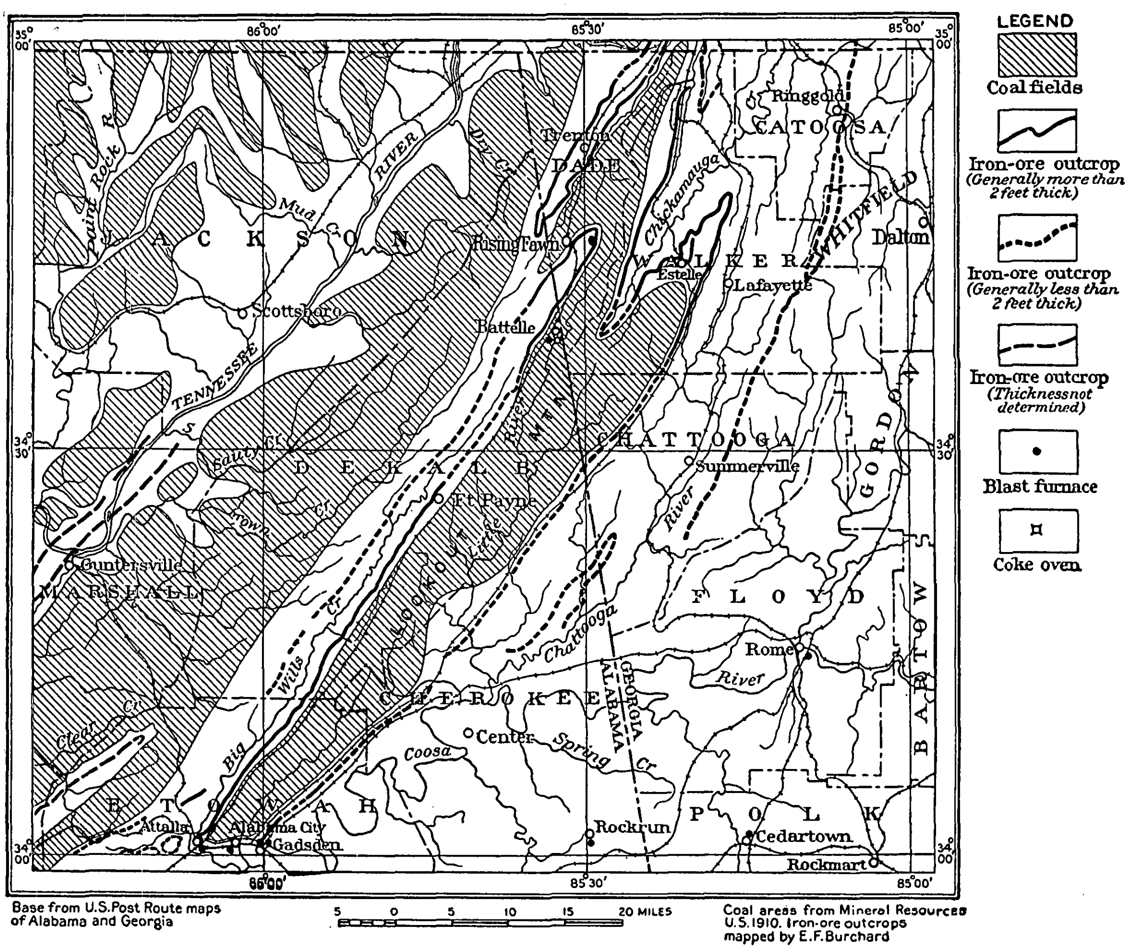
The area of "Rockwood" iron ore in northeast Alabama extends from Attalla and Gadsden, Ala., northeastward to the Alabama-Georgia line. (See Pl. VI.) The ore-bearing "Rockwood" formation, which probably underlies the greater part of the Lookout Mountain syncline, outcrops, except where cut out by faults, along the northwest and southeast borders of the mountain.

Northeast from Attalla the ore bed outcrops in a low ridge called Red Mountain that extends parallel to the northwest base of Lookout Mountain at a distance of 1 to 1½ miles. The dips are here toward the southeast. On the opposite or northwest side of Wills Valley the ore bed outcrops with steep northwest dips except where it has been overturned or interrupted by faults. This outcrop approximately parallels the Red Mountain outcrop at a distance of about 3½ miles. Wills Valley extends along the axis of an anticline in which the ore beds and associated rocks dip away toward the synclinal basins of Lookout Mountain and Sand or Raccoon Mountain. The Alabama Great Southern Railroad passes along a narrow valley between the west border of Lookout Mountain and Red Mountain and is nearly everywhere within about a mile of the outcrop of the ore bed in Red Mountain.

Along the southwest end of Lookout Mountain between Attalla and Gadsden the outcrop of the "Rockwood" ore is cut off by a fault. From Gadsden northeastward the ore outcrops for about 20 miles in Shinbone Ridge nearly to Yellow Creek, where it is cut off by a fault that interrupts the outcrop for a distance of about 2½ miles. Near Sterling Gap the ore reappears in the section, and it may be traced thence almost continuously northeastward in Shinbone Ridge to the Alabama-Georgia line, a distance of 19 miles. The Shinbone Ridge outcrop represents the southeast limb of the Lookout Mountain syncline. The dips here are generally steep toward the northwest, or they may be overturned toward the southeast. The Tennessee, Alabama & Georgia Railroad traverses the narrow valley between Lookout Mountain and Shinbone Ridge and is nearly everywhere between a quarter and half a mile from the ore outcrop.

The only other "Rockwood" ore-bearing locality in this portion of northeast Alabama remaining to be mentioned lies north of Coosa River, in a ridge known in the southwest portion as Tucker Ridge and in the northeast portion, which extends into Georgia, as Dirtseller Mountain. Round Mountain, a small outlier of Tucker Ridge, also carries "Rockwood" ore. The outcrop of the ore bed in Tucker Ridge dips moderately to the southeast, forming one side of a narrow synclinal basin whose axis rises to the northeast and which extends in a northeast-southwest direction for about 12 miles. For about half that distance this outcrop is closely paralleled by a lower ridge carrying ore dipping northwest and representing the southeast edge of the syncline. The Rome & Attalla branch of the Southern Railway passes south of this area, the station of Cedar Bluff being about 3 miles from the nearest ore outcrop on Tucker Ridge. This ore-bearing area has been known also by the terms "Gaylesville area" and "Mill Creek area," on account of the proximity of the town and creek so named.

The areas of "Rockwood" iron ore in northeast Alabama, outlined above, lie principally in the Fort Payne quadrangle, although the southwest extremity of the ore-bearing region extends a few miles into the Gadsden quadrangle and the northeast portion extends a few miles into the Stevenson and Rome quadrangles. The United States Geological Survey sells topographic maps of all these quadrangles.




MAP SHOWING RELATION OF OUTCROPS OF RED IRON ORE TO COAL FIELDS, TRANSPORTATION ROUTES, AND INDUSTRIAL CENTERS IN NORTHEAST ALABAMA AND NORTHWEST GEORGIA.

### WILLS VALLEY.

The thickness and quality of the ore beds exposed in Wills Valley vary greatly from place to place. For the most part the bed in Red Mountain from Attalla northeast to the State line is more than 2 feet thick, and in places it is as much as 5 feet. The following thicknesses were noted during recent examinations of the ore: At Attalla, 2½ to 3½ feet; at Crudup, 2½ to 5 feet; at Keener, 1¼ to 2½ feet; at Collinsville, where some of it is shaly ore, 1½ to 4 feet; at Portersville, 3 to 4½ feet, with a shale parting 8 inches to 1½ feet thick; at Collbran, 3 feet 9 inches to 4 feet, including 1¼ feet of shaly ore and shale partings; at Fort Payne, 3 to 3½ feet; near Valley Head, 1 foot 3 inches to 1 foot 6 inches; at Battelle, 4 to 4½ feet (upper bed) with three thinner beds below. The dips are mostly between 15° and 30° SE., and the variations are generally gradual rather than abrupt.

On the west limb of the Wills Valley anticline there has been but little development of the "Rockwood" iron ore, for several reasons. (1) The ore is thinner than on the east limb of the anticline, probably averaging less than 2 feet thick where exposed; (2) it is generally in a much steeper position and faulting has broken it badly in places and buried it deeply, especially in the southwestern portion of the area; and (3) the distance from the railroad, 3 to 4 miles, is too long to haul much ore or to build a railroad spur unless an extensive deposit is to be tapped. Near Littleton, where the bed is overturned to the southeast, thicknesses ranging from 1½ to 2½ feet have been measured. At the northeast end of the area, near Sulphur Springs, the main ore bed is 2 feet 5 inches to 4 feet thick, but includes several shale partings, so that there is not more than 2 feet 9 inches of ore. The ore bed here dips about 50° NW. The anticline on whose margins these ore beds outcrop extends northeastward into Georgia and the axis plunges under Lookout Mountain in Johnson Crook, east of Rising Fawn.

### PUDDING RIDGE.

About 10 miles north of Battelle is situated the Pudding Ridge belt, only about 1½ miles of which lies in Alabama. This is a promising ore-bearing area that is mentioned also in the Georgia descriptions (p. 308). Pudding Ridge lies in the axis of an anticline at the head of Lookout Valley. The "Rockwood" ore crops out on each side of this valley and around the end of the anticline at Pudding Ridge. Several prospects have been made in Alabama in hard ore that was 2½ to 3¼ feet thick exclusive of a few thin shale partings.

### SHINBONE RIDGE.

Beginning at Gadsden and extending northeastward the "Rockwood" ore that outcrops in Shinbone Ridge shows a variable but progressive deterioration in both thickness and quality. Near Gadsden the ore is about 4 feet thick, but within 2½ miles it thins to 1 foot 8 inches. Near Gadsden the dip is steep to the northwest. Between 5 and 8 miles from Gadsden, in the vicinity of the Citico mines, the thickness of the ore ranges between 2 and 3 feet and the dip is less steep, ranging from 30° to 40° NW. The hard ore is limy and lean and the ore bed contains many kidney-shaped concretions of shale. In the next 5 miles the ore bed thins down to about 5 inches, then thickens northeastward, and opposite Slackland the section includes three seams of very sandy ore or ferruginous sandstone ranging from 1 foot to 2 feet in thickness. Here the beds stand nearly vertical. Near Bristow the "Rockwood" formation comprises eight seams of very sandy ore from 1 inch to 10 inches thick, parted by beds of shale 6 inches to 46 feet thick. The dip here is about 65° SE. Beyond Bristow measurements of 5 to 7 inches were made and the dips are 35°–40° NW. About 3 miles northeast of Bristow the "Rockwood" formation is cut out by a fault, but it reappears beyond, at a distance of about 2½ miles. From Starling Gap northeastward to the State line the greatest observed thickness of good ore was 1 foot, but in places the seam contains a few inches more of sandy and shaly ore. About a mile northeast of Taff there are within a section of 28 feet 3 inches 27 seams of poor sandy ore, ranging from 1 inch to 1 foot 3 inches in thickness, separated by shale. The dips in this part of Shinbone Ridge are toward the southeast, indicating that the ore bed has been completely overturned. Farther northeast, near Jamestown and beyond, the dips are generally 35°–40° NW. A measurement made about a mile from the State line showed 8 inches of iron ore.

#### TUCKER RIDGE (DIRTSELLER MOUNTAIN).

Northwest of Gaylesville, in Tucker Ridge, the ore bed ranges between 6 inches and 2 feet 2 inches in thickness and dips generally 15°–35° SE. It is in most places parted by thin seams of shale. There is probably some soft ore here that may be obtained by stripping, but if not, the bed can not be considered of commercial value. On the southeast limb of the syncline, near Mill Creek, the bed shows 1 foot to 1 foot 10 inches of ore, dipping 45°–48° NW.

#### ROUND MOUNTAIN.

In the small isolated hill known as Round Mountain, near the Southern Railway, about 3 miles southwest of the extremity of Tucker Ridge, a thin bed of "Rockwood" ore occurs. This bed varies in thickness from 1 foot to 2 feet 4 inches. The dips are also diverse. The ore on the outcrop is soft and has been mined on the surface and from short drifts, but has since been mostly obscured by slumping of the overlying shale.

### MINING.

The "Rockwood" ore has been mined at many places in northeastern Alabama, both west and east of Lookout Mountain. Stripping for soft ore has mostly been abandoned, and underground mines have been opened wherever the thickness and character of the ore beds appeared to warrant it. In Red Mountain there are two mines near Attalla, two near Crudup, and abandoned slopes near Portersville, Fort Payne, and Battelle. In Shinbone Ridge there are several slopes near Gadsden and an inactive mine (the Citico) about 7 miles northeast of Gadsden. Near Mill Creek, in the Dirtseller, syncline ore has been mined by stripping and from shallow drifts, and at Round Mountain the soft ores were mined many years ago to supply an old charcoal furnace.

The ore mined at Attalla is shipped to Chattanooga and also to local furnaces at Attalla and Gadsden. Crudup ore and Gadsden ore are reduced in blast furnaces at Gadsden, and when mining was carried on in the Dirtseller area the ore was shipped both to Chattanooga and to Gadsden.

### ANALYSES.

The following analyses show the character of the iron ore in northeast Alabama:

*Analyses of "Rockwood" iron ore from northeast Alabama.*[a]

| Locality. | Authority.[b] | Fe. | $SiO_2$. | $Al_2O_3$. | CaO. | MgO. | Mn. | P. | S. | $H_2O$. |
|---|---|---|---|---|---|---|---|---|---|---|
| Attalla | C. | 36.97 | 8.61 | ...... | 16.56 | ...... | ...... | 0.50 | ...... | ...... |
| Do | C. | 40.65 | 11.36 | 4.86 | 11.36 | ...... | 0.18 | .44 | ...... | ...... |
| Attalla (soft ore) | A. | 53.92 | 8.39 | ...... | ...... | ...... | ...... | .676 | ...... | ...... |
| Crudup (south) | S. | 35.80 | 13.94 | 5.07 | 15.34 | ...... | ...... | ...... | ...... | ...... |
| Crudup (north) | S. | 38.14 | 9.29 | 3.87 | 17.01 | ...... | ...... | ...... | ...... | ...... |
| Keener | S. | 25.60 | 12.50 | 5.37 | 22.34 | ...... | .26 | .35 | ...... | ...... |
| Portersville (average) | S. | 31.98 | 6.29 | | 24.80 | ...... | ...... | ...... | ...... | ...... |
| Collbran | U. S. | 20.85 | 6.89 | 1.10 | 30.21 | ...... | ...... | ...... | ...... | ...... |
| Fort Payne | O. | 25.39 | 4.11 | ...... | 30.13 | ...... | ...... | .34 | ...... | ...... |
| Do | O. | 26.41 | 3.97 | ...... | 29.80 | ...... | ...... | .375 | ...... | ...... |
| Fort Payne (soft ore) | O. | 56.02 | 7.93 | ...... | n. d. | ...... | ...... | .227 | ...... | ...... |
| Battelle (drill hole) | B. | 32.26 | 4.52 | 2.93 | 24.33 | ...... | ...... | ...... | ...... | ...... |
| Battelle (average hard ore) | L. | 27.65 | 4.70 | 3.90 | 25.15 | 0.73 | ...... | .376 | ...... | 0.48 |
| Gadsden | S. | 33.07 | 16.82 | 8.29 | 14.00 | ...... | ...... | ...... | ...... | ...... |
| Citico (7 miles northeast of Gadsden) | C. | 38.07 | 10.24 | 4.17 | 14.38 | 1.16 | .14 | .38 | ...... | ...... |
| Do | C. | 38.50 | 13.16 | ...... | 12.75 | ...... | ...... | ...... | ...... | ...... |
| Citico (soft ore) | C. | 54.87 | 8.05 | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| 4 miles northwest of Gaylesville (soft ore) | U. S. | 55.39 | [c]12.25 | | 1.16 | ...... | Tr. | .59 | 0.08 | ...... |

[a] Analyses represent hard ore unless otherwise indicated.
[b] Authorities: A, Alabama Geological Survey; B, W. M. Bowron; C, Citico Blast Furnace Co.; L, Lookout Mountain Iron Co.; O, owner of property; S, Southern Iron & Steel Co.; U. S., U. S. Geological Survey.
[c] Insoluble.

## NORTHWEST GEORGIA.

### GENERAL DISTRIBUTION OF ORE OUTCROPS.

Most of the outcrops of "Rockwood" iron ore in northwest Georgia are direct continuations of the outcrops in Alabama just outlined. (See Pl. VI.) On both sides of Lookout Valley they are continuous from Pudding Ridge to a point beyond the Tennessee line, the eastern outcrop dipping under Lookout Mountain and the western outcrop dipping below Sand Mountain. The Wills Valley outcrops end in Johnson Crook, where the "Rockwood" strata are exposed around the nose of the anticline. On the east side of Lookout Mountain the Shinbone Ridge outcrop extends northeastward to the extremity of Pigeon Mountain, around the end of that mountain into McLamore Cove, and thence northeastward on the east flank of Lookout Mountain and terminates in a fault near Flintstone, 2¾ miles south of the Tennessee line. The Tucker Ridge and Dirtseller outcrop continues northeastward into the Dirtseller synclinal area, which terminates about 2 miles west of Lyerly, Ga., and shows two outcrops of ore that converge and unite at the end of the syncline. In addition to these outcrop areas the "Rockwood" formation in Taylor Ridge carries beds of iron ore, which are thickest in the locality between Summerville and Gore, but a very thin bed may be traced northeastward to the Tennessee line into the Whiteoak Mountain area. According to McCallie[1] the length of outcrop of the "Rockwood" iron ore in Georgia aggregates about 175 miles, and, if the trace of the outcrops above described is scaled off on the map, the aggregate length may even be found to exceed that figure, but for a considerable part of the distance the ore is too thin to be of commercial value. These areas are comprised within the Stevenson, Ringgold, Fort Payne, and Rome quadrangles. For more detailed descriptions of ore outcrops and sections in northwest Georgia the reader is referred to the bulletin by McCallie, just cited. Brief descriptions of the principal areas are given below.

### LOOKOUT VALLEY.

On both sides of Lookout Valley, from New England southwest to Pudding Ridge, and also for about 2 miles northeast of New England, on the east side of the valley, the ore beds appear to be of considerable value. The soft ore has been worked at many places in this area, and the bed of hard ore has thus been made available for measurement. The general range in thickness of ore, exclusive of shale partings, is from 2 feet 5 inches to 3 feet, although in places the bed is slightly thinner and in places it attains a thickness of

[1] McCallie, S. W., The fossil iron ores of Georgia: Bull. Georgia Geol. Survey No. 17, 1908, p. 39.

nearly 4 feet. Locally there are two ore beds of about the same thickness in the section, but as a rule only one bed is of importance. In one place near the Alabama-Georgia line, where a thickness of nearly 6 feet is displayed with an 18-inch shale parting, the bed has doubtless been repeated by a small thrust fault. The ore in the area mentioned above is generally high in lime and could be used most advantageously in connection with an ore carrying considerable silica, such as a soft red ore, a siliceous hard red ore, or a brown ore. There is still some soft red ore available in this area. The dips of the beds on either side of the anticline are moderate toward the northwest or the southeast, as the case may be, ranging generally between 10° and 30°.

The outcrop on the east side of the valley is generally within a mile of the Alabama Great Southern Railroad. From the west side of the valley there would be longer hauls, but railroad spurs could be built to reach the ore outcrops at most places. The ore generally crops out at 100 to 200 feet above the valley floor, so that considerable ore can still be mined without involving much hoisting.

#### JOHNSON CROOK.

From Sulphur Springs station to Johnson Crook the "Rockwood" formation outcrops for a distance of about 8 miles on the southeast side of the anticline and about 6 miles on the northwest side, all within the State of Georgia. Little information is available concerning the character of the ore in this area except in Johnson Crook, where it has been mined for use in the old blast furnace 1 mile east of Rising Fawn. There are three or more seams of ore here, two of which are too thin to be worked and one carries 3 feet 8 inches to 5 feet of ore. This thickest seam contains one or two shale partings, from 3 to 15 inches thick. The ore in this seam, where hard, is high in lime and low in iron, as shown in the analyses on page 42. The workings in the soft ore at this place were formerly very extensive and a few short underground slopes have been driven, but not much ore has been mined since 1906. The ore-bearing beds dip, generally at a moderate angle, toward the north, northeast, and east into the Lookout Mountain syncline, from which they emerge again in McLamore Cove, 3½ miles distant.

#### MENLO TO BRONCHO.

On the east side of Lookout Mountain the Shinbone Ridge outcrop continues northeastward into Georgia. The beds are nearly everywhere steeply inclined at the outcrop, but the normal dip, which is toward the northwest, is reported to become more gentle within 100 feet below the surface. The thickness of the ore in this strip of outcrop from the State line 1½ miles southwest of Menlo to a point above Broncho ranges from less than 1 foot to about 3 feet, exclusive of shale partings. The ore on the outcrop is soft, and probably the leached condition of the ore extends deeper here than in places where the dip is less steep. The Tennessee, Alabama & Georgia Railroad runs nearly parallel to the ore outcrop at a distance of 1,000 to 1,500 feet and has afforded convenient facilities for shipment of ore to Chattanooga and Gadsden, so that soft ore has been mined from open cuts all along the outcrop. A little mining has been done also by means of slopes and drifts. One slope at Broncho is reported to have been sunk 204 feet in soft ore.

### PIGEON MOUNTAIN.

Pigeon Mountain is a spur extending northeastward from Lookout Mountain in the southern part of Walker County, Ga. Its rock structure is synclinal, the formations outcropping around the base of the mountain and dipping toward its axis. At Estelle the ore dips in general to the south and southeast. At the northeast end of the mountain, west of Copeland, the rock lies nearly flat, and where the ore-bearing formation outcrops around the southeast side of the ridge the dips are toward the west and northwest.

Near Estelle, for about 1 mile to the northeast and about 3 miles to the southwest of the Tennessee, Alabama & Georgia Railroad, the ore has been mined to a considerable extent on the outcrop and also from a number of drifts and tunnels. This area has been a large producer of soft ore in the past, most of it having been shipped to the furnaces at Chattanooga and La Follette, Tenn. Three beds of ore occur just below the middle of the "Rockwood" formation. They are about 25 feet apart, but only the lowest bed, which is 2½ feet or more thick, can be considered of great importance. One of the upper beds has been stripped for soft ore over a considerable area. In some places it is 1 foot 9 inches thick, including a shale parting that has a thickness ranging from a knife-edge up to 2 inches.

The large scale on which mining operations have been carried on in the vicinity of Estelle is due in great part to the fortunate relation between the ore bed and the local topography. A chain of hills, not well shown on the topographic map of the Ringgold quadrangle, extends parallel to the northwest side of Pigeon Mountain, from which it is separated by a long hollow. This chain of hills is cut transversely by numerous small hollows that open into the main hollow. The strata emerging from beneath Pigeon Mountain extend upward into the chain of hills at nearly the same angle as the surface slope of the hills. The bed of iron ore is so close to the surface in many places that the overburden may be stripped off and the ore mined in the open. The small hollows that cut the hills transversely afford favorable positions for opening entries into the ore bed and for laying tracks. The comparatively small thickness of cover has permitted the access of surface water to the ore bed in much of the area and thus produced considerable soft ore.

With regard to reserves of hard ore in the area near Estelle there appear to be encouraging possibilities. Beginning near the tunnel of the Tennessee, Alabama & Georgia Railroad and extending in a southwesterly direction for several miles there is a bed of semihard to hard ore of excellent quality dipping gently under Pigeon Mountain. This bed reaches 2 feet 9 inches in thickness in places and is generally more than 2 feet 6 inches thick. It commonly includes a shale parting 1 inch to 1½ inches thick just below the middle and is overlain by hard fine-grained sandstone or "jack rock." The dip at the outcrop ranges between 2° and 10° SE., but is generally 6° or 7°. The beds probably lie nearly flat under most of Pigeon Mountain, but near the southeastern outcrop they are thrown into a series of sharp folds. From the railroad tunnel southeastward to the outcrop on the southeast side of Pigeon Mountain the shortest distance is about 1½ miles, and there is no reason to doubt that the whole basin is underlain by this bed of iron ore. Analyses of this ore given on page 42 show that it is a very high grade hard ore.

Mining would necessarily have to be carried on here by underground work, but the apparent regularity of structure of the ore bed, the proximity of the railroad, and the excellent quality of the ore make it very probable that ore could be mined and loaded on railroad cars at a reasonable cost per unit of iron. In connection with the mining of soft ore from open cuts in the vicinity of Estelle some hard ore has also been mined from underground workings, and even during the summer of 1911, when the price of southern pig iron was only about $10 a ton, hard ore was steadily shipped from a small mine near Estelle.

The iron-ore outcropping on the southeast side of Pigeon [illegible] tain, nearly opposite Estelle, has been most recently mine[illegible] dale. Here the strata dip steeply toward Pigeon Mo[illegible] the main line of outcrop of the ore bed, but east of th[illegible] beds have been folded so as to produce in connection [illegible] surface two small truncated synclines of ore. A sing[illegible] shows five outcrops in a cross section of only a few [illegible] length, and it was at one time believed that there w[illegible] seams of ore here, all of about the same thickness[illegible] seam, too thin to work, is reported to lie 8 to 10 feet seam. A number of measurements at the mines that were in operation in 1911 showed a range in thickness of the main ore bed of 1 foot to 2 feet, though 1 foot 8 inches to 1 foot 10 inches appeared to be the general range. The seam contains no shale parting. The ore being mined in the fall of 1911 was obtained principally from drifts and shallow slopes, and it was reported that the soft ore continued to depths of 50 feet or more. The ore being shipped was a high-grade soft ore carrying 50 to 57 per cent of iron. On account of the folding of the strata the "spread" of the ore renders available an unusually large quantity of soft ore. Shipments were made in 1911 to blast furnaces at Dayton and La Follette, Tenn.

At the northeast end of the Pigeon Mountain syncline, about 2¼ miles west of Copeland and about 5 miles northeast of the Estelle mines, the "Rockwood" formation occupies a relatively broad outcrop area in which the rocks lie nearly horizontal. The surface consists of knobby hills and narrow ravines, around and into which the iron-ore outcrop winds in sinuous curves. There are two or three beds of ore in this area, the thicker ones carrying between 2 and 4 feet of ore parted by two to five seams of shale varying from less than 1 inch to 1½ feet in thickness. In certain places where the ore is well exposed it is soft and fairly rich in iron, but in many of the outcrops on the sides of ravines the hard ore shows at the surface and apparently is highly calcareous and consequently correspondingly lean in iron. On account of the large proportion of shale that is interbedded with the ore and would have to be mined with it, the grade of the ore would probably be materially improved by crushing, screening, and picking to remove the shale.

It is reported that a railway spur was built and mining operations were begun in this area a few years ago but were soon abandoned.

### McLAMORE COVE TO FLINTSTONE.

Southwest of Bluebird Gap on the east side of McLamore Cove, or southwest of the Estelle mine workings, the ore beds become shaly and sandy and in places very thin—in fact, the ore does not appear ... of much importance anywhere on the borders of McLamore ... outh of an east-west line drawn through Cedar Grove, although ... ockwood" formation outcrops all the way around the cove. ... tward from Cedar Grove the outcrop of the ore-bearing ... extends unbroken for 16 miles to a point near Flintstone, ... terminates in a fault. Throughout this strip of outcrop ... nearly everywhere steeply tilted to the northwest or over... he southeast, and there are in places minor synclines of ... e main outcrop. Near the church south of Cedar Grove ... foot 7½ inches thick was measured, and west of the village of Cedar Grove there are two seams, each 1 foot thick, showing an anticlinal structure.

From Cedar Grove to Cassandra the ore bed ranges between 1 foot and 1 foot 10 inches in thickness. In some of the exposures noted the bed contains several shale partings. About a mile north of Cassandra the bed becomes thicker, 3 feet being measured in one place, and a thickness between 2 feet 6 inches and 3 feet is apparently maintained nearly all the way to Eagle Cliff. Near Eagle Cliff measurements of the ore bed showed a variation in thickness of 1 foot 9 inches to 3 feet, and near Flintstone of 1 foot 8 inches to 2 feet 6 inches. Soft ore has been mined nearly all the way along the outcrop where the ore bed is thickest. From Cassandra northward the Tennessee, Alabama & Georgia Railroad is generally within one-fourth to three-fourths of a mile from the ore outcrop. Very little mining has been carried on here during the last seven or eight years.

### MISSIONARY RIDGE AND VICINITY.

The "Rockwood" formation outcrops in Missionary Ridge for a distance of about 2½ miles southwest from McFarland Gap, in the northern part of Walker County. At the southwest extremity of this strip the outcrop of the formation turns abruptly toward the north, following a low ridge, and extends to and beyond the Tennessee-Georgia line, the two outcrops forming a V-shaped area bordered by faults. The Tennessee, Alabama & Georgia Railroad is within a mile of the west outcrop at one place, and the Central of Georgia Railway touches it at McFarland Gap.

The ore in Missionary Ridge ranges in thickness from 1 foot 6 inches to 2 feet 6 inches and dips to the southeast at angles from a few degrees to 40°. The ore bed is generally parted by 1 to 2 inches of shale. The bed has been stripped and mined on the outcrop so as to reach the hard ore in several places, as much as 15 feet of cover having been removed. The hard ore is high in calcium carbonate and not very rich in iron, but the soft ore, although little probably remains available, is of high grade.

In the western ridge the ore is 1 foot 10 inches to 2 feet 7 inches thick near the State line, less than 2 feet thick near the south end, and still thinner at an intermediate place. This bed dips generally 15°–35° W., but toward the south end of the strip the angles are steeper. Soft ore has been dug at many places along this outcrop, hauled by wagon to the Tennessee, Alabama & Georgia Railroad, and shipped to furnaces at Chattanooga and Dayton, Tenn.

It should be noted in this connection that the extent of the ore in the direction of the dip in both strips of the V-shaped area is limited by faults, and according to the Ringgold geologic folio map the ore probably does not extend underground more than 500 to 700 feet, except near the State line, where the fault disappears.

### DIRTSELLER MOUNTAIN.

At the north end of Dirtseller Mountain, 2 to 3 miles southwest of Lyerly, Ga., red ore has been obtained from surface workings for many years. The structure of the Dirtseller Mountain "Rockwood" area is synclinal, the ore dipping southeastward from the crest of the ridge toward Panther Creek and rising again farther southeast to form the crest of a lower ridge. The synclinal axis rises to the northeast, so that the ore outcrops around the end of the syncline at a point about 2 miles west of Lyerly. The dips of the beds and the slopes of the sides of Panther Creek valley are very nearly the same, and the ore bed is overlain, for the most part, by a comparatively thin cover, so that it has been possible to strip the ore for several miles along its outcrop and for several hundred feet on the dip. A large tonnage of soft ore has been obtained here and shipped to furnaces at Rome, Ga., and Attalla, Ala. Most of the ore has been mined by means of stripping, but a little underground work has been done from drifts and tunnels. No mining is being done here at present.

The thickness of the ore bed ranges from 1 foot 2 inches to 2 feet 4 inches. The maximum is exceptional and the average thickness perhaps does not exceed 1 foot 6 inches. In some places the bed is a solid body of ore; in others it is parted by shale seams. The dips of the bed toward the synclinal axis along which Panther Creek flows are low, ranging generally between 4° and 15°. Evidences of a second syncline of ore were noted a short distance southeast of the outcrop of the ore in the southeast limb of the main syncline. This appeared to be a shallow appressed fold, separated from the main syncline by erosion, and probably does not extend a great distance northeast and southwest. There is still sufficient ore remaining in the Dirtseller area to require many years for its exhaustion at the rate of output that prevailed during the days of mining activity. The unaltered ore in this area generally carries less lime and more silica than the ore in the Lookout Mountain area.

### TAYLOR RIDGE.

Taylor Ridge, the southwestern portion of which lies about 3½ miles east of Summerville and Lyerly, extends northeastward to the Tennessee line and is part of the fold in the strata that produces Whiteoak Mountain in Tennessee. The only portion of the ridge that is of importance as a bearer of iron ore is the area southeast of Summerville. For about 4 miles along the ridge the ore in the thicker of two beds ranges from 1 foot 5 inches to 2 feet 5 inches in thickness. There is generally a parting of shale 2 inches to 3½ feet thick below the middle of the bed. The dip of the ore bed ranges generally from 12° to 20° SE. The bed outcrops near the crest of the ridge and as its dip is only a little steeper than the southeast slope of the ridge, there is a large area of soft ore here. Considerable of the ore below the outcrop, especially at the sides of ravines that cut the flank of the ridge, may be obtained by open-cut mining. By drifting in the direction of the strike of the ore bed from both sides of the narrow ravines and working up the dip the ore can be cheaply mined underground. Both of these methods of mining have recently been employed by the R. G. Peters Mining Co., which operated mines just west of Shackelton for a year or so prior to 1911. Openings were made along several of the ravines and the ore was trammed in small cars to bins near the foot of each ravine. From the collecting bins the ore was fed into small steel cars or conveyors, which traveled on an aerial cable. In one place ore was carried from one hollow to another over an intervening spur. From the main collecting point the ore was carried by the aerial cable line to the Rome & Northern Railroad at Shackelton and thence by railroad to the blast furnace of the Silver Creek Furnace Co., at Rome. It is understood that the operation of the aerial tramway was not a complete success.

The soft ore mined here is dark colored and rather rich in iron. The hard ore resembles the Dirtseller ore in carrying less lime, more silica, and more iron than the ore of the Lookout basin.

Southwest of the Peters mine the "Rockwood" ore extends nearly to High Point, the southern terminus of Taylor Ridge, but the thickness of the bed diminishes to 8 or 10 inches near High Point. Northeastward from the Peters mine the ore has been traced, as stated above, practically all the way to a point beyond the Tennessee line, and for about 17 miles, partly in Walker County and partly in Whitfield County, there are two outcrops of the ore on the limbs of a narrow synclinal basin. Gordon Spring, Whitfield County, is situated near the middle of this syncline. A few miles northeast of the Peters mine the ore becomes much thinner than at this mine, and, except where the Western & Atlantic Railroad crosses the outcrop, about 1 mile east of Ringgold, the ore does not lie near any railroad. Measurements made at 20 or more places in 1911 showed seams of ore ranging from 1 inch to 1 foot 1 inch in thickness, though most of them were between 3½ and 10 inches. At one place north of Gordon Spring there were seven seams of ore from 1 inch to 5 inches thick within a section of 70 feet. In some places there is much float, and this has given rise to local belief in the presence of thicker seams than it has been possible to find.

## ANALYSES.

The following chemical analyses exhibit the range in percentages of the various grades of ore:

*Analyses of "Rockwood" iron ore from northwest Georgia.*[a]

| Locality. | Authority.[b] | Fe | $SiO_2$ | $Al_2O_3$ | CaO | MgO | Mn | P | S | $H_2O$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Rising Fawn | S. | 26.47 | 9.00 | 3.88 | 25.13 | | | | | |
| Do | G. | 33.76 | 7.28 | 3.14 | 21.41 | 0.44 | 0.216 | 0.51 | Tr. | 2.14 |
| Pudding Ridge | O. | 28.42 | 5.88 | 5.32 | 25.96 | Tr. | | 2.14 | Tr. | |
| Do | G. | 32.53 | 4.62 | 3.89 | 24.95 | .40 | .177 | .572 | 0.10 | 1.02 |
| Trenton | P. | 36.85 | | | 18.15 | | | | | |
| Do | O. | 28.79 | 5.62 | 2.86 | 25.73 | | | .398 | | |
| Do | O. | 29.86 | 6.76 | 4.86 | 24.29 | | | .324 | Tr. | |
| Do | O. | 33.22 | 7.62 | 3.56 | 19.58 | | | .422 | | |
| New England | C. | 28.01 | [c] 9.50 | | | | | | | |
| Do | U. S. | 29.27 | 4.66 | 1.36 | 30.65 | | | | | |
| Do | U. S. | 26.16 | 7.07 | | 27.18 | | .12 | .21 | .04 | |
| Do | O. | 28.67 | 5.94 | 3.24 | 24.31 | | | .393 | | |
| Morganville | C. | 29.54 | 7.81 | | | | | | | |
| Broncho (semihard) | G. | 42.72 | 4.98 | 2.78 | 14.48 | 1.95 | .447 | .501 | .06 | .91 |
| Estelle, Southern Iron & Steel Co. mines | G. | 32.18 | 7.00 | 5.45 | 22.70 | .59 | .223 | .42 | .02 | 1.89 |
| Do | G. | 38.42 | 6.41 | 11.89 | 14.89 | .16 | .062 | .56 | .01 | 2.28 |
| Estelle, Estelle Iron Co | O. | 43.50 | [c] 8.12 | | 15.62 | | | | | |
| Do | O. | 42.63 | [c] 6.78 | | 16.81 | | | | | |
| Estelle, Estelle Iron Co. (soft ore) | O. | 57.87 | [c] 9.58 | | .56 | | | | | |
| Estelle, Estelle Iron Co. (composite samples from several prospects) | U. S. | 44.57 | 10.12 | 5.06 | 7.05 | | | | | |
| Do | U. S. | 41.35 | 7.21 | 4.18 | 11.94 | | .062 | .362 | .099 | |
| Do | U. S. | 43.85 | 6.74 | 2.89 | 11.11 | | | | | |
| Hillsdale (soft ore), northeast end Pigeon Mountain | LF. | 48.70 | 15.80 | 6.40 | .76 | | .30 | .34 | .10 | .20 |
| Cooper Heights (soft ore) | C. | 43.08 | 19.67 | 9.15 | .96 | .56 | .87 | .32 | | |
| Durham Junction | C. | 32.38 | 8.24 | | 21.52 | | | | | |
| Cenchatt | C. | 25.95 | [c] 19.54 | | 19.42 | | | | | |
| Do | C. | 32.76 | 17.38 | | 15.80 | | | | | |
| Eagle Cliff (semihard) | D. | 35.30 | 11.20 | 6.70 | 15.39 | | 1.60 | .453 | | |
| Three-fourth mile east of Blowing Spring | U. S. | 25.69 | 4.14 | 2.89 | 26.48 | | | | | |
| 1¼ miles southwest of Mission Ridge station | U. S. | 19.87 | | | | | | | | |
| 2 miles southwest of Mission Ridge station (soft ore) | U. S. | 42.33 | 18.81 | 10.00 | Tr. | | | | | |
| Do | U. S. | 48.94 | 13.95 | 6.85 | Tr. | | | | | |
| Dirtseller (nearly soft) | C. | 47.00 | 15.75 | 4.60 | 2.70 | | | | | |
| Taylor Ridge, near Shackelton (soft) | C. | 46.82 | [c] 27.64 | | | | | .64 | | |
| Do | C. | 52.10 | [c] 21.50 | | | | | .32 | | |
| Do | C. | 58.50 | [c] 21.94 | | | | | .61 | | |
| Do | U. S. | 48.01 | [c] 22.14 | | 1.65 | | | | | |

[a] Analyses represent hard ore unless otherwise indicated.
[b] Authorities: C, Citico Blast Furnace Co.; D, Dayton Iron & Coal Co.; G, Geological Survey of Georgia; LF, La Follette Iron Co.; S, Southern Iron & Steel Co.; O, owner of property; U. S., U. S. Geological Survey.
[c] Insoluble.

## SUMMARY OF "ROCKWOOD" ORE-BEARING LOCALITIES.

Although this paper is, in its entirety, little more than a summary, it has been thought best briefly to call attention once more to the areas carrying the most promising beds of iron ore. Considerable space is devoted to the description of relatively unimportant deposits of ore in the Tellico sandstone and the Grainger shale, because these de-deposits have not been described before by the Survey, but such descriptions should not obscure the fact that the bedded "Rockwood" iron ore is to be regarded as the mainstay of the southern iron industry.

By reference to the map (Pl. V) the situation in east Tennessee may be quickly grasped. The areas of outcrop of "Rockwood" ore beds more than 2 feet thick are distributed along the eastern edge of the coal field and are widely separated by areas in which the ore is less than 2 feet thick and can be worked profitably only by stripping. There are a few outcrops of ore east of Tennessee and Clinch Rivers. These are known as valley areas and contain beds that are of diverse thickness. In northeast Tennessee the workable ore occurs near La Follette and southwest of Cumberland Gap, and possibly the bed near Elk Valley may prove of value. The available ore in northeast Tennessee may be considered as tributary to blast furnaces at La Follette, Tenn., and Middlesboro, Ky. In central east Tennessee there are no very long outcrops of workable ore, but the ore beds are thicker here than elsewhere and support iron-manufacturing establishments at Rockwood and Dayton. In southeast Tennessee the greater part of the ore outcrop falls below 2 feet in thickness, but such beds as reach this thickness are near Chattanooga. There is no mining activity in Tennessee near Chattanooga at present. The ore beds that have been locally developed are not of attractive thickness and have been pretty thoroughly mined by stripping on the outcrop. Southward from Chattanooga, however (see Pl. VI), as these beds are traced into Alabama and Georgia, along opposite sides of Lookout Mountain, their thickness is found to increase, and there is considerable hard ore near Trenton, Ga., in Lookout Valley and Pudding Ridge, also under Pigeon Mountain near Estelle, that can be brought to Chattanooga furnaces at a low cost both for mining and transportation. In fact, the transportation problem is simpler for ores south of Chattanooga than it is for ores north of the city in the State of Tennessee. Southwest of Trenton and Estelle there are bodies of ore that have been mined and shipped to Chattanooga. On the west side of Lookout Mountain they extend as far as Attalla, Ala., and on the east side they extend to Gadsden, Ala., and comprise not only the area outcropping at the base of the mountain, but such valley outcrops as those of the Dirtseller and Taylor Ridge areas.

It is evident, then, that the greater part of the red ore to supply the iron industry at Chattanooga will logically come from neighboring areas in northwest Georgia and northeast Alabama, although blast furnaces in these areas will also continue to draw on local supplies of ore. The coke furnaces at Battelle, Ala., and Rising Fawn, Ga., and the charcoal furnaces at Attalla, Ala., and Cedartown and Rome, Ga., are idle at present, but the coke furnace at Alabama City, Ala., is active and is providing material for the manufacture of steel products at Alabama City. The coke furnace at Gadsden has been temporarily shut down pending reorganization of the operating company.

While this paper has not treated of the brown iron ore that forms so important a part of the furnace burdens in the South, it is well known that such deposits are becoming depleted faster than new supplies are being discovered. It is only a question of time, therefore, when this useful type of ore will have practically disappeared from the market, although, of course, that time is relatively remote. As brown ore becomes more difficult to obtain, the red ore of the Taylor Ridge and Dirtseller types containing high percentages of iron with lower lime and higher silica than ores farther west will come more into demand for mixing with the leaner and more limy red ore of the Trenton-Pudding Ridge type. The soft red ore of the Sweetwater type may also prove a source of considerable supply, and the semihard to hard ore of the Estelle type should prove of great value.

## IRON ORE IN GRAINGER SHALE.

### LOCATION.

At the request of the State geologist of Tennessee, a brief investigation of reported deposits of iron ore in the foothills of Chilhowee Mountain, southeast of Maryville, Blount County, was made by the writer in October, 1911. These deposits lie 6 to 7 miles in an air line southeast of Maryville, along "Little Mountain" or the foothills of Chilhowee Mountain, and 2 to 3 miles southwest of Little River.

### TOPOGRAPHIC AND GEOLOGIC RELATIONS.

In the Knoxville geologic folio the area containing these beds is mapped as underlain by a syncline of Grainger shale, a formation of Devonian and Carboniferous age. The formation here consists mainly of shale and sandstone dipping southeast at low angles into the hills. Several branches flowing northwestward down the slope have cut narrow gulches through the formation at right angles to the strike of the beds and thus afforded sections across some rather ferruginous rocks. The Knoxville folio map shows, at a point 1¼ miles southwest of the locality visited, lying along the axis of the syncline, the northeast end of a narrow strip of Newman limestone, which is described as bluish shaly and massive limestone, of Mississippian age. The fossils collected from the ferruginous beds in the Grainger shale have been determined by E. O. Ulrich to be Mississippian.

### PROSPECTS.

About 6.4 miles in an air line southeast of Maryville a large prospect pit was noted in which the following section was measured.

This pit is cut in the steep slope of a gap in Little Mountain through which a small creek descends, and is about 50 feet above the creek.

*Section of ferruginous beds 6.4 miles southeast of Maryville, Tenn.*

| | Ft. | in. |
|---|---|---|
| Shale and ferruginous sandstone showing concentric weathering. | | |
| Shale, sandy, ferruginous | 1 | 3 |
| Ore, soft, sandy, and argillaceous | 2 | 1 |
| Ore, soft and shaly | | 6 |
| Ore, tough and argillaceous | | 4 |
| Ore, soft and shaly | | 5 |
| Ore, soft and weathered, very fossiliferous | 2 | 2 |
| Shale | | 5 |
| Ore, tough, dark red | | 9 |
| Shale | | 2 |
| Ore, soft with rich streaks and shaly streaks | 2 | 1 |
| Shale | | 1 |
| Ore, soft and fossiliferous | | 4 |
| Shale, ferruginous. | | |

Dip, 40° S. 55° E.

Total ore, mostly lean, 8 feet 8 inches.

The material termed "ore" throughout the exposure has been thoroughly leached. It is generally soft and rather decomposed and shows limonite specks. The softest parts are brownish and do not give a very red streak. A carload of this ore is reported to have been shipped in 1907 to the blast furnace of the Embreeville Iron Co. and to have averaged 40 per cent of metallic iron. This bed is known locally as the "big seam." Analyses of this ore are given on page 320.

To judge from the content of fossil remains in the soft ore that have been leached of their lime, the hard ore probably contained considerable calcium carbonate and therefore much less iron than the soft ore. It was reported that this ferruginous bed has been tested on the outcrop by 75 pits between Little River and Tennessee River and has been found of about the quality indicated above. There is no information at hand concerning the extent of the soft ore in the direction of the dip, therefore it is not known whether the bed can be worked for soft ore or not. More light would be thrown on this question by a few drill holes, prospect slopes, and tunnels.

Between 300 and 400 yards southeast of the prospect just described, near the same creek, a prospect has been cut in another ferruginous series of beds. The stratigraphic relations indicate that these beds are higher in the formation than the "big seam," but they may represent the same beds, which have been brought to the surface again by synclinal fold, the southeast limb of which has been overturned so that the dips are toward the southeast. At both the prospects the beds dip in nearly the same direction.

At this prospect the following section was measured:

*Section of ferruginous beds 6.6 miles southeast of Maryville, Tenn.*

| | Ft. | in. |
|---|---|---|
| Shale, sandy, brittle. | | |
| Ore, alternating with streaks of shale one-half to 2 inches thick | 1 | 1 |
| Ore, with three shale partings one-half to 1 inch thick | 2 | 2 |
| Base concealed. | | |
| Dip 52° S. 55° E. | | |
| Total ore, about 2 feet 7 inches. | | |

The ore here is dark red, soft, and very similar to that in the "big seam" except that it may be slightly richer in iron.

One mile northeast from and about on the strike of the beds exposed at the pit first described a prospect was noted in beds of hard ore. The following section was measured:

*Section of ferruginous beds 2 miles southwest of Little River, Tenn.*

| | Ft. | in. |
|---|---|---|
| Ore, compact, firm, dark red, fossiliferous; contains little lime | 4 | 9 |
| Ore, similar to above but parted by several thin streaks of shale | 1 | 3 |
| Ore, dark, hard, fossiliferous, calcareous | 1 | |
| Dip, 32° S. 55° E. | | |
| Total ore, about 6 feet 9 inches. | | |

The material is jointed and when struck with a hammer tends to break into small blocks with nearly rectangular faces. This prospect is reported to have been made in 1908, but there was very little débris in it on account of the opening being situated on a steep hillside some 25 feet above the creek. Where this bed passes below creek level another pit had been cut, but this was full of débris at the time of visit.

## ANALYSES.

The following chemical analyses of this ore from the Grainger shale (except the one made by the United States Geological Survey) were kindly furnished by Mr. J. F. Britain, of Maryville:

*Analyses of iron ore in Grainger shale near Maryville, Tenn.*

| Locality. | Authority.[a] | Fe. | $SiO_2$. | $Al_2O_3$. | CaO. | MgO. | Mn. | P. | S. |
|---|---|---|---|---|---|---|---|---|---|
| Seam No. 1, bottom (soft ore) | T. | 36.14 | 26.50 | 9.81 | | | | 0.15 | |
| Seam No. 1, middle (soft ore) | T. | 40.21 | 18.40 | 8.72 | | | | .14 | |
| Seam No. 1, top (soft ore) | T. | 34.90 | 22.00 | 10.13 | | | | .16 | |
| Seam No. 2 (soft ore) | T. | 40.41 | 18.40 | 8.95 | | | | .14 | |
| Do | T. | 35.02 | 24.20 | 10.21 | | | | .19 | |
| Do | T. | 10.68 | 61.00 | 13.14 | | | | .06 | |
| Hard ore | U. S. | 33.47 | 25.58 | | 11.12 | | | .09 | 0.07 |
| Do | O. | 35.00 | 13.70 | 6.95 | 12.03 | 1.40 | 0.30 | .24 | |

[a] Authorities: T., Tennessee Coal & Iron Railroad Co., Ensley, Ala., 1907: O. owners of property; U. S., U. S. Geological Survey.

## MINING DEVELOPMENT.

### STAGES OF DEVELOPMENT.

In the southern Appalachians the mining of bedded iron ore has passed through two principal stages of development. The first stage consists in mining the ore on the outcrop and the second in mining it from underground drifts and slopes. Open-cut mining has been carried on along the outcrop practically wherever the ore has been found thick enough to be dug and shipped to market without entailing financial loss. Only in areas remote from the railways or where the ore is very thin are there no traces of former stripping operations. Stripping of the ore beds was done by hand and by scrapers drawn by horses or mules, and was carried to as great depth as was found to be profitable, depending on the thickness and quality of the ore bed, its dip, and the character of the overlying rock. A maximum thickness of 30 feet of stripping was observed at one place. The overlying shale is locally so hard that it is necessary to blast it out, after which the loosened material is shoveled into wagons and hauled to a convenient dumping place. Few of the old strip pits now show their former maximum depth, as they are partly filled by slumping of the wall, and in many places the shale has been "back filled" where the ore was removed. This phase of the iron-mining industry is now nearly obsolete, because of the exhaustion in most areas of the reserves of soft ore near the surface, although near Chamberlain, Tenn., ore is still being mined on a large scale from open cuts. Some of the old trenches and embankments that are encountered in the woods while following the outcrop of the ore beds are of considerable age, as is indicated by the size of the forest trees that have grown over them since mining was abandoned.

Underground mining has succeeded surface mining generally where the ore beds are of attractive quality and of more than the average thickness, or else where they are so situated that the cost of transportation to blast furnaces is relatively low. This does not necessarily imply that the ore is now being mined underground at all the localities at which it is available, for there are several well-located areas in Tennessee, Alabama, and Georgia underlain by good "Rockwood" ore that are not yet under development.

A further stage to which the mining of bedded iron ore may eventually progress is that of shaft mining. This would possibly be the most practicable method of working the ore below the Cumberland and Lookout plateaus if it is ever mined there. In the area between La Follette and Elk Valley and also northwest of the Rockwood-Cardiff strip the "Rockwood" ore is probably of workable thickness, although very deep below the surface. No shaft mining of "Rockwood" ore has yet been attempted in the South, but it is reported that a 50° slope is being sunk to an ore bed 1,900 feet below the surface near Oxmoor, Ala., and the results of this work will be watched with close attention by everyone interested in the development of southern iron-ore fields.

## CONDITIONS AFFECTING UNDERGROUND MINING.

A summary of the most important points to be considered in relation to underground mining of bedded iron ore in the South would include (*a*) thickness of beds; (*b*) quality of ore; (*c*) attitude and structure of beds; (*d*) relation to topography and water level; (*e*) continuation of ore in depth; (*f*) distance from transportation routes; (*g*) relation to markets. The question of markets in the area under consideration is not at present serious, for most of the blast furnaces at Chattanooga, Dayton, Rockwood, and La Follette, Tenn., Gadsen and Attalla, Ala., and Rome, Ga., are, when in blast, willing to buy ore at market prices.

With regard to the minimum workable thickness, the poorest acceptable quality, and the other limitations that may be imposed by the various factors mentioned above, it may be said that all are more or less interdependent. For instance, a very rich ore can be worked in thinner and more disturbed beds than a lean ore. A rich and thick ore bed whose extent is known to be limited by a fault may not warrant the outlay necessary for a railway spur and the necessary mining equipment, which might be warranted by a thinner and leaner bed whose extent has been proved by prospecting to be much greater. The ore beds near Ooltewah are worked in a small way for paint material, but the writer has observed in the southern region no extensive underground mining of beds, whose thickness averaged less than 2 feet, nor does self-fluxing ore carrying less than an average of 25 per cent of metallic iron seem to be considered minable. In fact, no one acquainted with iron making in the South would at present be likely to become enthusiastic over mining a 2-foot bed of ore averaging 25 per cent of metallic iron, no matter how extensive or easily accessible it might be. With changing conditions, however, such an ore bed may become of considerable value at some future time, and for this reason it was thought best to include mention of the outcrop of such beds in the present report.

The maximum distance down the dip measured from the outcrop or the maximum vertical depth below the level of the outcrop to which an ore bed may profitably be worked are greatly affected by other factors. In some slopes where the ore is thin or of poor quality the limit of workability under present conditions has already been reached and mining has been discontinued. Probably when the prices of ore have risen sufficiently some of these slopes may be reopened. Other slopes that are driven in fairly thick ore of good quality have penetrated to far greater distances than the abandoned slopes and are still being operated at a profit. Obviously no workable limit can be applied to ore in such localities. For the purpose of making hasty approximations as to the tonnage of iron ore available in various parts of the United States[1] in 1908, a vertical depth of 1,000 feet was taken as an arbitrary limit to which the bedded iron ore in east Tennessee might be considered available under conditions prevailing at that time. No active slope had been reached more than half that vertical depth and some had been abandoned at much less depths. Although less than five years have elapsed since these estimates were made, one would now hesitate to place a limit of workable ore at 1,500 feet, or even at 2,000 feet, vertically below the surface. It is therefore evident that the limit of workable ore in depth is a rapidly progressing factor, and one which can not be assumed with any degree of certainty in making estimates of ore reserves.

The question has often been asked how far surface conditions could be depended on to indicate the thickness, quality, continuity, and structure of the ore bed beneath the surface. Surface indications in regard to the quality of an ore bed, provided it has been prospected back to the hard ore, are generally reliable. If prospect pits extending a sufficient distance along the outcrop have disclosed hard ore of uniformly good quality it may reasonably be assumed that the bed will continue below the surface with but little deterioration. A few exceptions to this rule have, however, been noted. The variations in quality and thickness along the outcrop should be carefully noted. Variations are characteristically more abrupt in the direction of the dip than along the strike of the ore beds. The structure of the beds overlying the ore should be noted carefully, as there naturally exists a certain parallelism in structure between surface and underlying beds. Faults or dislocations in the strata should be carefully noted, and it should at once be determined whether the beds beyond the fault have moved relatively up or down. If they have moved upward, was the upthrow sufficient to bring the ore bed above the surface and thereby terminate its extent in that immediate vicinity? If the rocks beyond the fault were dropped, instead, to what depth is the ore depressed? To what depth has the ore dipped below a given point on the surface? These questions can perhaps be answered by careful geologic study, but it may require deep drilling to settle such points definitely. The writer has in mind an operation in which, had the geologic evidence been given due weight, much expense and futile search for ore might have been avoided. At the outcrop the ore

[1] Hayes, C. W., Iron ores of the United States: Bull. U. S. Geol. Survey No. 394, 1909, pp. 70–113.

dipped at a moderate angle and conditions were evidently favorable for the driving of a slope, but a few hundred feet beyond the outcrop, in the direction of the dip, an abrupt change occurred in the surface rocks. A highly fossiliferous chert adjoined an area of nonfossiliferous chert and dolomite. The fossiliferous beds were those of the Fort Payne chert, which normally lies 150 to 200 feet above the iron ore; the nonfossiliferous beds were those of the Knox dolomite, which normally lies many hundred feet below the ore. No attention was paid to these geologic conditions, but a slope was driven and elaborate preparations were made for mining. Within a few hundred feet the slope ran into broken ground and the ore was lost. Two other slopes were driven, both of which encountered the same difficulties. The evidences of a fault were plain enough, but instead of heeding them the owners drilled a hole nearly 1,000 feet deep in search of ore in the Knox dolomite. Thorough deep drilling—in the right place—is most strongly advocated. Too little drilling has thus far been done in the ore fields, probably because of the great expense, but the expense is generally well justified, by the information obtained concerning depth to ore, thickness and quality of ore, dip of the beds, etc., provided a preliminary geologic study is made so that the drill hole is judiciously located.

The great extent to which the soft-ore beds were formerly worked at the surface is one of the factors that has led to the worst misapprehension concerning southern iron ores in general. To persons who are engaged in pursuits wholly unrelated to mining, but who may be interested in mineral lands from whose surface there was produced 20 to 50 years ago a considerable tonnage of rich soft ore, it naturally appears reasonable to believe that this mining activity should at some future time be revived. It should be necessary only to recall two points in this connection. First, surface mining is the cheapest method of working the ore beds. It requires comparatively little outlay for equipment, and it can be terminated and the outfit moved away without great loss when the work becomes unprofitable. Second, the soft ore, which was obtainable at the surface, was much richer in metallic iron than the hard ore which is to be expected below the ground-water level. If these two points are borne in mind, it will readily be seen that to be workable underground an ore bed must have a thickness much greater than the 6 to 18 inch seams that were once stripped and trenched for many miles along their outcrop in the southern Appalachian area.

## CONCENTRATION OF ORE.

With the gradual depletion of the highest grade of iron-ore reserves in all countries increasing attention is being paid to the possibilities of utilizing lower grades of ore. Beneficiation of iron ore in the

Lake Superior district has been accomplished by means of extensive plants for washing, concentrating, roasting, nodulizing, and briquetting ores at various places in Minnesota, Michigan, and Wisconsin.

In the South the best-known process of beneficiating iron ores has been applied to brown ore and consists of crushing the ore, washing it in a log washer, screening the washed material, and picking the oversize on a picking belt. Why some similar methods of treatment are not more generally applied to the betterment of the shaly grades of red iron ore is difficult to understand, in view of the success that has attended certain efforts in this direction in Tennessee and Alabama within the last three years. In mining a 4-foot bed of "Rockwood" ore with thin shale partings aggregating only 4 inches in thickness, over 8 per cent by volume of shale is shot down with the ore, to which must be added more or less roof shale. In many places the total percentage of shale is probably not less than 20 per cent, and it is difficult underground to separate this broken shale from the ore; consequently most of it is hauled to the surface, and if not separated at the tipple goes on to the blast furnace. At the mines of the Brown Mining Co., in the Rockwood-Cardiff area, picking tables have been given a practical trial extending over a period of three years. The results as gaged by analyses of the picked ores compared with analyses of the ores delivered prior to the installation of the picking tables are reported to have shown a marked improvement in the ores, although inspection was necessary in order to maintain the improved grade. Gains in the average percentages of metallic iron and decreases in the average percentages of silica are apparent. Similar results are reported from operations at the Crudup mine, in northeastern Alabama, where the ore contains a considerable percentage of shale in the form of irregular seams and nodules.

Interesting experiments have been made recently in a private laboratory at Wilmington, Del., in the concentration of iron ores by the Moxham and Du Pont haloid process. In this process the ore is ground to pass 100-mesh screens and is fed into troughs containing haloid solutions of high specific gravity in which the tailings float. Separation of the lighter siliceous impurities from the heavier iron oxide concentrates is thus effected. Three tests were made of siliceous Alabama ore carrying 34.32 per cent of iron and 44.80 per cent of insoluble matter, and therefore not of workable grade. On treatment this ore yielded concentrates ranging from Fe, 41.10, insoluble, 34.50, to Fe, 53.32, insoluble, 16.90. The richer the concentrates the smaller their quantity. Of the poorer concentrates the yield was 81.2 per cent and of the richer, 48.8 per cent; but the efficiency in the latter is 97.2 per cent, compared to 75.7 per cent in the former. It is reported that this process can be carried on economically; and if so, there would appear to be a great opportunity for its application in conserving large quantities of siliceous and shaly red iron ores in the Southern States.

A series of experiments in concentrating Alabama red hematite were made by W. B. Phillips[1] in 1895 to 1897. Soft red ore containing high percentages of silica in the form of fine to coarse grains and small pebbles was crushed and screened, with the result that the percentage of iron oxide was materially increased. Considerable increases in the percentage of iron oxide were also produced by crushing and screening the ore and feeding the screenings to a magnetizing machine. As to the results Phillips says:

> These tests were * * * made on carload lots of ore and extended over several months. Conditions as to fineness of material treated, speed of the machines, amperage and voltage used, and character of the raw material were such as to give a wide range of observation. The conclusions reached were that it was entirely feasible to make concentrates of 50 per cent of iron and above from ores that were worthless for the blast furnace, and the yield of such concentrates would be not less than 50 per cent by weight of the raw ore. The extraction of the available iron in the raw ore was about 85 per cent. In some important instances the yield of workable concentrates was about 60 per cent of the raw ore treated, an ore otherwise worthless.

Similar tests were also made on limy red ores with the result that they were generally improved.

Although none of these special processes have yet been put into commercial application, it is possible that they will some time be commercially successful. It is of interest to know what would be the result of treating ore containing a large proportion of shale interlaminated with the hematite, as ore of this type is common in the vicinity of Chattanooga on both sides of the State line.

## POSSIBILITY OF STEEL MANUFACTURE.

The desirability of utilizing in the vicinity of Chattanooga the products of southern blast furnaces has long been realized by the foremost iron makers of the South. According to Killebrew,[2] the Roane Iron Co. possessed at Chattanooga as early as 1881 a Siemens-Martin (open-hearth) plant for making steel and was engaged in making steel and iron rails and in rerolling old rails, but no steel plants are now operating in this vicinity.

There are no longer any serious obstacles in the way of making steel from southern iron ores so far as the character of the ore is concerned, as is shown by the successful operations of steel plants at Ensley and Gadsden, Ala. The possibilities of Chattanooga as a steel-making center are now engaging the attention of owners of

[1] The results of this work are reviewed by Phillips in "Iron making in Alabama," 3d ed., 1912, pp 102-112.
[2] Killebrew, J. B., Iron and coal of Tennessee, Tennessee Comm. Agr., Statistics, and Mines, 1881, p. 92.

iron and coal lands, technical experts, and capitalists, and it is hoped that a plan may be evolved whereby the city's great advantages for manufacturing and distributing may be grasped and still further developed by the establishment of steel mills.

Certain comprehensive reports by mining engineers and metallurgists on an assemblage of iron ore, coal, and timber properties situated within a short radius of Chattanooga in Tennessee, Georgia, and Alabama have been placed at the disposal of the writer. According to these reports it is considered feasible to utilize the raw materials at Chattanooga and to carry the manufacturing process to the last stages of the finished iron and steel products. These reports can not be reproduced here, nor can the details on which their conclusions are reached be quoted, but a few of the essential features considered in fixing on Chattanooga as the logical location for a steel plant and emphasized in a comprehensive paper already published [1] on the subject may be properly mentioned:

1. Ore resources. It is considered that sufficient ore is available in the district to warrant the establishment of a steel plant. In arriving at this conclusion the large quantities of available ore that is low in iron and silica and high in lime have been included, as well as smaller supplies of high-grade siliceous red and brown ore. The greater part of the available red ore should be mined at a reasonable cost per unit of iron.

2. Coal resources. The supplies of coking coal are considered adequate, although, owing to the irregularities of the local coal beds in both thickness and quality, the coal fields of eastern Kentucky and southwestern Virginia are also figured into the general estimates.

3. Cost of producing pig iron. This is the critical factor in steel manufacture. The cost of making pig iron under the most favorable conditions would probably be somewhat higher here than in the Birmingham district, where it is made most cheaply in the South, but it is considered that the cost should not exceed that at Birmingham by more than $1.20 a ton. The average cost at Birmingham is taken at $9.68 a ton and the estimates for Chattanooga range from $10.40 to $10.85. These estimates, it should be noted, are conditioned on large output, regular operation, and good management. The higher cost at Chattanooga is due in large part to the difference in cost of coke at the furnaces in Chattanooga and at Birmingham, and in lesser part to the difference in the cost of ores. The figures quoted are those for the early part of 1910. It is possible that the prices of coke and iron ore may have increased during the last three years. The cost of converting iron into steel should be no greater at Chat-

[1] Porter, J. J., The steel-making resources of Chattanooga: Manufacturers' Record, Baltimore, Md., May 12, 1910, pp. 49–54.

tanooga than elsewhere, and perhaps less, for steam coal is cheap and labor conditions are, as a rule, excellent.

4. Manufacturing sites. There are many favorable manufacturing sites at Chattanooga, and Tennessee River furnishes an unlimited supply of good water. Indeed, the prestige that this city has already attained is due in no small degree to the abundance of cheap factory sites and the large amount of pleasantly located land available for workmen's homes.

5. Markets. Chattanooga is, properly speaking, the most centrally located city in the South and enjoys a large and rapidly increasing local demand for structural steel and steel for general manufacturing purposes, as well as a large and expanding trade territory that will doubtless be greatly increased by the opening of the Panama Canal.

6. Competition. It is considered that in the manufacture of roofing and other light sheets, structural shapes, and light rails Chattanooga would have relatively little competition from other steel plants in the South, including those on Ohio River in Kentucky.

7. Transportation facilities. Chattanooga is especially favored in the matter of railways, no less than five systems radiating from the city. Tennessee River is navigable for eight months in the year from Chattanooga to Ohio River, and on the completion of the dam and lock at Hales Bar, below Chattanooga, there will be a sufficient stage of water to make navigation upstream more practicable than it is at present and to afford water transportation for coal from mines below the city.