IRON AND MANGANESE.

AN ESTIMATE OF THE TONNAGE OF AVAILABLE CLINTON IRON ORE IN THE BIRMINGHAM DISTRICT, ALABAMA.

By Ernest F. Burchard.

INTRODUCTION.

In a previous paper[a] it was stated that a forthcoming more detailed report on the iron ores of the Birmingham district would contain an estimate of the red-ore reserves in the district. This detailed report has been completed, and it is expected that it will be published some time after July 1, 1908. The above-mentioned estimate of ore reserves has been prepared by the writer and included in the text of the detailed report, but for the sake of more prompt publication it is given here, necessarily, however, without the mass of data, comprising measurements of thickness and extent of ore seams, and the chemical analyses and other experimental results on which the calculations are based.

By the Birmingham district is meant the area from which the furnaces at Birmingham, Ensley, and Bessemer derive their iron ores, and it is practically coextensive with Birmingham Valley, the heart of the Alabama red-ore field. This valley extends from the vicinity of Springville, on the northeast, beyond Vance on the southwest, and from the Warrior coal field, or Sand Mountain, on the northwest, to the Cahaba coal field, or Shades Mountain, on the southeast. To the southwest the inclosing ridges pass below unconsolidated Cretaceous and Tertiary clays and sands, so that the iron-bearing rocks are deeply buried. Birmingham Valley therefore has a length of nearly 75 miles, an average width of more than 6 miles, and an area of 450 to 500 square miles.

The red ores occur in the Clinton (Rockwood) formation, which consists of shale, sandstone, iron ore, and a little ferruginous limestone. This formation extends in a northeast-southwest direction on both sides of the valley, dipping away from it on each side, and there are a few small areas or strips within the valley, principally in its

[a] Burchard, E. F., The Clinton or red ores of the Birmingham district, Alabama: Bull. U. S. Geol. Survey No. 315, 1907, p. 150.

southwestern portion, but only in Red Mountain has the ore been found of sufficient thickness and purity to be worked on an important scale. The geologic relations of the rocks and ores have been described in the paper previously mentioned.[a]

DIVISIONS OF THE DISTRICT.

Owing to the considerable extent of Birmingham Valley, to the distribution of the ore beds along the margins and at the ends of the valley, and to the variation in the character of the ore from place to place, the district has been divided, for convenience of description in the complete paper, into seven parts. The order of the divisions from A to G represents in a general way their commercial importance, based on quality of ore, quantity of ore, structure of ore beds, accessibility, and distance from smelters. It should be understood, however, that this outline of divisions is not intended as a definite estimation or appraisal of relative values. Such facts as were obtained in the field study of the district will be presented in the later report, so that interested persons may draw their own conclusions therefrom.

Division A includes that part of Red Mountain which extends from Morrow Gap, in sec. 32, T. 16 S., R. 1 W., southwestward to Sparks Gap, in sec. 32, T. 19 S., R. 4 W., a distance of about 26 miles. This is the only portion of the district considered in the present paper, and its outline is shown in fig. 19.

All but two of the productive mines of the district are in this strip of Red Mountain. In all there were 30 workings in operation in 1906, including slopes, open cuts, and combination mines. These mines are served by the Birmingham Mineral Division of the Louisville and Nashville Railroad, which is built along the slope of the ridge 100 to 350 feet below the summit. The railroad runs first on one side of the mountain, then on the other, threading its way back and forth through several natural passageways, such as Sadlers Gap, Lone Pine Gap, Walker Gap, and Readers Gap. From Readers Gap it runs into Bessemer, with a spur extending southwestward along the ridge to the Potter slopes. Some mines, especially those in that part of the mountain where the railroad passes along the west side, are so situated that their tipples can be built directly on a siding. Others, facing the east, have built spurs reaching back into lateral ravines. Through Red Gap, between Irondale and Gate City, five railroads enter Birmingham from the east and north; at Graces Gap the Louisville and Nashville Railroad passes southward across the Cahaba coal field to the Gulf, and at Sparks Gap the Southern Railway finds an outlet southeastward. This portion of the district is therefore well supplied with transportation lines and consequently its development has been facilitated.

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[a] Burchard, E. F., op. cit., pp. 132-146.

In July, 1906, the deepest slope in Red Mountain was reported to be more than 1,800 feet long. Three other slopes have been driven for nearly 1,800 feet each, and there were twelve slopes between 900 and 1,500 feet long. All the slopes 900 feet or more in length are in the strip of mountain southwest of Birmingham. The newer mines at the extremities of the district have slopes ranging between 260

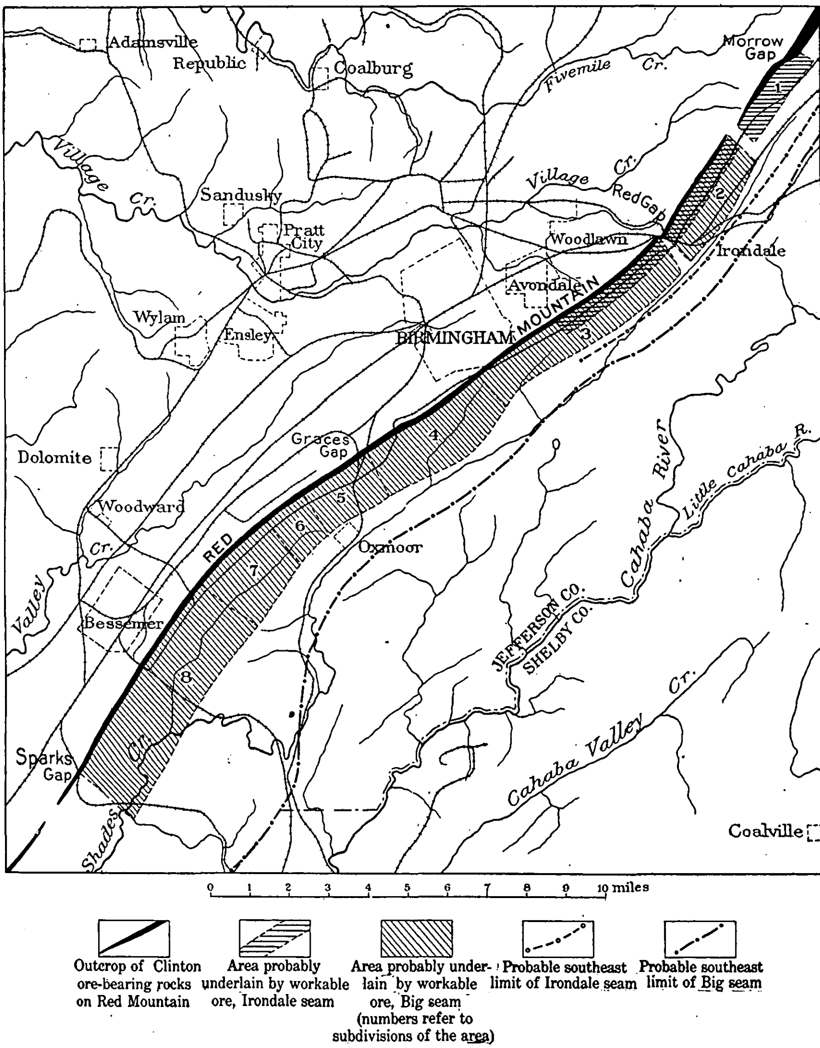

FIG. 19.—Sketch map of main portion of Birmingham iron-ore district, Alabama, showing subdivisions on which are based estimates of iron ore reserves.

and 800 feet in length. The deepest slope goes down on beds whose average dip is about 22°, so that its present depth is about 650 feet below the level of the valley at a point directly above the bottom of the slope. Projected at the same angle to a point directly below Little Shades Creek the slope would have a length of about 6,400 feet and a depth below the creek of 1,800 feet. It is not known whether the ore extends with an unchanged dip and thickness to this depth. Drill records obtained farther south in Shades Valley indicate that the ore beds with their associated strata flatten out and locally rise toward the surface. The surface rocks in the valley indicate irregularities in structure, including faulting, which would naturally be shared by the beds below.

No great deterioration in either quality or thickness of the hard ore in the direction of the dip has yet been disclosed by the deeper slopes—an encouraging fact in so far as it can be used as a measure of the ore ahead of shorter slopes. At one of the larger mines, centrally located, systematic analyses have been made of the ore at intervals of a few feet from the outcrop to the bottom of the slope and throughout the extent of each entry to the right and left of the slope. The composition of the ore has been found to vary appreciably from place to place and the degree of variation is likely to be as great within a few yards as it is between remote parts of the mine, but the average run of the hard ore in the mine is remarkably regular. The facts brought out by this series of analyses show that the content of metallic iron increases about 1 per cent for each 1,000 feet below the upper limit of the hard ore, that the lime (CaO) decreases about 1 per cent in the same distance, and that the silica content increases a trifle. Slightly different facts are shown, however, by a series of analyses of ore from a mine also on the Big seam, northeast of Birmingham, and distant about 18 miles from the mine just mentioned. Here the lime is increasing slightly with the depth, while the insoluble material as well as the iron is decreasing slowly. This change can be accounted for, in all probability, by the fact that the iron ore here is still being mined from the zone of transition from soft to hard ore and that the completely hard ore has not yet been reached.

Studies by members of the Alabama Geological Survey extending over many years have shown that the Clinton (Rockwood) formation tends to thin out and become sandier toward the southeast. There is no reason why this change should not be shared proportionately by the inclosed ore beds, and it is believed that the drill records just referred to indicate that such is the case. However, the complete drill records available from the valley east of Red Mountain are so few that reliable conclusions can be based on them only regarding that part of the ore basin which lies in the southern third of the district. Ore can, perhaps, be expected to underlie the valley southeast of Red Mountain, probably as far as Shades Mountain. The width of Shades Valley is a rough indication of the relative extent of the Red Mountain ore toward the southeast, and the width of the valley is sensibly greater southwest than it is northeast of Readers Gap.

ORIGIN OF THE CLINTON ORE AND ITS BEARING ON ORE SUPPLY.[a]

The answer to the question as to how the ores were formed has a very practical bearing on the extent and quantity of unexploited ore. Several theories have been advanced to explain its formation and three of these have received attention from persons who have considered the subject. Briefly the processes may be outlined as follows:

1. Original deposition: The ores were formed at the same time as the rocks with which they are associated.

2. Residual concentration: The ore beds represent the weathered outcrops of ferruginous limestones, from which the lime and other soluble matter have been leached.

3. Replacement: The ores have been formed by the replacement of beds of limestone by iron-bearing waters, and are therefore of much later origin than their inclosing rocks.

If the ore beds are due to replacement or to surface decay of limestone beds they can be expected to decrease in value regularly and at a fairly rapid rate with distance from the outcrop, until the beds consist entirely of limestone. Moreover, this condition should be encountered within distances less than the lengths of some present mine slopes.

If, however, the ores originated with their inclosing rocks, no regular decrease in richness is to be expected as the beds are exploited deeper beyond the limit of soft or leached ore. Areas of low-grade ore or even barren rock may be struck, but such areas are the result of original deposition, and a mine slope may pass onward through such a patch of lean ore or rock into ore of good grade. Finally, the ore bed may be expected to thin and disappear or to split and become shaly, and in this way to so deteriorate as to become unprofitable to work, but unless structural complications render it unworkable the ore should continue down the dip of Red Mountain well toward Shades Mountain.

It may be stated that all the new facts observed in the course of the work in the Birmingham district are in accordance with the hypothesis that the ore is the result of original deposition of ferruginous sediments. The transition, vertically, between sandstone and ore or between shale and ore is as sharp as that between coal and its inclosing rocks. The variation in composition of an ore bed from place to place is not unlike the local changes in composition and character of a coal bed. The lenslike form of the beds is common to both coal and ore. Finally, as the lens thins, whether of coal or of ore, it tends to become shaly and siliceous rather than calcareous. That the ore is due entirely to the replacement of limestone seems

[a] This subject is discussed much more fully by Mr. E. C. Eckel in the complete report.

hardly possible when it is considered that instead of a marked decrease in percentage of iron and an increase in that of lime, with depth, until the bed becomes a limestone, very little tendency toward that condition has been noted. The lime in the bed is perhaps an accessory deposit, as is the silica. The term "depth" in this connection may be subject to misconception, for the sediments were deposited in a horizontal position, or nearly so, and their present attitudes are the result of subsequent foldings. The depth to which the beds now extend is therefore incidental, and in no way affects their character beyond the soft-ore limit. Indeed, the best criterion for judging the character of the unexploited ore beds in the direction of their dip, or in the basin southeast of Red Mountain, is the strike section of the same beds that has been afforded by the mine workings. From northwest to southeast there are likely to occur changes similar in nature to those that are known to take place from northeast to southwest, although the changes will probably be found to be more abrupt, for the reason that the former direction is toward the shore of the water body in which the sediments were deposited, whereas the latter is parallel to this shore. Keeping all these possibilities in mind and using such data as are suggested below, the geologist or the engineer should be able to make a fairly close estimate of the tonnage of the red-ore reserves in the district, or in any portion of it.

METHOD OF MAKING ESTIMATES.

First, the area should be divided into parts in somewhat the manner outlined on page 309. Then each division should be subdivided again and again until areal units are obtained in which the cubical contents of the ore can be calculated with not more than 10 per cent of error. The percentage of recoverable ore should enter into the calculations, as well as the specific gravity of hard ore carrying not more than the average percentage of metallic iron.

THE ORE RESERVES IN DIVISION A.

It has been stated that red ore might be expected to underlie the valley southeast of Red Mountain probably as far as Shades Mountain, and there are indications that it extends still farther, as a thin ore seam is brought to the surface by faults east of Cahaba River. It is hardly probable, however, that the ore continues with workable thickness beyond the line of Shades Mountain, and it is not likely that it continues workable that far toward the southeast, to judge from the thinness of the seam where it is faulted up, and from drill records in Shades Valley. The lenslike character of the ore beds and the thinning and other changes in the beds that take place more abruptly at right angles to the ancient shore line than parallel to it make it reasonable to assume that at a certain distance from the outcrop the ore bed will naturally become so thin as to be negligible. Structural conditions indicate that this line, which contains what may be called the "vanishing point" of the ore, lies below Shades Mountain, the border of the heavy cover of coal measures to the southeast. As there are several seams of ore, this maximum distance naturally applies to the largest and most persistent bed, viz, the Big seam. The other, smaller seams, such as the Ida and the Irondale, probably would not continue so far, to judge from their extent and the relations exhibited along their strike. If there is a vanishing point, or a point beyond which the ore continues only a few inches in thickness, it will not be practicable to mine the ore as far as this point, and the limit to which it will pay to drive slopes will be determined by the minimum thickness at which the ore can be mined with profit. In using these factors, some of which are to a certain extent hypothetical, as a basis for estimating the tonnage of ore still in the ground in Division A, it is also necessary to assume that there is a fairly regular decrease in thickness of the seams from their outcrop to the vanishing point, and that therefore they form long, wedge-shaped bodies, the thick end of the wedge lying along the outcrop on Red Mountain, and the thin end, somewhat less regular in outline, lying below the crest of Shades Mountain, with the limit of workability following a northeast-southwest line intermediate between the two extremes.

An estimate of the ore reserves in Division A has been made in connection with the study of this subject, but the fact is here emphasized that while many more details have been considered than there is space to enumerate here or necessity for describing at present, the estimate must be regarded as only approximate. The tonnage of ore that should be contained under the assumed conditions, first in the Irondale seam, from Morrow Gap to Clifton Gap, and second in the Big seam, from Morrow Gap to Sparks Gap, has been computed. From the sum of these estimated quantities is subtracted the total tonnage of red ore that has been produced in Alabama from 1880 to 1907, inclusive. In making this estimate, Division A is subdivided into eight parts, in two of which the Irondale seam is considered of sufficient importance to be regarded as a source of future ore supplies. These eight units of area (see fig. 19), whose ore-bearing strata outcrop along Red Mountain, are as follows: (1) From Morrow Gap to and including the Olivia mine (Irondale seam); (2) Bald Eagle to Clifton Gap (Irondale seam); (3) Bald Eagle to Lone Pine Gap (Big seam, upper bench); (4) Lone Pine Gap to Graces Gap (Big seam, upper bench); (5) Graces Gap to a point beyond Ishkoodo (Big seam, upper bench); (6) Ishkoodo to Tennessee Coal, Iron and Railroad Company's slope No. 10 (Big seam, upper bench); (7) Tennessee Coal, Iron and Railroad Company's slope No. 10 to middle of Woodward Iron Company's property (Big seam, upper bench); (8) middle of Woodward Iron Company's property to Sparks Gap (Big seam, upper bench). The estimate is considered to be conservative for the following reasons: (1) No account has been taken of any possible available ore except that in Red Mountain; (2) no ore seams besides the upper bench of the Big seam and the Irondale seam have been considered; (3) only such portions of the outcrop of these seams have been considered as are known to be workable, and wherever the seams are faulted out or badly broken up, such portions are not included in the area on which estimates are based; (4) the percentage of recoverable ore has apparently been placed low enough to be on the safe side; (5) conservative figures have been used as representing the average workable thicknesses at the outcrop and the minimum workable thickness, as under favorable conditions the former may be considerably greater and the latter may be less; (6) the percentage of the metallic iron used as a factor in determining the specific gravity of the hard ore has been taken with a view to the possible reduction rather than increase of iron content with depth; (7) in deducting the tonnage of red ore already produced the total red ore for the State has been taken, which is greater than that produced by the Birmingham district, and consequently in excess of that produced by this area, the main portion of the Birmingham district. In regard to this last factor it should be stated that the excess is not great, however, for the Birmingham district has produced almost 90 per cent of the red ore of the State, and Red Mountain between Morrow Gap and Sparks Gap has produced between 97 and 98 per cent of the red ore of the district.

In obtaining the specific gravity of the hard ore in relation to its content of metallic iron, use has been made of the laboratory determinations of Mr. R. T. Pittman, chief chemist of the Sloss-Sheffield Steel and Iron Company at Birmingham. The experiments consisted of grinding lumps of ore down to cubes 1 inch on an edge, determining the specific gravity of each by displacement of water, and afterwards analyzing the ore thus treated. The results of certain of these tests and analyses are as follows:

Specific gravity tests and analyses of calcareous hematite.[a]

Sample No.	Weight in air of 1 cubic foot of ore (pounds).	Specific gravity.	Analyses.		
			Fe.	Insoluble.	CaO.
1	213.47	3.42	36.25	13.80	17.98
2	215.97	3.46	37.05	12.40	18.14
3	219.23	3.50	37.60	11.42	17.43
4	220.71	3.53	38.05	10.60	17.52
Average	217.35	3.48	37.24	12.05	17.78

[a] Experiments by R. T. Pittman, Birmingham, Ala.

If we assume, then, that the ore in a certain seam within a given area forms a fairly regular prism, the base and altitude of which may be measured, and that the minable ore of this seam constitutes a truncated portion of this prism, the cubic contents of this truncated prism of minable ore may be calculated conveniently by substituting in a formula the values of the average thickness, length, and width of the truncated prism of ore. From this result (in cubic feet) may be deduced in the same operation the tonnage of ore of a definite grade by use of the factors, percentage of recoverable ore and specific gravity, based on the average percentage of metallic iron in the hard ore. Multiplying by 62.5, the weight in pounds of a cubic foot of water, will give the pounds of ore, which can then be reduced to long tons by dividing by 2240.

Therefore, to establish a general formula for calculating the ore content for a given ore seam in a given area, let—

L = Length of outcrop.
V = Average distance of "vanishing point" from outcrop.
T = Average thickness of ore seam at outcrop.
t = Minimum thickness to which ore may be worked.
D = Distance from outcrop at which thickness of ore seam becomes t, or maximum distance practicable to drive slopes.
R = Per cent of recoverable ore.
C = Average per cent metallic iron in hard ore.
G = Specific gravity of ore based on value of C.

Then to obtain the value of D in terms of the known quantities T, t, and V, T:V::t:V—D, whence $D = \frac{T V - t V}{T}$ and the total tonnage is $\frac{\frac{1}{2}(T+t) \times L \times D \times R \times G \times 62.5}{2240}$. On applying this formula to the area included in Division A, we obtain the result given in the following table:

Estimated ore reserves in main portion of Birmingham district.

Subdivision.[a]	L	V	D	T	t	R	C	G	Total ore.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Per cent.*	*Per cent.*		*Long tons.*
1	11,000	8,000	2,720	4.54	3	80	32	3	7,896,804
2	32,000	6,800	2,000	4.24	3	80	35	3.27	16,910,570
3	37,000	10,600	5,000	8.5	3.5	80	35	3.27	100,846,671
4	16,500	12,000	7,300	9	3.5	80	33	3.08	51,755,855
5	10,000	12,000	6,750	8	3.5	80	34	3.17	27,445,981
6	6,000	13,000	7,167	7.8	3.5	80	36	3.36	18,222,097
7	12,000	16,800	9,656	8.23	3.5	80	36.6	3.42	51,835,132
8	29,500	24,000	9,500	8.32	5	60	36.8	3.44	107,488,381
Grand total									382,401,491
Production 1880 to 1907, inclusive									43,683,445
Total red-ore reserves in main portion of Birmingham district									338,718,046

[a] 1. Irondale seam, Morrow Gap to point beyond Olivia mine.
2. Irondale seam, Bald Eagle to Clifton Gap.
3. Big seam, upper bench, Bald Eagle to Lone Pine Gap.
4. Big seam, upper bench, Lone Pine Gap to Graces Gap.
5. Big seam, upper bench, Graces Gap to point beyond Ishkoodo.
6. Big seam, upper bench, Ishkoodo to Tennessee Company's mine No. 10.
7. Big seam, upper bench, Tennessee Company's mine No. 10 to middle of Woodward property.
8. Big seam, upper bench, Middle of Woodward property to Sparks Gap.

It is frankly admitted that the magnitude of the figures obtained by this estimate is rather surprising. When it is considered that the present annual production of red ore in Alabama is not greatly in excess of 3,000,000 long tons, and that this production has not increased rapidly in recent years and does not promise to increase rapidly in the near future, the results of the estimate indicate that the iron-ore reserves in this district will last for seventy-five to one hundred years longer at the present rate of output. If the estimate of the writer, 340,000,000 long tons of red ore in the Birmingham district workable under present conditions, is compared with the estimate of 1,000,000,000 long tons of red ore in reserve in the State of Alabama, recently published by E. C. Eckel,[a] it would appear that the present estimate is fairly conservative, when it is recalled that the Birmingham district probably contains 90 per cent of the workable red ore of the State. In explanation of Mr. Eckel's apparently higher estimate it should be stated that much ore at present unworkable has been included therein.

It should be repeated, in conclusion, that the present estimate is based on the belief that the ores are the result of original deposition, that they occur in the form of regular lens-shaped bodies, that their content of metallic iron does not greatly diminish from the point where the hard ores are first encountered in the mine slopes to the point where the minimum workable thickness is reached, and finally, that the structure remains fairly constant as indicated in the foregoing discussions. This last element, it should be remembered, is one of the most uncertain, and can be rendered more certain only by thorough and systematic prospecting with the drill between Red Mountain and Shades Mountain. Unexpected structural complications and "horses" of barren rock may greatly reduce the quantity of workable ore counted on in this estimate. On the other hand, in the less favorably regarded divisions of the district which are described in detail in the forthcoming paper, there are large reserves of ore which have not been included at all in this estimate of ore tonnage available in the Birmingham district.

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[a] Production of iron ores and iron products in 1906: Mineral Resources U. S. for 1906, U. S. Geol. Survey, 1907, p. 79.

THREE DEPOSITS OF IRON ORE IN CUBA.

By Arthur C. Spencer.

INTRODUCTION.

The Iron Age for August 15, 1907 (vol. 80, pp. 421–426), contained a description of a large deposit of iron ore in the Mayari district, Cuba, which has been under development by the Spanish-American Iron Company since January, 1904. The engineers of this company believe that the deposit contains more than 500,000,000 tons of ore, carrying above 40 per cent of iron, and it is pointed out that this amount adds 5 per cent to the world's reserve of iron ore, as estimated in 1905 by the Swedish geologist Törnebohm. Though the statistical importance of the deposit is considerably decreased by the latest estimate of the iron-ore reserves of the United States, indicating that our home supply is at least 10,000,000,000 tons,[a] the industrial importance of this new source of iron ore is in no manner affected.

It is stated in the article referred to above that explorations since 1898 have revealed many iron-ore deposits in various parts of the island. "Deposits of a few tons were numerous and those of a few hundred thousand tons were perhaps three in number." Data presented in the following pages indicate that the word "thousand" in the sentence quoted should read "million," so that, to the uninformed reader, the paragraph of which the sentence quoted forms a part is misleading in regard to the prospective importance of Cuba's medium-grade iron-ore deposits.

The Mayari ores are distinct, both in kind and in occurrence, from the well-known iron ores occurring in the Sierra Maestra near the south coast of Oriente Province, or Santiago de Cuba as it was formerly called. The Cuban ores which have been mined up to the present time are hard hematites with an admixture of magnetite, containing rather high sulphur and a small amount of copper. They occur as large and small irregular masses associated with a variety of

[a] Eckel, E. C., Advance chapter from Mineral Resources U. S. for 1906, U. S. Geol. Survey, 1907.

embedding rocks, which include hornblende and epidote schist, marble, diorite, and porphyry.[a]

The ores of the Mayari type are essentially hydrous brown iron ores, coming under the general head of limonite. They occur in blanket form as a surficial mantle covering massive serpentine and related rocks. Average analyses show a small percentage of chromium, rather high alumina, very low sulphur, and phosphorus below the Bessemer limit. Iron, ranging from 30 to 50 per cent, is usually above 40 per cent.

The three ore fields to be described pass under the names Moa, Mayari, and Cubitas. The first two are in Oriente Province, near the north coast, and the third is in Camaguey Province (formerly Puerto Principe), midway between Camaguey City and the north coast of the island. (See fig. 20.)

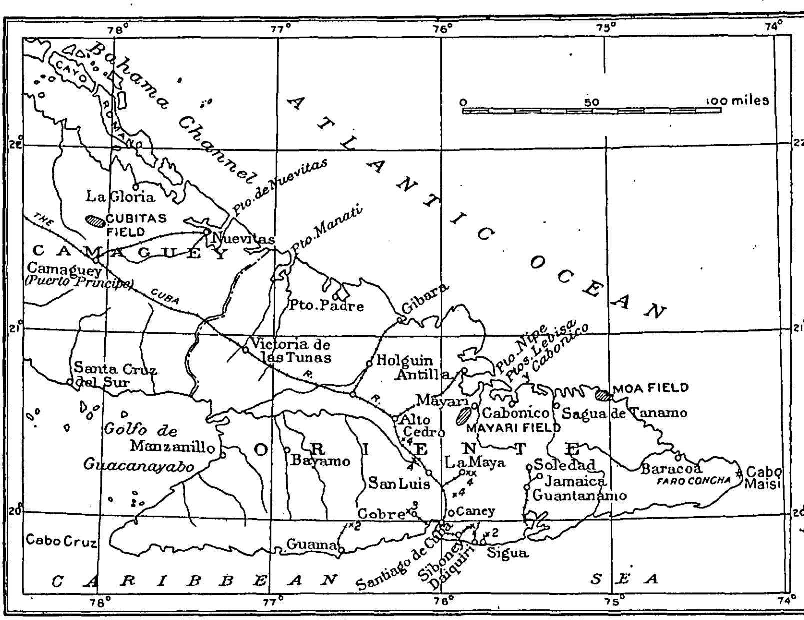

FIG. 20.—Sketch map of Camaguey and Oriente provinces, Cuba. 1, Iron mines in operation; 2, abandoned iron mines; 3, copper mines; 4, manganese deposits.

Until the announcement of the results of explorations carried on by the Spanish-American Iron Company appeared, the only available account of the occurrence and character of the Cuban iron-ore deposits of the Mayari type was a short note contributed by the present writer to a report on the mineral resources of Cuba, which was published in

[a] Kimball, J. P., Geological relations and genesis of the specular iron ores of Santiago de Cuba: Am. Jour. Sci., 3d ser., vol. 28, 1884, pp. 416–429; The iron-ore range of the Santiago district of Cuba: Trans. Am. Inst. Min. Eng., vol. 13, 1885, pp. 613–634.

Graham, T. H., Sigua iron mines, Cuba: Iron Age, vol. 41, p. 140.

Chisholm, F. F., Iron-ore beds in the province of Santiago, Cuba: Proc. Colorado Sci. Soc., vol. 3, 1891, pp. 259–263.

Cox, J. S., Eng. and Min. Jour., vol. 16, pp. 745–758.

Wedding, H., Stahl u. Eisen, vol. 12, p. 545; Iron Age, vol. 49, p. 607.

Spencer, A. C., Eng. and Min. Jour., vol. 72, pp. 633–634.

the annual report of the military governor of Cuba for the year 1901.[a] The following paragraphs are quoted from this report:

Occupying the general region between Nipe Bay and Moa Bay and somewhat back from the northern coast there is a region reaching a general elevation of from 1,500 to 2,000 feet, and occupied by serpentines and other igneous rocks. Upon the top of this sierra there are many large areas which are practically level, and these are always covered by a thick mantle of red clay which contains a large proportion of iron ore in the form of spherical pellets. Locally this material entirely replaces the clay, and the separate particles are cemented together by ferruginous materials, making a spongy mass of brown iron ore. Similar occurrences of shot and massive ore were noted upon the tops of certain hills lying to the north of the city of Puerto Principe, and following the general trend of the Sierra Cubitas. The rock in this vicinity is also serpentine, and the ores have identical characteristics with those of the region mentioned above. Analyses were made from samples of these residual ores collected near Rio Seco along the trail between Mayari and San Luis.

	1.	2.
Moisture	....	0.56
Iron	52.00	54.69
Manganese	.364	.594
Phosphorus	.0368	.0189
Silica	2.62	2.51
Chromium	Trace.	Present.
Titanium	.25	....

1. Iron ore from Sierra Nipe near trail crossing of Rio Naranjo, about 10 miles from Mayari, Santiago Province.
2. Iron ore from Sierra Nipe near Rio Seco, Santiago Province.

These residual ores are locally known as "tierra de perdigones," or "moco de herrero," signifying shot soil and blacksmith's waste, either of which terms is a very apt designation. Rodriguez Ferrer is authority for the statement that hydrated oxide of iron in the form of pellets in the soil occurs at various points in the island. The following localities are mentioned: Province of Pinar del Rio, between Consolacion del Sur and Candelaria; Matanzas Province, in the Sierra Morena, between Cardenas and Sagua la Grande; Loma Iman, near the city of Puerto Principe; and Monte Libano north of Guantanamo, Santiago Province. The amount of these ores in various parts of the island is certainly very large, and it seems not improbable that they may eventually find a market in the United States in cases where they are situated near a sufficient supply of running water for washing them free from the clay with which they are mixed.

MAYARI DISTRICT.[b]

The Mayari iron-ore fields are situated south of Nipe Bay in the northern part of Oriente, so named because it is the easternmost province of Cuba. The ore deposit is a blanket formation, extending as a practically unbroken mantle over a gently rolling elevated plateau, roughly10 miles long and 4 miles wide; or, more accurately, about 27,870 acres in extent. Except for a few groups of hard-wood trees in moist situations, the ore field is covered by pine forest, averaging about 40 trees of medium size to the acre. The direct distance to the shipping point on Nipe Bay is about 12 miles, but the distance over the transportation route, including two inclines and

[a] Report on a geological reconnaissance of Cuba made under the direction of Gen. Leonard Wood, military governor, by C. Willard Hayes, T. Wayland Vaughan, and Arthur C. Spencer.

[b] Abstract of article in Iron Age, August 15, 1907.

a railroad, is somewhat more than 15 miles. The seaward edge of the plateau is about 1,600 feet above tide, from which elevation there is a gradual rise to 2,200 and 2,300 feet. Two peaks of 2,600 and 3,200 feet elevation are stated to have no iron on their slopes, from which it may be inferred that ore does occur upon the crests. The mantle of ore extends out onto the ridges between the streams which drain the edges of the plateau, and the deposit stops only where abrupt declivities begin.

The ore, which is chiefly earthy, is dark red near the surface and yellow at greater depths. In addition to this earthy ore, which forms the great bulk of the deposit, from an inch to a foot of gravelly ore composed of particles like bird shot occurs at the surface of the ground, and locally near the sources of streams similar ore particles cemented together form large lumps and flat-lying layers amounting in the aggregate to several million tons. The yellow clayey ore rests upon serpentine rock which is partly decomposed and locally soft enough to be penetrated by augers. The ore is said to be mainly a limonite, though some analyses indicate the presence of hematite as well.[a]

The deposit was explored in part by pits, but was sampled principally by means of 2-inch augers, borings being spaced 100, 300, 500, and 1,000 meters apart. During one year the average depth of borings was nearly 17 feet and the maximum depth attained was 51 feet. In all 3,030 borings were made and more than 15,000 analyses. A fair average depth of the ore over 18,525 acres is 15 feet, which, at 20 cubic feet to the ton, gives 605,000,000 tons. It is thought that this figure may be exceeded when every acre of the deposit has been examined, and it is regarded as certain that not less than 500,000,000 tons of ore is accessible for profitable mining. With the average given and the amount of ore at 605,000,000 tons, the tonnage per acre is 34,159. About 5 per cent of the borings were in material carrying below 27 per cent of iron and correspondingly high in silica or alumina, or both. An idea of the general run of the ore is presented by the table here given:

Composite analysis of iron ore from Mayari district.

[Dried at 212° F.]

	Number of samples.	Per cent.
Fe	918	46.03
SiO_2	918	5.50
Al_2O_3	889	10.33
Cr	889	1.73
P	889	.015

[a] Some of the ore pellets are attracted by a pocket magnet suggesting that magnetite is also present. My notes of 1901 indicate that the accumulations of shot ore at the surface have been washed out of the underlying deposit by the action of rains, and that to a depth of several feet great numbers of similar pellets are disseminated through the dark-red clayey matrix.—A. C. S.

In 67 samples the hygroscopic water averaged 31.63 per cent and in 37 samples the combined water averaged 13.62 per cent. The large amount of hygroscopic water and high alumina combine to give a clay-like consistency to the ore, such that in shafts which have stood two years every pick mark is still visible.

The uniformity of the deposit is shown by a table indicating that 94 per cent of the material is workable ore:

Percentages of iron in Mayari iron ore.

	Per cent.
10 to 20 per cent of iron	4
20 to 30 per cent of iron	2
30 to 40 per cent of iron	6
40 to 43 per cent of iron	6
Above 43 per cent of iron	82
	100

The occurrence and nature of the ore are favorable for steam-shovel mining, but because of its sticky character it has been necessary to design a special form of car to insure ready dumping. The presence of 45 per cent of moisture also makes drying indispensable to avoid import duty and freight charges on so much water, and the ore will have to be clinkered to make it physically suitable for use in the blast furnace.

The company plans the production of 2,500 tons of dry ore per day, but will install a plant capable of handling a very much larger tonnage. No description of the drying plant or details of mining methods are given. As Cuba is deficient in mineral fuel, it will be necessary to import coal for the calciners.

MOA DISTRICT.

The Moa iron-ore fields are contiguous to the protected deep-water harbor of Moa Bay, on the north coast of Oriente Province, about 50 miles east of Nipe Bay. The deposit is very much like the one at Mayari, but its situation makes it more easily accessible for mining and ocean transportation.

The Moa district lies upon the northern and seaward slope of the group of mountains which, with several other groups, enter into the make-up of a general range extending from the Mayari district south of Nipe Bay to the east end of Cuba and there merging with the mountains which border the south coast of Oriente Province. The general summit elevations of these northern mountains may be estimated at 2,000 to 2,500 or perhaps 3,000 feet. In the Moa country the highest summits are roughly about 2,500 feet, and it is probable that the northward-flowing streams of the district all rise within 10 to 15 miles of the coast. Looking toward the Moa Mountains from the sea one notes a gradual rise of the land from the shores of Moa Bay, and sees that the valleys of the larger streams are shallow and narrow at their mouths and that they gradually widen and deepen upstream. A traverse of the region bears out this first impression, and between each river broad, smooth surfaces are found to rise from the water's edge toward the interior with an average grade of 250 feet to the mile. These interstream areas extend from 5 to 8 miles back from the coast, and upon them the ore deposits occur in the form of a surface mantle.

The district is well watered and at the same time mostly well drained. Pine forest covers the greater part of the ore ground, the trees being more thickly set and on the average somewhat larger than in the Mayari district. Hard-wood forest and thick jungle is encountered everywhere along the watercourses and in moist patches on the upland surface.

The whole district appears to be underlain by serpentine, for no other rock is found either on the slopes of the river valleys or in the stream gravels, part of which must have been derived from the distant mountains. The country is dissected by river courses in such a manner as to exhibit the relations of the iron ore and the bed rock in many places. The typical occurrence is as follows: At the surface there is several feet of red clay containing from 50 to 75 per cent by weight of brown iron ore in the form of round pellets from a minute size up to that of a buckshot or a cherry. Beneath the shot ore is a more or less continuous layer of spongy brown ore which is usually seen to be composed of similar round pellets bound together by a ferruginous cement. Below the solid layer lies yellow clay, in places containing scales and irregular concretions of brown ore. It will be noted that the above description corresponds in a general way with that of the Mayari deposit. The thickness of the different layers named varies from place to place and locally any one, any pair, or all of the layers may be missing.

The mantle of ore is a prominent feature within an area of about 60 square miles, being practically continuous, except where it has been cut out by erosion along the stream valleys. It can hardly be doubted that the deposit was formerly not only actually continuous within the present field of its occurrence, but also of considerably greater extent.

The 60 square miles referred to has been fully explored, and all of it has been denounced or claimed by different parties. It is roughly estimated that 60 per cent of the area taken up, or about 36 square miles, will afford ore of minable grade and quantity. The ratio of barren ground to ore ground becomes less and less as one proceeds from the mountains toward the coast, the most nearly continuous deposits occurring in a strip of country 2 or 3 miles wide adjacent to the bay, where the river valleys are both shallow and narrow.

A considerable part of the field has been systematically prospected by the Spanish-American Iron Company, but other owners have not yet adequately explored their holdings. Though the writer's examination of the field was too cursory to form the basis of a trustworthy estimate of tonnage, it is thought that the amount of ore per unit area is likely to exceed that of the Mayari field, provided the yellow clay at Moa shows the same high iron content as that at Mayari. The thickness of the shot ore was seen to range from a few inches up to 20 feet; that of the layer ore up to 12 feet; and the yellow clay is locally more than 50 feet thick.

Taking the area of workable ore as 36 square miles, and, as at Mayari, taking the average depth as only 15 feet and allowing 20 cubic feet of material per ton of dried ore, we get 752,000,000 tons for a first approximation of the available tonnage of iron ore in the Moa field. The shot and layer ore from Moa, when dried at 212° F., give practically the same analysis as the Mayari ore. (See composite analysis, p. 321.)

CUBITAS DISTRICT.

The Cubitas iron-ore fields are situated from 12 to 15 miles north of Camagüey City, in the province of Camagüey. The port of Nuevitas, on the north coast, lies about 40 miles northeast of the district, which is as yet without transportation facilities. Within an area measuring roughly 10 miles east and west and 4 miles north and south, there are several flat-topped mesas rising 300 to 400 feet above the general level of an almost featureless plain which extends for many miles in all directions except toward the north. Two or three miles north of the ore fields there is a narrow range of rugged limestone mountains, known as the Sierra Cubitas.

The ore deposits are all surface mantles covering the plateau-like mesas. Shot ore in the red clay matrix and brown spongy layer ore are exposed in many places, and as at Moa where both are present the layer ore is invariably beneath the shot ore. Observations made in several separated localities indicate that the two varieties of ore are together at least 10 feet thick over much of the ore ground. It is probable that yellow clay exists beneath the brown ore, though no exposures of this material were noted by the writer during his short examination of the deposits. The observations on which the present notes are based were so casual that no trustworthy estimate can be given of the areal extent of the deposits. It is thought, however, that there must be at least 6,000 acres of the ore ground and that at least 150,000,000 tons of ore exists within the field.

In their physical character and occurrence the Cubitas ores are practically identical with those of the Moa and Mayari districts. No analyses of the ores can be given at the present time, but there is every reason to believe that the material will show the same chemical features as the ores from Moa and Mayari.

The bed rock of the district, being serpentine, is identical with that underlying the two other ore fields here described, but in the Cubitas field there is practically no pine or other timber, the principal growth being palmetto, bracken ferns, and coarse grasses of little or no value for grazing. Serpentine occurs also over much of the surrounding country, and in places other crystalline rocks are found. Outside of the serpentine country, but within the general region in which the Cubitas deposits are found, there are several bed-rock deposits of hard ore, consisting of hematite and magnetite and showing above 60 per cent of iron. Several bodies of rich chromite ore are also known.

ORIGIN OF THE DEPOSITS.

The yellow ferruginous clays and associated brown iron ores of the Moa, Mayari, and Cubitas districts are considered as residual materials, derived from the serpentine rocks upon which they rest, through the process of surficial weathering and decomposition. Strong evidence that the serpentine has contributed the material of the deposits lies in the fact that all the ores contain chromium, which is an element known to be characteristically associated in occurrence with certain serpentine and related rocks, and which may therefore be assumed to be present in small amounts in the serpentine that underlies these particular accumulations of iron ore. The case of these ores is closely similar to that of certain small deposits of brown iron ore embedded in brownish, earthy material, which occur on Staten Island, New York, and which have been described and commented upon by Dr. T. S. Hunt,[a] as follows:

> This material rests immediately upon the serpentine rock of the region into which it gradutates, and from the subaerial decay of which it has evidently been derived; the lower portion of the earthy matrix still preserves the peculiar jointed structure of the underlying serpentine.
>
> * * * This limonite which is now mined to a considerable extent, contains, as several analyses have shown, from 1 to 2 per cent of chromic oxide, which is also known to be present in small amounts in the serpentine. An impure argillaceous specimen, containing 59.63 of ferric oxide, yielded the writer 2.81 of chromic oxide in a condition readily soluble in chlorhydric acid.
>
> * * * It is, I think, evident that the decay of the serpentine, and the concentration, in the residuum, of its iron in the form of limonite, was a process anterior to the glacial erosion, and that the ore banks are areas of the decayed material which has escaped this action.

The Clealum iron ores of Washington, as described by Smith and Willis,[b] show a general similarity in composition to the Cuban ores, but contain nickel as well as chromium. They occur in the form of lenses, from a foot or two up to 30 feet in thickness, on an old eroded surface of an extensive formation of serpentine, and lie at or in the

[a] Mineral Physiology and Physiography, 1886, p. 268.
[b] Trans. Am. Inst. Min. Eng., vol. 30, 1901, pp. 356-366.

base of the Swauk sandstone. The ore, which contains both hematite and magnetite, is partly of oolitic nature, and is thought to have been deposited originally in the condition of ferrous carbonate or hydrous sesquioxide of iron. It contains from 1.9 to 5.2 per cent of Cr_2O_3 and from 0.20 to 0.68 per cent of NiO. A sample of serpentine analyzed gave 0.47 and 0.10 per cent, respectively, of Cr_2O_3 and NiO, so that the ore is regarded as the result of concentration from the serpentine. It is, however, thought to be not strictly a residual deposit accumulated in place, but instead a sedimentary deposit of which the materials were furnished mainly by the serpentine.

That the Cuban ores here under discussion were derived from the serpentine rocks with which they are associated can be accepted without reservation, and there is good reason to believe that they were formed by decomposition of the rock in place rather than that the materials of which they are composed were brought into their present positions either as washed-in sediments or as dissolved salts. Evidence for this last conclusion is seen in the facts that the ore material contains no grains of sand and that the deposits are spread over extensive areas which are almost completely lacking in local topographic relief, except such as can be seen to have originated since the accumulation of the ores. It is thought that the surfaces of low relief upon which the ore mantles occur must be remnants of formerly more extensive plains, which have been uplifted and warped by mountain-building forces and largely destroyed by subsequent erosion. At Moa the destruction of the ore ground is evidently even now progressing at a geologically rapid rate. Theoretically, plains of this sort are the natural end products of subaerial erosion continued through very long periods undisturbed by mountain-building forces, and the thick accumulation of strictly residual materials is the natural and perhaps necessary accompaniment of the later stages of the process of planation. Peneplains (surfaces of extremely low relief reduced by subaerial decomposition, decay, and solution of the rocks over a wide region) are recognized as existing over a large part of the Atlantic and Gulf slopes of the United States. An extensive and now considerably dissected peneplain which is seen in the Piedmont Plateau of our Eastern States is known to have been formed during late Tertiary time and to have become partly buried by sedimentary materials that are now grouped together and described as the Lafayette formation.

Orange-colored and red sands and gravels characterize this formation in many districts and though no direct means of correlation are at present known, it seems very likely that those uplifted and warped peneplains of Cuba which are covered by deep soils and clays may eventually be found to correspond in age with the pre-Lafayette, or, as it is more commonly called, the Tertiary peneplain of the eastern United States.

Though the general conditions under which the Cuban iron ores accumulated were probably those which have been outlined, the actual mode of origin is a problem that demands a large amount of detailed chemical work and a comparison with similar problems presented in other regions. Consideration of the fact that the red and brown materials, consisting of shot ore in an earthy matrix and of porous layer ore, occur in the surficial part of the residual masses leads to the idea that they are the products of secondary weathering of the yellow clays which are thought to be the direct residuals from the decomposition of the serpentine. What may be termed the primary change, from serpentine to ocherous clay, involved the depletion of silica, magnesia, and lime and the concentration of alumina, iron oxide, and chromic oxide; the secondary change to brown and red materials seems to have consisted mainly in partial dehydration and deoxidation. These last effects, though probably slight, are evidenced by the marked difference of color, by the slightly higher iron content of shot ore occurring on the immediate surface, by the reported presence of some hematite in addition to the hydrated oxides that constitute the bulk of the iron ore, and by the presence of magnetite, which is indicated by the magnetic property of a portion of the shot ore.

MINING CONCESSIONS.

The Republic of Cuba as a former colony of Spain has inherited mining laws based on the principle that the ownership of all deposits of metallic minerals is inseparable from the State. In the case of iron ores, concessions of any desired size may be acquired from the Government by the procedure known as denouncement. The expense of denouncement, attendant surveys, and title of concession amounts to $2.86 per hectare, equivalent to 2.47 acres. The law provides for an annual tax of $2.50 per hectare, nonpayment of which is the only cause of forfeiture. Collection of this charge has been suspended since 1901, so at the present time mining rights once secured by a small expenditure may be held without further cost.

Where the surface rights to land containing mineral deposits are held by private interests arrangements must be made to satisfy all damages which may ensue, but in the case of wild or forest lands owned by the Government the concessionary apparently acquires full surface rights with the title of the concession. The feature last mentioned is of great importance both at Moa and at Mayari, where large tracts which have been held by the Church of Rome became Government lands when the Republic was established.

With the exception of a few small claims at Moa, all the ore lands in the Moa and Mayari districts have been denounced within the last four years, so that in these districts titles are likely to be clear. In the

Cubitas district most of the denouncements were made many years ago, and in some cases, at least, titles to ownership are more or less clouded.

METALLURGY.

The high alumina of the Mayari and similar ores produces an unusual slag, demanding careful and intelligent operation. The chromium which is present goes into the pig iron and most of it must be removed in the manufacture of steel. Extended experimentation by the engineers of the Pennsylvania Steel Company has resulted in the discovery of a method by which chromium can be sufficiently eliminated in the Bessemer converter, and the effect of the portion of chromium remaining on the quality of the product has been carefully studied. The following account of the process which has been developed for the removal of chromium appeared in the Engineering and Mining Journal October 7, 1905:

> An invention calculated to increase the value of chromiferous iron ores has lately been patented by H. H. Campbell, of Steelton, Pa. (U. S. No. 795193.) Using iron ores containing from 1 per cent to 5 per cent chromium, he succeeded in producing a steel containing only 0.08 per cent Cr. It is well known that, if a steel has a content of Cr in excess of a certain small proportion, it is unfit for use for most purposes in engineering works; and also that it has not been practical to make use of iron rich in Cr as a starting metal for the manufacture of steel on a profitable scale because of the inability to effect the economical removal of the Cr. Mr. Campbell's method is to first treat the chromium iron in a basic Bessemer converter, producing a basic slag, and then to oxidize the Cr by prolonging the blow beyond the usual period, which causes the Cr to enter the slag. The charge is then drawn from the converter into a ladle (having a device for drawing the metal from beneath the slag), and then stopping or controlling the flow of slag. The subsequent treatment depends on the final use for which the steel is intended. For low-carbon steel, where the dechromized metal does not contain much oxygen, it is incorporated with ferromanganese to obtain the usual reaction; where the dechromized metal contains considerable oxygen, it is charged in a second converter having a siliceous lining with an addition of unblown molten iron (free from Cr and having a higher carbon content) and finally recarburizing.

The removal of chromium from pig iron in the open-hearth process of steel making has been described by A. W. Richards in a recent paper entitled "A method of producing high-class steel from pig iron containing chromium, nickel, and cobalt,"[a] from which the following extract is taken:

> Doctor Massenez, the inventor of the new process, conceived the idea of working in a basic or neutral lined open-hearth furnace provided with slag notches, thinking that the chromium might be removed by forming successive voluminous quantities of oxidizing slags and, as the chromium oxide was formed, removing these slags through the slag notches before they became too thick.
>
> Into an open-hearth furnace is charged 3 tons each of lime and basic slag, the latter produced by melting hematite pig iron on a basic hearth, and over this is added 3 tons of hematite iron ore. The mixture is heated until the ore becomes pasty. Two ladles

[a] Jour. Iron and Steel Inst., No. 1, 1907, pp. 114–120. United States patents Nos. 754154 and 772164.

containing 10 to 11 tons each of molten chrome nickel iron are then added. Thick and foaming slag is gradually formed, containing a portion of the chromium as chromic oxide, and this at the end of forty-five minutes to one hour is run out at the slag notches. A second slag is then formed from the materials remaining on the bottom of the furnace hearth, which do not all melt at first, and by further additions of basic slag, fluor spar, and lime. This slag after melting contains an additional quantity of chromic oxide, and is also removed, but owing to its viscous character it can only be made to pass the slag notches by mechanical assistance. This operation of forming slag is repeated according to the percentage of chromium in the iron. When working with an iron containing 4 per cent of chromium it is generally necessary to make and run out four such slags, after which practically all of the chromium is removed. When this point is reached the metal is worked like an ordinary open-hearth charge. The resulting steel contains about 0.3 per cent of chromium, as it derives some of this during the decarburizing period in the open hearth, being reduced from the chromic oxide in the slag.

The boil commences in from nine to ten hours after the furnace is charged, and only lasts an hour before the steel is ready for tapping.

The slag contains from 5 to 10 per cent of chrome oxide.

The steels produced by Mr. Richards contain from 0.52 to 0.69 per cent of carbon, 0.016 to 0.032 per cent of phosphorus, and 0.12 to 0.51 per cent of chromium. The iron used was made from ore of the following analysis, the source of the ore not being stated:

Fe (as received)	45.69
Mn	.232
Cr	2.35
Ni, Co	.90
SiO_2	12.32
Al_2O_3	9.25
CaO	.55
MgO	2.14
S	.029
P	.02

The pig iron contains—

Cr	4.00
Ni, Co	1.75
Si	.40

And the steel made from it contains—

Ni	1.50
Co	.25
Cr	.12 to .51
P	.016 to .032
C	.52 to .69

IRON ORES NEAR ELLIJAY, GA.

By W. C. PHALEN.

INTRODUCTION.

The Ellijay quadrangle of the United States Geological Survey lies mainly in the northern part of Georgia, but includes narrow strips of Tennessee and North Carolina along its northern border. The area is entirely within the mountain division of the Appalachian province.

The existence of iron ores in and near this area has long been known, but it is only recently that systematic effort has been made to prospect them thoroughly with a view to their commercial exploitation. It is the purpose of this paper to present briefly the latest information regarding these ores, gathered in the field season of 1907.

GEOLOGY.

The rocks in the area are for the most part southwesterly continuations of belts which have been carefully studied by Arthur Keith in the Murphy and Nantahala quadrangles on the north and northeast and are in part of sedimentary and in part of igneous origin. Nearly all have been metamorphosed, some to such an extent that all traces of their original nature have disappeared, a condition which adds greatly to the difficulty of their study. According to Keith, they range in age from the Archean into the Cambrian, those of the latter system constituting the Ocoee group. Named in order from the top of the geologic column represented they comprise the Murphy marble, Valleytown formation, Brasstown schist, Tusquitee quartzite, Nantahala slate, and Great Smoky conglomerate, all probably of Cambrian age, and granites and gneisses belonging in the Archean. It is probable that the nomenclature given above may be changed in part when the Ellijay folio is published, as it is quite certain that some of the lithologic units used in mapping the Nantahala quadrangle either merge with others or die out completely in passing southward from North Carolina into Georgia. Most of these rocks, except the Murphy marble, are cut by dikes of igneous origin, many of which are quartz diorite, though much of the intruded rock is more basic than this.

All the rocks of this region have been folded and faulted, as a result of which they have been greatly compressed and metamorphosed. Faulting has aided in the formation of certain ore deposits to be subsequently described.

THE IRON ORES.

GENERAL OUTLINE.

Iron ore occurs at many localities in and near the Ellijay quadrangle, but in comparatively few places is it present in sufficient quantity to repay systematic development. Most of the ore belongs in the class of hydrous ferric oxides, the so-called "brown ore," but the available analyses given in this paper are so incomplete that little can be told about the original content of water in the ore, and thus it is uncertain exactly which hydrous oxide is present—turgite, goethite, or limonite. From the fact that the ores are entirely amorphous it is clear that they are more recent than the rocks with which they are associated and are also later than the periods of deformation during which the neighboring rocks have been affected. The deposits therefore are not original but secondary in nature.

The occurrences visited and studied are located as follows:

(1) Ore Knob, a small and somewhat isolated peak between Whitepath and Little Turniptown creeks, just east of the Atlanta, Knoxville and Northern division of the Louisville and Nashville Railroad, and nearly 4 miles northeast of Ellijay.

(2) About a mile east of Ellijay and just north of Cartecay River.

(3) About 6 miles southwest of Ellijay, just outside of the Ellijay quadrangle, near the mouth of Talona Creek and 1½ miles north of Talona station.

DEPOSITS AT ORE KNOB.

Occurrence.—At Ore Knob, iron ore has been exposed by several open cuts and pits, most of which are in a quartzitic sandstone or quartzite, though one test pit from which considerable ore has been removed has a foot wall of lustrous blue schist, characteristic of the Valleytown formation as exposed along the road between Blue Ridge and Ellijay. Several shipments of ore are reported to have been made from the property, one of 29 cars having been specified. All the ore seen is situated well above drainage level.

As mentioned above, the rock with which the bulk of the ore is associated appears highly siliceous. Along the public road south of Ore Knob, silvery mica schist, probably of the Valleytown formation, outcrops in several places, east of which were seen ore and sandy débris. A short distance to the east, in the valley of Little Turniptown Creek, the typical blue Nantahala slate was observed. All the observations made in the locality indicate dips of 40° or more, generally to the southeast. The strike of the rocks is usually east of north, but in places swings around nearly to north, and as nearly as could be determined the trend of the ore belt conforms closely to that of the adjacent rocks. Thus the ore occurs in a belt close to the contact of the Valleytown formation and Nantahala slate. As the beds are disposed the Nantahala overlies the Valleytown, being thrust over on it from the east. The ore apparently lies along the line of the thrust fault.

Character and origin of ore.—This conclusion as to the location of the ore with respect to the fault is in accord with observations on the character of the ore itself, some of which is a quartzite breccia cemented by iron oxide. Much of the ore is highly siliceous, being in some places a mere film of iron oxide on a quartzitic nucleus. Some of it is black, suggesting an admixture of manganese oxide; but the bulk of the material is the common limonite or brown ore. Though the ore is siliceous in part, much of it is very pure, and the study of that already uncovered indicates that with careful culling good ore exists in large enough quantity to make the occurrence an inviting one for future development.

A faulted zone is one along which waters might either descend or ascend. The ores here discussed appear to have been leached from the surrounding rocks and deposited by descending waters, for there are no sulphides associated with the ore, as would probably be the case if it were due to ascending waters. If this hypothesis as to the origin of the ores be correct, the deposits will be limited in depth but may have considerable linear extent. Such being the case, careful search along the western edge of the blue-slate belt, where these rocks are thrust upon the Valleytown formation and Murphy marble, may reveal the presence of other valuable deposits.

DEPOSITS NORTH OF CARTECAY RIVER.

Occurrence.—The deposits a mile east of Ellijay are located just north of Cartecay River, on the west side of Randall Branch. The hill in which the ore occurs rises about 300 feet above the bed of the river. The old workings are now inaccessible, but according to reports the ore occurs in at least two veins, a main vein and another of less width, which are exposed in a tunnel 200 feet long, driven from a point near the east base of the hill. In the tunnel a winze was reported nearly 50 feet deep, wholly in ore. A surface cut has also been made at one point, exposing an ore body said to be 40 feet thick, though the width shown in the tunnel is much less than this, or about 25 feet. A few open cuts and an old shaft said to be 70 feet deep have also been sunk on the ore. On the south side of the hill at the roadside another tunnel has evidently been started. The ore can be traced intermittently for several hundred feet along the hill to the north, and the underground and surface observations point to a fairly large body above drainage level. The rocks in the immediate locality, among which the blue Nantahala slate predominates, have variable strikes, ranging from N. 15° E. to N. 44° E., and the strike of the main ore body is about N.

30° E., with a dip of 50° SE. The ore body is thus conformable to the inclosing slates. The country rock immediately east is blue slate, regarded as characteristic Nantahala. Farther south, in the town of East Ellijay, the same slate outcrops along the roadside, striking about 30° east of north, and dipping at high angles to the southeast. At the bridge over Cartecay River the blue slates also outcrop. Some of the rock in the valley of Randall Branch is grayish mica schist, not entirely characteristic of the Nantahala, and it is possible that here, as at Ore Knob, the ore is situated close to a fault contact.

Character and origin of ore.—The ore itself is the usual brown ore or limonite. Some of it is rather siliceous, but the available analyses indicate a high-grade ore, as shown below:

Analyses of iron ore east of Ellijay, Ga.

	1.	2.	3.	4.
Metallic iron	51.48	54.61	55.71	50.88
Silica and insoluble	8.29	....	4.65	9.28
Phosphorus	1.06	.917	.226	1.90
Sulphur	Trace.	....	.148	.01
Moisture at 212° F	....	....	....	1.12

1 From an average sample taken across the big vein in the main tunnel, by Hall Brothers, mining engineers, Atlanta, Ga. Analysis made in the N. P. Pratt laboratory, Atlanta, Ga.
2. Ore from vein in main tunnel. John M. McCandless, chemist, Atlanta, Ga.
3. Ore from outcrop. Hodge & Evans, chemists, Anniston, Ala.
4. From sample taken entirely across the face of vein and collected by S. W. McCallie. Analysis made in the N. P. Pratt laboratory, Atlanta, Ga.

These analyses show an ore with a fair content of metallic iron, high in phosphorus, and, with the exception of the outcrop sample analyzed by Hodge & Evans (No. 3), low in sulphur.

Like the occurrence at Ore Knob, the ores east of Ellijay appear to be due to surface or shallow underground waters which have leached the iron from the garnet, staurolite, pyrite, and other iron-bearing minerals contained in surrounding rocks and deposited it in its present position. The planes of schistosity which exist in the slates of this region, especially if the rock is at all calcareous, would facilitate the movement of such solutions. Along a fault which, it is quite possible, exists here, the movement of such waters would probably be more pronounced, and in such a position the ore most likely would occur in largest amount.

DEPOSITS NEAR TALONA.

Occurrence and development.—Near the point where Talona Creek crosses the Louisville and Nashville Railroad, about 1½ miles north of Talona station, a wide vein of iron ore has been exposed in an open cut on the west side of the valley near the valley floor. The Murphy marble underlies the valley here and extends upward a short distance on the hillside to the west. The ore occurs between the marble on the east and a satiny schistose phase of the Valleytown formation, which in the immediate vicinity is a dull reddish brown or blue, on the west. The attitude of the schist could be readily determined; not so easily, however, that of the marble, owing to the difficulty of identifying true bedding planes. The schist strikes between 20° and 25° east of north and dips from 40° to 50° SE. In the open cut already excavated the ore appears as a practically solid ledge. To judge from ore in place to the west, the lead is nearly 50 feet thick, although it may not be all solid ore. It can be traced for a long distance to the north and not so far southward. At the time of visit several hundred tons of ore had been mined and placed on the stock pile since the beginning of operations in August, 1907, and the North Georgia Marble Company, which controls the property, was at that time building a spur track to the railroad.

Character and origin of ore.—The ore is limonite and does not differ materially from that above described. Its origin, however, is distinctly different in that it is apparently not along a fault plane. The Murphy marble, as has been mentioned, underlies the valley floor and the schist to the west is probably in the Valleytown formation, lying normally below the marble. Such a contact between insoluble schists and a marble offers a natural channel for the descent of superficial waters, and it is quite possible for the iron oxides leached from the ferruginous minerals in the adjacent formations to concentrate along such a contact and to be subsequently oxidized. The ore body will probably be found to extend only to moderate depths, but the quantity of ore above ground-water level will be large owing to the linear extent of the deposit.

Two analyses of this ore, kindly furnished to the writer by Mr. H. A. Field, of Ellijay, are as follows:

Analyses of Talona iron ore.

	1.	2.
Metallic iron	49.00	51.80
Silica	16.50	12.04
Manganese	....	.30
Phosphorus	.37	.67

1. Childers & Hunter, Knoxville, Tenn., analysts.
2. Analysis made by the Virginia Coal and Coke Company.

These analyses show the Talona ore to be of a fairly good grade. Phosphorus is high, but if it does not run any higher on further development it is not objectionable.

SURVEY PUBLICATIONS ON IRON AND MANGANESE ORES.

A number of the principal papers on iron and manganese ores published by the United States Geological Survey or by members of its staff are listed below. In addition to these papers, several geologic folios contain descriptions of iron ore deposits of more or less importance. When iron is an important resource in the particular area covered by a folio, it is listed in italics in the tables (pp. 9–11).

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