GEOLOGICAL SURVEY OF GEORGIA

S. W. McCALLIE, State Geologist

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REPORT

ON THE

FOSSIL IRON ORES

OF

GEORGIA

BY

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State Geologist

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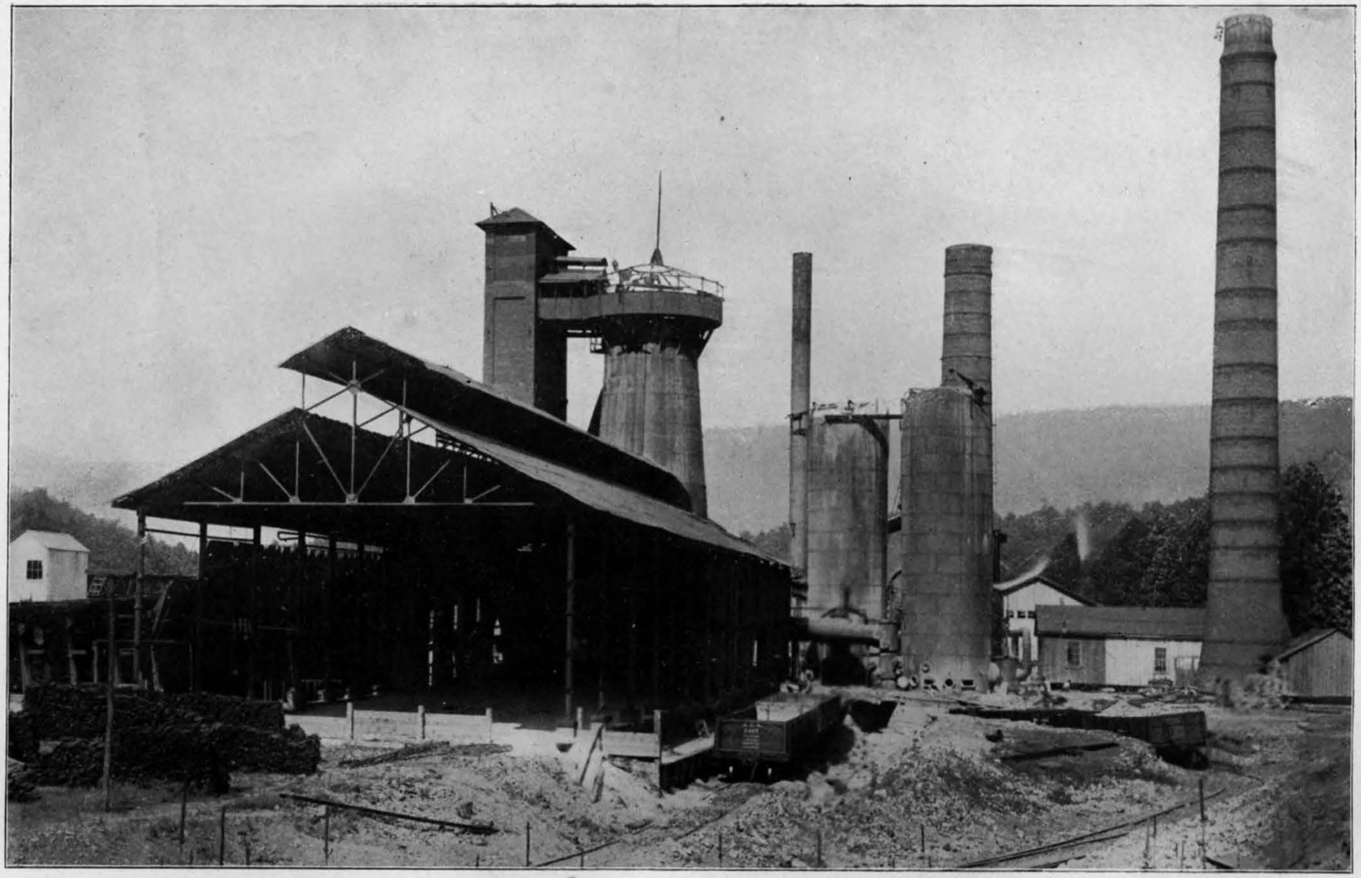
ERRATA.

1 On page 18, 20th line, for "McCuthen", read *McCutchen.*
2 On page 20, 15th line, for "appears", read *appear.*
3 On page 29, foot note, for "H. C. Smyth", read *C. H. Smyth.*
4 On page 46, 3rd line, for "evposure", read *exposure.*
5 On page 141, 21st line, for "crossed", read *crosses.*
6 On page 154, 11th line, for "writer's", read *writer.*
7 On page 168, 22nd line, for "at right angles to", read *parallel with.*
8 On page 179, 33rd line for "32", read *31.*
9 On page 180, 9th line, for "33", read *32.*
10 On page 180, 34th line, for "averaging", read *average.*



RISING FAWN FURNACE, NEAR RISING FAWN, DADE COUNTY, GEORGIA.

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LETTER OF TRANSMITTAL

GEOLOGICAL SURVEY OF GEORGIA,
ATLANTA, GA., August 2, 1908.

To His Excellency Hoke Smith, Governor and Chairman of the Advisory Board of the Geological Survey of Georgia.

SIR: I have the honor to transmit herewith my report on the Fossil Iron Ores of Georgia, to be published as Bulletin No. 17 of this Survey.

Very respectfully yours,
S. W. MCCALLIE,
State Geologist.

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INTRODUCTION

The fossil iron ores of Georgia were laid down in what is known in the geological time-scale as the Niagara period, one of the three subdivisions of the Upper Silurian era. This period, which is further subdivided into the Medina, Clinton and Niagara epochs, is represented in the State of New York, where its rocks were first systematically studied, by many feet of sandstone, limestone and shale.

THE MEDINA ROCKS.—The rocks of the Medina epoch, which are the oldest rocks of the Niagara period, are well represented in New York by what is known as the Oneida conglomerate and the Medina sandstone. The former covers a considerable area in Oneida and Herkimer counties in that State, and it also forms the Shawangunk Mountains in Ulster county, and the Kittatinny Mountains between New Jersey and Pennsylvania. Southwest of New York the Oneida conglomerate traverses the States of Pennsylvania and Virginia and passes into the valley of East Tennessee, where it occurs in two rather prominent ridges known as Clinch and Bays mountains.[1]

The Medina sandstone,[2] which apparently represents an off-shore

[1] Geology of Tennessee, by J. M. Safford, p. 298.

[2] Dana's Manual of Geology, Fourth Edition, p. 538.

phase of the Oneida conglomerate, consists mainly of fine-grained, ripple-marked, thin-bedded sandstone and argillaceous shales. It also occurs in Oneida county, New York; and is exposed in the bluff along the Niagara River at Lewiston. To the west it extends into Ontario, and is also found in eastern Ohio. South of New York, the Medina sandstone is associated with the Oneida conglomerate, and it likewise occurs as far south as the valley of East Tennessee.

There seems to be some doubt as to the presence of either of the above divisions of the Medina rocks in Georgia. Prof. J. M. Safford in his Geology of Tennessee,[1] places the sandstones of Taylor's Ridge, which is the southern extension of White Oak Mountain of Tennessee, as the lower member of the Niagara series, or the Medina sandstone.

Hayes notes the occurrence of heavy beds of sandstone in Northwest Georgia in Chattoogata and Rock Face mountains, having lithological characters similar to the sandstone forming Clinch Mountain in Tennessee; but he questions whether they occupy the same stratigraphical position.[2] Medina sandstone is spoken of by A. J. McCuthen as occurring in the northwestern part of the State in Chattoogata, Rocky Face, Johns, Horn and Lavender, and Gaylor's mountains, and in Dick's and Taylor's ridges; but he gives no data whatever to substantiate this statement.[3] As far as my own observations extend, there is no satisfactory evidence at hand to show definitely the exact stratigraphical positions of the lower sandstones occurring in these mountains. The only way to decide definitely the position of these rocks, is to make a study of their fossil remains, which occur in considerable abundance in some of the beds. A complete study of their lithological characteristics may also throw some light on their geological positions. These characteristics, however, are generally too variable to be relied upon in giving conclusive stratigraphical evidence.

THE CLINTON ROCKS.—The second division of the Niagara

1 Elementary Geology of Tenn., pp. 142-143.

2 Geol. Surv. of Ala., Bull. No. 4, p. 44.

3 The Commonwealth of Georgia, p. 87.

rocks, the Clinton group, has a much wider distribution than the Medina conglomerates and sandstones. It not only occurs in New York, Pennsylvania, Maryland, Virginia, Kentucky and Tennessee, but it is also well developed in Georgia and Alabama, and covers considerable areas in Ohio, Indiana and Wisconsin. The Clinton formation also occurs in Nova Scotia, where according to Dawson, it attains a thickness of 500 feet.

The rocks of the Clinton group are quite variable. In New York and Pennsylvania, they consist mainly of sandy shales with an occasional thin bed of limestone. In Georgia and Alabama, they are chiefly calcareous shales and sandstones with some limestone; while in Ohio, the entire group is made up largely of limestone.

The thickness of the Clinton rocks is also quite variable. Dana estimates the total thickness, at the falls on the Genesee River near Rochester, N. Y., at about 80 feet; and in Virginia, at 850 feet.[1] In East Tennessee, Safford estimates the thickness from 100 to 300 feet, which differs but little from the thickness given by Smith to the so-called Clinton formation of Alabama. To the northwest, the rocks formed during the Clinton epoch are still further reduced in thickness. In Ohio and Indiana, the entire formation rarely ever attains a thickness of more than 50 feet; and in Wisconsin, the thickness is even less.

The Clinton rocks are well represented in Northwest Georgia; but, as no effort has been made to differentiate them from the other rocks of the uppermost Silurian formations, it is impossible to give their thickness. However, if Safford's and Smith's estimates of the thickness of the Clinton formation in Tennessee and Alabama are correct, it would probably not be far wrong to assign to the Georgia deposits a like thickness.

THE NIAGARA ROCKS, or the rocks belonging to the upper division of the Niagara period, consist mainly of limestone. They have a wider distribution than either the Medina or the Clinton formations. Dana, in speaking of the distribution of these rocks, says:[2] "In New York, the beds reach quite to the Hudson River,

[1] J. D. Dana, Manual of Geology, Fourth Edition, p. 542.

[2] J. D. Dana, Manual of Geol., Fourth Edition, p. 540.

and are there distinguished as the Coraline limestone. They are, however, but a few yards in thickness. They spread westward through New York, making 250 feet of the height of the Niagara bluffs; continue beyond through Ontario, in Canada, with a thickness of 250 to 300 feet, to Lake Huron, west of Georgian Bay and to the Manitoulin Islands; extend around the north side of Lake Michigan to Illinois, Wisconsin, northeastern Iowa, and the adjoining parts of Minnesota—making in all a distance from east to west of 1,000 miles." South of New York, these beds seem to be poorly developed; they are entirely wanting in portions of Pennsylvania and West Virginia, but they appear again in Ohio, Kentucky and Tennessee.[1]

In the last named State, the beds occur in the valley of East Tennessee near the Tennessee-Kentucky line, but they soon thin out in going south, and appears to be entirely wanting in Georgia and Alabama. To the east, the Niagara limestones are well developed in Maine, New Hampshire and Novia Scotia; they are also found in the Arctic region as far north as the 76th parallel of latitude and occur in the Black Hills of South Dakota, and in Nevada, where they form thick masses of limestone.

Three different phases of rock deposition are well brought out in a study of the rocks laid down during the Niagara period above described. At the beginning of this period, we have first the Oneida conglomerate and the Medina sandstone. The former was deposited along the margin of the sea-coast, while the latter represents an offshore deposit of a shallow sea, with ever changing tides and swift currents. The land surface at this time seems to have been undergoing rapid denundation, and the rivers were rapid. These conditions were followed by a second stage, represented by the sandstones, shales and limestones of the Clinton epoch, a transitional phase between the Medina and the Niagara epochs. The sea during this epoch was evidently deepened to the westward, for there the Clinton is represented almost entirely by limestone. To the eastward, the sea was still comparatively shallow, as shown by the deposition of shales and sandstone; but, at the same time, there appear to

[1] Geology of Tenn., by J. M. Safford, p. 312.

have been short intervals during which the waters were comparatively deep and free from land sediments, as is revealed in the thin beds of limestones occurring at various horizons in the formations. Next, followed the deep sea of the Niagara epoch, in which were laid down the heavy beds of limestone extending from New York to the Black Hills of Dakota, and as far south as Tennessee.

Having thus given, in a general way, the distribution and the general character of the rocks deposited during the Niagara period, it is proposed, in the following chapter, to go into a more detailed description of these rocks as they occur in Georgia, and at the same time to compare them with the same formation in Tennessee, Alabama and elsewhere.

CHAPTER II

THE ROCKS OF GEORGIA DEPOSITED DURING THE NIAGARA PERIOD

The rocks of Georgia deposited during the Niagara period, as above stated, have never been differentiated or separated into different groups, corresponding to those divisions of the series both to the north and the west. It is true that Safford refers to the Medina sandstone in Taylor's Ridge, and McCutchen speaks of its occurrence in the ridges further to the east; but, as these statements are probably based upon purely lithological characteristics, they should not be accepted without question. Spencer, in speaking of these rocks in Georgia, says that they evidently belong to the Medina and Clinton groups, yet he was unable to find any evidence which would justify such a division. For this reason, therefore, Spencer groups the rocks all under one head, and discusses them under the name of the Red Mountain series, a term first used by Tuomey.[1]

Hayes likewise grouped these rocks under one head, and designates them as the Rockwood formation, on account of their typical development at Rockwood, Tennessee. The Rockwood formation, according to Hayes, embraces the Dyestone group, the White Oak, and the Clinch Mountain sandstones of Safford, being limited below by the Chickamauga limestone, and above by the Chattanooga or Devonian black shale. Hayes makes no attempt to separate these rocks into different groups; nevertheless, he speaks of three different sub-divisions occurring on the eastern edge of the Ringgold quadrangle, and so represents them on the map. The same method of grouping these rocks under one name has been adopted by Smith, of Alabama. In that State, they are usually designated as the Clinton or Red Mountain series, though the term Dyestone is also often

[1] Alabama Geological Survey, 1st Bien. Report, p. 10, 1850.

applied to them. Smith, in referring to the position of these rocks in the geological time-scale, says the Clinton or the Red Mountain formation is generally regarded as the lower member of the Niagara period, and is the only representative of the Upper Silurian in that region.[1]

The rocks, deposited in Tennessee during the Niagara period, referred to in the previous chapter, seem to be much better differentiated into groups than in either Georgia or Alabama. At any rate, Safford, in his Geology of Tennessee,[2] describes three different formations, which he correlates with the rocks laid down in New York during the Medina, Clinton and Niagara epochs. The Medina epoch he finds represented by the White Oak and the Clinch Mountain sandstone, while the Clinton and Niagara epochs are represented by the Dyestone Group and the Miniscus limestone, respectively. If the classification of the rocks, as here made out by Safford, is accepted as correct, there seems to be no question about the presence of the Medina sandstone in Northwest Georgia. This is evident, when it is recalled that Taylor's Ridge in Georgia is the southern extension of White Oak Mountain, and is made up of similar rocks. Granting the presence of the Medina sandstone in Taylor's Ridge, it necessarily follows, that it must also occur in the ridge lying further to the east, since the same formations are there much better developed. As there seems to be doubt as to the propriety of dividing the Niagara rocks of Georgia into groups, it is thought best to make no attempt at sub-divisions, but to discuss the whole series under one name, yet, at the same time, giving to each lithological sub-division such emphasis as its importance would seem to warrant.

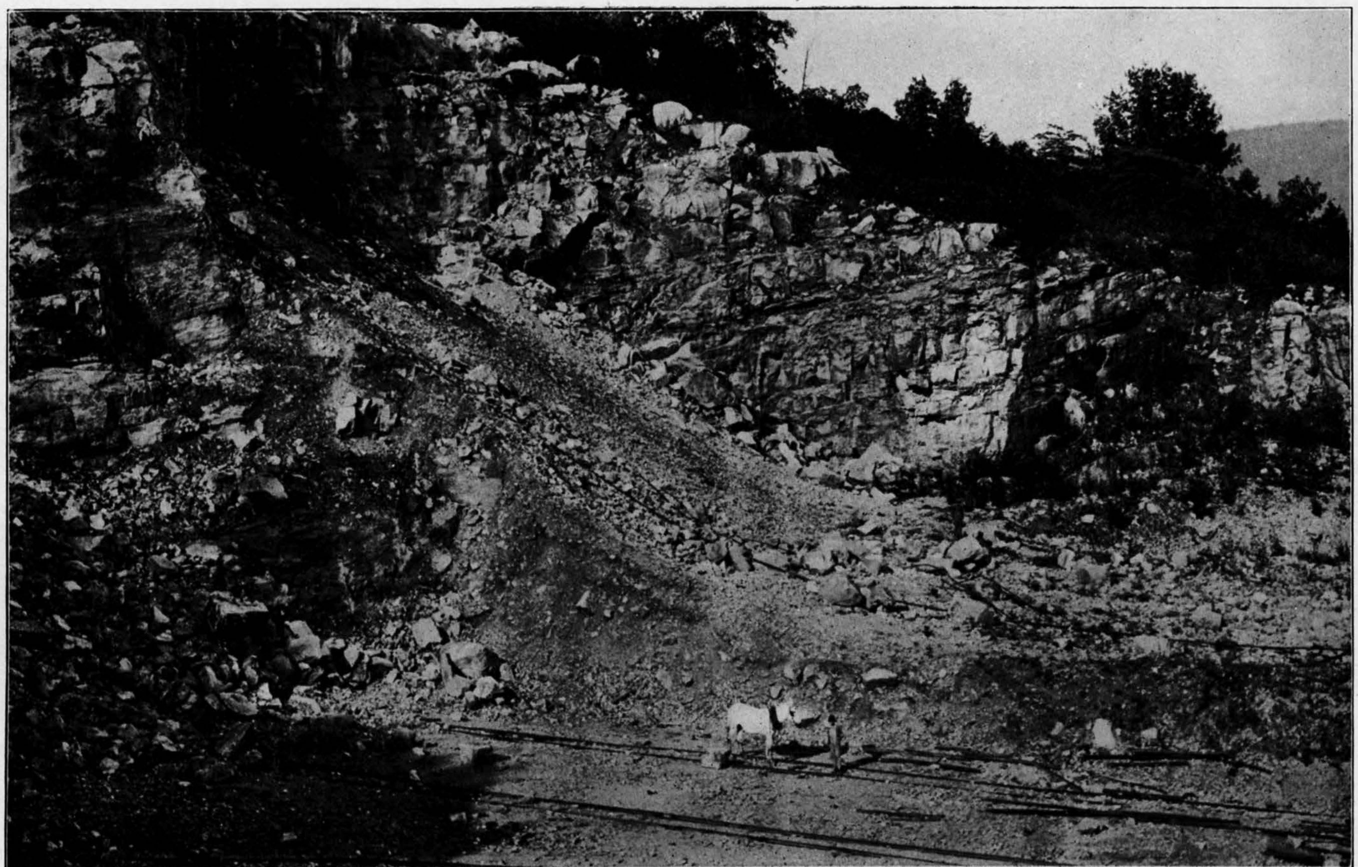
In selecting a name for the Niagara rocks of Georgia, from the several names above given, there seems to be a question as to which name to adopt. The U. S. Geological Survey, in naming formations, follows a binominal system, the first member of the name being a geographical, and the second, a lithological term, as, for example, the Knox dolomite or the Lookout sandstone. The geo-

1 Ala. Geol. Surv. Rept., on the Geology and Structure of Murphee Valley, p. 25.
2 Geology of Tenn., by J. M. Safford, p. 292.

graphical term is usually the name of a town, river, mountain or some other natural or artificial feature at or near which the formation is typically developed. When the formations are made up of several beds differing from each other in lithological character, as the Niagara rocks of Georgia, so that no lithological term is suitable, "formation" is substituted for the lithological term, as the Rockwood formation. It is also customary in naming formations to observe the law of priority, that is, when a formation has been previously named, to give that name the preference, unless it is misleading, or conflicts with some other name already in use.

The name Clinton, as applied to this series of rocks in Alabama by Smith, at first view would seem to be an appropriate name. Especially is this true, if priority alone is taken into consideration. The term Clinton, however, as used by Hall and Dana to designate one of the three subdivisions of the Niagara series of rocks in New York, would be misleading. This name would naturally suggest the idea that the series of rocks in Alabama and Georgia is identical with those of the same name in New York; whereas the name in the former case represents not only the Clinton of New York, but probably also a part of the Medina group of rocks. The same objection is applicable to the term Dyestone group, as used by Safford. This term, however, seems to be quite appropriate in Tennessee, where the Niagara rocks appear to be fairly well differentiated into three distinct groups, a condition which is not met with either in Georgia and Alabama.

The Red Mountain formation, at first used by Toumey, seems to be far less objectionable than either of the terms above named in designating these rocks. The name Red Mountain, as originally applied to this group of rocks, had reference to their typical development in a mountain by that name, which forms the eastern boundary of Jones's Valley, just east of Birmingham. The term meets all the essential requirements of a formation name, as laid down by the United States Geological Survey, and, at the same time, it gives prominence to its economic feature, which is so remarkably well developed in Red Mountain. Spencer, in his Paleozoic group, has adopted this name for the Niagara series of



LIMESTONE QUARRY, NEAR RISING FAWN FURNACE, DADE COUNTY, GEORGIA.

rocks of Northwest Georgia, and includes under the name all the rocks lying between the Chickamauga limestone and the Chattanooga black shale.[1] The term, as used by Spencer, embraces all the rocks included in Smith's Red Mountain group, and is the equivalent of Hayes's Rockwood formation. The name Red Mountain, as above defined, would appear to be a well selected name for the Niagara series of rocks in Georgia. However, it is thought advisable to use in this report the name Rockwood. This name has been adopted by the United States Geological Survey, and it is for this reason likely to become of more general use than any of the other terms suggested. Furthermore, the lithological character of the rocks of the Niagara period of Georgia differs but little from that of the typical locality, Rockwood, Tennessee, the place from which the name of the formation was taken. Hayes, in describing the formation in that region, says:[2] "This formation, which is the highest division of the Silurian in this region, varies widely in character and thickness within the limits of the sheet. It forms a narrow strip about the head of Sequatchie Valley, where it is 165 feet thick, and is composed of calcareous shales imbedded with blue limestone. Along the foot of the Cumberland escarpment, it is about 600 feet thick, and consists of calcareous and sandy shales. Still further east in the ridge, which extends from Iron Divide to Ten-Mile Stand, the formation attains a thickness of from 850 to 1,000 feet, a considerable portion of which is coarse sandstone imbedded with sandy shale."

The description here given agrees very closely in a general way with the Rockwood formation of Georgia. To the west along Lookout Valley, the formation, which consists of calcareous shales and thin-bedded limestone, with an occasional layer of sandstone, attains a thickness of only about 500 feet; while further east, in Horn, Rocky Face and other mountains, it reaches a maximum thickness of about 1,500, and at the same time is represented to a considerable extent by sandstone. In the Lookout Valley there is no exposure where the entire formation can be studied in one

[1] Paleozoic Group, the Geology of 10 counties in northwest Georgia, p. 48.
[2] Geologic Atlas of the United States, Kingston Folio, 1894.

section; however, there are various points at which partial sections can be made out. From these various partial sections a more or less complete section of the entire formation can be constructed. Such a section would show, at its base, a rather gradual change from the Chickamauga limestone to a calcareous reddish or bluish shale with interbedded limestones. Some of the shaly layers are sandy, but the sand rarely ever occurs in such abundance as to form a true sandstone.

Further up, or near the middle of the formation, occur the fossil iron ores. The rocks associated with these ores are chiefly shales, though thin beds of ferruginated limestone and layers of sandstone also occur. A good idea of the character of the middle portions of the formation may be had from the following section, made out near Rising Fawn furnace, one mile east of Rising Fawn station:—

1	Shale with an occasional layer of sandstone	40	feet
2	Shale and thin beds of ferruginous limestone	8	"
3	Ferruginous limestone	4	inches
4	Shale	6	"
5	Ore	24	"
6	Ferruginous fossiliferous limestone	9	"
7	Ore	12	"
8	Shale	1	"
9	Ore	6	"
10	Shale	3	"
11	Ore	6	"
12	Shale	1	"
13	Ore	12	"
14	Shale	8	"
15	Ore	10	"
16	Shale	——	

The section here given is made out in the ascending order and gives a fair idea of the character of the various beds or layers of rocks forming the middle portion of the Rockwood formation as seen throughout the Lookout Valley. One of the chief characteristics of this part of the formation is the beds of fossiliferous iron ore. These beds, as will be seen elsewhere in this report, are remarkably persistent, and occupy practically the same geological position, not only throughout Lookout Valley, but also as far east as Taylor's Ridge.

The upper part of the Rockwood formation in Lookout Valley differs chiefly from its middle portion in the absence of iron ores. It consists mainly of bluish or grayish fossiliferous shales, with an occasional thin layer of sandstone. In going east from Lookout Valley, the Rockwood formation becomes more sandy. This change in character is well shown in the section below, along the Chattanooga Southern Railroad, between the mouth of the tunnel on the west side of Pigeon Mountain and Estelle. The section extends from the Chattanooga black shale, exposed at the mouth of the tunnel, to the upper beds of the Chickamauga limestone, thus giving a complete section of the Rockwood formation in that locality.

1	Chattanooga black shale	20	feet
2	Bluish shale	100 (?)	"
3	Sandy fossiliferous shales	30	"
4	Blue shale, thin beds of limestone	40	"
5	Cross-bedded fossiliferous sandstone	8	"
6	Sandstone, thin bedded	20	"
7	Sandstone and thin bedded limestone	10	"
8	Bluish shales	20	"
9	Sandstone and thin beds of limestone	40	"
10	Iron ore	10	inches
11	Sandstone	2	feet
12	Thin-bedded sandstone and shale, some limestone	15	"
13	Iron ore	18	inches
14	Sandstone and shale	4	feet
15	Iron ore	2	"
16	Thin-bedded sandy shale	20	"
17	Shales with an occasional layer of sandstone and limestone	170	"
18	Limestone and shale	30	"
19	Chickamauga limestone		

The thicknesses of the several beds above given are not accurate measurements, but are only approximated. It is almost impossible to secure a complete measured section at this point, on account of the exposure not being continuous; nevertheless the section is sufficiently accurate for general comparison. The increase in sandstone as above pointed out is here quite noticeable, but it is not so marked as in Taylor's and other ridges further east.

The lower portion of the formation in Taylor's Ridge consists largely of reddish and bluish shales with but little limestone, and only now and then a thin bed of sandstone. Further up in the series, but still below the iron ores, the sandstone becomes well developed. It here consists of several beds which are of rather coarse texture, approaching a conglomerate, and often giving rise to bluffs several feet in height along the western crest of the ridge. That part of the formation lying above the iron ore beds, and including them, here still retains its argillaceous or shaley nature, though there also occasionally occur thin layers of sandstone. The total thickness of the formation in Taylor's Ridge, as given by Spencer, is about 1,200 feet or about twice its thickness in Lookout Valley. This increase in thickness is due largely to the increased development of the sandstone below the beds of iron ores, for the iron ores, as may be seen at Wood's Gap, lie only about 200 feet below the Chattanooga black shale. Still further to the east on Horn, Chattoogata and other mountains or ridges, the lower portion of the formation is further increased by additional beds of sandstone and conglomerate. Hayes in speaking of the formation in this region, says that it attains a thickness of about 1,500 feet, and is naturally divided into three subdivisions. The lower portion he finds to consist of thin purple sandstone, interbedded with sandy shales, which are overlain by 400 feet of heavy bedded sandstone. Following the heavy bedded sandstones in the ascending order, occur yellow shales and loose porous sandstone, but the iron ore bed which would naturally occur in this division is wanting.

The section here outlined, differs greatly from the section of the Rockwood formation in Lookout Valley, not only in the character of the Rocks, but in the thickness of the formation itself. The limestone and iron ore beds which are quite prominent in one region, are entirely wanting in the other. These changes in the lithological character of the rocks, as well as the increased thickness of the formation from west to east, are readily explained by supposing the land surface from which the sediments were derived lay to the eastward, or more probably to the southeast. The formation in Lookout Valley in this case represents the off-shore deposit, while those in Chattoogata and other mountains further east represent the shore deposits of the same formation.

CHAPTER III

DISTRIBUTION OF THE CLINTON ORES IN THE UNITED STATES

The fossil iron ores of Georgia, which are generally known elsewhere in the United States as the Clinton ores, form a part of one of the most remarkable iron ore deposits known. In order that the reader may have some idea of this deposit as a whole, it is thought advisable to introduce here a short resumé of the distribution of these ores in the United States, before taking up a detailed description of the Georgia deposits.

In general, these ores constitute one of the most prominent and constant lithological characters of the Clinton formation, and they are at the same time nearly always co-extensive with it. By an examination of the accompanying map, it will be observed that these ores are found as far north as western New York, being well developed in Oneida and Wayne counties, and are also found in Herkimer, Madison and Monroe counties.[1] In the first two named counties, the ores have been mined to a considerable extent to supply local furnaces. They occur usually in two beds which are sometimes 20 feet apart. Below the water level, the ores, which are made up largely of lenticular shaped grains, are quite compact, and yield from 44 to 48 per cent. of metallic iron. The following section made out at Clinton, Oneida county, the town from which the fossil ores take their name, gives a general idea of the Clinton formation, and its iron ore beds as they occur in the State of New York.[2]

1	Calcareous sandstone and thin shale layers	50	feet
2	Non-oölitic ore (Red Flux)	6	"
3	Calcareous sandstone	6	"
4	Blue shale and thin sandstone layers	15	"

[1] Mineral Resources of New York, 1895, p. 539.

[2] H. C. Smyth, Jr., Am. Jour. Science, June, 1892.

5	Oölitic ore	2 feet
6	Shale	2 "
7	Oölitic ore	1 "
8	Blue shale and thin-bedded limestone layers	100 "

The two lower ore beds only in the above section are workable, the other two known as the "Red Flux," being a highly ferruginous limestone, too low in iron to form a commercial ore.

In going south from New York, the Clinton ores again make their appearance in central Pennsylvania. Here they reach their greatest economic importance in Montaur, Snyder, Juanita, Blair and Bedford counties, where they were formerly worked on a very large scale. The ore in these counties occurs in a number of nearly parallel continuous outcrops, exposed along the sides of adjacent valleys. The section below, with notes by d'Invilliers, shows the nature of the ore-beds as they occur in a general section of the Clinton rocks in Union and Snyder counties.[1]

1	Sandy calcareous shales	175	feet
2	Ore (sand vein)	2–3	"
3	Sandstone (ore sandstone)	10–25	"
4	Purplish-red calcareous shale	10–30	"
5	Ore (Danville ore)	16–18	inches
6	Shale (middle olive shale)	150	feet
7	Iron sandstone (sandstones and shales)	60–70	"
8	Shale (lower olive shales)	500–600	"
9	Birdseye fossil-ore	8–10	inches
10	Shales (lower olive shales)	150	feet

The uppermost ore bed here given, known as the "Sand Vein," has been extensively worked in Juanita and Snyder counties. The bed is quite variable in thickness, and also in the percentage of iron present. Below the drainage level the ore is usually hard, lean and calcareous, rarely ever running over 40 per cent. metallic iron, but above this level where the ore bed has been leached of part of its calcium carbonate, the ore generally carries a correspondingly greater percentage of iron.

The second ore bed (Danville ore) which is well developed near

[1] Pennsylvania Geol. Surv., Report F-3, p. 65-68.

Danville, in Montour county, is usually divided into two or three divisions by partings of shale. The partings, however, are usually so thin that all of the divisions can be worked together. In some instances the aggregate thickness of these beds is forty inches, but the average would likely not exceed 18 inches. The ore is nearly always fossiliferous and, above the drainage level, runs high in metallic iron.

The Block Ore, No. 6, in the above section, constitutes the upper portion of the iron sandstone, which in places has become quite ferruginous. The percentage of iron in this bed is usually too low for furnace use, and it can hardly, therefore, be termed in a commercial sense, an iron ore bed. Its chief interest is stratigraphical rather than economical, as it constitutes the dividing stratum between the middle and lower olive shales.

The lower bed of ore in the section designated as the Birdseye fossil ore, occurs near the center of what is known as the lower Clinton shales. The bed is of considerable economic importance in Snyder county, where it has been extensively worked. The ore is of good quality, and when mined, breaks readily into blocks the thickness of the bed. In addition to the iron ore beds shown in the above section, there also occur at some points two other beds, but neither of them attains sufficient thickness to be of any economic importance.

The Clinton iron ores in passing south from Pennsylvania traverse the eastern part of Maryland and Virginia and the western part of West Virginia and Kentucky. In Maryland[1] the ores are found in Allegany county in two beds separated by six feet of calcareous shale. The upper bed is eight feet thick, while the lower is only about half this thickness. They occur in the lower part of the Clinton formation, approximately 160 feet above its base.

The deposits in West Virginia are found chiefly in Grant, Hardy, Pendleton, Greenbriar, Monroe and Mercer counties, but only at a few points have they been worked. Pumpelly in speaking of these deposits in the first three counties above named, says that they rival the deposits of Alabama and range from 3 to 30 feet in thickness.[2]

1 Maryland Geol. Surv. Allegany County, p. 90.
2 Tenth U. S. Census, Vol. XV, p. 13.

The Clinton ores in Virginia have been mined west of the Great Valley in Wythe, Giles, Bland, Tazewell, Russel, Scott, Lee and Wise counties. The ores in Bland county are described by Campbell as being somewhat siliceous. He adds, however, that the ore beds found in the shale of the formation are quite promising, and appear in sufficient abundance to be of commercial value. Further south in Wise and Lee counties the ores become better developed, and at the same time carry a higher percentage of iron.

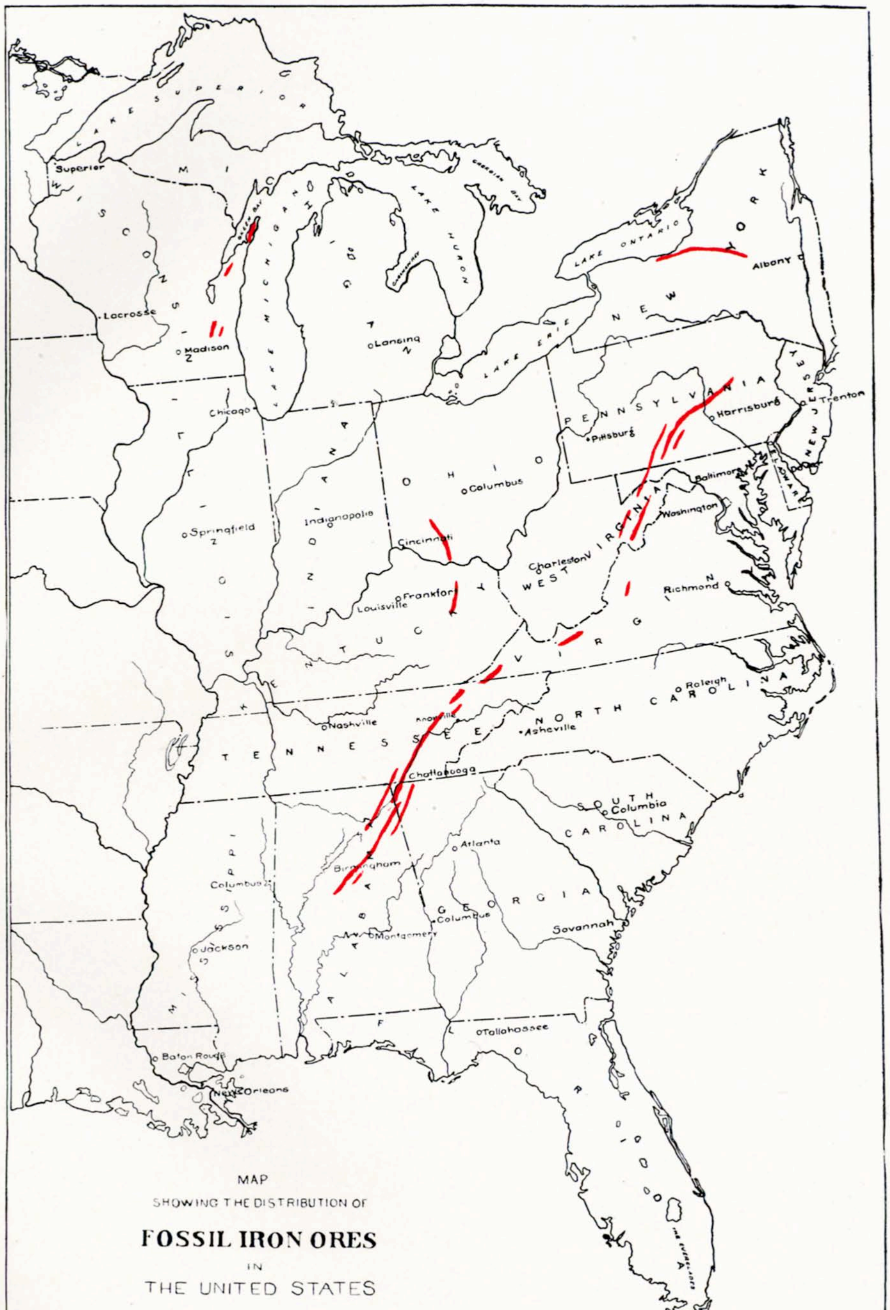
South of Virginia, the Clinton iron ores continue southwest through East Tennessee, Northwest Georgia, and Northeast Alabama, finally disappearing a few miles southeast of Tuscaloosa. The deposits in Tennessee form an almost continuous series of outcrops from Cumberland Gap to Chattanooga. They are confined mainly to the western margin of the Valley of East Tennessee, at or near the base of the Cumberland escarpment, where they usually appear in two or more parallel ridges, having a northeast-southwest trend. A good idea of the Clinton iron ores of Tennessee, together with the associated rock, may be had from the following section by Safford:—[1]

1	Greenish shale	22	feet
2	Ore with parting of shale	1½	"
3	Sandstone, fine-grained	6	"
4	Greenish shale, occasionally ferruginous	67	"
5	Calcareous oölitic ore, counting fossils and shale	4	"
6	Greenish shale, much like 4	21	"
7	Calcareous ore	6	inches
8	Shale and thin beds of limestone	14	feet
9	Calcareous ore, like 7	3–6	inches

These ores, which have been more or less extensively worked in Claiborne, Campbell, Roan, Rhea, Hamblin, Sequatchie, and Marion counties, run from 35 to 50 per cent. metallic iron, the percentage depending largely upon the amount of carbonate of lime present.

It will be observed by an examination of the map that the iron bearing zone or belt, in which workable ores occur, greatly increases

[1] Geology of Tenn., by J. M. Safford, p. 304, 1869.



MAP
SHOWING THE DISTRIBUTION OF
FOSSIL IRON ORES
IN
THE UNITED STATES

in width as the Tennessee-Georgia line is approached. The distance from the eastern line of outcrops in the vicinity of Chattanooga to the western line of outcrops is more than 30 miles. This broadening of the belt, is due to an increase in the number of outcrops brought to the surface by a series of anticlinal and synclinal folds. In Northwest Georgia there are five different lines of these outcrops crossed in going east from the Georgia-Alabama line, in the vicinity of Rising Fawn to Taylor's Ridge, a distance of less than 20 miles. These numerous outcrops make the aggregate length of outcroppings of the ores in Georgia, probably greater than that of any other State if the limited area of their occurrence is taken into consideration. The nature of the ores in Georgia, together with the character of the associated rock, will be fully discussed elsewhere in this report.

The Clinton or fossil iron ores reach their greatest economic development in the United States near Birmingham, Ala. The ores enter this State from Georgia and Tennessee in the extreme northeast corner, in five different lines of outcrops. Further to the southwest in the vicinity of Gadsden, these outcroppings become even more numerous, as the structural geology of the region becomes more complicated. Still further to the southwest in the Birmingham district, the number of lines of outcrops is reduced to two. Some of the ore beds here, however, become immensely thickened, thus making the deposits of very great economic value.

The total thickness of the Clinton, or Rockwood, formation of Alabama usually approximates 150 feet. It is variable in character, consisting of shale, sandstone and thin beds of limestone, with from three to five beds of iron ore. The workable ore beds, which are usually two or more in number, vary from three to twenty-five feet in thickness. The ore is generally fossiliferous, and occasionally oölitic. Above the drainage level it is of a high grade, running from 45 per cent. to 52 per cent. of metallic iron, but below this level, it becomes calcareous and leaner.

The following general section of the Clinton or Rockwood formation of Alabama, by A. M. Gibson, is here inserted for comparison:[1]

[1] Geol. Surv. of Ala., Report on the Geological Structure of Murphrees Valley, p. 40.

1	Shaly and slaty beds, clay and some iron ore....	15	feet
2	Heavy bedded sandstone, sometimes 40 to 50 feet, usually	10	"
3	Iron bed, ore lenticular or concretionary........	2–4	"
4	Sandstone	10	"
5	Fossil iron ore bed ....6 inches to	2½	"
6	Sandstone	7–15	"
7	Iron ore bed	2–7	"
8	Sandstone and shale	20–40	"
9	Iron ore, hard	2–20	"
10	Sandstone	20–50	"
11	Iron ore	3–20	"

In addition to the iron ore beds in the section, it is said that there are also others, but they are only locally developed and too thin to be of commercial importance.

The Clinton or fossil iron ores as above described, form, as will be noticed, an almost continuous line of outcroppings from Central Pennsylvania to Central Alabama. In a few places, notably in Virginia and upper East Tennessee, there are, it is true, a few breaks in the continuity of the outcroppings, due to local faulting, but these breaks in no case exceed more than a few miles in extent. The total length of outcroppings of this remarkable iron deposit is approximately 1,000 miles, thus making one of the most extensive and important continuous iron ore deposits so far described, not only in the United States, but also in the world.

In addition to the continuous line of outcroppings of Clinton iron ore described above, together with those of New York, there also occur more or less extensive exposures in the Mississippi Valley. The most northern of these deposits occurs in Eastern Wisconsin, and is thus described by Professor Chamberlin.[1] "The deposit is peculiarly a local one. It attains its chief importance at Iron Ridge, Dodge county, where it reaches its maximum known thickness within the United States, about 25 feet. Traced from this point, it thins out and disappears within a short distance on either hand." He also notes the occurrence of the ore at Hartford and Cascade Falls and along the eastern shore of Green Bay. The ore

[1] Geological Survey of Wisconsin, Vol. I, p. 179.

which has an oölitic structure, forms regular beds nearly horizontal, associated with limestone and shale. In Dodge county where considerable mining has been done, it is claimed that the ore yields by furnace tests about 45 per cent. metallic iron.

The other deposits of Clinton ores in the Mississippi Valley occur in Ohio and Kentucky. The deposits of Ohio are found in Clinton, Highland and Adams counties.[1] Only in one of these counties, however, namely, Adams, has the ore been worked. The ore is made up of flattened grains, oölitic particles and is sometimes highly calcareous. In Clinton county the ore is highly fossiliferous, being made up largely of the casts of crinoid stems, and usually carries a high percentage of carbonate of lime.

The Clinton ores of Kentucky, like those of Ohio, are limited to three counties, namely, Bath, Montgomery and Fleming. The Bath county deposits have been worked for several years, and have produced considerable ore of good quality. The Kentucky ores appear to be the southern extension of the Ohio deposits, though there is a wide break of several miles between the two outcrops.

[1] Geological Survey of Ohio, Vol. V, p. 37.

CHAPTER IV

LOCAL DISTRIBUTION OF THE FOSSIL ORES IN GEORGIA

The fossil or Clinton iron ores of Georgia are confined to four counties in the extreme northwestern part of the State. These counties, namely, Dade, Walker, Catoosa and Chatooga all of which with the exception of the last named, are located along the Georgia-Tennessee line, only a few miles south of Chattanooga.

The fossil iron ores of Dade county occur in Lookout Valley and Johnson's Crook, the latter being the northern extension of Wills Valley in Alabama. The deposits of Lookout Valley, which traverse the central portion of the county, are found in two lines of outcroppings extending from the Georgia-Tennessee line to Deerhead Cove, the southern terminus of the valley, a distance of about eighteen miles. The outcroppings on the east side of the valley occur along the minor ridges at the base of Lookout Mountain, while those on the western side of the valley occur along the minor ridge at the base of Sand Mountain. The total length of these two almost parallel lines of ore outcroppings, not considering their minor meanderings along the various hollows and hillslopes, is approximately 40 miles. The ores, it should be stated, are not exposed as continuous outcroppings from one end of the valley to the other, but are often covered by detrital material derived from the hillslopes above. Nevertheless, there can be no doubt about their continuity. In Johnson's Crook the ores likewise form two main lines of outcroppings, similar to those of Lookout Valley. The eastern line of outcroppings, which appears along the base of Lookout Mountain, has a length of about seven miles, while the western line of outcroppings along the base of Fox Mountain, extends only about one-half that distance. Thus it will be seen that the aggregate length of outcroppings of the fossil iron ores in Dade county does not fall far short of 50 miles.

The fossil iron ores of Walker county outcrop along the eastern side of the Lookout Mountain from the Georgia-Tennessee line to the head of McLamore Cove. From this point the line of outcroppings turns at an acute angle to the northeast and continues for about twelve miles along the western foothills of Pigeon Mountain. Here it abruptly turns to the southwest and follows the eastern foothills of Pigeon and Lookout mountains, through the western part of Walker and Chattooga counties to the Georgia-Alabama line, a short distance south of Menlo. This line of outcroppings, which has a total length of about 70 miles, has but one break in its continuity. This break which is due to a fault, occurs in the vicinity of Flintstone, only a few miles south of the Georgia-Tennessee line. The length of the break in the outcroppings, due to the fault, does not exceed three miles, and is more than counterbalanced by a second line of outcroppings appearing only a mile or so further to the east.

All along Lookout and Pigeon mountains the ores occur generally along a line of low hills or ridges at the base of the mountains. At some points there occur small narrow valleys between this series of hills and the main mountain. The dip of the ore along this line of outcroppings is usually at a low angle toward the axis of the mountains, but in some cases, the dip is at a high angle, and in a few instances the ore beds are entirely overturned, thus giving rise to two lines of outcroppings instead of one. This complicated structure is to be seen at several points in the mines located in the vicinity of High Point.

In addition to the above outcroppings, the fossil iron ores are found also further to the east, along Gaylor's and Taylor's ridges and Dirtseller Mountain. Gaylor's Ridge which is located in the extreme southwestern corner of Chattooga county, is the northern extension of a ridge of the same name traversing the eastern part of Alabama. It is a typical synclinal ridge, having a maximum elevation of about 700 feet above the adjacent valleys. After crossing the Georgia-Alabama line, the ridge extends to the northeast, a distance of four or five miles, stopping only a short distance southwest of the southern terminus of Taylor's Ridge. The iron ore of

Gaylor's Ridge is confined mainly to its western side, where it is exposed at numerous points.

About six miles north of Gaylor's Ridge and running parallel with it, is Dirtseller Mountain. This mountain, like Gaylor's Ridge, is a synclinal, extending beyond the Georgia-Tennessee line some miles into Alabama. That portion of Dirtseller Mountain confined to Georgia, in which the fossil ores occur, has a length of only about four miles. The ores occur on both sides of this mountain, outcropping near its summit, and dipping at a low angle towards its central axis. It may be stated here in passing, as will be noted elsewhere, that all exposures of the Clinton ores east of Lookout and Pigeon mountains, occur near the summit of the mountains or the ridges, instead of along the margin of the valleys. The change in the topographical position of the ores is due, as will be noted elsewhere, to lithological conditions met with in going eastward.

The most eastern outcroppings of the fossil iron ores of importance occur in Taylor's Ridge, a very prominent mountain ridge traversing the central part of Catoosa and the western part of Walker and Chattooga counties. This ridge, known in Tennessee as White Oak Mountain, intersects the State line a few miles north of Ringgold, and extends in a southwesterly direction for more than 50 miles, terminating only a short distance east of the Georgia-Alabama line. Throughout the entire course of the ridge the fossil iron ores are nearly everywhere present, and at several points they have been more or less extensively exploited. This is especially true in Chattooga county, a short distance from Summerville, where the ores have been mined almost continuously for some years.

Taylor's Ridge is paralleled on its western side by Dick's Ridge, which also contains limited amounts of iron ore. Separating the two ridges is a narrow valley, receiving different names at different points along its course. A short distance east of Ringgold the fossil ores which occur in the ridge corresponding to Dick's Ridge further south, are cut out by a fault, but further to the west they are continuous in Taylor's Ridge, or White Oak Mountain to the State line. The ores in Taylor's Ridge always dip to the east usually at a moderate pitch, while the ores in Dick's Ridge dip to the west. In the latter ridge the ores are found outcropping near the summit on the western side, while in the former the opposite obtains, thus showing that the ores belong to the adjacent limbs of a synclinal fold.

Besides the above exposures, there are also limited outcroppings of red ores further 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 one mile east of Red Clay. 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 oölitic structure still remains, thus showing one of the most common characteristic structures of the fossil ores.

Not including the last described hematite ores, which Hayes has placed in a lower formation, the fossil iron ores of Georgia form, in the aggregate, rather extensive outcroppings. The entire length of all the several lines of exposures above described aggregate about 175 miles; however, not all outcroppings contain ore sufficiently pure, and in large enough quantities to be of commercial importance. In Taylor's Ridge, for instance, there is an almost continuous line of outcroppings, having a total length of more than 40 miles, but owing to the thinness of the ore beds, which in some cases are reduced to ten inches or less, much of the ore, from a commercial standpoint, is of little value. On the other hand, at some points the ore becomes highly siliceous or calcareous, and therefore too lean to be of value. As an offset to these defects, it may be stated that at some places more than one workable ore bed occurs. This is true at places in Lookout Valley, and also along the western side of Pigeon Mountain. And again, as elsewhere stated, there are local folds in the strata at different points, bringing the ore beds to the surface forming two or more lines of outcroppings. These various conditions, which increase or decrease the amount of ore along any given distance of outcroppings, approximately balance each other, so that in general, it might be stated, that the outcroppings would yield ore in sufficient quantity to make a workable bed for an approximate length of 175 miles. If this statement be correct, and the beds can be exploited to any distance below drainage level, the aggregate amount of ore occurring in the above described outcroppings must indeed be very great.

RELIEF MAP OF A PORTION OF NORTHWEST GEORGIA, SHOWING THE PRINCIPAL TOPOGRAPHIC FEATURES.

Modeled by E. E. Powell,
Washington, D. C.

Horizontal scale 8.8 miles–1 inch

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CHAPTER V

TOPOGRAPHY AND GEOLOGY

The topography of the area under consideration embraces parts of two physiographical divisions, namely, the Appalachian Valley and the Cumberland Plateau. The Appalachian Valley division includes all of the area of Northwest Georgia between Lookout and Pigeon mountains on the west, and Cohutta, Fort and Pine Log mountains on the east. It is an elevated valley region, traversed by numerous minor ridges and valleys, having a northeast-southwest trend (Pl. III.). Some of the minor ridges, such as Taylor's Ridge, and Horn, Chattoogata and Rocky Face mountains, obtain considerable prominence, but in no case do they reach the height of the mountains further to the east or west by several hundred feet. These ridges, as a general rule, all have a monoclinal structure, and as a result their slopes differ in steepness. This type of structure is quite noticeable in Taylor's Ridge, and also in Horn and other mountains further east. The variation in the slope of these ridges depends largely upon the angle of the dip of the underlying strata, that is, where the angle of the dip is high one face of the ridge is steep and rough, while the opposite side has a more general slant. The steeper side of the ridge in such cases, is always found on the side from which the strata dips. The most prominent of the minor ridges above named are formed largely of sandstone belonging to the Rockwood formation. Another series of ridges, traversing the Appalachian Valley division, is well rounded and has gentle slopes. They are often spoken of as the chert ridges from the abundance of chert covering their slopes. These ridges are usually broad and often have their sides furrowed by rather prominent hollows. They vary in elevation from one to several hundred feet above the adjacent valleys, and often continue for many miles without any break in their continuity. The valleys on either side of the chert ridges are generally wide, fertile and well watered. The streams, though usually sluggish, have at some points considerable fall, and furnish ample power to operate grist-mills and small factories. The topographical features here noted are some of the more prominent features met with throughout the valley region belt, extending from Pennsylvania to Central Alabama, which is termed the Appalachian Valley.

The topographical features of that part of the Cumberland Plateau region, here under consideration, are limited to Pigeon and to portions of Lookout and Sand mountains. Pigeon Mountain, which is a spur of Lookout Mountain, being separated from it by McLamore's Cove, projects well out into the great Appalachian Valley, but after continuing to the northeast for a few miles, it gradually decreases in elevation and finally disappears in a chain of low, irregular hills. The southern terminus of Pigeon Mountain, or the point at which it unites with the Lookout Mountain, has an altitude of nearly 2,000 feet above sea-level. The elevation of the mountain at this point is about the same as the average elevation of Lookout and Sand mountains, though there are points on the latter mountain rising from 300 to 400 feet higher.

Pigeon, Lookout and Sand mountains are all typical table mountains. They have broad, nearly flat tops, and often steep, precipitous slopes forming bold escarpments overlooking the adjacent valleys. These mountains are the remnants of a once continuous table land which in places has been dissected by narrow valleys of erosion. The drainage of these mountains is usually toward their central axes, their margins in most cases being slightly elevated. In gaining the valleys below, the streams have cut at many points along the brow of the mountains deep, precipitous gorges noted for their wild and rugged scenery. With these exceptions, the escarpments present an almost unbroken wall of bluffs from one end of the mountains to the other.

The only valley of note occurring within that part of the plateau region here described is the Lookout Valley. This valley, traversed by a creek of considerable size of the same name, is the main highway of travel between Chattanooga, Tennessee, and Northwestern

Alabama. It is long and narrow and has a comparatively level surface except near the base of the mountains, where is to be seen a line of broken hills. The length of the valley is about 18 miles, while its average width is only about one and a half miles. Its trend is northeast and southwest, corresponding in direction to the axes of the adjacent mountains.

That part of the Cumberland Plateau here described forms only a small part of the plateau region as a whole. The entire topographical division embraces all of the area underlain by the Southern Appalachian Coal Measures. Dr. C. W. Hayes, in speaking of this topographical division as a whole, says:[1] "The Cumberland Plateau generally presents a bold and regular escarpment toward the valley upon the east. Its western escarpment in Alabama and Tennessee is equally bold, but extremely irregular, forming a sinuous line between this division and the interior lowlands. In Kentucky the western margin is less distinct, the plateau merging with the lowlands through a belt of foot-hills. The surface of the plateau rises gradually toward the northeast from about 600 feet above sea-level in central Alabama to 2,000 feet in the latitude of Chattanooga. In Tennessee, Georgia and Alabama the plateau is separated into a number of more or less isolated plateaus varying greatly in extent." The plateaus here referred to include Sand, Lookout and Pigeon mountains traversing the northwestern corner of Georgia. These mountains are formed largely of nearly horizontal sandstones and conglomerates which have resisted erosion and thus preserved intact the remains of a once continuous table-land.

STRATIGRAPHY

The rocks, underlying that part of Georgia where the fossil iron ores occur, are all of sedimentary origin, and were deposited during Paleozoic times. They range in age from the Middle Cambrian to the upper Carboniferous, and they include representatives of all or nearly all of the main divisions of Paleozoic rocks met with throughout the Southern Appalachian region. The stratigraphy of this region has been admirably worked out, and the areal geology mapped by the United States Geological Survey under the direction of Dr.

C. W. Hayes (see maps), so that what will be said here on stratigraphy will be based largely upon Hayes' observations.

CAMBRIAN ROCKS

Hayes, in discussing the stratigraphy of this region, divides the Cambrian rocks into three formations, namely, the Apison shale, the Rome formation and the Connasauga shale.

THE APISON SHALE, so called from Apison, Tennessee, where the formation is typically developed, is the oldest of the Cambrian rocks, occurring near the outcroppings of the fossil iron ores. The formation is a vari-colored somewhat sandy shale much contorted and folded. It is a rather unimportant formation, being found only in one small area east of Ringgold, where it forms a narrow belt extending from near Catoosa Springs to the Georgia-Tennessee line. The thickness of this formation is difficult to determine, owing to its contorted and folded conditions; however, one would probably not be far wrong in placing its maximum thickness at 1,000 feet or more.

THE ROME FORMATION, the second oldest rock of the Cambrian series above given, consists of shales and sandstones, having an estimated thickness of 3,000 to 4,000 feet. The lower part of the formation is made up of thin-bedded sandstone and sandy shale, while the upper portion consists almost entirely of shales alone. This shale like the underlying Apison shales is variable in color, and also occasionally fossiliferous. Some of the layers are glauconitic and often carry considerable phosphate of lime. The source of the latter mineral appears to be the fragments of *lingula* which occur in considerable abundance in some of the argillaceous beds of this formation in the vicinity of Catoosa Springs. The Rome formation, it will be observed by examination of the accompanying map, is confined to a single belt traversing Catoosa and Whitfield counties, and a small area in the northern part of Floyd and the western part of Gordon counties. The upper portion of the formation, where the sandstone is well developed, is always ridge forming, while the lower portion being made up of shale, is valley forming.

THE CONNASAUGA SHALE, one of the uppermost divisions of the

Cambrian rock series, is composed of shales and limestones. The former consists of yellowish or greenish clay shales weathering into rather thin soils. The limestones, which occur both in the upper and lower part of the formation, are generally thin-bedded and occasionally oölitic. These limestones are also frequently much broken up and the fissures are filled with white calcite. The Connasauga shale, like the Rome formation, is confined to a few narrow belts traversing Catoosa, Walker and Chattooga counties, and also two or three small irregular areas in Gordon and Floyd counties.

SILURIAN ROCKS.

The Silurian rocks of the area, the series to which the Clinton ores belong, consist of three different formations, namely, the Knox dolomite, the Chickamauga limestone, and the Rockwood formation. These formations are largely calcareous and were apparently laid down in a sea which often teemed with molluscan life, as shown by the numerous fossil remains found in some of their beds.

THE KNOX DOLOMITE, the lowest of the Silurian rocks, is a heavy-bedded, magnesian limestone more than 3,000 feet in thickness. Some of its beds carry a large amount of siliceous material in the form of chert. Upon the weathering of the magnesian limestone, this cherty material is set free and forms a mantle on the surface, which in places has accumulated to a thickness of several feet. The Knox dolomite, owing to its slow weathering, always gives rise to low, well rounded ridges, distinguished from other ridges usually by a mantle of chert. The formation underlies much of northwest Georgia, where it occurs usually in the form of wide belts having a northeast-southwest trend. One of the most prominent of these belts is known as Missionary Ridge, traversing Walker and Catoosa counties and intersecting the Georgia-Tennessee line at Rossville. The ridge is of considerable historic interest on account of battles fought on it during the Civil War in the vicinity of the State line.

THE CHICKAMAUGA LIMESTONE, so called from Chickamauga Valley, where the formation is well developed, is made up chiefly of fossiliferous, blue, flaggy limestone, attaining a maximum thickness of 1,000 feet or more. The formation, which is always valley forming, covers a considerable superficial area in northwest Georgia, the largest single evposure being a wide belt extending from the Georgia-Tennessee line, in the vicinity of Chickamauga National Park, to McLamore's Cove.

THE ROCKWOOD FORMATION, the division of the Silurian rocks in which the fossil iron ores occur, forms the uppermost member of the Silurian rocks. It consists of shales and sandstones with a few thin strata of limestone and one or more beds of fossil iron ore. The sandstones of this formation become well developed in Chattoogata and Horn mountains and also in Taylor's Ridge, but in Dade and the western part of Walker counties, shale predominates. The thickness of the formation varies from 600 to 1,500 feet, the greater thickness being confined to that part of the area where the sandstone is best developed. A more detailed description of this formation will be found elsewhere in this report.

DEVONIAN ROCKS

The Devonian rocks of the area are represented by a thin layer of black shale known as the Chattanooga shale. This formation at no point exceeds more than 40 feet in thickness, and from a geological standpoint, it is of but little importance, as it covers only a very small area. The shale contains a large amount of carbonaceous material and is often mistaken for an indication of coal.

CARBONIFEROUS ROCKS

The Carboniferous rocks are represented by five different formations, the three lower divisions of which, viz., the Fort Payne chert, the Floyd shale and the Bangor limestone are all highly calcareous, while the two upper divisions are siliceous. These rocks are best developed in Pigeon, Lookout and Sand mountains, though they are also found in the valleys and mountains east of Taylor's Ridge.

THE FORT PAYNE CHERT, the lowest of the Carboniferous rocks, consists of a highly siliceous limestone varying from 75 to 200 feet in thickness. Its chief distinguishing characteristic is its abundance of chert, which in places is largely made up of the fragments of crinoid stems. The formation usually gives rise to a line of low, sharp hills, often locally spoken of as the "shinbone" ridges. Such hills become quite prominent along the base of Sand, Lookout and Pigeon mountains near where the fossil iron ores outcrop.

THE FLOYD SHALE which appears to be a shore phase of the Fort Payne chert and the Bangor limestone, is confined mainly to the eastern part of the area. It consists of dark and gray calcareous shales with an occasional thin bed of limestone or sandstone. This formation is well developed in Armuchee Valley east of Taylor's Ridge, and also along the eastern base of Horn Mountain, but it attains its greatest development further south in Floyd county, where it reaches a maximum thickness of something like 1,200 feet. The gray, calcareous shales of the formation are often quite fossiliferous, especially is this true in West Armuchee Valley. The fossils are largely bryozoans and crinoids, the former in places being especially abundant. The dark colored or black shales, on the other hand, are entirely free from fossils, but at the same time they carry a high percentage of carbonaceous material.

THE BANGOR LIMESTONE, like the Fort Payne chert, occurs mainly along the bases of Sand, Lookout and Pigeon mountains. At some points this limestone extends well up the sides of the mountains, while at other points it forms narrow valleys at their bases. The formation consists of a heavy bedded gray or blue limestone, often fossiliferous and occasionally partially crystalline. Its thickness along Sand and Lookout mountains has been variously estimated from 750 to 900 feet. East of Pigeon Mountain the Bangor limestone rapidly thins out and it is finally nearly or wholly replaced by the overlying Floyd shales.

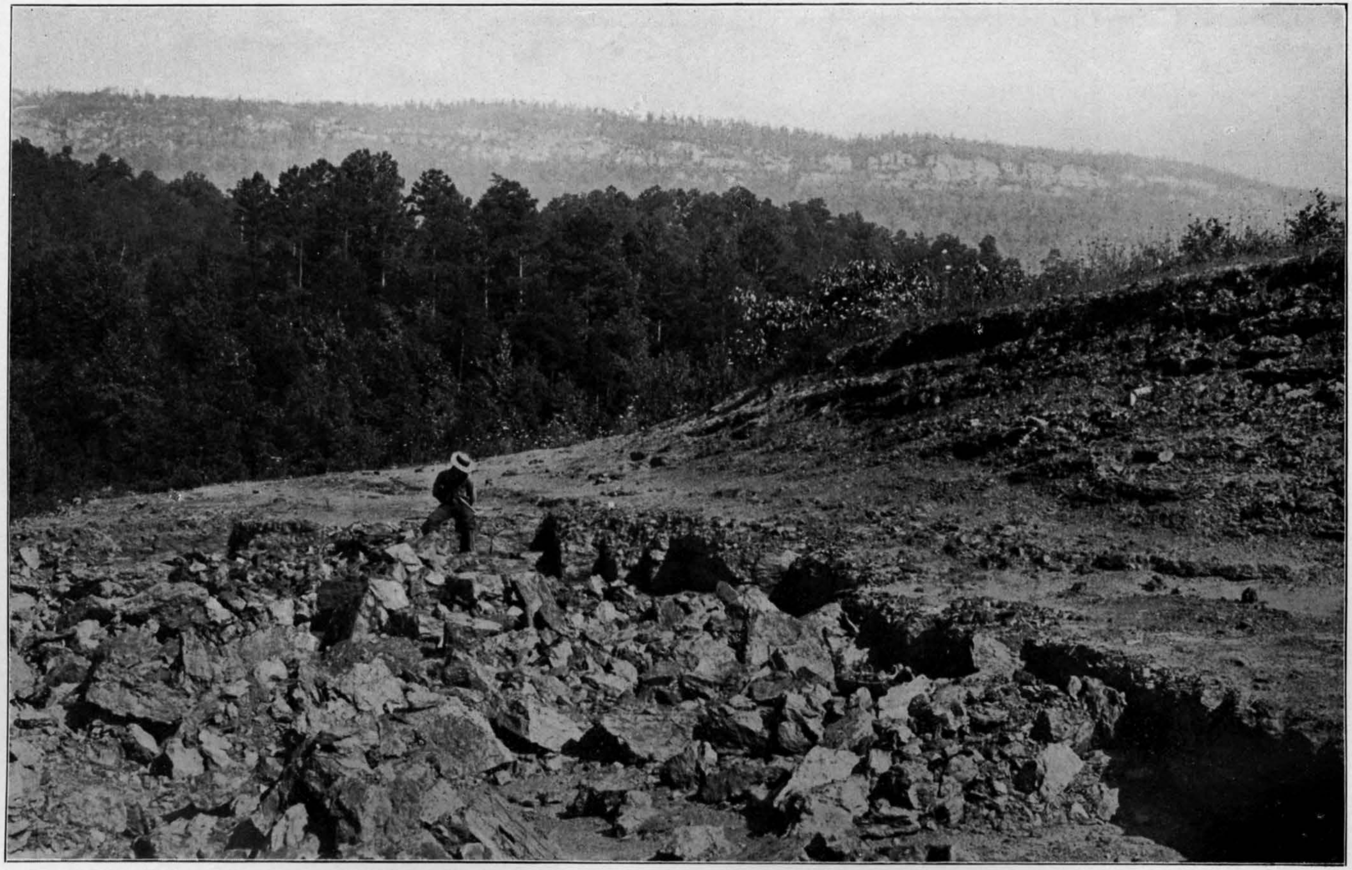
THE LOOKOUT AND WALDEN'S RIDGE SANDSTONES.—The upper division of the Carboniferous rocks above spoken of as being siliceous, constitutes the Coal Measures. This part of the Carboniferous rocks has been divided into two divisions, namely, the Lookout sandstone and the Walden sandstone. These formations, which are quite similar in character, consist of sandstone, conglomerates, shales and coal. The maximum thickness of the two divisions has been placed by Dr. J. W. Spencer at 1,600 feet.[1] They are both confined mainly to Sand, Lookout and Pigeon mountains, where they form the surface rock of these mountains. There are also small areas of the lower member of the division occurring on Rocky and Little Sand mountains east of Taylor's Ridge in Chattooga and Floyd counties.

STRUCTURAL GEOLOGY.

The structural geology of Northwest Georgia is that commonly met with in regions where the strata have been subjected to intense lateral strain, resulting in a series of rather close pressed parallel folds and a number of faults of greater or less throw. The strata, as originally laid down on the sea bottom, were all practically horizontal, but during the great Appalachian upheaval which probably extended through a long period of time, they were deformed and left to the degrading action of atmospheric and aqueous agencies. The forces which produced the folding and the faulting of the strata seemed to have acted from the east towards the west, as shown by the variation in the intensity of the effect. Along the eastern margin of the area it will be noticed by an examination of the accompanying structural sections, that the folds are more numerous, and at the same time closer pressed than the folds along the western margin. This is especially noticeable if a comparison is made between the strata of Sand, Lookout and Pigeon mountains, and the strata east of Taylor's Ridge. In the former case the strata have been thrown into broad gentle anticlinal and synclinal folds with nearly vertical axial planes, while in the latter case the folds are sharp and their axial planes dip at rather high angles to the east.

The structure of the western portion of the area here under consideration, or what has been termed the Cumberland Plateau region, is best described by taking it up as a whole and pointing out its main structural features. In passing from the Georgia-Alabama line, just south of Trenton to the eastern side of Pigeon Mountain, two anti-

[1] Geol. Surv. of Ga., Paleozoic Group, p. 53.



FOSSIL IRON ORE STRIPPINGS, NEAR WILDWOOD, DADE COUNTY, GEORGIA.

clinal and two synclinal folds are crossed. The anticlinal lying further to the west forms Lookout Valley, which lies between the Sand and Lookout synclinals. The Lookout anticlinal is nearly symmetrical, that is the angle of dip of the strata on each side of the axis of the fold is about the same. The pitch of this anticlinal fold is towards the southwest, and as a result the fold gradually dies out in that direction. The southern terminus of the anticlinal may be said to be the head of Deerhead Cove, however, the actual point at which the fold entirely disappears is some distance further to the southwest. Just east of the southern terminus of the Lookout Valley anticlinal and separated from it by Fox Mountain synclinal, is the northern terminus of a second anticlinal extending into Georgia from Alabama. The erosion of this fold has given rise to Will's Valley in Alabama, the northern extension of which, in Georgia, is known as Johnson's Crook.

East of the Lookout Valley anticlinal and forming Lookout Mountain, is the Lookout Mountain synclinal. This synclinal is a broad, shallow, trough like depression extending from the Georgia-Tennessee line near Chattanooga across the northwestern corner of the State. The axial plane of the fold is very nearly parallel with the axial plane of Lookout Valley anticlinal, and the angle of dip of the strata on each side of the mountain is practically the same. The fold near the Georgia-Tennessee line is comparatively narrow, but to the northwest it broadens. The broadening of the fold to the southwest is due to its absorbing the Pigeon Mountain synclinal hereafter to be described.

The second anticlinal fold lies just east of Lookout Valley, and corresponds to what is known as Chattanooga Valley. It extends from the Georgia-Tennessee line to the head of McLamore's Cove, a distance of about 25 miles. This fold differs from Lookout Valley synclinal in being unsymmetrical, the dip of the strata of the eastern limb being greater than that of the western limb. This is due to the top of the fold being pushed over toward the west, thus causing the strata at some points along its western limb to stand at a very high angle. Near the State line where the foldings of the strata are most marked, the tension was relieved by faulting. These displacements, however, are limited to a few hundred feet, and as a result the general character of the anticlinal is not very materially affected.

The Pigeon Mountain synclinal, the second synclinal above referred to as being one of the main structural features of the Cumberland Plateau region, lies immediately east of the Chattanooga Valley anticlinal. It is an unsymmetrical fold, forming Pigeon Mountain and extending to the northeast beyond the State line. To the southwest, a short distance south of the head of McLamore's Cove, the fold blends with the Lookout Mountain synclinal, and thus entirely disappears in that direction. The strata forming the eastern limb of the fold, as shown along the eastern side of Pigeon Mountain, usually dip at a high angle, while on the opposite side of the mountain the dip is more gradual. The structure of the mountain, therefore, as revealed in its strata, simulates a broad shallow trough with its eastern margin much more upturned than its western margin.

The structural geology of the Appalachian Valley region, as previously stated, differs considerably from that of the Cumberland Plateau. The anticlines and synclines are here more numerous and crowded together, and at the same time the apices of the folds are pushed over further toward the west. A good illustration of these closely pressed, over-turned folds is to be seen in the Chattanooga Valley anticline just east of Pigeon Mountain. This anticlinal which has its steeper slope to the west, traverses the northeastern corner of the State, intersecting the State line a short distance west of Graysville. It is the most persistent and uniform fold of the entire valley region. To the south of this anticlinal and a few miles north of Trion, a second anticlinal develops, which continues to the southwest to within a short distance of the Georgia-Alabama line. This fold, together with the Chattanooga Valley anticlinal further north and west, is succeeded on the east by the Armuchee Valley synclinal, whose western and eastern limbs are formed by Taylor's and Dick's ridges respectively. The Armuchee Valley synclinal differs from the synclinals heretofore described in being broken up into isolated basins by a number of transverse anticlinals. South of Taylor's Ridge along the Georgia-Alabama line are two other synclinals which give rise to Gaylor's Ridge and Dirtseller Mountain. Neither of these synclinals extends far into Georgia; however, they are both of special interest in this report, as they have along their central axes more or less extensive deposits of fossil iron ores.

The faults of the Appalachian Valley, with the exception of those above referred to as occurring along the eastern base of Lookout Mountain in Chattanooga Valley, are confined chiefly to the area east of Taylor's Ridge. The most important of these displacements occurs along the eastern limb of the Taylor's Ridge synclinal, and has been designated as the Taylor's Ridge fault. The southern terminus of this fault is in Floyd county only a short distance south of the Chattooga-Floyd county line. From this point the fault extends to the northeast along the eastern sides of Little Sand Mountain and Dick's Ridge to the Georgia-Tennessee line, a few miles northeast of Ringgold. The amount of displacement or the throw of the Taylor's Ridge fault is quite variable. Along the base of Little Sand Mountain and the southern portion of Dick's Ridge it is limited to a few hundred feet, or occasionally to a sharp fold without faulting, while to the northeast in the vicinity of the State line, the displacement is so great that it brings the Carboniferous rocks down on a level with the Middle Cambrian, thus representing a displacement of several thousand feet.

Another fault of this area which is worthy of note is known as the Rome fault. This fault, which traverses the southeastern margin of the Ringgold Quadrangle, not shown in the accompanying map, extends 200 miles to the northeast through Tennessee and Virginia, and also many miles to the southwest into Alabama. In Floyd county, the Rome fault is an overthrust, in which the Middle Cambrian rocks have been pushed for a long distance over the overlying Carboniferous strata on a plane nearly horizontal and corresponding approximately with the bedding of the strata. In some instances these older rocks have been thrust over the younger rocks for a distance of five or six miles, thus making the structural geology quite complicated and difficult to work out.

Two other faults occur in the area here under consideration, but they are only of minor importance. These faults, which represent a displacement of only a few hundred feet, extend from the Georgia-Alabama line, a short distance northeast of Ringgold, to Tunnel Hill. They are nearly parallel for the greater part of their course, and less than a mile from each other.

CHAPTER VI

GENERAL DESCRIPTION OF THE FOSSIL IRON ORES OF DADE COUNTY

DISTRIBUTION

The Clinton iron ores of Dade county, as elsewhere stated, are confined to Lookout Valley and Johnson's Crook. The exposures in Lookout Valley occur on both sides of the valley where they form two continuous and almost parallel lines of outcroppings extending from one end of the valley to the other. The western line of these outcroppings intersects the Georgia-Tennessee line about two miles northwest of Wildwood, where the ore is well exposed in a cut on the Nashville, Chattanooga & St. Louis Railroad. From this point the outcroppings extend to the southwest, parallel with and about three-quarters of a mile east of the Alabama Great Southern Railroad, as far south as Trenton. Here the line of outcroppings veers more to the west and continues along the foot-hills of Sand Mountain to the head of Deerhead Cove, at which point it changes its course and runs to the northeast, crossing the Alabama Great Southern Railroad about three miles south of Trenton. After crossing the railroad this line of outcroppings continues to the northeast along the foot-hills of Lookout Mountain to the Georgia-Tennessee line about one and a half miles east of the point where the western line of outcroppings crosses the State line. Along these two lines of outcroppings the exposures of the ores are usually continuous, except where they are buried beneath residual or alluvial clays. Such breaks in the continuity of the exposures of the ores, as here referred to, are to be seen along Lookout Creek immediately east of Trenton, and along Squirrel Creek west of New England City, the former on the eastern and the latter on the western line of ore outcroppings. In addition to these main breaks in the continuity of the exposures there are also minor breaks due to the creeping of the soils or to small local landslides. The minor breaks, however, are usually limited in extent to a few rods, and as a consequence they do not seriously interfere with mining. It is possible that in some instances where there are no exposures of the ores for long distances, as in the case of Lookout Creek bottoms, east of Trenton, there may be some local displacement or faults causing the ores to be absent even below the alluvial clays, yet the structural conditions indicate that local displacements or faultings seldom occur.

The exposures of the fossil iron ores in Johnson's Crook are not so extensive as the exposures in Lookout Valley, yet their mode of occurrence is quite similar. The outcroppings along the western side of the Crook near its northern terminus in the immediate vicinity of the Rising Fawn iron furnace, are especially well developed, but to the southward along the base of Lookout Mountain, there are often to be seen long stretches where no ore whatever is exposed on the surface. The absence of the ores here, as in the case of Lookout Valley, appears to be entirely due to the presence of an overburden of residual clays. That this is a true interpretation of the absence of the ores is proven by their presence at all points wherever the residual clays have been removed by erosion.

On the western side of the Crook the line of ore outcroppings, which follows for some distance the bottoms of Lookout Creek at the base of Fox Mountain, also shows considerable breaks. The main exposure of ore on this side of the Crook occurs along the east side of a chert ridge near the Alabama Great Southern Railroad, about one mile south of Rising Fawn. Between this point and the Georgia-Alabama line, owing to the heavy overburden of alluvial and residual clays, there is only an occasional exposure of ore.

THE MODE OF OCCURRENCE

The workable fossil iron ores of Dade county are confined chiefly to one ore bed. This bed, which is continuous throughout Lookout Valley and Johnson's Crook, has an average thickness of about three feet. At some points, as in the vicinity of the Rising Fawn furnace, this bed is reported to attain a thickness of seven feet. Such maximum thicknesses, however, appear to be only locally developed and probably limited to small areas. In addition to the main workable bed there are often locally developed from one to two other beds, which at some points yield ore carrying a sufficiently high percentage of iron to be of commercial value. These beds often attain a much greater thickness than the main workable bed, but at the same time they are relatively leaner in iron. At the points where they attain their greatest thickness, they consist largely of ferruginated limestone or sandstone, the former being the more common. A good example of the ferruginous sandy beds is to be seen a short distance east of the Rising Fawn furnace, where an attempt was made some years ago to mine the material for furnace use. The calcareous beds, on the other hand, appear to be best developed along the eastern line of outcroppings of Lookout Valley, both north and south of Trenton. Near New England City and at one or two localities south of that place, the calcareous beds seem to carry considerable iron, but at no point has any attempt been made to mine these leaner ores. As a general rule the main ore bed occurs below the leaner ore beds, but this is not always the case, as may be seen on the east side of Lookout Valley near Wildwood. In this instance the main ore bed seems to occupy its natural position, while a secondary bed has been developed below it. Such instances as this appear to be comparatively rare, yet it demonstrates the fact previously brought out that ore beds are likely to occur at any horizon in the Rockwood formation wherever porous calcareous or sandy beds are found.

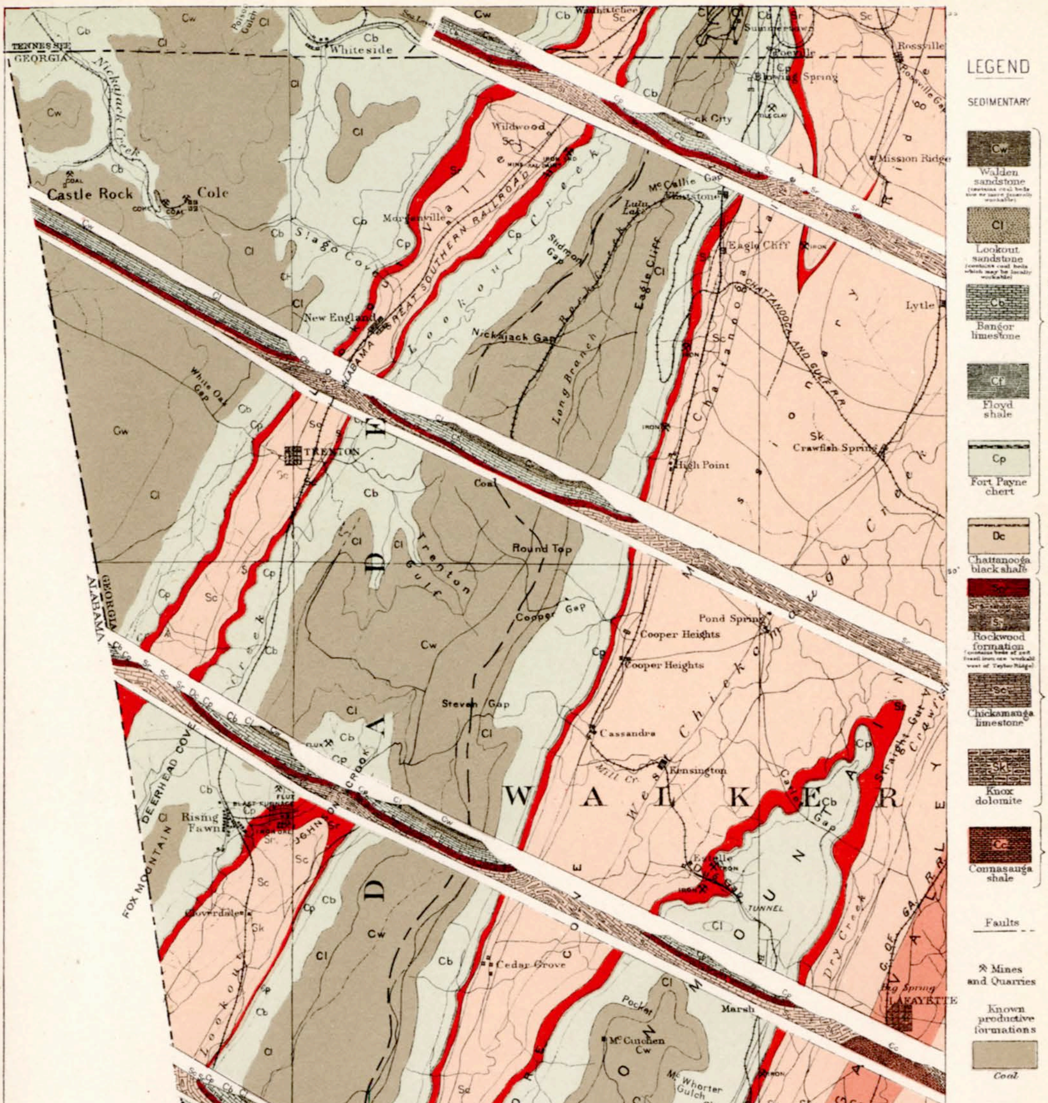
THE EXTENT OF DEVELOPMENTS

The fossil iron ores have been worked to a considerable extent in Lookout Valley, but more largely in Johnson's Crook in the neighborhood of Rising Fawn. The latter workings are confined mainly to the head of Johnson's Crook, in the immediate vicinity of Rising Fawn furnace. They consist both of strippings and underground workings, the former being far more extensive than the latter. The total length of the strippings as revealed by the old excavations in Johnston's Crook, would probably aggregate several miles. In these workings, which rarely ever exceed a maximum depth of more than ten or twelve feet, the ore mined was mainly soft, running high in metallic iron, and low in carbonate of lime. The amount of ore mined by the stripping method along any given length of outcroppings depends largely upon the angle of dip of the ore bed and the slope of the surface of the ground in the immediate vicinity of the exposure. The conditions most favorable to this method of mining ore are where the ore bed outcrops near the top of a hill or ridge and dips with the slope towards its base. Under these conditions the ore bed may mantle the whole side of the hill or ridge with only a thin covering of soil or residual clays above. Exposures of this nature in Johnson's Crook are now in a large measure worked out and future workings will have to be confined principally to underground or deep mining. It would be a difficult matter to estimate in actual tons the amount of iron ore that has been mined from time to time in Johnson's Crook. However, some idea may be formed as to the aggregate when it is stated that these ores were the main source of supply to the 150-ton furnace at Rising Fawn for a number of years.

The iron ore workings of Lookout Valley occur in the vicinity of New England City and also at several points along the Alabama Great Southern Railroad south of Trenton. The most extensive workings in the New England City locality are situated along the eastern line of outcroppings. These workings, which consist of both stripping and underground working, commence near Squirrel Creek just east of New England City and extend beyond Morganville a distance of 4 or 5 miles. The workings are not continuous this entire distance, there being an occasional break, due to some unfavorable topographical feature. The amount of ore taken from these various workings in Lookout Valley is not so great as that taken from Johnson's Crook, though the total tonnage has been large.

CONDITIONS FAVORABLE FOR MINING

The fossil iron ores of Dade county are usually quite favorably located for working. This is especially true of that portion of the beds which outcrops on the hillside. Many of these exposures have an elevation of from 100 to 200 feet above the general stream level, and as a consequence the mines in most cases can be made self-drain-



GEOLOGIC MAP OF A PART OF NORTHWEST GEORGIA

With structure sections, showing distribution of the Fossil Iron Ores.

Reproduced from the Ringgold and the Stevenson Folios, U. S. Geological Survey.

ing to the depth of many feet. Other conditions favorable to economical mining are the low dip of ore beds, their uniformity in thickness and the absence of thick partings of shale. The dip of the ore-beds varies usually from 10 to 20 degrees, but at some places it is much greater. The higher dips, however, are usually quite local and extend only for a short distance along the strike. Generally speaking, it might be said that the dip of the iron ore beds, both in Lookout Valley and in Johnson's Crook, varies from 10 to 30 degrees. In some places the minimum dip is less than here given, but such dips are usually confined to small areas and can hardly be considered as of common occurrence.

Where the dip is at a low angle the ore in many cases can be worked by stripping. The most favorable location for this method of mining is along hillslopes where the angle of the slope corresponds with angle of dips of the ore-bed. In such cases the ore often covers the hillside as a mantle, and to mine it requires only to remove a thin overburden of soil or residual clay and to break it up with a crowbar. Mining by stripping is also facilitated by the jointed structure of the ore which enables the miner to remove the ore from its bed in the form of blocks without the use of explosives.

The uniformity in the thickness of the fossil ore-beds, the second condition above referred to as favorable to their economical working, is quite remarkable. This is particularly true of the main bed which often continues for long distances with but little or no variation in thickness. The less important beds, on the other hand, are more variable in thickness and frequently thin out completely in only a short distance. It is not an uncommon thing to find the main ore bed varying in thickness much more in the direction of its dip than in the direction of its strike. This variation, however, is due to weathering and not to any irregularity in the bed itself. As a general rule the beds are all found to increase slightly in thickness near the water level or at the point of union of the soft and the hard ores. In mining ores which occur in uniform beds as in the case of the main ore-beds here described, there is usually a minimum amount of dead work necessary, and as a result the cost of mining is comparatively small. It might be here stated that the main ore-bed, both in Lookout Valley and Johnson's Crook, generally has sufficient thickness to permit the ore being mined without the removal of any overlying or underlying shales.

The thinness or the entire absence of shale partings in the ore-beds is the other factor referred to as favorable to the economical working of the ore. It is a general rule that the fossil iron ore beds when they become of sufficient thickness to pay to work, have one or more partings of shale. Sometimes these shale partings exceed in thickness the ore itself, in which case the expense of mining is so great that it ceases to be profitable. The shale partings of the main ore beds of the Dade county fossil ores rarely ever exceed four or five inches, which by no means seriously interferes with mining.

DETAILED DESCRIPTION OF INDIVIDUAL IRON ORE PROPERTIES IN DADE COUNTY

INTRODUCTION

The greater part of the fossil iron ores of Dade county is owned by three companies, namely, the New England Company, the Phœnix Iron and Coal Company, and the [1] Georgia Iron and Coal Company. The iron ore lands of the first two companies here named are located in Lookout Valley, while the lands of the other company are located in Johnson's Crook. In the following detailed account, the holdings of these companies will be taken up and described separately, and afterwards the properties owned by individuals will be described. This method of describing each property as a whole will no doubt prove more satisfactory to the owners than a description of the various exposures of the ores in the consecutive order of their occurrence.

FOSSIL IRON ORES OF JOHNSON CROOK

THE GEORGIA IRON & COAL COMPANY'S PROPERTY

The fossil iron ores owned by this company are confined to Johnson's Crook. The only workings to be seen on the west side of Lookout Creek occur on lot 83, 18th district, a few hundred yards south of the Alabama Great Southern Railroad bridge. The working here, which consists of open cuts, was done a number of years ago, and the

[1] This property is now owned by the Southern Steel Company.

excavations are now all more or less completely filled with earth. The ore where exposed to view has a thickness of about 30 inches and dips at a high angle to the westward. Near the old workings here described, the fossil iron ore crosses Lookout Creek and continues to the northeast along the left bank of Hurricane Creek, traversing lot 82 of the 18th district, and lots 252 and 251 of the 11th district. This line of outcroppings has been extensively worked on lot 251 which lies just across Hurricane Creek from the Rising Fawn furnace. East of the creek at this point there occurs a series of knobby hills rising 75 feet or more above the stream bed. The ore here which dips at a low angle to the northwest, in the direction of Hurricane Creek, occurs along the western slopes of these hills in the form of a blanket deposit or as a continuous bed overlain by only a few feet of overburden. The ease with which the ore at this point was worked accounts for the extensiveness of the old workings. A section of the ore-bearing formation at this point is here given in the descending order:—

1	Ore (overlain by shale)	10	inches
2	Shale	8	"
3	Ore	12	"
4	Shale	1	"
5	Ore	6	"
6	Shale	3	"
7	Ore	6	"
8	Shale	1	"
9	Ore	12	"
10	Shale	24	"
11	Ferruginous, fossiliferous limestone	9	"
12	Shale	6½	feet
13	Fossiliferous limestone	4	inches
14	Shale with thin layers of sandstone and limestone	40	feet

In addition to the fossil ore given in the above section there are to be seen in places two other thin beds in the shales above. One of these beds, which is about 12 inches in thickness, lies about 10 feet above the uppermost layer of ore given in the section and the other about 15 feet above. Both of these beds usually run low in iron ore, and are rarely of sufficient thickness to be economically worked.

About a half mile east of the workings here described, and a hundred feet or more below the lowest beds in the above section, occurs another bed of ore. This bed is known as the "sand vein" on account of the ore running high in silica. Some years ago 300 tons of this ore is said to have been mined and used in the Rising Fawn furnace, but the ore was found to be too siliceous to be worked with profit. This bed lies just beneath a heavy layer of sandstone, which in places is made up largely of casts of brachiopods, while the ore itself consists chiefly of crinoid buttons, rarely more than ¼ of an inch in diameter. A short distance west of the "sand vein" is to be seen the upper beds of the Chickamauga limestone dipping to the eastward at a low angle beneath the iron-bearing formation.

LOT 251.—The workable ore on lot 251 may be said to be confined to the upper part of the above section. The ore on this lot with its partings of shale has an aggregate thickness of 62 inches, the shale partings being 16 inches and the ore proper 46 inches. The character of the ore taken from this point is shown by the following analysis made by Dr. Edgar Everhart, Chemist of the Geological Survey of Georgia:—

Hygroscopic water	0.10
Combined water	2.04
Ferrous oxide	2.65
Ferric oxide	45.29
Alumina	3.14
Manganous oxide	0.28
Lime	21.41
Magnesia	0.44
Silica	7.28
Sulphur	trace
Phosphorus pentoxide	1.17
Carbon dioxide	16.50
	100.30
Metallic iron	33.76
Phosphorus	.51

The sample of ore, the analysis of which is here given, is known among the miners as hard ore. It is usually found below or near the permanent water level and always contains a high percentage of lime. It consists largely of organic remains in the form of fragments of brachiopod shells, and bryozoans, all of which have been more or less completely replaced by iron oxide. A microscopic section of the ore shows that the iron oxide fills all of the minute pores of the brachiopods and bryozoans, as well as the spaces between the numerous small calcite crystals which make up a great part of the section. The iron also occurs in the form of layers surrounding the rounded fragments of shells and bryozoans, and in a few instances it is seen to surround quartz granules.

The residue after being treated with hydrochloric acid consists mainly of rounded granular masses often having a concentric structure and still retaining in a more or less perfect degree the form and structure of the original particles.

LOTS 184, 213, 214, 218 AND 219.—A short distance west of Rising Fawn furnace, the main line of iron ore outcroppings leaves lot 251, and after crossing Hurricane Creek extends to the northwest through lots 218, 219, 214, 213 and 184. The workings here have been extensive, especially on lots 218 and 219, where underground mining as well as mining by open cuts has been carried on. In places it is said that underground workings extended to a depth of a hundred feet or more. Great yawning cuts are now to be seen in places along this line of old workings many feet in depth, but only at a few points is any ore exposed to view. Frequently the cuts extended to water level and are now partially filled with water, but more generally the fallen earth obscures the ore. Most of the ore taken from these workings with the exception of that mined by tunneling, was soft ore and ran high in metallic iron. The ore, after traversing the above lots, enters upon lot 185, owned by Solon Gwinn, hereafter to be described, and again enters upon the Georgia Iron and Coal Company's property on lot 212. The line of ore outcroppings, here marked by an almost continuous series of old workings, consisting chiefly of open cuts, now veers to the south and traverses lots 221 and 248. The following section taken from a recent opening on lot 212, only a short distance from Hurricane Creek, shows the thickness of the ore, together with the thickness of the shale partings: —

1	Ore	16	inches
2	Shale	4	"
3	Ore	6	"
4	Shale	3	"
5	Ore	6	"
6	Shale	1	"
7	Ore	16	"
8	Shale	10	feet

Within a short distance of the above section and on the same lot, another recent exposure shows the section given below:—

1	Ore	16	inches
2	Shale	5	"
3	Ore	8	"
4	Shale	½	"
5	Ore	10	"
6	Shale	½	"
7	Ore	13	"
8	Shale	20	"
9	Limestone	3	"
10	Shale	7	"
11	Limestone	6	"
12	Shale	22	"
13	Limestone	14	"
14	Shale	16	"
15	Limestone	3	"
16	Shale	1	"
17	Limestone	8	"
18	Shale	24	"
19	Limestone	4	"

It will be noticed that the main difference between these two sections is the occurrence of thin beds of limestone, in the second section, below the iron ore. These are not represented in the first section. This local development seems to be characteristic of the thin limestone layers associated with the iron ores in this district. They appear in the form of flattened lenses and soon thin out in the direction of their strike. Above the ore in the last section there is an exposure of about 10 feet of decomposed shale interlaminated here and there with thin partings of reddish clay, marking the position of thin layers of limestone, the calcium carbonate of which has been carried off in solution. The ore, together with the associated rocks at the points where the above sections occur, has a dip of only 5°, but further to the south the dip increases and in places some folds or faults occur, bringing the ore to the surface in two different lines of outcroppings. The workings on all of these lots, with the exception of the points where the above sections occur, were done many years ago, and the excavations are more or less filled with fallen earth. The character of the ore is practically the same as that found in the vicinity of Rising Fawn furnace; however, as shown by the following analysis by Dr. Everhart, Chemist of the Geological Survey, it seems to be lower in metallic iron and higher in alumina.

Hygroscopic water	0.32
Combined water	0.87
Ferrous oxide	4.03
Ferric oxide	22.50
Alumina	17.17
Manganous oxide	0.30
Lime	28.24
Magnesia	2.14
Silica	7.03
Sulphur	0.07
Phosphorus pentoxide	0.38
Carbon dioxide	16.60
Total	99.65
Metallic iron	18.89
Carbon dioxide	0.166

This specimen of ore, as shown by the high percentage of lime present, is hard ore. But little of the soft ore is now to be seen on the Georgia Iron & Coal Company's property, the greater part of which was worked out several years ago when the Rising Fawn furnace was operated by Governor Joseph E. Brown and others.

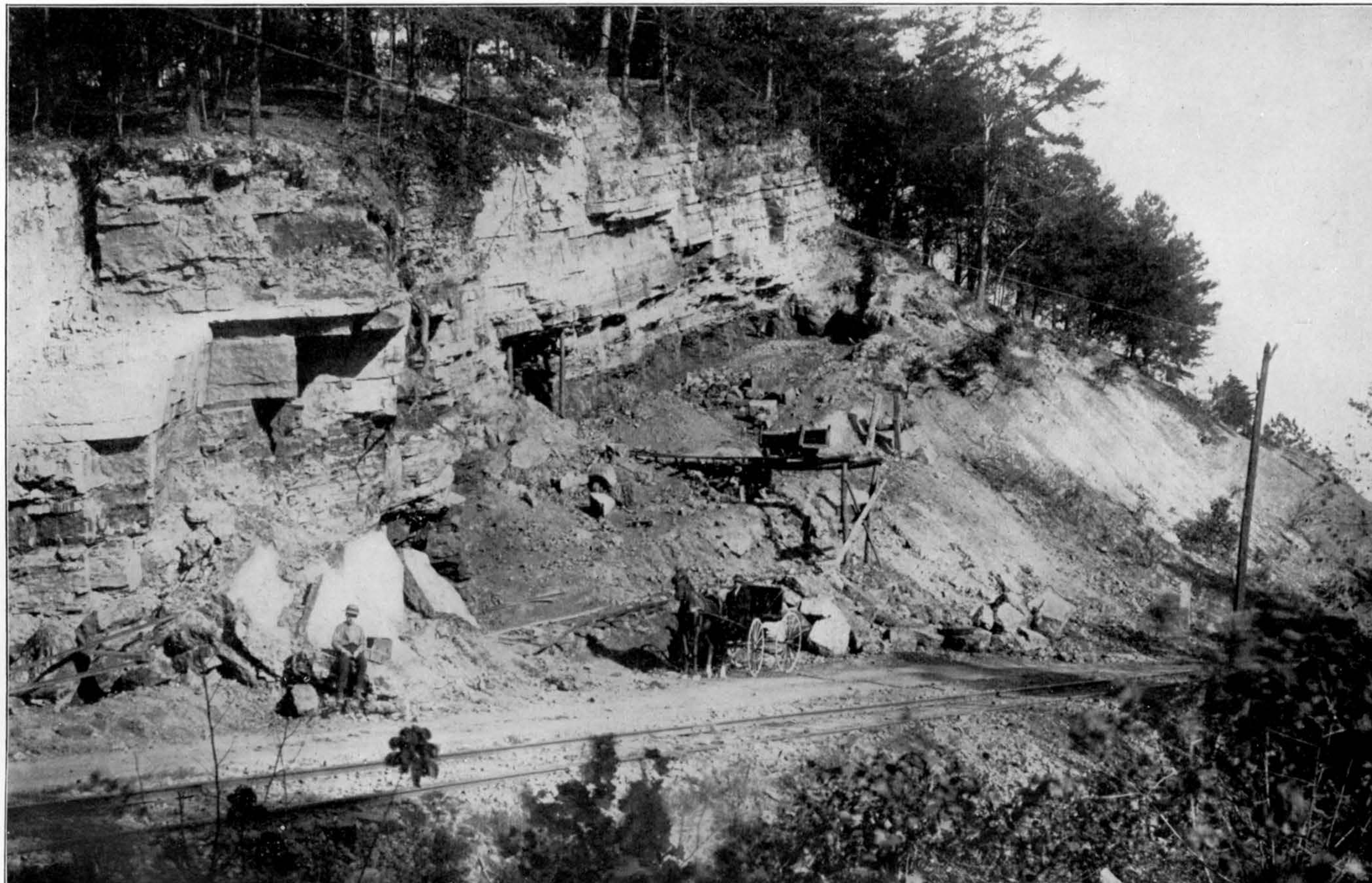
THE RISING FAWN FURNACE,[1] which belongs to the Georgia Iron & Coal Company, is located on Hurricane Creek one mile east of Rising Fawn Station, a small town on the Alabama Great Southern Railroad, 26 miles southwest of Chattanooga. The original Rising Fawn furnace, which had a daily capacity of only 50 tons, was

[1] Since the above was written the Georgia Iron & Coal Company has sold its property to the Southern Steel Company.

erected by a company of New York capitalists in 1874. The New York company operated the furnace for only a short time when it went into the hands of a receiver. A few months after the appointment of a receiver, the furnace was purchased by the Walker Iron & Coal Company, Governor Joseph E. Brown and J. C. Warner being the principal stockholders. Under the management of this new company the furnace was operated quite successfully for 4 or 5 years, when Mr. Warner disposed of his interest to the company, after which the company again changed its name to the Georgia Mining & Manufacturing Company. Under this management the furnace was enlarged to a hundred ton furnace and operated quite successfully until 1896, when it was closed and remained idle until February, 1903. In the meantime the furnace passed into the hands of the Georgia Iron & Coal Company, its present owners, who enlarged it to a 225-ton furnace. Since the last named date, the furnace has been continuously operated with the exception of from June, 1905, to January 6, 1906, during which time it was undergoing repair.

In addition to the furnace here described, the Georgia Iron & Coal Company owns numerous cottages, a large store, well equipped offices, machine shops, etc., all of which are located in the immediate vicinity of the furnace. The furnace is connected with the Alabama Great Southern Railroad at Rising Fawn by a standard-gauge branch railroad one mile long. The company also owns another branch road of nearly equal length, extending from the furnace to the limestone quarry from which stone is secured for fluxing purposes. The quarry here referred to is located at the base of Lookout Mountain less than a half of a mile in a direct line north of the furnace. The limestone here quarried is the Bangor limestone, one of the lower divisions of the carboniferous rocks. It is a bluish-gray limestone, quite free from impurities and well suited for fluxing purposes. The formation is about 200 feet in thickness and dips at a low angle to the northeast.

The iron ore formerly used in the Rising Fawn furnace was chiefly obtained from the fossil iron ore outcroppings on the company's property in the immediate vicinity of the furnace, but since the fur-



A VIEW NEAR THE GEORGIA-TENNESSEE LINE, SHOWING THE CHATTANOOGA BLACK SHALE OVERLAIN BY THE BANGOR LIMESTONE.

nace went in blast in February, 1903, brown iron ore from the company's mines in Bartow county has been largely used.

SOLON GWINN'S PROPERTY.—This property heretofore referred to as lot 185 of the 10th district, is located in the head of Johnson's Crook. It is surrounded on all sides by the Georgia Iron & Coal Company's property. The ore on this lot was extensively worked by open cuts in the early '80's, but it is now exposed only at a few points. The greater part of the soft ore appears to have been taken out, though at one or two places small exposures of this ore are still to be seen. From a sample of ore taken from one of these exposures the following analysis was made by Dr. Edgar Everhart, Chemist of the Geological Survey:

Hygroscopic water	0.65
Combined water	3.57
Ferrous oxide	none
Ferric oxide	81.57
Alumina	5.57
Manganous oxide	0.43
Lime	0.29
Magnesia	0.42
Silica	6.55
Sulphur	0.25
Phosphorus pentoxide	0.45
Carbon dioxide	none
Total	99.75
Metallic iron	57.10
Phosphorus	.197

This ore is very soft and consists largely of the cast of bryozoans. It appears to contain but little silica in the form of sand. The following section taken near where the above sample of ore was obtained shows the thickness of the layers of ore and the intercalated shale partings:

1	Ore	12	inches
2	Shale	7	"
3	Ore	8	"
4	Shale	2	"
5	Ore	8	"
6	Shale	1	"
7	Ore	4	"
8	Shale	1	"
9	Ore	4	"
10	Shale	2	"

The ore here dips to the northward at an angle of 10°.

Along the eastern side of Johnson's Crook south of the Georgia Iron & Coal Company's property no workings or outcroppings of iron ore of any importance are seen until the John Slaton property is reached.

THE SLATON PROPERTY, lot 286, 11th district, and also the adjoining property, lot 291, owned by Sevier Powell, are traversed by the bed of fossil iron ore, but the ore has been prospected at only a few points. In most places the ores on these properties are covered by residual material which has resulted from the weathering of the overlying Fort Payne chert, and can only be seen when this overburden is removed by the action of running water or by artificial means.

THE TATUM & GILBERT PROPERTIES.—These properties, lots No. 322 and 326, both of the 11th district, and which lie to the southwest of the Powell property, have exposures of fossil iron ore, but here as on the adjoining properties to the north, the exposures are limited. The prospecting on the properties has been meagre and the old excavations are so full of fallen earth that nothing can be definitely stated as to the thickness of the bed or the character of the ore.

G. A. R. BIBBLE'S PROPERTY.—The Bibble property, lot 2, 12th district, lies immediately south of the Gilbert property. The main exposures of the iron ore on this property occur on a steep hill-slope only a few hundred yards south of the Bibble residence. The ore here has a thickness of about 3 feet and stands almost perpendicular. The exposures show chiefly hard ore which seems to be of a good quality. The total amount of ore mined on the Bibble property has probably not exceeded 50 tons.

W. P. GILBERT'S PROPERTY.—Previous to traversing lot No. 2, the fossil iron ore traverses lot No. 1 and also the northwest corner of lot No. 36 of the 12th district. The few openings which have been made on these lots are now partially filled with earth and no ore is to be seen in place, owing to the heavy covering of residual material from the Fort Payne chert.

T. B. BLAKE'S PROPERTY.—Southwest of lot No. 2 the line of ore outcroppings crosses the district line and is to be seen on the Blake property, lot 118 of the 18th district. After traversing this property, it appears on lot 124. On the latter property, known as the Brown property, there was considerable ore mined several years ago. The workings, which consisted of open cuts and strippings, are now much fallen in and no ore is to be seen *in situ*.

E. M. THOMAS' PROPERTY.—Lot 127, 18th district, adjoins the Brown property on the south. This property and also the T. B. Smith property, lot 128, immediately south of the Thomas property, were quite extensively worked some years ago. The workings, which consisted of strippings, open cuts and tunneling, are to be seen on the hillsides a short distance east of Lookout Creek and within a few hundred yards of the Alabama Great Southern Railroad. With the exception of the Hartline property, lot 129, which lies on the Georgia-Alabama line, the Smith property might be said to mark the southern limits of the eastern outcropping of the fossil ore along the eastern side of Johnson's Crook.

SARAH HARTLINE'S PROPERTY.—There is but one exposure of ore on this property and it occurs on a rather steep hillside on the Alabama Great Southern Railroad, a few hundred yards south of the Sulphur Spring station. A sample car of ore was shipped from this point some five years ago to Birmingham. The ore contains considerable clay and sand. It occurs in a bed about three feet in thickness and dips eastward at an angle of about 65°; underlying the iron ore is a limestone resembling the Chickamauga limestone. The ore appears to be a different bed from the one worked on the Smith property and at the other points further north on the east side of Johnson's Crook.

The Nesbitt and Other Properties.—In addition to the fossil iron ore above described, there is also another line of outcroppings on the west side of Johnson's Crook. This line of outcroppings enters Georgia from Alabama on lot 113, 18th district, owned by Mrs. Mahulda Steel. After traversing the southeastern corner of this lot, it passes through the northwest corner of lot 112, owned by the same party. It then enters upon and traverses J. A. Nesbitt's property, lots 100 and 103, 18th district. Still further to the northeast it occurs on lot 92 and also on lot 90, the former owned by Lena Goff and the latter by James Hall. After traversing lot 90 it enters upon lot 83, the property of the Georgia Iron & Coal Company, which has been previously described. The ore along the eastern line of outcroppings is usually concealed from view by residual material, and is to be seen at only a few places. One of the best exposures occurs on the Nesbitt property, lot 100, on the right bank of Lookout Creek. The ore, which here has a thickness of about 3 feet, is hard and carries a high percentage of lime.

Each of the several properties above named has been prospected more or less and at some points a limited amount of ore has been mined, but as a whole, leaving out the workings of the Georgia Iron & Coal Company, there may be said to have been but little development of the fossil iron ore on the west side of Johnson's Crook between the Georgia-Alabama line and Rising Fawn.

DESCRIPTION OF THE FOSSIL IRON ORE OF LOOKOUT VALLEY

The southernmost exposure of fossil iron ore in Lookout Valley occurs on the west side of Pudding Ridge, near the headwaters of Crawfish Creek and only a short distance from the Georgia-Alabama line. The exposure here is near the point of the union of the eastern and western line of ore outcroppings of Lookout Valley. The several iron ore properties of Lookout Valley are here described in detail.

The Dean Property, lot 65 (?), 18th district, is located on the

Georgia-Alabama line a short distance from the base of Sand Mountain. The ore outcroppings on this property are to be seen on the west side of Pudding Ridge. The total thickness of the main bed of ore at this point is 30 inches. Twelve inches from the base the bed has a parting of shale three inches in thickness. About three feet above the main bed is a second layer eight inches thick, which in turn is followed by a third bed about three feet thick, and still higher in the series is another, having a thickness of 18 inches. The two small layers carry a high percentage of lime, and could hardly be used with profit in a furnace. The ore here has a dip to the east at an angle of about 5°. It is exposed on both sides of a ravine for a short distance, but it finally disappears beneath the overlying shales.

Within a short distance of this exposure on the same property, the ore occurs in the deep ravines on the opposite side of Pudding Ridge. The ore here is all hard ore and would probably not run over 32 per cent. metallic iron.

L. S. COLLIER'S PROPERTY.—This property, lot 64, joins the Dean property on the east. Fossil ore occurs here on the west side of Pudding Ridge at an elevation of about 400 feet above Crawfish Creek, where it forms a more or less continuous series of outcroppings continuous with the outcroppings on the Dean property just described. The following section, in the ascending order, shows the thickness of the ore and character of the associated rock:

1	Ore	2	feet
2	Shale	2	inches
3	Ore	9	"
4	Shale with thin beds of limestone	125	feet

The ore dips at a low angle to the east and is favorably located for working. It consists largely of hard ore. In addition to the lot here described, Mr. Collier also owns lot 45 of the 18th district, on which considerable soft ore has been mined. The ore occurs on this lot on a hill having an elevation of about 100 feet above Crawfish Creek which flows at its northern base. A section of the ore-bearing formation at this point is here given:

1	Ore	12	inches
2	Shale	18	"
3	Ore	8	"
4	Shale	6	"
5	Ore	16	"
6	Shale	2	"
7	Ore	16	"
8	Shale	—	

The ore dips eastward at an angle of about 10°.

THE SMITH PROPERTY.—This property, lot 56, 18th district, lies chiefly on the east side of Pudding Ridge, 2½ miles northwest of Rising Fawn. The main exposure of ore is near the head of a deep ravine at an elevation of more than 100 feet above the general stream level of the vicinity. The ore is about three feet thick and lies almost horizontal. It is chiefly hard ore, though soft ore also occurs where the outcroppings have been protected from surface erosion. After traversing this lot, the ore again appears on the adjoining lot here described.

W. A. ALLISON'S PROPERTY.—The Allison property, lot 55, is located immediately west of the Smith property. The ore on this property, as on the adjoining lot, lies nearly horizontal and consists almost entirely of hard ore. The following section shows the thickness of the ore and the shale partings:

1	Ore	3	feet
2	Shale	½	inch
3	Ore	5	inches
4	Shale	18	"
5	Ore	3	feet
6	Shale	—	

This section shows an unusual thickening of the ore which is probably only local. In general where the beds are thus abnormally developed, not all of the ore is workable, either the lower or upper bed being too low in iron and too high in lime for furnace use.

THOMAS PAYNE'S PROPERTY.—Lot 53, 18th district (mineral interest owned by L. S. Collier), is located on the Georgia-Alabama line. This lot has a rather extensive outcropping of iron ore, which has an average thickness of about 3 feet. The best exposure is to be seen on the slope of one of the western foothills of Pudding Ridge at an elevation of about 100 feet above the valley. The dip is to the westward at a low angle. After traversing this lot and crossing the State line, the ore again appears in Alabama, where it has been prospected at several points near the head of one of the tributaries of Crawfish Creek.

THE TINKER PROPERTY.—This property, lots 50 and 51, 18th district, lies due east of the Payne property and directly south of the Collier property, lot 45, previously described. One of the main iron ore exposures on the property is to be seen in a deep ravine near the Tinker residence. The section here exposed is as follows:

1	Ore	9	inches
2	Shale	¾	"
3	Ore	28	"
4	Shale	—	

The ore and the associated shales dip to the northeast at an angle of about 10°. All of the ore in the above section is hard and carries a rather high percentage of lime, as shown by the following analysis by Dr. Edgar Everhart, Chemist of the Geological Survey:

Hygroscopic water	0.27
Combined water	0.75
Ferrous oxide	2.05
Ferric oxide	42.20
Alumina	3.89
Manganous oxide	0.23
Lime	24.95
Magnesia	0.40
Silica	4.62
Sulphur	0.10
Phosphorus pentoxide	1.31
Carbon dioxide	19.40
Total	100.17
Metallic iron	32.53
Phosphorus	.572

This ore is made up largely of oölitic particles about the shape and size of flaxseed.

SILAS PRICKET'S PROPERTY.—Lot 42 (?), 18th district (mineral interest owned by L. S. Collier). There is quite an extensive outcropping of ore on this property. In places the ore dips at a low angle conforming to the slope of the hill, and as a result can be cheaply worked by stripping. Both hard and soft ore occurs, but the latter is the most abundant. The total thickness of the ore is about 3 feet.

THE PHŒNIX IRON & COAL COMPANY'S PROPERTY

The property of this company, which consists of 3,224 acres, is confined largely to the northern part of the 18th district of Dade county. The greater part of the property was secured from the Empire State Coal & Mining Company. The latter company was organized just prior to the Civil War with a view of manufacturing iron for the Confederate government. Mr. R. H. F. Millington, former superintendent of the Empire State Coal & Iron Company, in speaking of the property, says: "It was purchased for the purpose of erecting furnaces to manufacture iron under a contract with the late Confederate States government, amounting to $8,000,000. The furnace here referred to was being erected under my supervision and was the first of six we were about to erect when the forces of U. S. Grant gained possession of that part of the State and drove us away, but left the furnace intact." The furnace to which Mr. Millington here refers is still standing in a fair state of preservation. It is a small furnace, having a supposed capacity of only 20 tons per day. No attempt has been made since the abandonment of the furnace in 1863 to put it in operation. The description of the iron prospects on the Phœnix Iron & Coal Company's property is here given by lots:

LOT 22, 18TH DISTRICT.—This lot, on which the old furnace above referred to is located, lies on the west side of Lookout Creek, about 3 miles south of Trenton. The main exposure of ore on the lot occurs near the top of a ridge a few hundred yards northwest of the

MINING HARD IRON ORE ON THE FRANK COSTELLO PROPERTY, NEAR HIGH POINT, WALKER COUNTY, GEORGIA.

old furnace. Considerable ore was mined at this point some years ago. The works, consisting of open cuts, are now well filled with earth, and but little ore is to be seen *in situ*. The main bed of ore, which is here about 30 inches thick, occurs in two parallel lines of outcroppings, due to a synclinal fold. Just below the main ore bed on both sides of the hill is to be seen an exposure of the so-called "sand vein," which attains a thickness of several feet. It runs low in iron and may be described as a highly arenaceous, ferruginous limestone. The main seam of ore dips to the west and is quite favorably located for working. Near the eastern base of the ridge above referred to and near Lookout Creek, is to be seen the same seam which has been worked on the ridge. The ore at this point dips at a high angle towards the east.

Lot 35, 18th District.—the ore after traversing lot 22 continues to the southwest through lot 35. Exposures of ore are to be seen at several places on this lot. They are confined mainly to the east side of the ridge, but they are also to be seen on the west side. On the east slope of the ridge the ore dips in a westerly direction, while on the west side it dips in the opposite direction. This shows the hill to be a synclinal fold. The top of this iron-bearing ridge, as well as the one on lot 22, is capped with Fort Payne chert. The ridges are noted for their precipitous slopes and sharp tops. They vary in height from 250 to 300 feet above Lookout Creek, which flows at its eastern base. The ore on lot 35 and also on 36, is mainly hard. The seam is usually about 3 feet in thickness. The "sand vein" probably also occurs on this lot; however, no outcroppings were noticed.

Lot 37, 18th District.—Iron ore outcrops on this lot along Tadpole Branch and Crawfish Creek, and also along the western side of the Fort Payne chert hill, which lies between these streams. With the exception of a few tons of soft ore mined on this lot prior to the Civil War, no work has been done. The ore here as on the two lots further to the north, occur in a synclinal fold and as a result present two parallel lines of outcroppings. The thickness of the ore which is principally hard ore, is about three feet. It is favorably located for working.

OTHER LOTS.—In addition to the lots here described, the Phœnix Iron and Coal Company owns several lots on the west side of Lookout Valley which have more or less iron on them. The principal lots in this group are lots 10, 18, and 23, all of the 18th district. The ore on these lots has never been prospected, and is only to be seen in the natural outcroppings. The ore on this side of the valley is mainly hard, and is exposed chiefly along the sides of the hill and in the ravines. The main seam of ore is usually divided near its center by a thin parting of shale, rarely more than three or four inches in thickness. The total thickness of the ore averages about thirty inches. The dip is to the westward at an angle varying from 10° to 15°. Besides the main bed here described, there is often to be seen in places two other small beds, neither of which, however, appears to be of sufficient thickness to be of economic importance. There also occurs in places about fifty feet below the main ore bed, a rather heavy-bedded, ferruginous, sandy limestone which weathers into a fair iron ore. The ore on these lots contains considerable lime, and would not probably average more than 35 per cent. metallic iron. The location of the outcroppings on the side of the ridges and the hills, 100 feet or more above stream level, is quite favorable for economic mining.

THE NEW ENGLAND COMPANY

The New England Company's property consists of about 16,000 acres of land located chiefly in the 10th, 18th and 19th districts of Dade county. Much of these lands lies in Lookout Valley and contains valuable deposits of fossil iron ore. It is claimed by the company that they own in fee simple and in mineral rights sixty land lots, 160 acres each, in Lookout Valley, all of which have more or less fossil iron.

The New England Company, which consists chiefly of Eastern capitalists, with ex-Governor Roswell Farnaham, of Vermont, president, was organized about twenty years ago with a view of carrying on extensive mining and manufacturing industries in Dade county. Among the various industries contemplated were smelting furnaces, rolling mills and a coking plant. There was also planned and laid out a model manufacturing town covering an area of several hundred acres. With the exception of a three-story, modern hotel and a few other buildings, all of which are now more or less out of repair, but little has been done toward the development of the property since the organization of the company. Prior to the purchase of this property by the New England Company, the fossil iron ore seemed to have attracted considerable attention. The locality was visited by Prof. James Hall, late State Geologist of New York, in 1866, and later by C. H. Hitchcock, State Geologist of New Hampshire. The reports of both of these eminent geologists, as well as other geologists of less eminence, all speak in high terms of the property. Some of the reports appear to be somewhat misleading in regard to the extent of the ore and the iron contents; nevertheless, there can be no doubt but that the company owns a valuable iron ore property, a detailed description of which is here given by lots:

Lot 5, Eighteenth District.—The western line of fossil iron ore outcroppings traverses this lot, and is to be seen at several places along the sides of the knobby hills lying west of the Trenton-Rising Fawn public road. At places along the hillside occur many open cuts from which ore was mined some years ago. The workings appear to be confined chiefly to the surface, and only the soft ore was mined. The ore consists of one main seam with an average thickness of three feet. The dip is to the northwest at an angle of about 20°. On the roadside, some 300 yards east of these old workings, and only a short distance from an exposure of the upper beds of the Chickamauga limestone, occurs a highly ferruginous sandy limestone, carrying a high percentage of iron. The bed is several feet in thickness, and when weathered forms a brown, spongy, siliceous mass, in which are seen numerous rounded grains of sand cemented by dark-brown iron oxide. This material forms a rather impure ore, but apparently too low in iron to be of commercial value. The location of the main bed, 150 feet or more above the valley, is quite favorable for economic working. The position usually renders the mines self-draining, and at the same time makes the underground haul largely down grade.

LOT 8, EIGHTEENTH DISTRICT.—This lot is located on the east side of Lookout Valley, only a short distance west of Lookout Creek. The ore is confined chiefly to a rather prominent ridge which lies between the Trenton-Rising Fawn public road and the Alabama Great Southern Railroad. The ridge rises to an elevation of about 300 feet above the valley. Its slopes are steep and covered with a heavy growth of virgin trees. The main seam of ore to be seen on this lot corresponds to the ferruginous arenaceous bed referred to on lot 5. This impure ore here has a thickness varying from five to six feet. It is to be seen on both sides of the hill. On the west side it dips to the east at an angle of about 15°, and on the east side it dips to the west at an angle of 30°. It will thus be seen that the ore occurs in an unsymmetrical synclinal fold, with the steeper pitching limb to the east. The bed carrying the higher grade of iron ore does not appear to occur on this lot. As this bed naturally lies many feet above the bed of impure iron it has probably been entirely removed by erosion, and is therefore not likely to be found at all on the ridge.

LOT 37, ELEVENTH DISTRICT.—Iron ore has been worked on this lot along the side of a hill a short distance east of the Alabama Great Southern Railroad. Judging from the character of the old workings, there are two beds here, varying from two to three feet in thickness and about five feet apart. The old workings, which extend for nearly a half of a mile, consist of open cuts from five to ten feet deep. The ore mined here was chiefly shipped to Chattanooga, but it is said that a considerable amount of it was also used at Urrups forge, a small bloomary or Catalan furnace operated in the early forties on Lookout Creek, only a short distance from where the ore was mined.

LOT 251, TENTH DISTRICT.—This lot, formerly owned by the Cherokee Iron Works, is located on the west side of Lookout Valley, about one mile north of Trenton. The ore on this lot was worked to a considerable extent shortly after the Civil War, and supplied a great part of the ore used in the Cherokee furnace, which was located on the east side of the Alabama Great Southern Railroad, one mile north of Trenton, and about half a mile east of the western line of ore outcroppings. The furnace here referred to was built by Dr. J. H. McLean, of Louisville, and Mr. Brown, of Philadelphia, in 1865. It was constructed for a forty-ton furnace, but is said to have never been very successful. Only one bed of ore is exposed on this lot. It is about thirty inches in thickness, and divided near the center by a thin parting of shale. The dip is 30° to the northwest. The only ore exposed to view at the time of the writer's visit was soft ore, an analysis of which made by Dr. Edgar Everhart, Chemist of the Geological Survey, is here given:

Hygroscopic water	0.43
Combined water	3.01
Ferrous oxide	none
Ferric oxide	77.04
Alumina	5.21
Manganous oxide	0.69
Lime	1.02
Magnesia	0.47
Silica	11.85
Sulphur	0.04
Phosphorus pentoxide	0.62
Carbon dioxide	none
Total	100.38
Metallic iron	53.93
Phosphorus	0.27

The sample of ore from which the above analysis was made was highly oölitic.

Lot 212, Tenth District.—This lot lies directly east of New England City, and is traversed by the eastern line of fossil iron ore outcroppings, which has been extensively worked. The old excavations, which consist of open cuts and considerable underground work, now largely filled with fallen earth, are to be seen along the western side of a series of Fort Payne chert hills. The workings beginning on this lot extend in an almost unbroken line to the northeast for about three and a half miles. To the southwest of lot 212 there occur no workings of any importance, due chiefly to the ore being deeply buried beneath the residual and alluvial material which in places has accumulated to a depth of ten feet or more. At a point near the southeastern corner of this lot where the ore is to be seen in an old tunnel, it attains a thickness of about thirty-five inches, and dips at a rather high angle to the east. The greater part of the ore remaining on the lot is hard, the soft ore having been largely mined out some years ago.

LOT 186, TENTH DISTRICT.—The fossil iron ore, after traversing lot 212, continues to the northeast through lot 186. The character of the old workings here consisting of tunnels from 25 to 100 feet in length, and open cuts five or more feet in depth, is quite similar to those on lot 212. The ore averages about three feet in thickness, and has a general dip to the southeast at an angle varying from 15° to 25°. At two different points on the lot the ore occurs in small synclinal folds. In the vicinity of the axes of these folds the ore is nearly always thicker than it is along the limbs of the fold. At one point it is said that the ore along the axis of one of the synclines attained a maximum thickness of nine feet. These abnormal thickenings, however, are usually quite local and augment but little if any the aggregate ore contents of the bed as a whole. Where these enlargements occur there is generally a corresponding thinning of the ore along the limbs of the synclines in the immediate vicinity of the axis, so that in reality there is no actual increase in the amount of ore in the bed, but only a shifting of the ore from one point to another. The main bed of ore on this lot is divided near the center by a parting of shale about eighteen inches in thickness. In addition to this main ore bed there is also to be seen in the old workings at many points a few feet above the workable bed, a thin layer of ferruginous, fossiliferous limestone too low in iron, however, for furnace use. The greater part of the workings on this lot as well as the workings on the adjoining lots, is said to have been done in 1885-86-87.

LOTS 173 AND 174, 10TH DISTRICT.—These lots lie northeast of lot 186, and are both traversed by the eastern line of fossil iron ore outcroppings. On lot 173 are to be seen old workings. At one point the ore measured 3 feet in thickness. It seemed to be of a good quality, and dipped to the east at an angle of about 25°.

LOT 152, 10TH DISTRICT.—This lot is also traversed by the fossil iron ore outcroppings and several exposures of the bed are to be seen along the side of the hills. At one of these exposures where the bed measures about 3 feet in thickness, a sample of ore was taken from which the following analysis was made by Dr. Edgar Everhart, Chemist of the Geological Survey:

Hygroscopic water	0.45
Combined water	0.90
Ferrous oxide	0.90
Ferric oxide	56.53
Alumina	4.16
Manganous oxide	0.52
Lime	16.76
Magnesia	0.55
Silica	7.93
Sulphur	trace
Phosphorus pentoxide	0.79
Carbon dioxide	12.01
Total	101.50
Metallic iron	40.27
Phosphorus	0.35

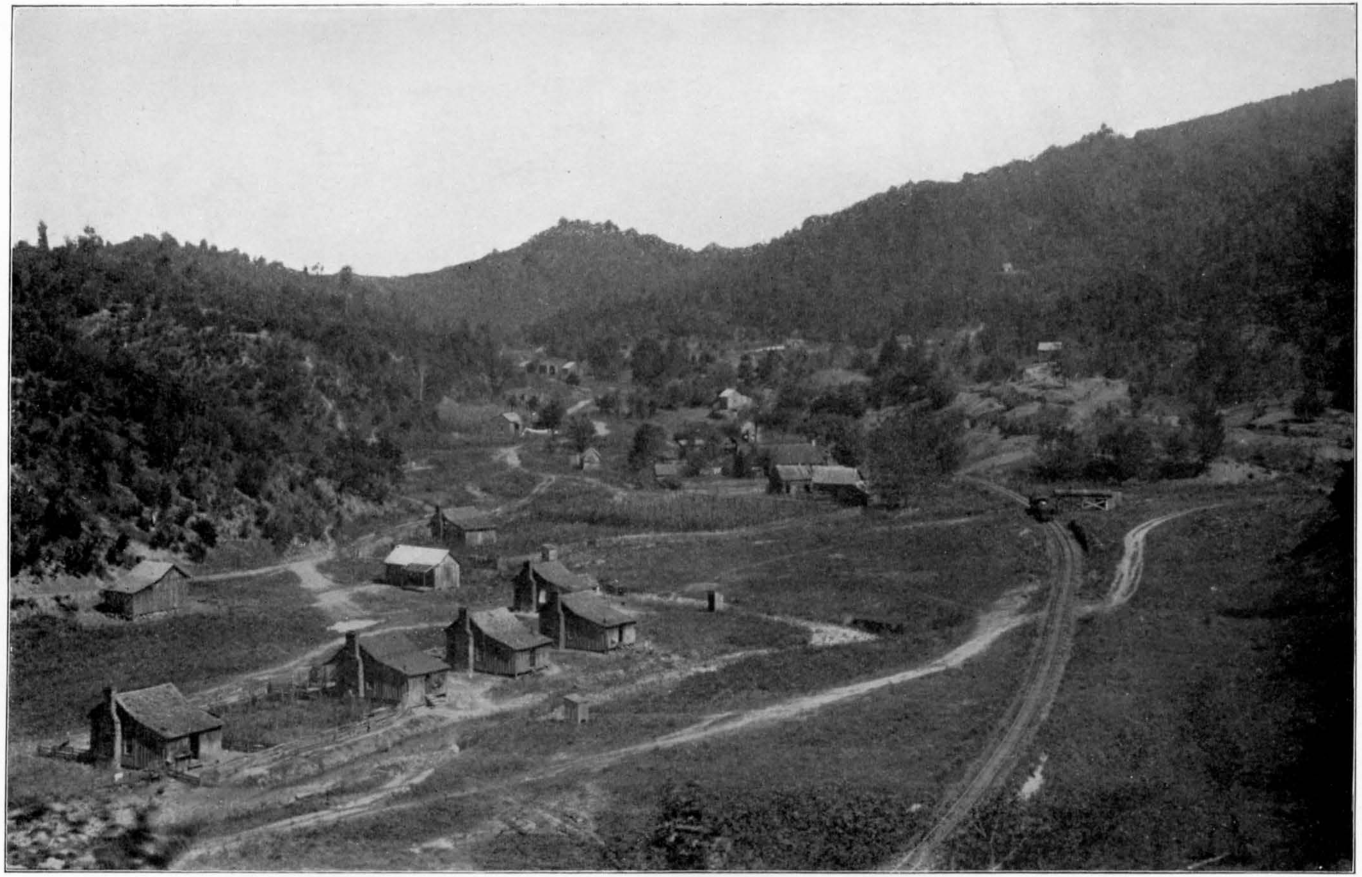
A microscopic examination of this ore shows it to be made up largely of fragments of brachiopod shells, bryozoans and coral, largely replaced by iron oxide, with the intervening spaces filled with calcite. Every pore and cavity of the organic remains appear to be filled with iron oxide; only a few grains of quartz occur in the section.

OTHER LOTS.—Besides the lots above described, the New England Company owns other lots on the east side of Lookout Valley, traversed by the eastern line of ore outcroppings, the most important of which are as follows: 136, 135, 119 and 98, all of the 10th district. The character of the ore on these lots is practically the same as on the lots further to the southwest, though there seem to be secondary beds which in places attain a thickness of 8 inches or more. These smaller beds, which are usually two in number, appear to gradually increase in size to the northeast. An analysis by Dr. Edgar Everhart, Chemist of the Geological Survey, of a sample of ore taken from the main bed on lot 98 is here given:

Hygroscopic water	0.70
Combined water	2.40
Ferrous oxide	1.00
Ferric oxide	48.49
Alumina	1.98
Manganous oxide	0.36
Lime	19.65
Magnesia	1.23
Silica	7.67
Sulphur	0.09
Phosphorus pentoxide	0.36
Carbon dioxide	15.60
Total	99.53
Metallic iron	34.72
Phosphorus	0.57

This is a hard ore, and when examined under the microscope in a thin section it is seen to be made up largely of the rounded fragments of the shells of brachiopods and bryozoans which have been replaced more or less by iron oxide. The spaces between the rounded fragments are filled with calcite. In addition to the altered organic fragments, there also often occur rounded fragments which seem to have undergone but little change, and therefore consist mainly of the original calcium carbonate. No silica in the form of sand is to be seen in the section. The last named lot is the northern terminus of the New England Company's iron ore property on the east side of Lookout Valley. The company, however, owns several lots further to the north on the west side of the valley, some of the most important of which are here described.

LOT 25, 10TH DISTRICT.—This lot lies about one mile west of the Alabama Great Southern Railroad, and one-half mile south of the Georgia State line. It is also within a short distance of the Nashville, Chattanooga and St. Louis Railroad. The fossil iron which



GENERAL VIEW OF ONE OF THE MINING CAMPS AT ESTELLE, WALKER COUNTY, GEORGIA.

traverses this lot is the northern extension of the line of outcroppings beginning in Deerhead Cove. The ore has never been worked on this lot, and there are but few natural exposures where the ore can be seen *in situ*. Southwest of lot 25, ore occurs on lots 48, 81, 101 and 115, all of the 10th district.

LOT 115, 10TH DISTRICT.—This lot is of special interest on account of one of the secondary beds previously referred to, here becoming of economic importance. The lot is located about one half mile west of Morganville, and the ore is to be seen in the old working along the eastern slope of the ridge which faces the valley. The main workings here are along the outcroppings of the secondary bed. This bed, which lies near the base of the Rockwood formation, has a thickness of about 3 feet. It is of a dual nature, being parted near the centre by a thin layer of shale. The upper part of the bed consists of a pure clean semi-soft block ore, while the lower part is a dark red, somewhat earthy, shaley ore. Some 75 feet above this bed, which is here designated the secondary bed in order to distinguish it from the main workable bed, is a second bed. This bed occurs near the center of the Rockwood formation and appears to be the main workable bed throughout Lookout Valley. At this point it has a thickness of about 36 inches; however, it is divided by a layer of shale 8 feet or more in thickness. This thick parting of shale seems to be quite local and appears to thin out to a few inches on the lots both to the northeast and southwest. An analysis by Dr. Edgar Everhart, Chemist of the Geological Survey, of a sample of ore taken from the lower or secondary bed is here given:

Hygroscopic water	0.41
Combined water	1.75
Ferrous oxide	1.70
Ferric oxide	52.16
Alumina	5.22
Manganous oxide	0.21
Lime	15.23
Magnesia	0.06
Silica	10.52
Sulphur	0.06
Phosphorus pentoxide	1.83

Carbon dioxide	11.01
Total	100.16
Metallic iron	37.83
Phosphorus	.798

The ore is highly oölitic. This is especially true of the upper part of the bed.

OTHER LOTS.—Southwest of lot 115, the fossil iron ores continue through lots 114, 128, 129, 149, and 177 of the 10th district. On the last named lot are to be seen old workings from which some 20 or 30 carloads of ore are said to have been taken about 20 years ago. The main fossil ore bed at this point is 30 inches thick. It dips to the west at an angle of about 20 degrees, and is divided near the centre by a thin parting of shale. The ore occurs on a hillside at an elevation of a hundred feet or more above the valley; on the opposite side of this hill is to be seen an outcropping of hard ore. Similar workings to the above occur on lot 149 near the right bank of Squirrel Branch. The ore in these old workings is said to have attained a thickness of 4 feet. The excavations are now all filled with earth and no ore is to be seen *in situ.*

LOT 214, 10TH DISTRICT.—Still further to the southwest, fossil iron ore occurs on lot 214, property of the New England Company. The ore is here exposed on a hillside at an elevation of something like 100 feet above New England City. The main bed of ore which dips to the northwest at an angle of 30°, is 30 inches in thickness, and is divided near its centre by a thin parting of shale. In addition to the main bed there are also two other beds of ore to be seen on this hill-slope, one above the main bed about 20 feet, and the other below about the same distance. The thickness of these smaller beds averages from 6 to 10 inches. The ore after traversing this lot continues southwest through the McLean property and again enters the New England property, lot 251, which has been previously described.

A. MCLEAN'S PROPERTY.—This property, lot 218, 10th district, is located 2½ miles north of Trenton, only a few hundred yards west of the Alabama Great Southern Railroad. The best exposure of ore on the property is to be seen along a small stream a short distance west of the McLean residence. The main ore bed here exposed has a thickness of 3 feet. The ore is hard and dips at an angle of 15°. The bed is divided near the centre by a thin parting of shale. Twenty feet below this bed is a second bed having a thickness of 8 inches. Still further down the stream, about 100 yards, occurs a third bed which is about 5 feet thick. The last named bed is located near the base of the Rockwood formation and appears to be different from the bed generally worked throughout the valley. It probably corresponds to the lower bed described on lot 115, though the ore is not of such a good quality. This, however, is likely due to its still retaining a greater part of its original lime.

THE SUTTON PROPERTY.—The Sutton property, lot 321, 10th district, is located on Lookout Creek, one mile west of Trenton. Fossil iron ore occurs on this property near Sutton's Mill, on the west side of Lookout Creek. Here along the side of a hill is to be seen partially filled open cuts which were made about 20 years ago in mining the ore. None of the ore is now to be seen in place. It is reported that three separate beds were worked here, each having a thickness varying from 10 inches to 2 feet. The ore on top of the hill, which has an elevation of about 30 feet above the creek, dips at a low angle to the southeast, while directly opposite the mill it dips in the opposite direction. After traversing this lot, the ore continues to the northeast through lots 292 and 285. The latter lot, which is owned by Mr. Austin, has been rather extensively worked for ore, but the excavations are so filled with earth that no ore is now in sight.

D. MARTIN'S PROPERTY.—The Martin property, lots 50 and 59, 10th district, is situated on the east side of the Alabama Great Southern Railroad, 1½ miles south of the Georgia-Tennessee line. It is traversed by the eastern line of fossil iron ore outcropping. Some years ago a great deal of ore was mined on this property and used in the manufacture of paint, a mill having been erected on lot 59, for grinding the ore used for this purpose. The old works are now partially filled with fallen earth and the ore is to be seen at only a few points. They are mainly located along the sides of a series of hills lying just east of the Trenton-Chattanooga public road. The bed of ore here has an average thickness of about 30 inches. It dips to the east at angles varying from 10° to 15°. The old workings consisted chiefly of open pits from five to ten feet deep, only the soft ore having been mined. About 50 feet below this bed is a second bed. It is well exposed in the public road near Mr. Martin's residence. At this point it is about three feet thick. The ore is semi-hard and contains considerable clay. It is made up largely of the casts of brachiopods and oölitic particles about the size of flaxseed. Samples of ore were collected from both of these beds, the analyses of which made by Dr. Edgar Everhart, Chemist of the Geological Survey, are here given:

SAMPLE OF ORE FROM UPPER BED

Hygroscopic water	0.62
Combined water	2.01
Ferrous oxide	1.00
Ferric oxide	47.67
Alumina	2.02
Manganous oxide	0.27
Lime	18.39
Magnesia	0.79
Silica	11.85
Sulphur	0.06
Phosphorus pentoxide	0.77
Carbon dioxide	15.06
Total	100.51
Metallic iron	34.05
Phosphorus	0.335

SAMPLE FROM LOWER BED

Hygroscopic water	0.82
Combined water	2.41
Ferrous oxide	0.65
Ferric oxide	44.50
Alumina	5.74
Manganous oxide	0.23
Lime	22.33
Magnesia	0.08
Silica	4.16
Sulphur	trace

Phosphorus pentoxide	0.87
Carbon dioxide	18.00
Total	99.79
Metallic iron	31.66
Phosphorus	0.379

The microscopic section of the ore from the upper bed shows that it consists of a ground mass of calcite, with rounded fragments of brachiopods and bryozoans replaced largely by iron oxide. Some of the iron particles have a greenish nucleus, which is probably glauconite. No grains of sand were noticed in the section.

In addition to the lots here described, there are also other lots further to the north, traversed by the eastern line of ore outcroppings. Among these may be mentioned the Deakins lot, No. 23, the McGill lot, No. 22, and the Fuller lot, No. 15, all of the 10th district.

CHAPTER VII

FOSSIL IRON ORES OF WALKER COUNTY

INTRODUCTORY

The fossil iron ores of Walker county occur along the eastern foothills of Lookout Mountain, along the eastern and western foothills of Pigeon Mountain and along the eastern slope of Taylor's and Dick's ridges. There is also in addition to the localities above named a small V-shaped line of outcroppings traversing the knobby hills west of Chattanooga Valley in the vicinity of the Georgia-Alabama line. The ore along the western foothills of Lookout Mountain begins a short distance southwest of Flintstone and continues southwest with but few breaks to the head of McLamore's Cove; here it changes its course and continues along the western foot hills of Pigeon Mountain to its northern terminus, when it again changes its direction and continues along the eastern foothills of Pigeon Mountain to the Walker-Chattooga line. The total length of this broken line of ore outcroppings aggregates more than fifty miles.

The outcroppings along Taylor's and Dick's ridges are to be seen in the heads of all the hollows on the western side of the latter and the eastern side of the former. This line of outcroppings is practically unbroken, and extends from the Walker-Chattooga line to the Walker-Whitfield line, a distance of twelve miles, while the line of outcroppings west of Chattanooga Valley has a length of about eight miles, thus making the total length of outcroppings of the fossil ore in Walker county more than seventy miles.

DETAILED DESCRIPTION OF INDIVIDUAL PROPERTIES

LOOKOUT MOUNTAIN

MRS. J. T. ALGOOD'S PROPERTY.—The Algood property, lot 144, 9th district, is located about one mile southwest of Flintstone, at the base of Lookout Mountain. The fossil iron ore is to be seen at several points on this lot, but at no place has it been worked. Two or three shallow prospect pits, now partially filled with fallen earth, is the extent of the development work attempted on the property. The ore which has a thickness of twenty inches dips at a high angle to the west. In places the bed is reported to attain a maximum thickness of thirty inches. The ore exposed is soft ore and appears to be of a good quality. The ore on the Algood property appears to be the northern terminus of the line of fossil iron ore outcroppings extending along the eastern slope of Lookout Mountain, the disappearance of the ore at this point being due to a fault.

THE STONER-CALDWELL PROPERTY.—The Stoner-Caldwell property, lot 45, 9th district, the mineral interest of which is owned by the Chickamauga Iron Company, is located immediately south and adjoins the Algood property above described. This lot as well as lot 180, known as the Hickson lot, and also lots 181 and 219, the mineral interest of which belongs to the Chickamauga Iron Company, all lying in the same tier of lots further to the south, are traversed by iron ore outcroppings, but no working or prospecting of importance has been done on any of the lots. Judging from what was seen in the natural exposures, the character of the bed of iron ore on these lots is practically the same as on lot 44, where it varies from twenty to thirty inches in thickness, and has a high dip to the westward.

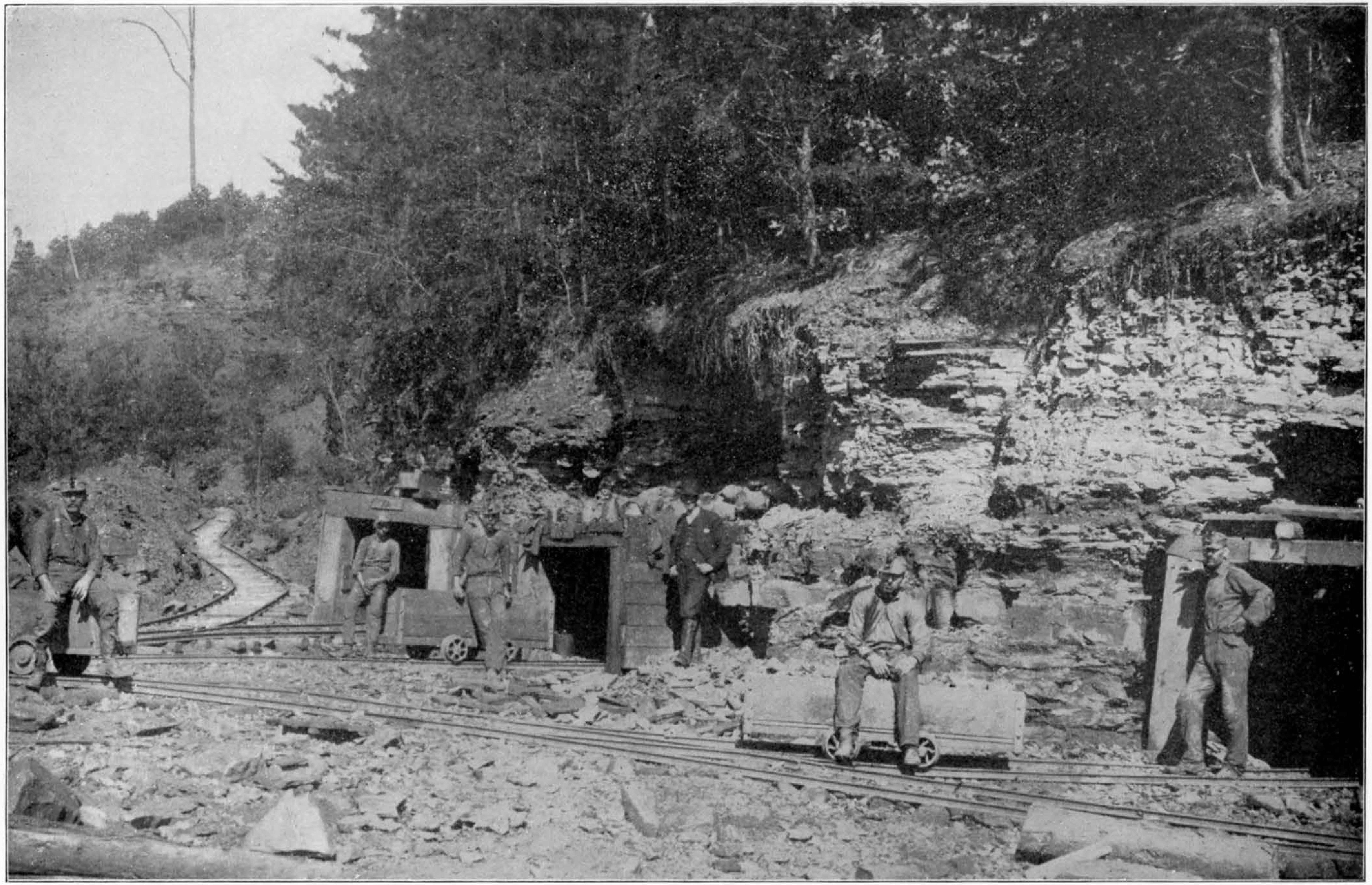
THE WEST PROPERTY.—This property, lot 199, 10th district, is intersected by the Central of Georgia Railway, about one mile west of where it crosses the Chattanooga Southern Railway. The mineral interest of the lot is owned by the Chickamauga Iron Company. During the time of the writer's visit to the West property the ore was being mined and shipped to Chattanooga. Up to that date it was estimated that 5,000 tons of ore had been mined. The output then being about six cars of twenty-five tons each per week. The greater part of the ore mined consisted of soft ore, less than one-fifth being hard. The method of mining adopted in raising the ore is usually by stripping or by open cuts; though at some points where the ore dips at a high angle, underground work is also successfully carried on. The ore which occurs only in one workable bed has a thickness varying from thirty to thirty-two inches. The character of the ore is shown by the following analysis, made by Dr. Edgar Everhart, Chemist of the Geological Survey:

Hygroscopic water	0.67
Combined water	0.83
Ferrous oxide	0.56
Ferric oxide	65.63
Manganous oxide	0.98
Alumina	0.20
Lime	11.56
Magnesia	0.92
Silica	9.07
Sulphur	0.11
Phosphorus pentoxide	0.97
Carbon dioxide	9.04
Total	100.54
Metallic iron	46.37
Phosphorus	0.423

This is an oölitic soft ore quite free from clay.

Lot 162 Tenth District.—Fossil iron ore occurs on lot 162, 10th district, which lies immediately west of lot 145, 9th district above described as the Stoner-Caldwell property. After traversing this lot, the ore continues to the south through lot 198, also of the 10th district. The mineral interests of these lots are owned by the Chickamauga Iron Company. No mining of any importance has been done on either of the lots. They are both located north of the Central of Georgia Railway, among the knobby hills at the base of Lookout Mountain.

Moses Long's Property.—The Long lot, No. 234, 10th district, is located directly south of the West property. During the time of



A VIEW OF THE UNDERGROUND WORKINGS, KENSINGTON IRON AND COAL COMPANY'S PROPERTY, NEAR ESTELLE, WALKER COUNTY, GEORGIA.

the writer's visit to this property in 1900 about forty hands were engaged in mining fossil iron ore and from two to three cars of ore were shipped daily to the Chattanooga furnaces. The workable bed of ore which varies from two and a third to three feet in thickness, is often faulted and appears at the outcroppings as two separate beds. In places the fault is to be seen to pass into a close pressed fold. The faulting or the folding of the strata is quite general throughout the lot, but the individual faults and folds are usually limited to a few hundred yards in length; on account of this crumpled like condition of the strata, the ore dips at all angles, varying from horizontal to perpendicular. At some points the small anticlinals are overturned and the dip is thus reversed. In addition to the main workable bed of ore, there are also to be seen at some of the old workings two other beds which vary from six to eight inches in thickness.

The ore is largely mined by open cuts and strippings, but at some points considerable underground work has also been done. The greater part of the ore mined on this lot is soft ore, and it runs high in metallic iron, as shown by the following analysis by Dr. Edgar Everhart, Chemist of the Geological Survey of Georgia:

Hygroscopic water	0.40
Combined water	2.02
Ferrous oxide	none
Ferric oxide	77.70
Alumina	5.61
Manganous oxide	0.48
Lime	2.34
Magnesia	0.08
Silica	10.41
Sulphur	trace
Phosphorus pentoxide	1.65
Carbon dioxide	none
Total	100.69
Metallic iron	54.39
Phosphorus	0.729

This ore is a clean, well-leached, porous, soft ore, made up largely of oölitic grains and casts of crinoid stems.

LOT 235, TENTH DISTRICT.—This lot, which is owned by the Dayton Iron and Coal Company, of Dayton, Tenn., joins the Long lot, No. 234, on the south. About twenty years ago several hundred cars of ore were mined on this lot and shipped to Dayton, Tenn. The old works which are now partially filled with fallen earth, were originally connected with the Chattanooga Southern Railway by a branch road about half a mile in length. The ore varies from two to three feet in thickness and usually dips at a high angle to the west.

THE WISDOM PROPERTY.—This lot, 270, 10th district, known as the Wisdom heirs' property, is located directly south of and adjoining the Dayton property above described, on the north. The mineral interest in the lot is said to belong to the Chickamauga Iron Company. At the time the property was visited considerable ore was being mined and shipped to Chattanooga, where it was reported to be ground and used for paint. The main bed of ore where exposed has an average thickness of about thirty inches and dips at an angle varying from 5° to 90°. A short distance above the main workable bed are to be seen in places two other smaller beds varying from two to eight inches in thickness.

FRANK COSTELLO'S PROPERTY.—The Costello property, lot 271, 10th district, lies directly south of the Wisdom property. At the points where the ore was examined on this lot, the bed stands almost upright. It has a thickness of about twenty-four inches. The ore is chiefly hard, though at some points soft ore occurs to a depth of six or eight feet. At the time of the writer's visit the ore was being mined at two points on the opposite side of a sharp, steep hill. The workings consisted of both open cuts and tunnels. The underground workings are self-draining to a depth of fifty feet or more, due to the ore outcroppings being cut at irregular intervals by deep hollows which form natural drain ways. An analysis of a sample of the ore from one of the recent excavations on this lot made by Dr. Edgar Everhart, Chemist of the Geological Survey of Georgia, is here given:

Hygroscopic water	0.40
Combined water	.34
Ferrous oxide	.22

Ferric oxide	68.02
Alumina	3.84
Manganous oxide	.28
Lime	10.21
Magnesia	.58
Silica	6.84
Sulphur	.33
Phosphorus pentoxide	1.32
Carbon dioxide	7.40
Total	99.78
Metallic iron	47.78
Phosphorus	0.58

The sample of ore from which the above analysis was made was obtained about fifteen feet below the surface, and is known as hard ore. The sample is supposed to be about an average of the hard ore which was then being mined on the property.

THE PARRISH PROPERTY.—R. M. Parrish's lot, 306, 10th district, the mineral interest of which is owned by the E. W. Marsh estate, joins the Costello lot on the south. A limited amount of work was done on this lot some years ago, but the excavations are now well filled with earth and no ore is to be seen *in situ*. Judging from the hilly nature of the surface, the ore can be economically mined as the underground workings would be largely self-draining to a depth of fifty feet or more.

M. M. PHILLIPS' PROPERTY.—Lot 308, 10th district, lies southwest of and corners with lot 306. It is located about one mile west of the Chattanooga Southern Railway. About 2,500 tons of ore are said to have been mined on this lot prior to 1890. The ore averages about thirty-four inches in thickness, and in places occurs in three different lines of outcroppings. It has been supposed by some that these three different lines of outcroppings were separate beds. A study of the geological structure of the associated rocks, however, shows the three different lines of outcroppings are one and the same bed brought to the surface along two or more lines by folding or faulting. The following analysis by Dr. Edgar Everhart, Chemist of the Geological Survey, shows the character of the soft ore which has been extensively mined on the Phillips lot, the mineral interest of which is owned by the Chickamauga Iron Company:

Hygroscopic water	0.58
Combined water	3.20
Ferrous oxide	0.10
Ferric oxide	79.37
Alumina	2.30
Manganous oxide	0.56
Lime	3.00
Magnesia	0.08
Silica	10.82
Sulphur	0.12
Phosphorus pentoxide	0.65
Carbon dioxide	none
Total	100.78
Metallic iron	55.64
Phosphorus	0.283

THE PATTERSON AND WILSON PROPERTIES.—These properties, lots 15 and 16, 10th district, join the Phillips property on the southwest. The ore has been worked on both lots to a limited extent. It is of good quality and favorably located for working. The mineral interest of these lots is said to be owned by the E. W. Marsh estate.

THE PARTAIN PROPERTY.—This lot, 21, 11th district, known as the Partain property, is owned jointly by the E. W. Marsh estate, Frank Costello and L. Partain. The greater part of the lot belongs to the Marsh estate, however, the main workings are located on the part owned by Costello and Partain. The ore lies nearly horizontal on the Costello part of the lot, but on the other portion it dips at various angles, often becoming nearly perpendicular. In addition to the main bed which has been worked, there are also two or more small beds to be seen at various points on the lot. Two of these smaller beds lie above the workable bed and one or two below. They are all small, and appear to be of little economic importance. The workable bed has a thickness of about three feet. The greater part of the ore mined on the property has been soft ore, and is of an excellent quality, as shown by the following analysis made by Dr. Edgar Everhart, Chemist of the Geological Survey of Georgia:

Hygroscopic water	0.50
Combined water	2.00
Ferrous oxide	none
Ferric oxide	84.17
Alumina	3.60
Manganous oxide	0.51
Lime	0.89
Magnesia	0.47
Silica	7.13
Sulphur	0.14
Phosphorus pentoxide	1.09
Carbon dioxide	none
Total	100.50
Metallic iron	58.92
Phosphorus	0.475

J. M. Henry's Property.—This property, which consists of two lots, viz., Nos. 20 and 52, 11th district, joins the Partain property just described on the east and south. Both lots are traversed by fossil iron ore outcroppings, but no ore has been mined. The mineral interest of the property is said to be owned by the Chickamauga Iron Company. As no exposure of the ore was to be seen on the lots, nothing can be definitely said as to the thickness of the bed.

South of the Henry property the lead of iron ore outcroppings continues through lots 87 and 88, but on neither of these lots has the ore been worked. Still further to the southwest the ore continues through G. W. Shaw's property, lot 95. The mineral interest in the last three lots here named are reported to be owned by the E. W. Marsh estate.

W. A. Bloom's Property.—The Bloom property, lot 122, 11th district, the mineral interest of which is owned by the Chickamauga Iron Company, is located directly south of lot 95. The lot has several prospect pits on it, but no ore of any consequence has been mined. The ore where exposed has a thickness varying from two to three feet, and dips to the west at an angle of about 20°. The exposures which occur chiefly along the hill slopes, consist mainly of soft ore of a good quality. Beyond the Bloom property the outcroppings of the fossil iron ore continue to the southwest through lots 131 and 157. The former lot is owned by G. B. Baker and the latter by J. P.

Finley. Both of these lots have been prospected to a limited extent, but no ore has been mined.

J. D. STEPHENS' LOT.—This lot, No. 168, 11th district, joins the Finley lot on the south. The soft ore on this lot has been worked along its outcroppings for an average depth of about seven feet. Mr. Stephens reports the ore to vary from two to three feet, but at the points examined by the writer the maximum thickness of the main workable bed did not exceed thirty inches. The dip is to the west, usually at a high angle. Above and below the main workable bed are often to be seen other beds, but they rarely ever attain a thickness of more than a few inches, and are therefore of no economic importance. The mineral interest of the Stephens lot is owned by the E. W. Marsh estate.

THOMAS COULTER'S LOT 193, 11TH DISTRICT, lies immediately south of the Stephens lot. It has been worked to a considerable extent. The main part of the work was done some ten or twelve years ago by Mr. Stephens, and the old excavations which consisted of open cuts from five to ten feet deep, are all now partially filled with earth. Here, as on the Stephens lot, only the soft ore was mined. The workings are located chiefly along the hill slopes fifty feet or more above the general stream level. After traversing this lot the ore occurs again on lots 204 and 229 further to the southeast. The mineral interest in the last two lots belongs to the E. W. Marsh estate. With the exception of a few test pits, no work has been done on either of these lots.

J. C. MORGAN'S PROPERTY.—This property, lots 228 and 241, 11th district, has been prospected at several points, and shows a good quality of ore. The dips are to the west at angles of about 45°. The ore outcrops along the sides and near the summits of the hills, and is, therefore, well located for working. The mineral interest of the Morgan property is owned by the E. W. Marsh estate, which also owns the mineral interest in the J. M. Mathis lot, 299, the F. L. Ball lot, 314, and the A. Andrews lot, 335, all of the 11th district, and lying farther to the south along the line of fossil iron ore outcroppings.

THE ANDREWS PROPERTY.—The Andrews property, lot 181, 12th district, is located along the northern margin of the 12th district about one-quarter of a mile west of Cedar Grove. The mineral interest in the lot is said to be owned by the E. W. Marsh estate. The ore seems to be much folded, and in places it stands almost perpendicular. At the time of the writer's visit, with the exception of a few old prospect pits, which were then partially filled with fallen earth, no work had been done on the lot toward exposing the ore. Fossil iron ore is also reported on Thomas Roland's lot, No. 180, lying immediately west of the Andrews lot, but as this last was not visited, nothing can be said as to the character of the ore and the size of the ore bed.

SOUTH OF CEDAR GROVE the fossil iron ore forms an almost continuous line of outcroppings along the foothills of Lookout Mountain to the head of McLamore's Cove. The names of some of the principal property-owners along this line of outcroppings, together with the number of lots owned by each, are here given: John S. Ball, lot 179; Minda Hatfield, lot 147; Jas. Henson, lot 148; A. Hunt, lot 140; R. W. Jackson, lot 139; Millican and Looney, lot 138; Owens and Millican, lot 137; O. Thurman, lot 136; Mrs. Lizzie Henson, lot 135. But little prospecting for ore has been done on any of these lots and no ore is to be seen except in the natural exposures. The character of the ore here appears to be pretty much the same as on the lots further to the north, only it usually carries more silica, which is largely in the form of water-worn grains of sand. An analysis of a sample of the ore from Mrs. Lizzie Henson's lot, made by Dr. Edgar Everhart, Chemist to the Geological Survey, is here given:

Hygroscopic water	0.32
Combined water	2.22
Ferrous oxide	1.25
Ferric oxide	41.38
Alumina	11.57
Manganous oxide	0.42
Lime	3.63
Magnesia	1.89
Silica	32.68
Sulphur	0.12

Phosphorus pentoxide	0.60
Carbon dioxide	3.60
Total	99.68
Metallic iron	29.94
Phosphorus	0.261

PIGEON MOUNTAIN

A short distance south of the Henson property above referred to, the line of fossil iron ore outcroppings changes its course and continues in a northeasterly direction along the western foothills of Pigeon Mountain to its northern terminus, a distance of about ten miles. This line of outcroppings traverses several lots near the head of McLamore's Cove, but at only a few points is the ore exposed to view. One of the southernmost exposures occurring on this line of outcroppings examined by the writer is the Evitt property here described:

EDMUND EVITT'S PROPERTY.—This property, lot 220, 12th district, is located about one and a half miles southeast of Cedar Grove, on one of the tributaries of West Chickamauga Creek. There appears to be considerable fossil ore on the property, but at only two or three points has it been prospected. One of these excavations shows the following section:

1	Shale	——
2	Ore	2 feet
3	Shale	4 "
4	Ore	10 inches
5	Shale	——

The ore at this point dips to the east at an angle of about 20°. The exposures occur along a hillside, a location favorable for economic mining.

THE KENSINGTON IRON & COAL COMPANY'S PROPERTY

This property, which is now under lease to the Southern Steel Company, has been more extensively worked than any fossil iron ore property in the State. It is located on both sides of the Chatta-

THE DOUBLE TIPPLE, KENSINGTON IRON AND COAL COMPANY'S PROPERTY, NEAR ESTELLE, WALKER COUNTY, GEORGIA.

nooga Southern Railway in the immediate vicinity of Estelle and comprises lots 220, 249, 254, 255, 287, 288 and 289 of the 8th district, and lots 289, 307 and 341 of the 11th district. The main workings on this property are along the foothills of Pigeon Mountain on its western side, in what is known as McLamore's Cove. The surface of this part of the cove is quite irregular, being made up of ridges and knobs often attaining an elevation of something like 300 feet above the general stream level. The main chain of hills runs parallel with Pigeon Mountain, at right angles to which are numerous hollows in which the ore has been chiefly worked. The chief ore outcrops occur on the east side of the main parallel ridges and also along the adjacent side of the hollows furrowing these ridges. It dips usually at a low angle to the east, and as a result is often exposed along the side of the hills for some distance. Much of the ore is mined by stripping, but where the overburden attains a thickness of 12 feet or more underground mining is resorted to. The greater part of the ore mined on this property has been chiefly soft ore, which frequently extends to several feet beneath the surface. The main ore bed, which continues throughout the property, has a thickness varying from 30 to 40 inches. In addition to the main workable bed there are two other smaller beds at higher levels. One of these beds, which is found at about 20 feet above the main bed, has a thickness of something like 20 inches and always carries an excellent quality of ore. In a number of places it has been successfully worked where the overburden is limited to a few feet in thickness. The other bed is located 10 or 15 feet above the bed here described and attains a thickness varying from 6 to 10 inches. The latter bed, on account of its limited thickness, has been worked only at a few points. Still above the last named bed occur two other small beds, but neither of them seems to attain a sufficient thickness at any point to be of commercial importance.

Some idea of the rocks associated with the iron ore on this property may be had from the following section, which occurs at the old workings on lot 342, 12th district:

FIG. I.

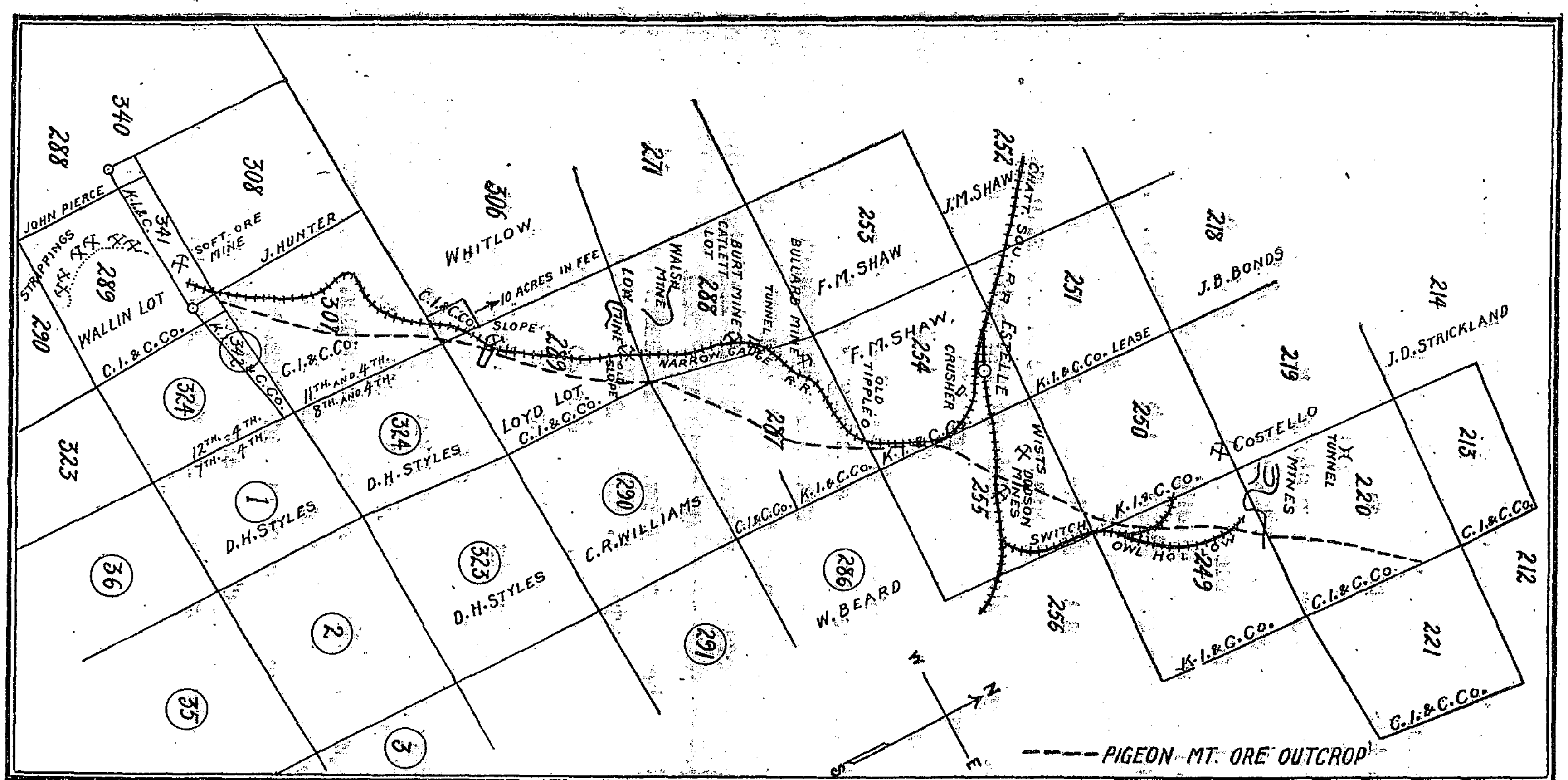


FIG. I.—Land lot map showing the iron ore workings on the property of the Kensington Iron and Coal Company and the land lots owned by the Estelle Mining Company, the latter being indicated thus O. C. I &C Co. lots formerly under the control of the Chattanooga Iron and Coal Co. and subsequently taken over by the Southern Steel Company.

1	Soft ore	30	inches
2	Sandstone	14	"
3	Shale	8	"
4	Sandstone	2	"
5	Shale	2	"
6	Sandstone	5	"
7	Shale	8	"
8	Sandstone	4	"
9	Shale	15	"
10	Sandstone	2	"
11	Shale	2	feet
12	Soft ore (marker)	2	inches
13	Shale	18	"
14	Sandstone	6	"
15	Shale	3	feet
16	Sandstone	7	"
17	Ore	16	inches

Another exposure located on lot 307, 12th district, about 200 yards from the above, gives the following section:

1	Ore	30	inches
2	Sandstone	2	feet
3	Shale	18	inches
4	Ore (marker)	5	"
5	Shale	12	"
6	Sandstone	—	

The character of the ore is shown by the following analyses, made by Dr. Edgar Everhart, Chemist of the Geological Survey of Georgia:

	I	II	III	IV	V
Hygroscopic water	0.19	0.51	0.90	0.16	0.32
Combined water	1.70	2.77	1.89	3.56	1.96
Ferrous oxide	3.15	.07	.07	1.94	1.34
Ferric oxide	42.47	77.66	76.81	51.91	53.40
Alumina	5.45	5.33	4.66	5.98	11.89
Manganous oxide	.29	.22	.27	.22	.08
Lime	22.70	1.25	2.33	16.82	14.89
Magnesia	.59	.33	.16	.05	.16
Soda	.01	.06	.16	.16	trace
Potash	.47	.34	.73	.16	.38
Titanium dioxide	.18	.18	.12	.12	.12
Sulphur	.02	.01	.02	.04	.01
Phosphorus pentoxide	.96	1.65	1.71	1.08	1.28

Silica	7.00	9.32	9.63	5.18	6.41
Carbon dioxide	15.20	......	......	12.34	8.42
Total	100.38	99.70	99.46	99.72	100.66
Metallic iron	32.18	54.42	53.83	37.85	38.42
Phosphorus	.42	.72	.74	.48	.56

Number I is hard ore from lower bed just east of the Chattanooga Southern Railway.

Number II is soft ore from upper bed near tunnel No. 3.

Number III is soft ore from lower bed west of the Chattanooga Southern Railway.

Number IV is hard ore from lower bed, about 25 inches thick, near third tipple.

Number V is hard ore from lower bed, 31 inches thick, near tipple, on the Chattanooga Southern Railway.

The Southern Steel Company, the lessees of the Kensington Iron & Coal Company property, after carrying on successful mining operations for about three years, suspended operations in November of last year on account of depression in the iron industry.

It is estimated that the Southern Steel Company has $150,000 invested in equipment—railway, cars, houses, etc. A large crusher for hard ore, having a capacity of 25 cars of ore per day, has been constructed near the station at Estelle at a cost of about $30,000.

ESTELLE MINING COMPANY.[1]—The Estelle Mining Company owns the following lots along the west side of Pigeon Mountain:

8th district, 4th section	7th district, 4th section
Lots 285	Lots 1
286	2
290	3
291	35
323	36
324	37
	71
	72

Also fractional lot 342, 11th district, 4th section, lot 324, 12th district, 4th section, and 80 acres in lot 254.

[1] Notes by Mr. Otto Veatch, Assistant State Geologist.

The ore on this company's property is almost entirely hard ore. The ore dips into Pigeon Mountain at 8° to 12°, and without much question extends entirely under the mountain and appears again on the Bronco side. It is proposed to mine the ore by sinking slopes from the outcrop and then driving entries. A slope was sunk into Pigeon Mountain on lot 289 (see map for location) a distance of 146 feet from the ore outcrop. The hard ore at the head of this slope is reported 36 inches in thickness, shale parting absent, and to have been of exceptional quality.

The property of this company is accessible to railway transportation and is altogether of much promise.

Mrs. Johnson's Property.—Fossil iron ore occurs on this property, lot 211, 8th district, in what is known as Catlett Gap, two and a half miles northeast of Estelle. The main bed of ore here appears to be broken up into three or four small seams separated by layers of shale. The dip is at a low angle to the east. No attempt has been made to prospect the property, so that nothing can be said as to the economic importance of the ore.

THE GLENN-WARTHEN PROPERTY

The Glenn-Warthen property, comprising a large area of land in the 8th district, is located among the knobby hills which constitute the northern terminus of Pigeon Mountain. There appears to be two or three beds of iron ore on this property, varying from two to four feet or more in thickness. As a general rule, however, the beds, where they attain their maximum thickness, usually run high in lime and correspondingly low in iron. No ore of any consequence has been mined on the Glenn-Warthen property; nevertheless, there has been more or less prospecting on all of the lots, so that a pretty fair idea may be had of the extent and character of the ore. A somewhat detailed description of some of the principal excavations on each lot is here given.

Lot 115, which is the most northeastern lot of the property, is said to have three or four excavations on it exposing the ore, but only two of these were visited by the writer. One of these excavations, which exposes what is known as the upper bed, is located near the top of a hill and shows the following section:

1	Shale	——
2	Soft ore	12 inches
3	Shale	3 "
4	Sandstone	2 "
5	Soft ore	10 "
6	Sandstone	2 "
7	Shale	6 "
8	Soft ore	12 "
9	Shale	——

The ore here lies nearly horizontal and at an altitude between 200 and 300 feet above the valley of Crawfish Creek—a short distance to the west. The chemical composition of the ore is shown by the following analysis made by Dr. Edgar Everhart, Chemist to the Geological Survey of Georgia:

Hygroscopic water	0.30
Combined water	3.29
Ferrous oxide	none
Ferric oxide	76.50
Alumina	5.68
Manganous oxide	0.30
Lime	0.28
Magnesia	0.24
Silica	12.81
Sulphur	0.11
Phosphorus pentoxide	0.63
Carbon dioxide	none
Total	100.14
Metallic iron	53.55
Phosphorus	0.275

This is a thoroughly leached, somewhat porous, oölitic ore, containing numerous casts of rather large sized crinoid buttons. A second excavation on this lot discloses another bed of ore which appears to lie about twelve feet above the bed just described. This bed is about two feet thick and has near its center a thin parting of shale.

LOT 116, which adjoins lot 115 on the west, is, in part, underlain by fossil iron ore, but only a small amount of prospecting has been done on the lot. One of the best exposures here to be seen is a nat-

FIG. 2.

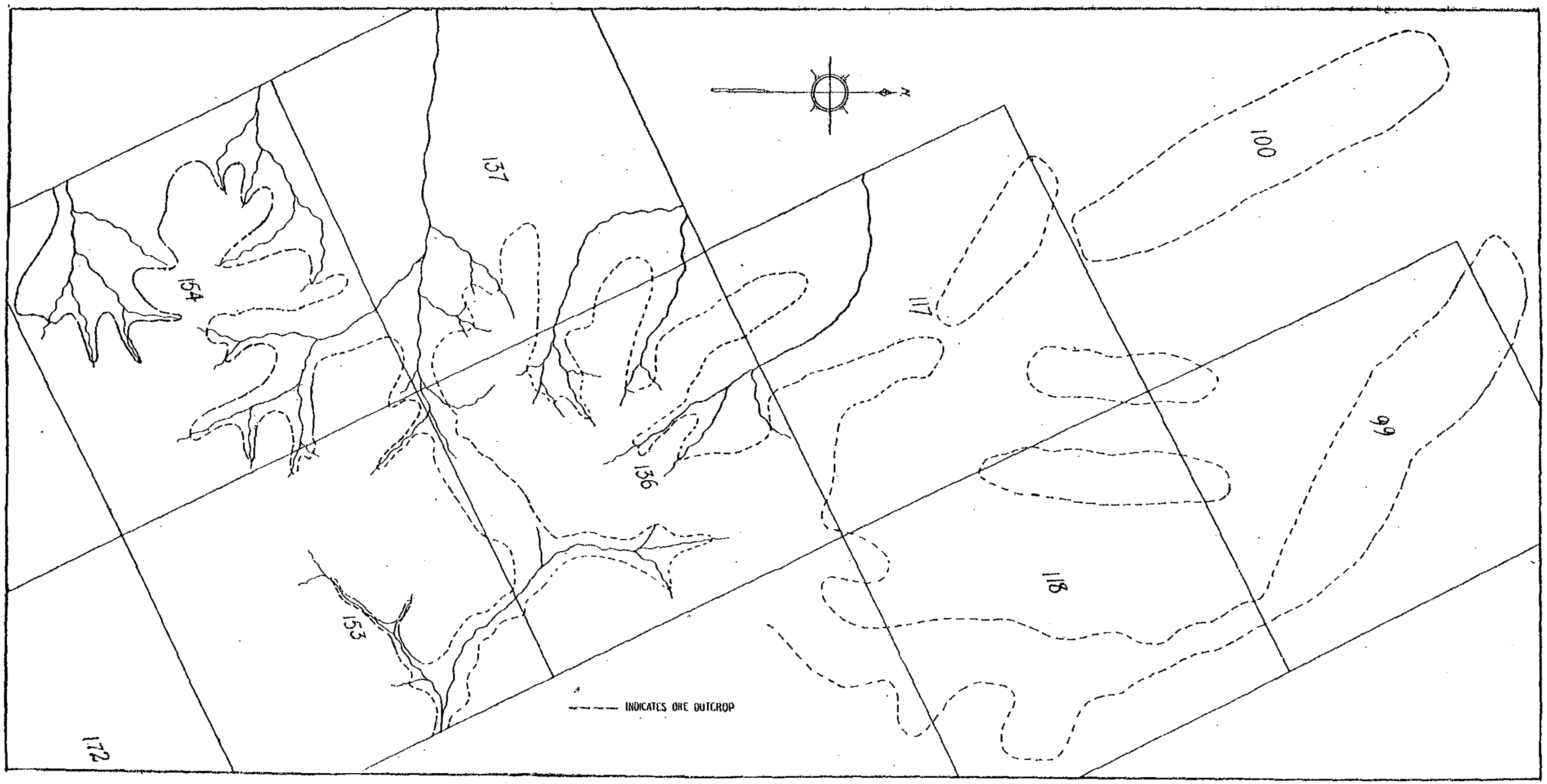


FIG. 2.—Land lot map of a part of the Glenn-Warthen property, Walker County, Georgia. The ore outcroppings are indicated by broken lines.

ural outcropping on a hillslope. The ore occurs chiefly in the form of large boulders weighing from 200 to 300 pounds, embedded in reddish clay. It carries considerable clay and appears to run low in metallic iron.

Immediately south of lot 115 is lot 136, on which is to be seen a number of prospect pits. One of the main excavations on this lot shows the following section of what is known as the lower bed:

Shale	——	
Soft ore	10	inches
Shale	4	"
Soft ore	2	"
Sandstone	2	"
Shale	2	"
Soft ore	16	"
Sandstone	4	"
Shale	2	"
Soft ore	12	"
Shale	——	

The ore exposed in this excavation is soft and of good quality. It dips at a low angle to the southwest. About 250 yards southeast of the above prospect pit is a second opening on the upper bed. This exposure is located on a hillside about sixty feet below the upper seam, and shows the section here given:

Sandstone	2	inches
Soft ore	16	"
Sandstone	2	"
Shale	6	"
Soft ore	12	"
Shale	——	

A third prospect pit near the western boundary of the lot gives the following section:

Shale	——	
Ore	4	inches
Shale	5	"
Ore	2	"
Sandstone	7	"

THE UNDERGROUND WORKINGS, KENSINGTON IRON AND COAL COMPANY'S PROPERTY, ESTELLE, WALKER COUNTY, GEORGIA.

Ore mixed with clay	20	inches
Sandy shale	8	"
Ore	12	"
Shale	——	

The ore here exposed probably belongs to the upper bed, though the ore is not so high in metallic iron as it is in the first section given, owing to the increase in the amount of clay present.

LOT 153 joins lot 136 on the south. Two prospects were examined on this lot, one near the center of the lot and the other near its northeast corner. The former, which is located in a deep hollow, shows the following section:

Shale	——	
Ore	8	inches
Shale	5	feet
Ore, hard	30	inches
Shale	4	"
Ore, hard	8	"
Shale	4	"
Ore, hard	8	"
Shale	18	"
Sandstone	24	"
Shale	——	

The small bed, eight inches in thickness, lying just above the five-foot layer of shale in this section, is called "The Marker," and is usually found from three to eight feet above the upper workable bed. The second excavation on lot 153, above referred to, shows the lower bed which lies about sixty feet below the upper bed. The section here exposed is as follows:

Shale	——	
Ore (soft)	12	inches
Sandstone	8	"
Ore (soft)	12	"
Shale	8	"
Ore (soft)	12	"
Shale	8	"
Ore (soft)	12	"
Shale	——	

The ore exposed in this cut seems to carry considerable sand and clay. Here, as well as in the cut near the center of the lot, the ore lies nearly horizontal.

LOT 152 lies immediately west of lot 153. It has several prospect pits on it, but only three were visited by the writer. The first excavation examined is located near the head of a deep hollow where a good exposure of the lower bed is to be seen exhibiting the following section:

Shale	——
Ore (hard)	6 inches
Shale	5 feet
Ore (hard)	5 "
Sandstone	2 "
Ore (hard)	6 "

The ore shown in this section carries a high percentage of lime, and would probably not average more than 30 per cent. metallic iron. A second opening on the side of a hill about 250 yards west of the above exposure, gives the following section:

Shale	——
Ore (soft)	20 inches
Shale	2 "
Ore (soft)	12 "
Shale	10 "
Ore (soft)	14 "

This ore lies about sixty feet below the bed exposed in the last section, and is known as the lower bed. The following analysis by Dr. Edgar Everhart, Chemist of the Geological Survey of Georgia, was made from a sample of ore collected at this exposure:

Hygroscopic water	0.32
Combined water	3.51
Ferrous oxide	none
Ferric oxide	76.88
Alumina	1.13
Manganous oxide	0.67
Lime	0.30

Magnesia	0.17
Silica	16.12
Sulphur	0.12
Phosphorous pentoxide	0.22
Carbon dioxide	none
Total	99.44
Metallic iron	53.82
Phosphorus	0.096

The ore is somewhat porous and contains numerous casts of crinoid buttons; microscopic examination of thin sections shows no calcite, but numerous grains of sharp sands.

Some 300 yards southwest of the last excavation and on the opposite side of the hill, is a third exposure. The ore at this point is only twenty-four inches thick; however, there occurs here a five-inch bed in the shales about five feet above. The ore in this excavation, and also in the other exposures, lies almost horizontal, and is favorably located for working.

J. L. WARRENFEL'S PROPERTY.—This property, lot 172, 8th district, lies immediately south of the Glenn-Warthen lot, No. 153, above described. The only exposure of ore examined on this lot occurs along a hillside near a small stream. Two or three carloads of ore were mined and shipped from this point during the spring of 1899. The ore is all hard and carries a high percentage of lime. This is especially true of the middle part of the bed which in places passes into a ferruginous limestone. The following section shows the thickness of the layers of ore, together with the thickness of the interlaminated layers of shale:

Shale	——
Ore (worked)	6 inches
Shale	5 feet
Ore	18 inches
Shale	3 "
Ore	18 "
Shale	4 "
Ore (upper part ferruginous limestone)	2 feet
Shale	——

In addition to the above lot, Mr. Warrenfel also owns the adjoining lot, 173, which also has fossil ore on it.

THE E. W. MARSH PROPERTY.—After traversing the Warrenfel property, just described, the line of fossil iron ore outcroppings continues to the southwest along the eastern foothills of Pigeon Mountain. It is here to be seen on the following lots, property of the E. W. Marsh estate: 224, 259 and 294, all of the 8th district. Only two exposures of ore were examined on the first lot here named; one was located near the summit of a small hill which has an elevation of less than 100 feet above the general stream level. The other exposure was at the base of the hill in the bed of a small stream. The ore at both of these exposures attains a thickness of twenty-four inches, and dips at an angle of about 45° to the westward. Two openings were also examined on lot 259; one of these shows an almost perpendicular bed eighteen inches thick, and the other shows a bed of about the same thickness, but lying nearly horizontal. Lot 294 has three openings where the ore can be seen. The ore in these excavations, which are located on the hillsides, dips to the west at a high angle. The ore varies in thickness from twenty-four to thirty inches.

J. P. HALL'S PROPERTY.—This property, lot 219, 8th district, lies immediately south of lot 294. There has been a limited amount of work done on the Hall lot, but at the time of the writer's visit no ore was to be seen, except that strewn about the surface.

In addition to the lots above described there are several other lots in the 8th district which are known to have ore on them, but they were not visited as it was reported there was no exposure, and only float ore was to be seen.

W. H. SHAW'S PROPERTY.—This lot, No. 6, 7th district, joins the Hall lot just referred to, on the south. Only two small excavations were examined on the lot. The ore, which is soft, occurs in a bed about two feet thick. The dip is to the west at an angle of about 60°. The surface is much broken and hilly. Considerable ore is seen in places strewn about the surface. The mineral interest is said to belong to the E. W. Marsh estate.

I. W. COPELAND'S LOT, NO. 31, 7th district, lies just south of the

Shaw lot. Fossil ore is to be seen at several places on this lot, where it has been excavated for chimney-jambs and backs for fireplaces. Near the center of the lot on a hill the ore lies almost horizontal, forming what the miners call a "spread," but a short distance further to the west the ore is almost perpendicular. There appears to be a large quantity of workable high grade ore on this lot. The thickness of the ore is about thirty inches. The mineral interest of the lot belongs to the E. W. Marsh estate.

LOT 42, 7TH DISTRICT, joins lot 31 at its northeast corner. The mineral interest of the lot is owned by the E. W. Marsh estate. The only opening examined is located a few rods from the Blue Bird Gap public road. The excavation was made some years ago, but just prior to the writer's visit it had been reopened so that a satisfactory examination of the ore could be readily made. The section here exposed is as follows:

Shale	——
Ore	2 inches
Shale	3 feet
Ore	22 inches
Shale	1 "
Ore	8 "
Shale	18 "
Sandstone	——

In addition to the ore occurring in this section, there are also two other beds higher up in the series. These beds vary from six to eighteen inches, and usually carry a high grade ore.

VIRGINIA IRON, COAL & COKE COMPANY'S PROPERTY.—The Virginia Iron, Coal & Coke Company owns the mineral interest in the following lots: 77, 105, 111, 146 and 147, all of the 7th district. The lots are located on both sides of the Chattanooga Southern Railroad, north and south of Bronco. The fossil iron ore is confined mainly to the eastern slope of what is known as Shinbone Ridge, a series of knobby hills parallel to Pigeon Mountain. The natural outcroppings are most generally seen along the slopes from 50 to 75 feet above the general stream level.

Mining operations were begun on this property in 1889 and continued with but few interruptions until 1900. The workings are about 2½ miles in length, and extend in places to a depth of 200 feet. It is reported that when the mines were in operation the daily output was about 75 tons. The ore was shipped chiefly to Chattanooga, Bristol and Dayton, Tennessee. Most of the ore was soft ore, but at some points, as at "The Shaft," located only a few hundred yards from Bronco Station, and at "The Slopes," further to the north, a large quantity of hard ore has been mined. The shaft here referred to has a depth of about 200 feet. At the bottom of the shaft there are drifts extending along the ore bed for a distance of about 1,000 feet, and much of the ore has been worked out above by stripping. The ore in these workings is said to vary from 3 to 4 feet in thickness. The dip is to the west at an angle of about 65°. The character of the ore is shown by the following analysis by Dr. Edgar Everhart, Chemist of the Geological Survey of Georgia, the sample being from the bed near the bottom of the shaft:

Hygroscopic water	0.11
Combined water	0.80
Ferrous oxide	3.75
Ferric oxide	56.86
Alumina	2.78
Manganous oxide	0.58
Lime	14.48
Magnesia	1.95
Silica	4.98
Sulphur	0.06
Phosphorus pentoxide	1.15
Carbon dioxide	12.40
Total	99.90
Metallic iron	42.72
Phosphorus	0.501

The slopes above referred to are three in number. Slope No. 1 is located on lot 111, 7th district, about a mile north of "The Shaft". The workings here consist of a slope, following the pitch of the ore, 200 feet in depth, with side drifts and slopings extending along the ore body for about the same distance. The bed of ore is not quite so thick as at the shaft. The dip is to the west at an angle of about 40°.

About one-fourth of a mile north of slope No. 1 is slope No. 2, and still further to the north about the same distance is slope No. 3. The character of the ore and the extent of the workings at both of these points are about the same as at slope No. 1. The ore in the deeper part of all of these workings is all hard ore, and of an excellent quality. Slope No. 1 is connected with the Chattanooga Southern Railroad by a branch road about one-fourth of a mile in length, while tramways have been constructed to slopes No. 2 and No. 3.

D. J. Hammond's Property.—The Hammond property, lots 179 and 182, 7th district, joins the property of the Virginia Iron, Coal & Coke Company on the south. The fossil iron ore has been mined along its outcroppings on these lots for a distance of nearly a half mile, to a maximum depth of about forty feet. The ore which varies from twenty-four to thirty inches in thickness often stands nearly perpendicular. The main workings are located along the hillslope at an elevation of about seventy-five feet above stream level, and only a few hundred yards west of the Chattanooga Southern Railway. At the time of the writer's visit the excavations were partially filled with fallen earth, and no sample of the ore was collected for analysis. The ore mined, however, is said to have been largely soft ore, and of a good quality.

The Dickson-Cameron Property.—Lot 181, 7th district, lies immediately west of the Hammond lot 182. The line of old workings on this lot extends for nearly half a mile. They vary in depth from ten to thirty feet. The work was chiefly done about ten years ago. The ore has an average thickness of about twenty-two inches only. It usually dips at a high angle, but at some points owing to local folding the dips become nearly horizontal.

The character of the ore is shown by the following analysis by Dr. Edgar Everhart, Chemist of the Geological Survey of Georgia:

Hygroscopic water	0.14
Combined water	0.85
Ferrous oxide	0.90
Ferric oxide	36.51
Alumina	2.18

Manganous oxide	trace.
Lime	29.84
Magnesia	0.14
Silica	6.89
Sulphur	0.06
Phosphorous pentoxide	0.61
Carbon dioxide	22.49
Total	100.61
Metallic iron	26.26
Phosphorus	0.266

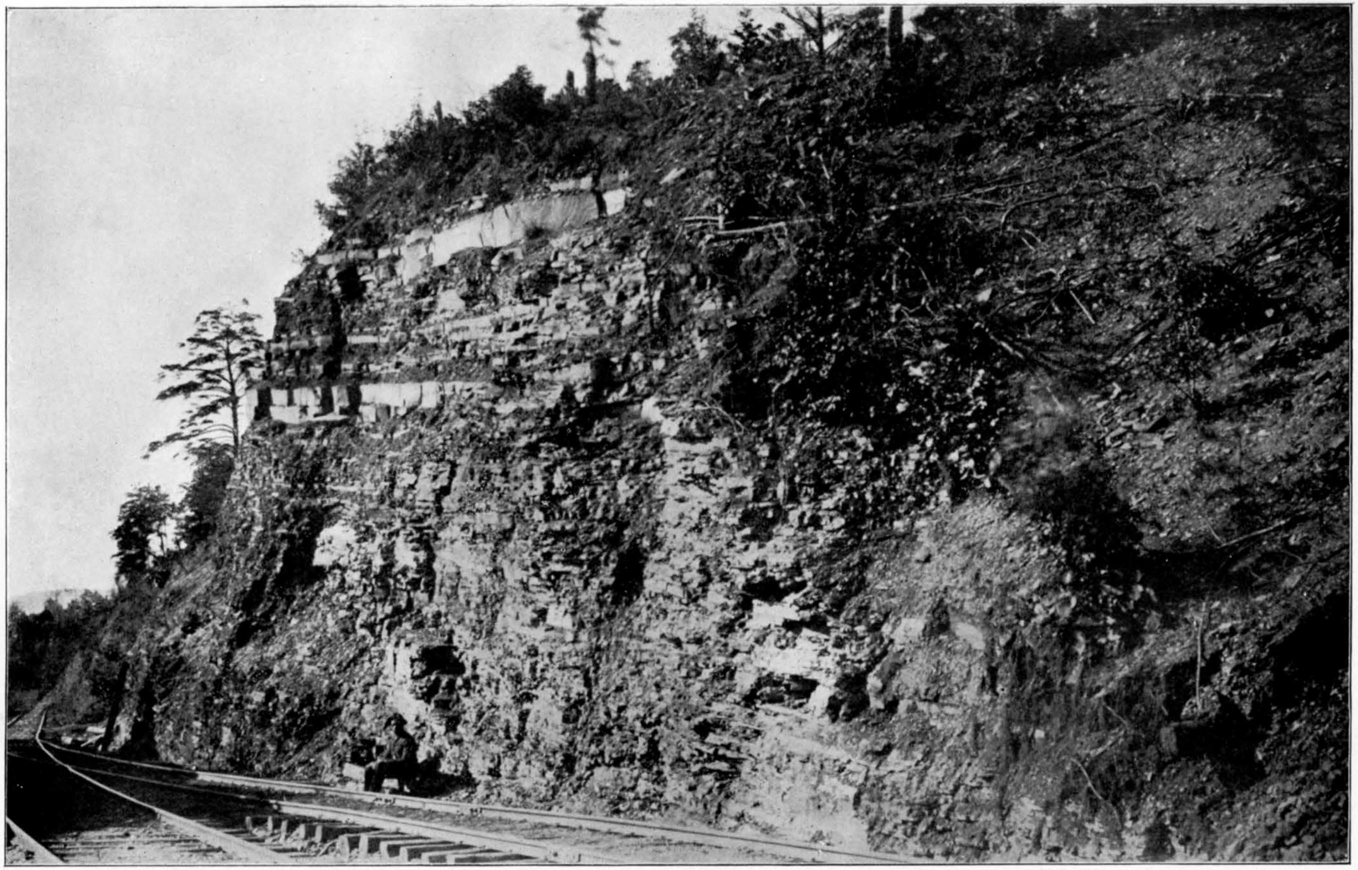
The specimen of ore used in the above analysis was unleached, hard ore, and is of a much lower grade than the average ore mined, which consisted largely of soft ore with a low percentage of lime.

J. A. Williams' Property.—The Williams property, lot 216, 7th district, joins the Dickson-Cameron property on the south. This lot was prospected to some extent in 1900, and a few carloads of ore were shipped. The ore seems to have a nearly vertical dip. The following section occurs at one of the main excavations:

Shale	——	
Ore (soft)	10	inches
Shale	8	"
Ore (soft	2	"
Shale	8	"
Ore (soft)	5	"
Shale	24	"
Ore (soft)	18	"
Shale	——	

It will be noticed that the aggregate thickness of the ore in this section is thirty-five inches, which is somewhat above the average thickness for this region. The number of layers into which the ore is divided is also unusually large and some of the shale partings have become much thickened. Such irregularities as these are often met with at other points along Pigeon and Lookout mountains.

J. D. McConnell's Property.—The fossil iron ore, after traversing the Williams property above described, passes through the Wear lot, 311, 12th district, and the McConnell lot, 310, 12th dis-



A CUT ON THE CHATTANOOGA SOUTHERN RAILROAD AT ESTELLE, WALKER COUNTY, GEORGIA, SHOWING SHALES AND SANDSTONES ASSOCIATED WITH THE FOSSIL IRON ORES.

trict. No work has been done on the Wear lot, but several carloads of ore have been shipped from the McConnell lot. On the latter the workings, which consist chiefly of open cuts, are located on a hill-slope. The ore mined was largely soft ore. The average thickness of the workable bed is only about twenty inches.

E. L. THURMAN'S PROPERTY.—This property, lot 304, 12th district, joins the southwest corner of the McConnell lot. The iron ore on this lot has been pretty well prospected, and some two or three carloads of the ore mined, but none has been shipped. The following section is to be seen in one of the excavations:

Shale	——
Ore (soft)	5 inches
Shale	3 "
Ore (soft)	2 "
Shale	2 "
Sandstone	2 "
Ore (soft)	7 "

The character of the ore is shown by the following analysis, made by Dr. Edgar Everhart, Chemist of the Geological Survey of Georgia:

Hygroscopic water	0.11
Combined water	1.20
Ferrous oxide	0.18
Ferric oxide	82.63
Alumina	2.59
Manganous oxide	0.49
Lime	1.41
Magnesia	0.34
Silica	10.00
Sulphur	0.10
Phosphorous pentoxide	1.36
Carbon dioxide	none
Total	100.41
Metallic iron	57.98
Phosphorus	0.593

The sample of ore from which the above analysis was made was a somewhat porous, well leached, soft ore, quite free from clay.

South of the Thurman property the line of the fossil iron ore outcroppings traverses lots 272 and 270, known as the Long and the Napier properties, and then crosses the county line into Chattooga county, the fossil iron ore of which is described elsewhere in this report.

TAYLOR'S AND DICK'S RIDGES.

Taylor's and Dick's ridges, which are formed by the two adjacent limbs of a synclinal fold, traverse the extreme southeastern part of the county. To the north, in the vicinity of the county line, the ridges are united by a series of cross ridges, but to the south they diverge and form the eastern and western boundaries of west Armuchee Valley. The fossil iron ore of Taylor's Ridge outcrops on its eastern side, and dips to the east, while on Dick's Ridge it outcrops on its western side and dips to the west. The dip in places differs but little from the slope of the ridges, and as a consequence at such points the ore often mantles the slopes of the ridges and can be raised at small cost.

THE GEORGIA IRON & RAILROAD COMPANY'S PROPERTY.

The mineral interests in nearly all of the lots located on these ridges, which are known to have iron ore on them, are owned by the Georgia Iron and Railroad Company. The several lots owned by this company either in fee simple or in mineral right, are here given: 91, 126, 127, 161, 162, 163, 164, 197, 233, 236, 237, 268, 269, 273, 274, 303, 304, of the 7th district, and 4, 7, 23, 30, 31, 32, 33, 34, 39, 66, 70, 71, 73, 74, 78, 103, 107, 108, 113, 114, 180, 248, 249, 322, of the 26th district. With but few exceptions, all of these lots have more or less fossil ore on them. A fair idea of the character and the mode of occurrence of the ore may be had from the following notes on some of the exposures:

LOT 304, SEVENTH DISTRICT.—There occurs on this lot, which is located along the western side of Taylor's Ridge, an exposure of fossil iron ore varying from eight to ten inches in thickness. The ore is well leached and dips to the east at an angle of about 20°.

Near this exposure are reported other exposures where the ore is said to be thicker. The chemical composition of the ore is shown by the following analysis by Dr. Edgar Everhart, Chemist of the Geological Survey of Georgia:

Hygroscopic water	.56
Combined water	1.90
Ferrous oxide	none
Ferric oxide	69.92
Alumina	2.14
Manganous oxide	1.76
Lime	0.30
Magnesia	0.78
Silica	22.46
Sulphur	0.29
Phosphorous pentoxide	0.23
Carbon dioxide	none
Total	100.34
Metallic iron	48.94
Phosphorus	0.100

Lot 236, Seventh District.—The fossil iron ore is exposed in considerable abundance in a hollow on this lot near an old road, locally known as Mill's trail. The individual blocks of ore strewn about the surface vary from six to twelve inches in thickness. The exposure occurs at an elevation of about 350 feet above the valley, and only about 200 yards from the top of Taylor's Ridge. On the north side of Mill's trail in a deep hollow occurs another outcropping of the ore, the individual blocks of which measure fifteen inches in thickness.

Lot 200, Seventh District.—One of the best exposures of fossil iron ore on this lot is to be seen near the Lafayette-Greenbush public road, only a short distance west of the summit of Taylor's Ridge. Considerable ore has been raised here for lining fireplaces, but none apparently has been shipped to the iron furnaces. The following section was made out at this point:

Sandstone in thick layers	——
Ore somewhat sandy	6 inches

Ore in regular block	10 inches
Decomposed shale and sandstone	——

The dip is to the east at an angle of about 20°. The ore is very compact and contains many small gastropods. The analysis of the ore by Dr. Edgar Everhart, Chemist of the Geological Survey of Georgia, is here given:

Hygroscopic water	0.42
Combined water	1.82
Ferrous oxide	none
Ferric oxide	82.13
Alumina	3.83
Manganous oxide	0.29
Lime	0.86
Magnesia	0.08
Silica	10.46
Sulphur	0.04
Phosphorous pentoxide	0.85
Carbon dioxide	none
Total	100.78
Metallic iron	57.49
Phosphorous	0.37

The analysis of the ore here given was made from a sample taken from the lower ten inches of ore shown in the above section.

Lot 127, Seventh District.—This lot, known as the Walthon Hollow lot, is located on the east side of Taylor's Ridge about two miles north of the Lafayette-Greenbush road crossing, or what is locally known as Smith's Gap. At one place in this hollow the fossil iron ore is exposed in a continuous bed for a distance of a hundred yards or more, where it has been washed clean by the action of recent rains. The bed varies from eight to twelve inches in thickness. The ore appears to be of an excellent quality, but at some points when split parallel with the bedding it is seen to contain small kidney-shaped masses of sand. Between the exposure of the ore on this lot and lot 200, above described, there are many exposures of ore on the east side of Taylor's Ridge, but the character of the ore and the nature of the exposures are practically the same as those heretofore mentioned.

Lot 70, Twenty-Sixth District.—Lot 70 lies on the eastern side of Taylor's Ridge, a short distance north of Maddox Gap, near the northern end of west Armuchee Valley. The main exposure to be seen on this lot occurs in a deep hollow and along the side of a spur ridge which extends at right angles to Taylor's Ridge. Considerable ore is said to have been mined on this lot prior to the Civil War, and used in a small blast furnace then operated in east Armuchee Valley, a few miles to the east. The following section was made out at one of the exposures on lot 70:

Massive sandstone	——
Sandstone with shale partings	6 feet
Ore	12 inches
Shale with thin beds of sandstone	20 feet

At some points on this lot the ore increases to a thickness of sixteen inches, while at others it is reduced to eight inches, the general average being about the thickness as given in the section above. Something like a mile north of the last described lot there occurs a rather prominent east and west ridge uniting Taylor's Ridge and Dick's Ridge; on this cross ridge are located the following lots: 31, 32, 33 and 34, all of which are owned by the Georgia Iron and Railroad Company, and are reported to be traversed by outcroppings of fossil iron ore.

Lot 7, Twenty-Sixth District.—Lot No. 7 is located on Dick's and Taylor's Ridges, about one and a half miles north of Wood's Gap. There are considerable exposures on this lot, both on Dick's Ridge and on a spur of Taylor's Ridge. The ore is ten inches in thickness and dips at a low angle to the east. The main exposures occur on the side of the ridge near Mr. Hamilton's residence. The ore has been used only for lining fireplaces. The analysis of the ore taken from near Mr. Hamilton's residence, made by Dr. Edgar Everhart, Chemist of the Geological Survey of Georgia, is here given:

Hygroscopic water	0.53
Combined water	1.49
Ferrous oxide	none
Ferric oxide	80.69
Alumina	1.76

Manganous oxide	1.41
Lime	2.26
Magnesia	0.54
Silica	10.91
Sulphur	0.12
Phosphorous pentoxide	0.52
Carbon dioxide	none
Total	100.23
Metallic iron	56.48
Phosphorus	0.227

LOT 66, TWENTY-SIXTH DISTRICT.—Another exposure of fossil iron ore on Dick's Ridge occurs on the side of the public road in Wood's Gap. At this point is to be seen an old excavation now partially filled with earth, which is said to have exposed a bed of ore varying from eight to ten inches in thickness. Considerable float ore occurs on the side of the ridge, but at no point is there any natural outcropping showing the ore in place. It is reported that fragments of ore are frequently met with all along the western slope of Dick's Ridge, as far south as the West Armuchee Creek Gap. But the ore here, judging from a small exposure on lot 248, 26th district, located on the west side of the ridge near the junction of Dick's and west Armuchee creeks, is probably of but little economic importance, owing to the thinness of the seam.

FOSSIL IRON ORES WEST OF CHATTANOOGA VALLEY NEAR THE GEORGIA-TENNESSEE LINE.

This line of fossil iron ore outcroppings, as previously stated, has a V-shape, with the western limb of the V cut short by a fault about three miles south of the Georgia-Tennessee line. The eastern limb of the V, on the other hand, which has a nearly north and south trend, extends beyond the State line. The main part of the workings along this V-shaped line of outcroppings is located near the apex of the V, about one and a half miles due east of Eagle Cliff Station. The most southern of these workings, locally known as the Hall ore bank, occurs on Mrs. Alice Parks' property, here described.

MRS. ALICE PARKS' PROPERTY.—Lot 176, 9th district, has recently been worked for fossil iron ore by C. A. Hall on a more or less extensive scale. During 1904-5 Mr. Hall mined and shipped to Bristol, Tenn., from this property 240 carloads of ore. The greater part of this ore was mined by stripping, although on some portions of the lot there was also considerable underground mining. The southernmost part of the workings are located in the apex of the V, or at the point where the eastern and western line of outcroppings unite. The entire length of the workings is something like three-quarters of a mile. The thickness of the ore varies from twenty-two to forty-four inches, the greater thickness, however, is usually quite local, being confined chiefly to the apices of small folds. The dip is variable, but it is generally from 20° to 35°. At some points small anticlinal and synclinal folds are to be seen, which to some extent interfere with mining.

The following analysis by Dr. Edgar Everhart, Chemist of the Geological Survey of Georgia, shows the chemical composition of a sample of hard ore taken from the Park property:

Hygroscopic water	0.19
Combined water	2.04
Ferrous oxide	2.00
Ferric oxide	45.00
Alumina	4.05
Manganous oxide	.49
Lime	24.80
Magnesia	.38
Silica	5.16
Sulphur	.25
Phosphorous pentoxide	.72
Carbon dioxide	15.00
Total	100.08
Metallic iron	33.05
Phosphorus	0.32

The following is the analysis of an average sample of soft ore from the same property:

Hygroscopic water	2.15
Combined water	4.84
Ferrous oxide	none
Ferric oxide	71.17
Alumina	3.89
Manganous oxide	.65
Lime	.10
Magnesia	.72
Silica	15.44
Sulphur	trace
Phosphorous pentoxide	.75
Carbon dioxide	none
Total	99.71
Metallic iron	49.82
Phosphorus	0.33

North of the Park property the fossil iron ore forms two entirely distinct lines of outcroppings, which diverge from each other as they approach the Georgia-Tennessee line. The outcroppings to the east, forming the eastern limb of the V, have a northeast-southwest trend, and traverse lots 149, 139 and 115, the mineral interests of which are owned by the Dayton Coal and Iron Company. The western limb of outcroppings, on the other hand, which has a nearly due north trend, traverses lots 149, 140, 113, 104, 78, 67, 42, 31 and 5. The mineral interest in all of these lots, with the exception of 31, 42 and 140, is also said to be owned by the Dayton Iron and Coal Company. All of the lots here named show more or less fossil iron ore, but only the ores above described have been prospected or worked to any extent.

M. M. Fisher's Property.—This lot, 104, 9th district, which is located only a short distance north of the Eagle-Rossville public road, has been prospected for ore to a limited extent. Float ore is to be seen at several places on this lot, along the hill slopes, but only one point was visited by the writer where the ore was exposed to view. This exposure which occurs in a small excavation less than three feet in depth, discloses soft ore fifteen inches in thickness, with a nearly perpendicular dip. The character of the ore here exposed is shown by the following anaysis by Dr. Edgar Everhart, Chemist of the Geological Survey of Georgia:

MINING FOSSIL IRON ORE BY SURFACE STRIPPING, NEAR ESTELLE, WALKER COUNTY, GEORGIA.

Hygroscopic water	.85
Combined water	2.47
Ferrous oxide	none
Ferric oxide	85.24
Alumina	1.57
Manganous oxide	.35
Lime	.08
Magnesia	.23
Silica	8.58
Sulphur	.08
Phosphorus pentoxide	.92
Carbon dioxide	none
Total	100.37
Metallic iron	59.66
Phosphorus	.40

The ore from which the above analysis was made is more or less porous and contains numerous casts of crinoid buttons. Exposure of ore, similar to that occurring on the Fisher property, is to be seen along the roadside on the Talley lot, 113, immediately south of lot 104.

W. C. McFarland's Property.—The fossil iron ore after traversing lots 78 and 67 continues to the north through the McFarland property, lot 42. The ore here is to be seen along the hillsides in some open cuts where a limited amount was mined some years ago. The main ore bed varies in thickness from eighteen to twenty inches.

On Mrs. Simms' lot, 205, located on the State line about three-quarters of a mile northwest of the McFarland property, the ore occurs in two separate beds about four feet apart, varying from eighteen to twenty inches in thickness. The ore here, as on the McFarland lot, is mainly soft, and appears to be of a fair quality.

CHAPTER VIII

DESCRIPTION OF THE FOSSIL IRON ORES OF CHATTOOGA COUNTY

INTRODUCTION

The fossil iron ores of Chattooga county occur along the line of knobby hills at the base of Lookout Mountain, both north and south of Menlo, on Dirtseller Mountain, near the Georgia-Alabama line, and on Gaylor's and Taylor's ridges farther to the south and west. The aggregate length of these four different lines of outcroppings is approximately twenty-five miles. The most extensive of these outcroppings, and the one which has been worked the most, is the line of outcroppings along the base of Lookout Mountain, here described in detail.

LOOKOUT MOUNTAIN

The Lookout Mountain line of fossil iron ore outcroppings of Chattooga county is the southern extension of the Lookout Mountain line of fossil iron ore of Walker county, previously described. The ore on the lots immediately south of the county line is only occasionally exposed, but farther to the south there are to be seen numerous old workings, as well as some natural exposures. The most important of these old workings and exposures are here described in detail:

A. J. NEAL'S PROPERTY.—The Neal property, lot 122, 13th district, is located in the knobby hills near the base of Lookout Mountain, about two miles south of the Chattooga-Walker line. One of the small tributaries of Teloga creek here gives a very complete cross-section of the Rockwood formation, and thus shows a good exposure of the fossil iron ore. The best exposure is to be seen along the stream near Mr. Neal's residence. The ore at this point occurs in three different beds, separated by layers of shale. None of the beds appear to attain a thickness of more than ten inches. The ore on the Colter and other properties further to the north is said to attain in places a maximum thickness of fifteen inches. As the old workings on these properties were filled more or less with earth and no ore was to be seen *in situ*, this statement could not be verified. South of the Neal property the ore traverses lots 132, 133, 154 and 155, but none of these lots have been prospected.

W. T. HENRY'S PROPERTY.—The ore on the Henry property, lot 171, 13th district, is to be seen in two excavations on a hillslope near the public road about a quarter of a mile west of Chelsea. The ore, which has been exposed to the depth of fifteen feet, stands almost perpendicular. The excavation shows the following section:

Shale	——	
Ore	14	inches
Shale	22	"
Ore	4	"
Shale	6	"
Ore	2	"
Shale	——	

A few feet west of the above excavation is a second excavation showing the following section with other thin seams of ore:

Shale	——	
Ore	7	inches
Shale	24	"
Ore	7	"
Shale	——	

An analysis by Dr. Edgar Everhart, Chemist of the Geological Survey of Georgia, of a sample of ore taken from the first excavation described, results as follows:

Hygroscopic water	0.50
Combined water	1.75
Ferrous oxide	none
Ferric oxide	63.90

Alumina	9.01
Manganous oxide	0.28
Lime	5.44
Magnesia	0.33
Silica	15.14
Sulphur	0.10
Phosphorous pentoxide	2.62
Carbon dioxide	1.50
Total	100.57
Metallic iron	44.73
Phosphorus	1.142

A. J. LAWRENCE'S PROPERTY.—This property, lot 188, 13th district, is about three-quarters of a mile south of the Henry lot above described. Considerable prospecting has been done on this lot, but no ore of any consequence has been shipped. The thickness of the bed is shown in the following section, taken from one of the cuts located on the hillside about 120 feet above the general stream level:

Shale	——
Ore	6 inches
Shale	18 "
Ore	12 "
Shale	——

The ore in this exposure has a brownish color, and as shown by the following analysis by Dr. Edgar Everhart, Chemist of the Geological Survey of Georgia, runs unusually high in silica and combined water:

Hygroscopic water	0.30
Combined water	7.00
Ferrous oxide	none
Ferric oxide	54.41
Alumina	5.31
Manganous oxide	0.43
Lime	0.26
Magnesia	0.25
Silica	30.90
Sulphur	0.09
Phosphorous pentoxide	0.27

Carbon dioxide	none
Total	99.22
Metallic iron	38.09
Phosphorus	0.117

The large amount of combined water shown in this analysis, as well as the brownish color of the sample itself, seems to indicate that the ore is partially altered into limonite.

LOT 210, THIRTEENTH DISTRICT.—This lot, which is jointly owned by the Menlo Iron Company and the Woodstock Iron and Coal Company, is located only a short distance north of Menlo. Considerable ore has been mined on this lot. Some of the old workings have a maximum depth of thirty-five feet. The ore, which is mostly soft and of a good quality, dips at a high angle to the west. A section exposed in one of the excavations is here given:

Shale	——	
Ore	2	inches
Shale	18	"
Ore	9	"
Shale	5	"
Ore	7	"
Shale	1	"
Ore	7	"
Shale	——	

The character of the ore is shown by the following analysis by Dr. Edgar Everhart, Chemist of the Geological Survey of Georgia:

Hygroscopic water	0.30
Combined water	1.90
Ferrous oxide	1.85
Ferric oxide	77.97
Alumina	4.81
Manganous oxide	0.50
Lime	1.11
Magnesia	0.42
Silica	10.63
Sulphur	0.08
Phosphorous pentoxide	0.96

Carbon dioxide	none
Total	100.53
Metallic iron	56.02
Phosphorus	0.418

LOT 223, THIRTEENTH DISTRICT.—This lot, the property of the Dalton Iron and Coal Company, lies directly west of lot 210. The only exposure of ore visited on this lot is near the summit of a hill, which has an elevation of about 100 feet above Menlo. The ore which here attains a thickness of about thirty inches, is nearly perpendicular. The chemical composition of the ore is shown by the following analysis made by Dr. Edgar Everhart, Chemist of the Geological Survey of Georgia:

Hygroscopic water	0.61
Combined water	2.76
Ferrous oxide	none
Ferric oxide	76.63
Alumina	5.48
Manganous oxide	0.40
Lime	0.20
Magnesia	trace
Silica	12.29
Sulphur	0.12
Phosphorous pentoxide	0.69
Carbon dioxide	none
Total	99.18
Metallic iron	53.64
Phosphorus	0.301

LOT 222, THIRTEENTH DISTRICT.—This lot, which is also owned by the Dalton Iron and Coal Company, joins lot 223 on the south. The ore was quite extensively worked on this lot some years ago. The old workings which consist largely of open cuts, vary from five to fifteen feet in depth. They are located chiefly along the hill-slopes, fifty feet or more above the valley. A section exposed in one of the cuts is here given:

Shale		——
Ore	2	inches
Shale	18	"
Ore	22	"
Shale	1	"
Ore	6	"
Shale	2	"
Ore	4	"
Shale	3	"
Ore	4	"
Shale		——

Another exposure on the same lot shows the following section:

Shale		——
Ore	2	inches
Shale	18	"
Ore	20	"
Shale	3	"
Ore	2	"
Shale	2	"
Ore	4	"
Shale		——

South of lot 222 the fossil iron ore continues through lots 248, 249, 256 and 286 to the Georgia-Alabama line. There are more or less old workings and prospect pits to be seen on each of these lots. The character of the ore as shown by the analysis of a sample taken from lot 256, here given, differs but little from the ore occurring on the lots further to the north. Analysis by Dr. Edgar Everhart, Chemist of the State Geological Survey of Georgia:

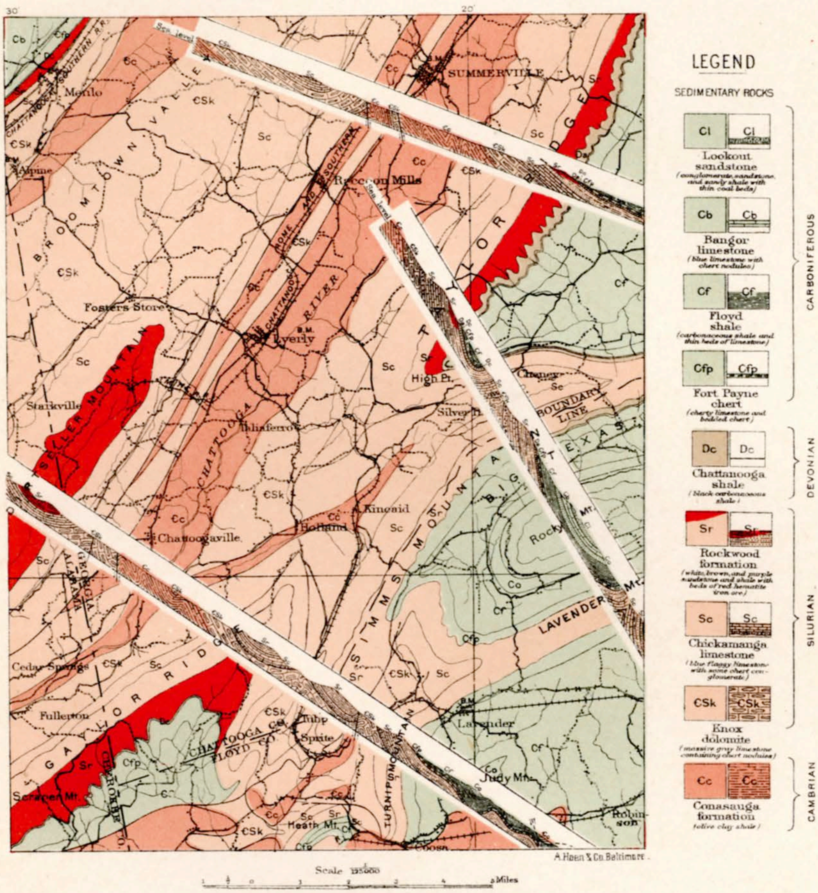
Hygroscopic water	0.40
Combined water	3.15
Ferrous oxide	none
Ferric oxide	80.48
Alumina	3.28
Manganous oxide	0.09
Lime	trace
Magnesia	trace
Silica	11.47
Sulphur	0.10

Phosphorus pentoxide	0.57
Carbon dioxide	none
Total	99.54
Metallic iron	56.34
Phosphorus	0.248

DIRTSELLER MOUNTAIN

Dirtseller Mountain is a very prominent trough-like synclinal ridge intersecting the Georgia-Alabama line about midway between Lookout Mountain and Gaylor's Ridge. The greater part of this mountain lies in Alabama, only its northeastern extension, less than six miles in length, being confined to Georgia. The top of the mountain, or rather its elevated ridge-like brows, attaining a maximum height of 700 feet above the valleys on either side, is made up entirely of the Rockwood formation, consisting of shale and heavy bedded sandstone with one or more thin beds of fossil ore. Near the eastern side of the mountain occurs a minor synclinal flexure which becomes quite prominent as the State line is approached, but appears to die out entirely further to the west. These structural features affect to a greater or less extent the cost of mining. The ore in most cases outcrops only a few rods from the brow of the mountain, and dips at a low angle towards its lower central axis. At many places the dip of the ore varies but little from the slope of the surface, in which case often large quantities of ore have been mined by stripping. On the other hand, where the dip of the ore exceeds the slope of the surface, underground mining has to be resorted to.

The main part of the ore located on Dirtseller Mountain is at present owned by the Rome Furnace Company. This company has been actively engaged in mining on the mountain for nearly twenty years, and has shipped to their Rome furnace more than a quarter of a million tons of high-grade ore. In order to facilitate the transportation of the ore at a minimum cost, the company has had constructed a branch standard gauge road three and a half miles long from the foot of the mountain to Lyerly, a station on the Central of Georgia Railway. The company has also had constructed an incline road, several hundred feet in length, from the terminus of the



GEOLOGIC MAP OF A PART OF CHATTOOGA AND FLOYD COUNTIES, GEORGIA

With structure sections, showing distribution of the Fossil Iron Ores.

Reproduced from the Rome Folio, U. S. Geological Survey.

branch road in the valley to the top of the mountain, and from thence to the trough-like valley traversing the central axis of the mountain, where the mining camp, consisting of commissary store and a number of miners' cottages, is located. The main workings which consist largely of strippings, are confined chiefly to the eastern side of the mountain, only a short distance west of the brow. The overburden in these workings varies from a few inches to five feet or more in thickness. Further toward the central axis of the mountain the ore lies deeper, and underground mining has to be resorted to. The latter method of mining is limited to a few tunnels and drifts, the most extensive of which consists of a tunnel 400 feet long, located near the northern terminus of the iron ore outcroppings, and within a short distance of the end of the incline railroad.

The character of the ore on Dirtseller Mountain, together with associated rocks, differs considerably from the ore and rocks making up the Rockwood formation further to the north and west. The prevailing rocks here are sandstones, which often become heavy bedded and form bold bluffs along the brow of the mountain. In places immediately below the iron ore, the sandstone contains waterworn boulders, often a foot or more in diameter. At some points these boulders are embodied in the ore itself. In the latter position they consist of sand with a matrix of carbonate of lime and more or less oölitic granules of iron oxide. The boulders often have the appearance of waterworn fragments of ore, which have been detached by wave action, and after having been rounded by the same force, been deposited further seaward. The ore itself as a rule contains much more silica in the form of sand than the ore further to the north and west, and also a corresponding decrease in the percentage of lime. The number of the beds of ore together with the thickness of the same, is shown by the following sections, to be seen at different exposures on the lots named.

Section on lot 172, 14th district, located on the Georgia-Alabama line:

Decomposed shale and surface clay	5	feet
Ore (impure, not worked)	12	inches
Shale	12	"
Ore (worked)	20	"

Sandstone	3	feet
Ore (impure, not worked)	18	inches
Sandstone	3	feet
Shale	2	"

Section on lot 143, 13th district, west side of the mountain:

Surface clay	5	feet
Shale	3	"
Ore	8	inches
Shale	4	"
Ore	6	"
Sandstone	——	

Section on lot 150, 14th district, near the incline:

Decomposed shale and surface clay	9	feet
Ore	4	inches
Shale	4	"
Ore	2½	"
Shale	1	"
Ore	1	"
Shale	2	"
Ore	3	"
Shale	1	"
Ore	6	"
Sandstone (heavy beds)	——	

By comparing these different sections, it will be seen that the individual beds of ore differ considerably in thickness from place to place, and that there is also a considerable variation in the thickness of the shale partings.

The character of the ore taken from lot 140 is shown by the following analysis by Dr. Edgar Everhart, Chemist of the Geological Survey of Georgia:

Hygroscopic water	0.67
Combined water	2.40
Ferrous oxide	0.25
Ferric oxide	77.29
Alumina	0.89

Manganous oxide	0.28
Lime	1.09
Magnesia	0.13
Silica	15.64
Sulphur	0.03
Phosphorus pentoxide	1.06
Carbon dioxide	none
Total	99.73
Metallic iron	54.30
Phosphorus	0.462

A second analysis by Dr. Edgar Everhart from a sample of ore taken from lot 141, is here given:

Hygroscopic water	0.56
Combined water	1.74
Ferrous oxide	0.10
Ferric oxide	82.48
Alumina	3.78
Manganous oxide	.03
Lime	.80
Manganese	.11
Silica	9.19
Sulphur	.07
Phosphorus pentoxide	.83
Carbon dioxide	none
Total	99.69
Metallic iron	57.82
Phosphorus	.36

In addition to the lots above referred to, the Rome Furnace Company also owns the following lots on Dirtseller Mountain, all of which are located in the 14th district: 149, 170, 171, 173, 174, and 197. All of these lots have more or less ore on them, and in places extensive surface mining has been carried on. There still remains on the mountain, at different points, considerable ore which can be raised by stripping, but the greater mass of ore, however, can only be obtained by underground mining.

Besides the several lots owned by the Rome Furnace Company there is another lot on the mountain, No. 122, 13th district, owned by Miss R. Hertz, of Atlanta, which has a limited amount of ore on it. The lot is located only a short distance north of the incline and joins lot 141 on the north. The ore on this lot seems to mark the northern limit of the ore on the mountain.

GAYLOR'S RIDGE

Gaylor's Ridge, like Dirtseller Mountain, is a very prominent synclinal ridge, intersecting the Georgia-Alabama line about seven miles south of and parallel with Dirtseller. That part of the ridge which is confined to Georgia, occupies the extreme southwestern corner of Chattooga county; its northern terminus being about two and a half miles south of Kincaid, a station on the Central of Georgia Railway. The southern side of the ridge is deeply indented by numerous finger-like hollows, while the northern slope, as shown by the nearly straight crowded parallel contour lines of the topographical map of the region, is steep and difficult of ascension. Its geological structure is practically the same as that of Dirtseller Mountain; however, there does not seem to occur here any minor synclinal folds.

The fossil iron ore which occurs on Gaylor's Ridge, appears to be confined mainly to the north of its central trough-like valley. The only point at which the ore was examined by the writer was in the Miller Orchard Company's peach orchard, located near the northern terminus of the ridge. The ore here occurs as float ore, strewn along the western slope of the central valley only a few hundred yards southwest of the residence of the superintendent of the Orchard Company. From the character of the float material to be seen about the surface, it would seem that the ore here does not attain more than a few inches in thickness. It is quite possible, however, that at some favorable points, where the ore lies near the surface, it may be mined with profit, but as its thickness is limited to a few inches, the deposit is not likely to prove of very great economic importance. The character of the ore seems to be of fair quality, but the most of the samples found about the surface are badly weathered, being of a brownish color and partially altered into limonite.

TAYLOR'S RIDGE

The fossil iron ore of Taylor's Ridge is the southern extension of the fossil iron ore previously described under the description of the fossil iron ore of Taylor's Ridge in Walker county. The ore here, as in Walker county, is largely owned by the Georgia Iron and Railroad Company. Some of the most important exposures of the ore on this company's property, visited by the writer, are located on the following lots, all of which are in the 5th district and are situated chiefly on the eastern slope of the ridge: 65, 66, 104, 105, 110, and 111. The ore on none of these lots has been worked, but all of them show more or less ore in the deep hollows. On the east side of the ridge, there is an especially fine exposure on lot 110. The ore here is found in large rectilinear blocks, strewn about the surface, and also in the natural bedding where it has been laid bare by washing rains. At one point, where the ore was exposed to view, the following section occurs:

Heavy-bedded sandstone	——
Ore	5 inches
Shale	1 "
Ore	13 "
Shale	——

At another point in a hollow nearby were seen blocks of ore strewn about the surface, measuring 17 inches in thickness. As the ore usually occurs in two layers, this would seem to indicate that the ore here has a maximum thickness of 20 inches or more. The exposure of the ore on lots 65 and 66, located only a short distance north of what is known as High Point, the southern terminus of Taylor's Ridge, appears to verify the commonly expressed opinion that the ore becomes reduced in thickness to the south. On the Lyerly–Dirt Town public road, the exposure of ore measures only from 8 to 10 inches in thickness.

In addition to the above lots, the Georgia Iron and Railroad Company also owns the following lots in the 6th district: 166, 168, 205, 207, 208, 209, 223, 224, 247, 248, 249, 250, 251, 254, and 256. These lots, like those of the 5th district, lie chiefly on the east side of Taylor's Ridge, and all have more or less extensive outcroppings of fossil iron; one of the most extensive exposures occurs on lot 166, which lies just north of the Maddox lot, hereafter to be described. The main exposure is to be seen near the head of a deep hollow on the east side of Taylor's Ridge. At the time of the writer's visit no work had been done on this lot, nevertheless there was considerable ore to be seen in its natural bedding, as well as a large quantity of float ore strewn about the surface. At one point the following section was exposed to view:

Sandstone	18	inches
Shale	24	"
Sandstone	36	"
Shale	3	"
Ore	6	"
Shale	2	"
Ore	5	"
Shale	12	"

The ore on this lot probably attains a greater thickness at places than is given in the above section.

I. W. Maddox's Property.—This property, lot 161, 6th district, is located on the west side of Taylor's Ridge about three and a half miles due east of Summerville, on what is known as the Maddox Gap road. In the last eight or ten years, many thousand tons of fossil iron ore have been mined from this lot and shipped to the Rome furnace. The workings, which consist largely of open cuts and strippings, extend along the line of outcroppings for something like a quarter of a mile. The ore varies from fifteen to twenty inches in thickness, and dips at a low angle to the east. The character of the ore is shown by the following analysis by Dr. Edgar Everhart, chemist of the Geological Survey of Georgia:

Hygroscopic water	0.31
Combined water	1.14
Ferrous oxide	0.05
Ferric oxide	76.98
Alumina	5.23
Manganous oxide	0.26
Lime	1.21
Magnesia	0.17
Silica	14.91
Sulphur	0.06
Phosphorus pentoxide	0.97
Carbon dioxide	none
Total	101.29
Metallic iron	53.93
Phosphorus	.423

In addition to above lot, Mr. Maddox also owns lot 160, just north of lot 161. This lot has also been extensively worked, and the ore shipped to Rome. At one of the recent excavations the following section was exposed to view:

Sandstone	—	
Ore	7½	inches
Shale	3	"
Ore	13½	"
Shale	7	feet

The greater part of the ore mined on the Maddox property is what is known as soft ore, which always yields a high percentage of metallic iron. The physical appearance of the ore is very similar to that occurring on Dirtseller Mountain. It is more or less oölitic, often fossiliferous and occasionally contains small, rounded masses of clay, shale or argillaceous sandstone.

The Cleghorn, Billings & Shropshire Property.—Lot 127, 6th district, lies southwest of and corners with the Maddox lot, 161. The ore on this lot has never been worked; however, it is said that the ore occurs on it in large quantities. The ore in places is reported to attain a maximum thickness of 2 feet or more, and is favorably located for working. The same parties also own lot 77, 5th district, which, likewise, has much ore on it.

W. F. KYLE'S PROPERTY, lot 144, 5th district, joins the Cleghorn, Billings & Shropshire lot 127, on the south, and lies chiefly on the east side of Taylor's Ridge. In the last few years large quantities of ore have been mined on the lot. The main workings, consisting chiefly of strippings, are located along the side of the ridge only a short distance east of its summit. There are to be seen here long lines of workings, consisting of open cuts from which the ore has been raised; similar workings are also to be seen on lot 109, which lies just west of lot 144. The ore mined from all these workings was soft ore, varying from 15 to 20 inches in thickness. The dip of the ore in places varies but little from the slope of the surface, thus reducing the cost of stripping to a minimum.

T. HILES' PROPERTY.—This property, lot 106, lies on the east side of Taylor's Ridge, about one mile nearly due south of Kyle's lot, 144. Considerable ore has been mined on this lot. The workings and the character of the ore are similar to those found on the lots further to the north. The ore after traversing lot 106, passes the southeast corner of lot 76, which is also owned by Mr. Hiles.

East of Taylor's and Gaylor's ridges is another ridge of like character, known as Simms' Ridge, which has in places limited exposures of fossil iron ore. The ore in this ridge, however, is so reduced in thickness that it seems to be of little commercial importance. The only place on Simms' Ridge where fossil ore was examined by the writer is near the gap of the ridge, where the public road crosses, about two miles southeast of Kincaid. The ore at this point is not over 8 inches in thickness, and seems to carry considerable silica in the form of sand.

A TIPPLE ON THE CHATTANOOGA SOUTHERN RAILROAD AT ESTELLE, WALKER COUNTY, GEORGIA.

CHAPTER IX

FOSSIL IRON ORES OF WHITFIELD COUNTY

The fossil iron ores of Whitfield county are confined to Taylor's and Dick's ridges in the extreme western portion of the county. These ridges are the northern extensions of the two fossil iron ore-bearing ridges of the same name, previously described, traversing the eastern portion of Walker and Chattooga counties. The ore in neither of these ridges has been worked to any extent within the limits of Whitfield county; however there are many places where the float ore is to be seen strewn about the hillsides. This is especially true of the rough, hilly country south of Gordon Spring, and also in the vicinity of Nickajack Gap, 6 or 8 miles further to the north. In the last named locality the ore is to be seen near the public road only a short distance from the top of Taylor's Ridge and also on Dick's Ridge along the public road leading to Tricum, one mile further to the east. At the latter point the ore is to be seen in considerable abundance scattered along the hillside, but at no point was it observed by the writer *in situ*. The number of beds and the thickness of the same were not determined. The individual blocks of ore vary from 6 to 7 inches in thickness, but whether these blocks represent the entire thickness of the bed, or only one of its individual layers, is not known. Between Nickajack Gap and the Whitfield-Catoosa line, float ore in more or less abundance is said to occur at various points along the slopes of both Taylor's and Dick's ridges, but at no point has the ore been mined, except for making chimney-jams.

Besides the fossil ore here described, there also occurs a very simiiar ore in the extreme northern part of the county on the Georgia-Tennessee line. This ore, which becomes better developed in Bradley county, just across the state line, occurs along a line of red hills associated with a reddish or chocolate-colored marble, a similar stone, and occupying the same geological position, as the marble which is so extensively worked in the vicinity of Knoxville. The ore appears mostly in the form of float in the reddish soils, and apparently has originated from the weathering of the more ferruginated layers of limestone or marble. The ore differs from the true fossiliferous ore, chiefly in the absence of oölitic structure and in the high percentage of magnesia, as shown in the analysis given below. Microscopic sections show the ore to consist largely of the fragments of bryozoans and corals and angular grains of quartz with a matrix of crystalline iron-stained calcite. In some places the iron oxide, which usually has a brownish color, is segregated in the cells or around the margin of bryozoans or corals, but more generally it seems to occur unevenly distributed throughout the entire mass in the form of a yellowish stain.

The only two places where this ore was examined by the writer, were R. W. Weatherly's property, lot 14, 11th district, and W. H. Shadden's property, lot 50 in the same district. The ore on the latter property, which is located near the Dalton-Cleveland public road, about one mile south of the State line, was worked to a considerable extent in 1870, and some 15 or 20 carloads of ore were shipped to Chattanooga. The old workings, consisting of open cuts originally from 5 to 15 feet deep, are now partially filled with fallen earth. The main part of the ore mined here is said to have been in seams which gradually became too small in the deeper excavations to be worked with profit. The chemical composition of the ore from the Shadden property is shown by the following analysis by Dr. Edgar Everhart, Chemist of the Geological Survey of Georgia:

Hygroscopic water	0.27
Combined water	4.05
Ferrous oxide	0.75
Ferric oxide	48.07
Alumina	4.35
Manganous oxide	0.42
Lime	9.81
Magnesia	0.55

Silica	22.79
Sulphur	0.06
Phosphorous pentoxide	0.79
Carbon dioxide	8.00
Total	99.91
Metallic iron	34.23
Phosphorus pentoxide	0.79

CHAPTER X

FOSSIL IRON ORES OF CATOOSA COUNTY

INTRODUCTION.

The fossil iron ores of Catoosa county occur only in Dick's and Taylor's ridges and in the northern extension of the latter ridge north of Chickamauga Creek, known as White Oak Mountain. Taylor's Ridge, together with White Oak Mountain, form the western limb of a synclinal fold which is made up of the Rockwood sandstone and shales, while Dick's Ridge formed of the same series of rocks, constitutes the eastern limb of the fold. The former limb traverses the entire width of the county in a northeast-southwest direction, but the latter limb is cut short by a fault just north of Panther Creek. While the Rockwood formation extends thus far to the north, Dick's Ridge proper terminates at the junction of Mill and Chickamauga creeks, some five miles further south. As the fossil iron ore is co-extensive with the Rockwood formation, it will be seen by examining a map of Catoosa county, that the aggregate length of the two lines of fossil iron ore is approximately 20 miles.

The eastern line of fossil iron ore outcroppings seems to be best developed in Dick's Ridge, only a short distance north of the Catoosa-Whitfield line. The ore here is exceptionally abundant as float ore, on what is known as the Smith property, lot 25, 27th district, a few hundred yards from a gap in the ridge, locally known as the Narrows. The ore, which is soft and of good quality, as shown by the analysis below by Dr. Edgar Everhart, occurs in rectangular blocks from six to eight inches in thickness, strewn along the hillside. At some points are to be seen some old excavations where the ore was mined for chimney jambs.

THE SMITH PROPERTY.—Analysis of ore from the Smith property by Dr. Edgar Everhart, Chemist of the Geological Survey of Georgia:

Hygroscopic water	0.42
Combined water	4.73
Ferrous oxide	none
Ferric oxide	81.01
Alumina	2.86
Manganous oxide	.01
Lime	.04
Magnesia	.59
Silica	9.29
Sulphur	.01
Phosphorus pentoxide	1.13
Carbon dioxide	none
Total	110.09
Metallic iron	56.75
Phosphorus	.500

On the property adjoining the Smith lot on the north are to be seen like excavations, but they are all now more or less filled with earth and no ore is to be seen *in situ*. Still further to the north, where the Houston Valley-Ringgold public road crossed Dick's Ridge, occurs another exposure. The ore at this point is mostly hard, and attains a maximum thickness of less than eight inches. North of the last exposure but little or no ore occurs on the surface south of Tiger Creek, but just north of this stream it again appears in the knobby hills on Mrs. Harris' property. Here the ore is only to be seen as float ore strewn along the hill slopes. Judging from the fragments examined the ore on the Harris property occurs in thin seams, and is of but little commercial importance.

The ore of Taylor's Ridge and White Oak Mountain appears to be somewhat more continuous than the ore on Dick's Ridge. The thickness of the seams and the character of the ore itself appear to be pretty much the same. Along the eastern side of Taylor's Ridge from the Catoosa-Whitfield line to Chickamauga Creek, float ore in greater or less abundance occurs on all the lots. This is especially true of the lots lying immediately east of the summit of the ridge. One of the best exposures of ore to be seen on the ridge occurs in an old peach orchard on William Ostrem's (?) property, lot 10, 27th district. The ore here occurs in the form of blocks strewn about the surface, varying from four to six inches in thickness. The ore is soft and carries considerable silica in the form of sand. The following analysis by Dr. Edgar Everhart, Chemist of the Geological Survey of Georgia, of a sample of the ore taken from the Ostrem lot, is here given:

Hygroscopic water	0.34
Combined water	5.40
Ferrous oxide	0.75
Ferric oxide	73.04
Alumina	4.97
Manganous oxide	0.26
Lime	0.15
Magnesia	0.73
Silica	13.17
Sulphur	0.07
Phosphorus pentoxide	1.34
Carbon dioxide	none
Total	100.22
Metallic iron	51.13
Phosphorus	0.584

On the east side of Taylor's Ridge, north of the Ostrem lot, the fossil iron ore occurs on the following lots owned by the Georgia Iron and Coal Company: 315, 299, 300, 279, 262, 263, 227, 228, 200, 192, 168, 169 and 157, all of the 28th district. The last four lots here named lie north of Chickamauga Creek, and are consequently located along the east side of White Oak Mountain. The only work done by the Georgia Iron and Coal Company for fossil iron ore is to be seen at the base of White Oak Mountain, on lot 192, only a short distance from the railroad bridge. The workings, which consist of open cuts, were made some years ago during the life of Governor Joseph E. Brown, who was at that time chief owner of the property, now owned by the Georgia Iron and Coal

Company. The total amount of ore mined here probably did not exceed 20 carloads. The ore in none of the old excavations at the time of the writer's visit was exposed to view, but at the base of a bluff on the opposite side of the creek nearby, the seam of ore measured only five inches in thickness.

North of the Georgia Iron and Coal Company's property the fossil iron ore continues along the western foothills of White Oak Mountain to the Georgia-Tennessee line. The only point at which the ore was examined along this line of outcroppings was at John Connelly's property, lot 95, 28th district, located about two and a half miles south of the State line. The ore on the Connelly property occurs along the sides of the foothills of White Oak Mountain, 75 feet or more above the valley. It was exposed at three different points in shallow excavations, where it seemed to occur in two distinct beds, separated by several feet of shale. The ore in these beds varies from four to eight inches in thickness, and dips at a low angle to the east. The following analysis by Dr. Edgar Everhart, chemist of the Geological Survey of Georgia, shows the ore to be of a good quality:

Hygroscopic water	0.25
Combined water	4.50
Ferrous oxide	0.10
Ferric oxide	80.03
Alumina	0.52
Manganous oxide	1.77
Lime	0.24
Magnesia	trace
Silica	11.40
Sulphur	0.08
Phosphorus pentoxide	0.79
Carbon dioxide	none
Total	99.68
Metallic iron	56.10
Phosphorus	0.392

CHAPTER XI

THE ORIGIN OF THE CLINTON ORES

Two theories have been advanced as to the origin of the Clinton iron ores, each of which has been strongly advocated by equally eminent observers. These theories may be designated as the sedimentary and the replacement theories. The former supposes that the iron is an original constituent of the ore-bed, being deposited at the same time as the calcareous material of which it is often largely made up; while the latter supposes that the iron is of more recent origin, having been derived chiefly from the overlying shales by leaching, and afterwards deposited in the calcareous beds below by replacement.

One of the earlier advocates of the sedimentary origin of these ores was Prof. H. D. Rogers, former State Geologist of Pennsylvania. Rogers, in discussing the origin of the Clinton ores, says:[1] "These regular ores of the Surgent (Clinton) series are to be regarded as among the permanent constituent strata of the formation, and as having originated with the other sedimentary materials in the form of very extended, but thin, sheets of ferruginous matter, covering at successive epochs the wide floor of the quiet Appalachian sea. Where all the oxide of iron was derived from which mingled the earthy deposits of clay, sand, carbonate of lime, and the fossils of these deposits, is a question which the present state of research scarcely enables us to answer." Prof. Rogers suggests that the primary source of these ore deposits, prior to their deposition in the Paleozoic sea, was the newly upraised land to the eastward. Having thus given what he considers was the probable original source of the ores, he continues: "We have only to imagine in the next place the operation of certain well-known chemical reactions, such especially as would arise upon the sudden introduction of cal-

[1] Geology of Pennsylvania, Vol. II, 1858, p. 729.

MINING FOSSIL IRON ORE BY SURFACE STRIPPING ON THE KENSINGTON IRON AND COAL COMPANY'S PROPERTY, NEAR ESTELLE, WALKER COUNTY, GEORGIA.

careous matter, to perceive a sufficient cause for the extensive precipitation of a definite quantity of iron in the form of the peroxide." To this source, he says, we may ascribe with some probability, perhaps, a large portion of the iron present in these beds, but he suggests that we must not overlook another train of causes, operating since the elevation of the strata, to increase the amount of the constituent. He thinks that an enormous quantity of ferruginous matter, both in the form of sulphuret and peroxide of iron, diffused throughout the shales, slates and marls in contact with the ore beds, has been dissolved in part by infiltrating waters in the form of a sulphate, and redeposited in the ore-beds, where the reaction of the lime of the fossils converted it into the peroxide. As an evidence of this secondary enrichment of the ore-beds, he adds that where the outcrop, the slope of the ground, and the thickness of the overlying strata, are favorable to a copious infiltration of surface water, the ore carries a higher percentage of iron than at less favorable places. In concluding his argument, Prof. Rogers says: "But I must here advert to another much more instrumental cause of inequality in the proportion of iron, compared with the other constituent. I mean the removal by infiltrating water of a part or all of the soluble portion of the ore, chiefly its carbonate of lime, both diffused, and in the shape of innumerable organic remains. The fossils, chiefly shells and joints of the crinoidea, constitute, in many instances, fully one-half of the weight of the ore in its original unaltered condition, as the reader can ascertain by inspecting the analysis of the Clinton fossil ores and comparing the amount of carbonate of lime of the compact specimens with that of the soft or porous ores. It is obvious that a given bulk of the ore must retain, after the abstraction of this large quantity of calcareous matter, very nearly twice its former percentage by weight of its peculiar ingredient, the peroxide of iron."

It will here be observed that Rogers, although he evidently advocates the sedimentary origin of these ores, nevertheless at the same time admits that the ores were probably afterward enriched by ferruginous infiltrating waters from the overlying shales. The concentration of the ore in the ore-beds by the loss of lime carbonate, carried off in solution by acidulated waters, is another feature of the theory which he lays special stress on in considering the economic phase of the deposits.

Another strong advocate of the sedimentary origin of the Clinton ores was the late Prof. J. S. Newberry. In discussing the origin of these ores he compares them with the Swiss lake ores, now in the process of formation. Owing to the eminence of this author, and his extensive opportunities for observing these ores in many localities, it is thought advisable to quote here rather fully what he has to say on this subject.

After describing the distribution and the general structure of these ores, Newberry remarks[1]: "If we look over the world for an iron-ore forming, which will illustrate the origin of the Clinton ore, we find it in the granular, or 'mustard-seed,' ore of the Swiss lakes. This is an oölitic ore, consisting of spherules of limonite, which have formed around minute particles of some foreign substance. The water which flows into these lakes is highly charged with iron, since it is the drainage of a district rich in this metal. In the lake oxygen is absorbed, and ferrous is converted into ferric oxide. This collecting around some nucleus ultimately sinks to the bottom a ferruginous oölite, which from time to time is gathered as a crop. The Clinton ore was apparently formed much in the same way.

The basin in which it accumulated was surrounded by a watershed underlain by ferriferous rock, which furnished an unusual quantity of iron to the draining streams. This iron was precipitated in granules, which in successive ages formed beds many feet in thickness. Then a change of physical conditions threw upon it a sediment of another kind, and it was ultimately buried beneath all the Devonian and Carboniferous rocks. By this weight its granules were compressed to flattened disks, and these were in some instances converted into solid rock; and, like all the older limonites, this has finally lost its water and has been changed to hematite."

1 School of Mines Quarterly, November, 1880, p. 14.

Here he adds: "We have a simple explanation of the formation of a wide-spread iron ore destined to play an important part in the future iron industry of the country."

In addition to the above authors, Lesley, Dana, Chamberlin and Smyth also advocate the sedimentary origin of the Clinton iron ores. One of Lesley's [1] main arguments in support of the sedimentary theory is the occurrence of ferric oxide in the unaltered normal beds below the surface drainage level. He argues that this fact is strong evidence against the supposition that the ores have been deposited in the ore-beds by percolating waters from above.

According to Dana: [2] "The beds of argillaceous iron ore, which spread so widely through New York, and some of the other States West and South, could not have been formed in an open sea; for clayey iron deposits do not accumulate under such circumstances. They are proof of extensive marshes, and, therefore, of land near the sea-level." In the fifth edition of his manual of geology, he says that the beds were evidently deposited over tide-washed, salt-water flats, where trituration is gentle. He makes no reference whatever as to the chemical condition of the iron in the waters prior to its deposition, or to the nature of the land surface from which it was supposed to have been derived.

Prof. Chamberlin in discussing the method of deposition of the Clinton ores, says: [3] "Some difficulty arises in conceiving the precise method of formation, particularly since in the Wisconsin deposits no contemporaneous formation has been observed connecting the detached deposits such as would naturally be expected, if the whole region were submerged. As no fossils occur here, it seems probable that the ore accumulated in lakes, lagoons, or estuaries, and that the intermediate territory was not submerged."

Chamberlin further says that the probable source of the ore is to be found in the ferruginated waters, derived from the low flat lands adjacent, or the more distant iron-bearing rocks of the Archean series. The location of the latter, he adds, however, were

[1] Geology of Penn., Rept. F, p. 39.
[2] Dana's Manual of Geology, Third Edition, p. 231.
[3] Geological Survey of Wisconsin, Vol. I, p. 179.

probably not favorably situated to become the source of such an accumulation. He agrees with Newberry in assigning to the deposits an origin similar to the Swedish lake deposits.

As to the chemical reaction involved in the process of deposition of the ores, he says: "While in process of transportation, the iron was a soluble protoxide, but by oxidation it was rendered insoluble, and deposited. In the ages that have since passed, these limonite granules have lost a part of their water of combination, and have been converted into red hematite."

Some of the most interesting and important papers so far published, on the origin of the Clinton iron ores, are those of Dr. C. H. Smyth, Jr., of Hamilton College, Clinton, New York. Dr. Smyth is a strong advocate of the sedimentary origin of the Clinton ores, but at the same time, he admits that there are places in which infiltration may also play an important part. His paper from which I shall here quote somewhat fully, deals chiefly with the deposits as they occur in the typical locality at Clinton, New York.

After devoting considerable space to the concretionary structure of the Clinton iron ores, Dr. Smyth says:[1] "If the ore represents oölitic limestone, each spherule has been altered from outside toward the center. This alteration has been by the replacement of the calcite by silica and iron carbonate. It would seem as though, after the exterior layers were thus altered, they must, to a greater or less extent, protect the interior layers from change, and that there would often be some trace of original calcite. In no case has this been seen, even in the leanest ores, although the layers of silica and iron ore often are so dense and impervious that hydrochloric acid can not dissolve all of the iron present.

"Further, it is difficult to account for the present chemical conditions of the ore on the substitution theory. This theory postulates that the iron is taken into solution in the overlying rocks by circulating waters containing organic matter. The iron would thus be brought to the limestone in the form of carbonate, and would be precipitated in that form. In highly tilted strata it is easy

[1] American Journal of Science, Third Series, Vol. XLIII, pp. 487-496, 1892.

to see that currents of water coming more directly from the surface along the dip, might contain oxygen instead of the products of organic decomposition, and thus cause the precipitation of the iron as hydrated oxide, or convert to that form a previously precipitated carbonate as described by Prof. Van Hise in his paper on the Marquette ores. But when, as in New York State, the strata are horizontal, such an explanation will not suffice. Yet in no case has there been seen anything to indicate that the ore was once a carbonate. If this ore was once a carbonate, what agent has so completely altered it to the peroxide?"

Smyth further remarks that it is a difficult matter to understand why meteoric waters should dissolve iron from one calcareous strata and deposit it in another at a lower level. He finds that the strata of shale and sandstone overlying the iron ore beds in New York are highly calcareous, and that the waters which have soaked through these strata deposit lime carbonate wherever there is an opportunity offered. "How," he asks, "can such water be the bearer of iron salts that are precipitated by lime carbonate at a lower level?"

Dr. Smyth also finds evidence of the sedimentary origin of these ores in the distribution of the iron oölites in the calcareous matrix. His argument is thus stated: "Associated with the ores are many irregular patches and layers, both calcareous and argillaceous containing ten per cent. of iron, still the spherules are just as ferruginous as in the pure ore. If they resulted from replacement, they would naturally be only partially changed. If thin sections be prepared from these specimens, it is seen that the spherules are identical with those of the ore, though completely surrounded by pure calcite. How is it possible for an iron-bearing solution to pass through this compact calcite until the spherule is reached, and then begin to deposit the iron and replace the calcite? It is not uncommon to see spherules of which the outer layers have partially separated from the core, the space thus formed being filled in by the clear calcite cement." Such occurrences as these, he concludes, can only be explained on the supposition that the spherules were ferruginous when incorporated into the rock. He further states that the iron of these ore-beds was probably deposited from a mechanical suspension, rather than from a chemical solution. In support of this idea, he cites the intimate relation of the iron and silica in the spherules.

The most conclusive argument to my mind, which Dr. Smyth presents in his paper in support of the original sedimentary origin of the Clinton ores, is the occurrence of fragments of ore in the overlying limestone. This occurrence, he states, is found at Ontario, Wayne county, New York. He says that these fragments are just as ferruginous as the ore in the beds below, yet they are at the same time enclosed in pure limestone. It would, indeed, seem to be a difficult matter to find a more convincing proof of the sedimentary origin of these ores than the one here given. These fragments of ore were apparently derived from the underlying ore beds after they had been consolidated and assumed practically the same form in which we now find them below the drainage level where lime cement constitutes one of the principal constituents. The breaking up of the ore beds was no doubt due to the action of the waves on a newly raised shore, where the ore-beds were exposed, and the currents were sufficient to bear detrital material seaward. In this way the fragments of the ore were carried and redeposited in calcareous beds, then forming on the overlying ore beds.

Among the more prominent writers who do not accept the sedimentary theory in regard to the origin of the Clinton iron ores, may be mentioned Prof. N. H. Shaler and James P. Kimball. Prof. Shaler[1] after a study of the Clinton iron ore in Bath county, Kentucky, arrives at the conclusion that the iron is a replacement of calcium carbonate in fossiliferous limestone beds, subsequent to their deposition. The main argument advanced by Shaler against the original sedimentary origin of the ore, and in favor of the subsequent replacement theory, is, as he states, there is no known way in which iron can be laid down in deep sea, where it is known from the organic remains that the Clinton ore was laid down, and it is not at all likely that deposits of this nature were deposited in Silurian times.

1 Geol. of Kentucky, Vol. III, p. 164.

James P. Kimball, in discussing the genesis of the Clinton ores, says:[1] "Parts of thin fossiliferous limestones of the Clinton group of strata are often replaced by red and brown ferric oxides from extraneous sources. In the Appalachians of Southern Pennsylvania, for example, where I have long had opportunity of closely observing the mode of occurrence of these ores, especially in flanks of Tussey, Dunnings's and Will's mountains, fossil-ore, so-called, rarely oölitic, occupies the weathered zone of highly fossiliferous beds of limestone, intercalated with shale and sandstone. This replacement has been wrought especially in steep dips by infiltration from drainage of adjacent ferruginous strata, particularly of an inferior series, outcropping topographically higher in the flanks of these parallel wall-like ridges. At or near water level or drainage level and in topographical position unfavorable to weathering action or to sources of infiltration, replacement has been found to cease. Supersaturation, as at water-level, and impenetration of solutions from topographical causes, are equally unfavorable for this process.

In portions of limestone beds, bordering ravines down the mountain side, dissolution of limestone sometimes has failed above immediate drainage level to be attended with replacement of ferric oxide, yet in such circumstances, the limestone has given way to the dissolving action of the passing waters, leached, insoluble residues retaining its original structure as well as moulds of fossils, occupying its place along with creepings from adjacent strata. Here transmission of seepage water has proved too rapid other than solvent or destructive action to have become sensible."

"Another local circumstance is also deserving of mention. It is this: Opposed to a rapid transmission of infiltrations in water sheds between successive cross-ravines, is a barrier known as Red Ridge, composed of a compact series of arenaceous argillite. This is locally developed at the top of the Surgent shales, and stratigraphically above, but topographically in front of the plane of the ore-limestone. Near where this barrier is scored by cross-ravines, underground as well as superficial drainage, has become accelerated.

1 American Geologist, Vol. VIII, pp. 352-376, 1891.

Preservation of Red Ridge from local erosion has therefore come to be regarded in Bedford and Huntington counties, Pennsylvania, as indispensable to a favorable development of the fossil-ore bed back of it, or to the absence of 'water.' Of these the distribution and extent are thus mainly determined by conditions of underground drainage as affected mostly by topographical features. Gentle dips under steep slopes are, for various reasons, inconducive for infiltration."

"The above remarks directly apply to the more or less hydrous fossil-ores of the Appalachian ridges in Pennsylvania, as distinguished from the oölitic hematite, or dyestone ores, likewise developed in favorable circumstances or lower horizons of thin crinoidal limestone, within compass of the Clinton or Surgent formations. Both types of ore, and often both series of developments, are generally referred to indifferently as Clinton fossil-ores. The stratigraphical relations between these two series of developments, even where both may be recognized in a single ridge or section, are extremely variable. In Southern Pennsylvania, where the Clinton shales attain a thickness of nearly 1200 feet, the fossil-ore beds are about 400 feet above the horizon of the Frankstown oölitic or dyestone ore, which in turn is about 300 feet above that of the black ore, so-called. All of these ores owe their development, as I believe, exclusively to secular replacement of elevated parts of these limestones—not, as sometimes explained, to direct sedimentation in whole or in part. For wherever oölitic iron-ores are developed within the Clinton series, they are found to gradate into non-ferriferous limestones, more or less crinoidal, and usually in circumstances only moderately favorable to weathering action. An equally significant fact is the absence of valuable iron-ores where the Clinton limestones, as in Southern Ohio, are massive and unaccompanied by a considerable thickness of overlying shales. Wherever, on the other hand, the limestones occur in numerous thin beds, and so alternate with more or less ferruginous shales; or, again, wherever overtopped by shales, they seldom fail, especially in steep dips to graduate unequally into oölitic hematite by replacement. Even in Ohio, where the Clinton group is represented by a single but

A VIEW SHOWING THE OLD WORKINGS OF THE UPPER AND THE LOWER IRON ORE BEDS ON THE MARSH PROPERTY AT ESTELLE, WALKER COUNTY, GEORGIA.

comparatively thick limestone member under gentle dips, the upper portion of the limestone is sometimes replaced by hematite, though of no economic importance. Imperfect replacement likewise occurs where the limestone becomes shaly, and expands in thickness."

"Non-ferriferous Clinton limestones, more or less magnesian, into which their associated iron-ores graduate, may be assumed to have been deposited in clear and moderately deep continental seas. That these seas were ramified by all but insulated land surfaces is indicated by the abundance of intercalated siliceous sediments from sub-aerial rock-decay. It is sometimes held that these limestones, and at least the oölitic hematites, developed upon the same horizons and, passing into each other, were necessarily deposited together. Yet direct ferric precipitation from extremely unstable natural solutions of ferrous salts, can not well be believed to have taken place so far from inland sources, or where conditions existed favorable to the accumulation of non-siliceous and extensive limestones."

"Again, notwithstanding the fact that the Clinton iron ores merge into pure marine limestones, they have, on the other hand, sometimes been assumed to afford proof of widespread marshes. A theory of this kind, however, is likewise opposed by the necessity of attributing extensive limestones of the Clinton type to mid-sea, and inferentially deep-sea deposits. And the objection still stands that ferric hydrate in suspension no more than ferrous salt in solution, can have materially contributed to marine non-siliceous limestone. The conclusions therefore seem justified that whatever considerable proportion of ferriferous material was deposited, within compass of the Clinton limestones, was alternately deposited in the form of siliceous sediments, represented by intercalations of shale. Such intercalations are common in Pennsylvania and Virginia. A less theoretical objection rests on the fact that the distribution of the Clinton iron ores, clearly depends on secondary and wholly on advantageous conditions, connected with topography and environments."

In further support of the replacement theory, Mr. Kimball cites the paper of Mr. Aug. F. Foerste, [1] who upon microscopic examination of fossil iron ores from Pennsylvania, Georgia and Ohio, re-

[1] Am. Jour. of Sci., Third Series, Vol. XLI, pp. 28-29.

EXPOSURE OF A HARD IRON ORE BED ON THE GLENN-WARTHEN PROPERTY, SHOWING LAMINATED STRUCTURE.

ports all stages of replacement of calcium carbonate, both cement and oölitic granules, by ferric oxide, the granules being fragments of Clinton species of water-worn bryozoan. Foerste also states that in no case was anything noticed leading to the opinion that the concretionary segregations of iron had taken place either around the bryozoan fragments or otherwise. Simple replacement of the iron ore, he says, was the rule, the attack being made first on the exterior parts of the grains.

I have above quoted at some length from Kimball's papers, on account of their containing the leading arguments in support of the replacement theory, and furthermore on account of the writer's having had what seems to have been an exceptionally good opportunity to study the ores in the field.

In addition to the above papers advocating the replacement theory of the fossil iron ores there is a recent article, occurring in the transactions of the American Institute of Mining Engineers, by H. M. Bowran, who takes the position that the ore in the present form is a replacement of thin bedded fossiliferous limestone, the replacement having taken place subsequent to the orogenic movement which closed the Paleozoic era. He thinks the ore originated from the pyrites of the overlying coal measures, and that an essential condition of their concentration into the form of commercial ore was synclinal folds. He illustrates his theory by the fossil ore of Lookout Mountain. In speaking of this synclinal mountain he says:[1] "When it was bent into a synclinal trough, the upper part was subjected to a crushing and the lower to a tensile strain. The members under compression are massive sandstone, while the members under tension were and are sandy, and calcareous shales, limestones and thin bedded rocks generally. As a result, the coal measures were gradually oxidized and the pyrites became sulphate of iron solution, which filtered through the sandstone to the axis of the mountain, where in course of time it formed a more or less concentrated solution of iron sulphate, and was constantly feeding the enriched solution. The mountain being axially fractured at its

[1] Am. Inst. Mg. Engrs., Trans., Vol. XXXVI, pp. 587-604, 1906.

central base as a result of tensile strain, the floors of the valleys were too high for the bottom drainage from this acid earth reservoir. It dissolved the iron from the calcareous shales of the Clinton period. By simple gravity it had already passed through the axial fissures of the Mountain limestone and the Black shale. The first limestones that were included in the terrestrial reservoir, however, were acted on chemically, and the water became charged with calcium sulphate, and was siphoned upward to the accidental level of the springs." In the chemical action here indicated, he thinks the iron replaced the calcium carbonate in the thin beds of fossiliferous limestone, and thus gave rise to the fossil iron ore. The argument here advanced by Bowran is fully answered by Smyth in his paper above quoted. Nothing short of a chemical miracle could explain how the iron sulphate derived from the alteration of pyrites of the coal measures could pass through several hundred feet of lower carboniferous limestone without being precipitated.

A further argument in support of the replacement theory of these ores is the abundance of organic remains formed in the ore beds. It is claimed that it would be practically impossible for corals and other animals to exist in water so ferruginated as to deposit thick beds of iron ore. Mr. J. W. Judd, in discussing the origin of a similar fossil iron-ore occurring in Northamptonshire, England, says:[1] "The abundance of molluscan remains in some of the beds of iron-stone, indicating, as we have seen, that the animals lived and died upon the spot, precludes the idea that the medium in which the beds were deposited could have been a strong solution of iron." In opposition to this argument, may be quoted the following statement from Prof. Franz Posepny:[2] "Of the various metals dissolved in sea water, iron is least injurious to animal life. Indeed, animal life assists, in the so called lake-ores, the segregation of this metal. Moreover, the precipitation of ferrous and ferric oxides from concentrated solutions is probable, so that a precipitation of iron-ores directly from sea-water seems to be established as a possible origin for some iron ore beds."

[1] "Geology of Rutland," Survey Memoir.

[2] Genesis of Ore Deposits, p. 121.

Having given above, at some length, the argument advanced by the advocate of the two different theories of the origin of the fossil ores, there are here introduced the conclusions of the writer, based upon his own personal observations and study of the fossil iron ores as they occur in Georgia. However, before taking up the genesis of the ores proper, the geological conditions, which seemed to have prevailed during the Clinton epoch, will first be described in some detail, following which will be introduced a description of the ores themselves.

Any plausible theory as to the origin of these ores, it seems to me, must be based, in a large measure, upon a correct knowledge of conditions under which the Clinton rocks were laid down, together with a knowledge of the character and nature of the ores themselves.

CHAPTER XII

THE GEOLOGICAL CONDITIONS DURING THE DEPOSITION OF THE CLINTON ROCKS

The geological conditions which prevailed during the deposition of the Clinton formation, are revealed in the lithological character of the rocks, the nature of the organic remains and the extent and nature of the pre-existing land areas.

The Clinton group of rocks, with the exception of the Oneida conglomerate and the Medina sandstone, as we have seen elsewhere, constitutes the oldest rocks of upper Silurian era. The dry land during the deposition of the Clinton rocks, may therefore be said to correspond very nearly to the land area at the close of the Lower Silurian era, a general idea of which may be had by an examination of Dana's map of North America, at the opening of the Upper Silurian.[1] It will here be noticed that the growth of land had been chiefly along the margin of the Archean continent. An elevation along the Atlantic seaboard had brought above the surface a broad Appalachian area, extending from New York to Alabama, and Wisconsin, parts of Illinois and Michigan had emerged, and the broad St. Lawrence channel, which in earlier times was a passageway between the Atlantic ocean and the Continental Interior was closed by dry land, the Cincinnati uplift had just brought above the waves a large island in Southern Ohio and Northern Kentucky, and another island of like extent in Middle Tennessee. Dana, in speaking of these islands, says:[2] "They partially divide off from the great Continental Interior a portion called the Eastern Interior Sea, which from this time onward was like a great bay, having a narrow

[1] See Fig. 3, p. 154.

[2] Dana's Manual of Geology, Fourth Edition, p. 537.

southwest opening, over Alabama, a length of about 700 miles, and its northern limits near the sites of Albany and Troy. Its waters communicated in the Upper Silurian era with those of the Central Interior Sea, over Michigan and Northern Ohio. But this connection was diminished during the progress of Paleozoic time. It had probably, also, a shallow connection with the Atlantic over Pennsylvania and Maryland, where the land is now low, permitting of an interchange of water and life. The conditions of this Eastern Interior Sea influenced not only its tides and currents, but also the

FIG. 3.

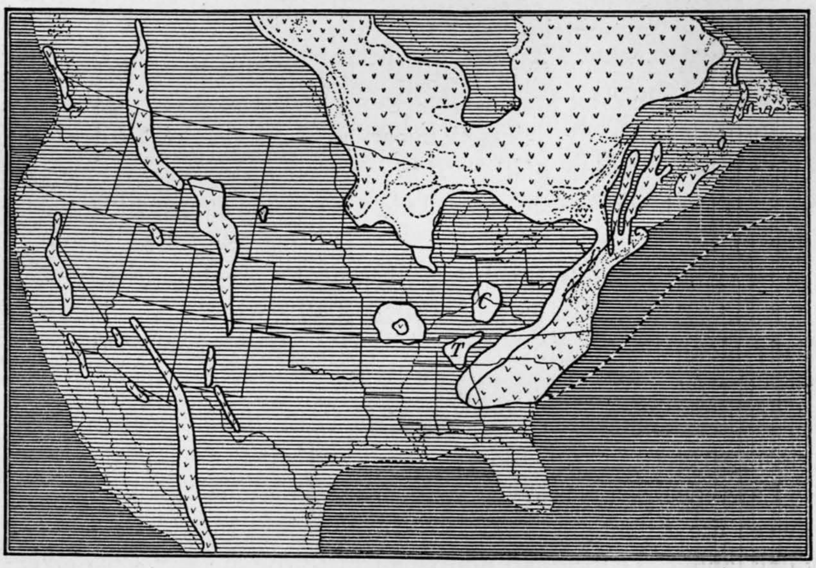


FIG. 3.—North America at the Opening of the Upper Silurian (after Dana).

temperature and purity of the waters, the supply of sediments, the kind of life, and hence in various ways modified rock-making and biological conditions."

This, in short, is a brief outline of the physical geography of the continent east of the Mississippi during the deposition of the Clinton rock. In order to satisfy more fully the present object of enquiry, it becomes necessary to enquire more fully into the character of this post-Clinton continent from which the sediments were derived that formed the Clinton rocks.

Just prior to the formation of the Upper Silurian rocks, following apparently a long interval of quiescence, there occurred epeirogenic movements, which materially increased the dry land, and at the same time probably re-elevated the pre-existent land surface, which had likely been reduced in many places by erosion to nearly sea-level. During this period of activity, the Taconic mountain range of New England and New York was formed, and uplifts occurred in Ohio, Kentucky, and Tennessee, and also in New Brunswick and Nova Scotia. The Taconic disturbance is thought to have extended far to the south, along the Atlantic, thus extending the pre-existent Piedmont Archean land eastward to, or, possibly, beyond the present limits of the coast line.

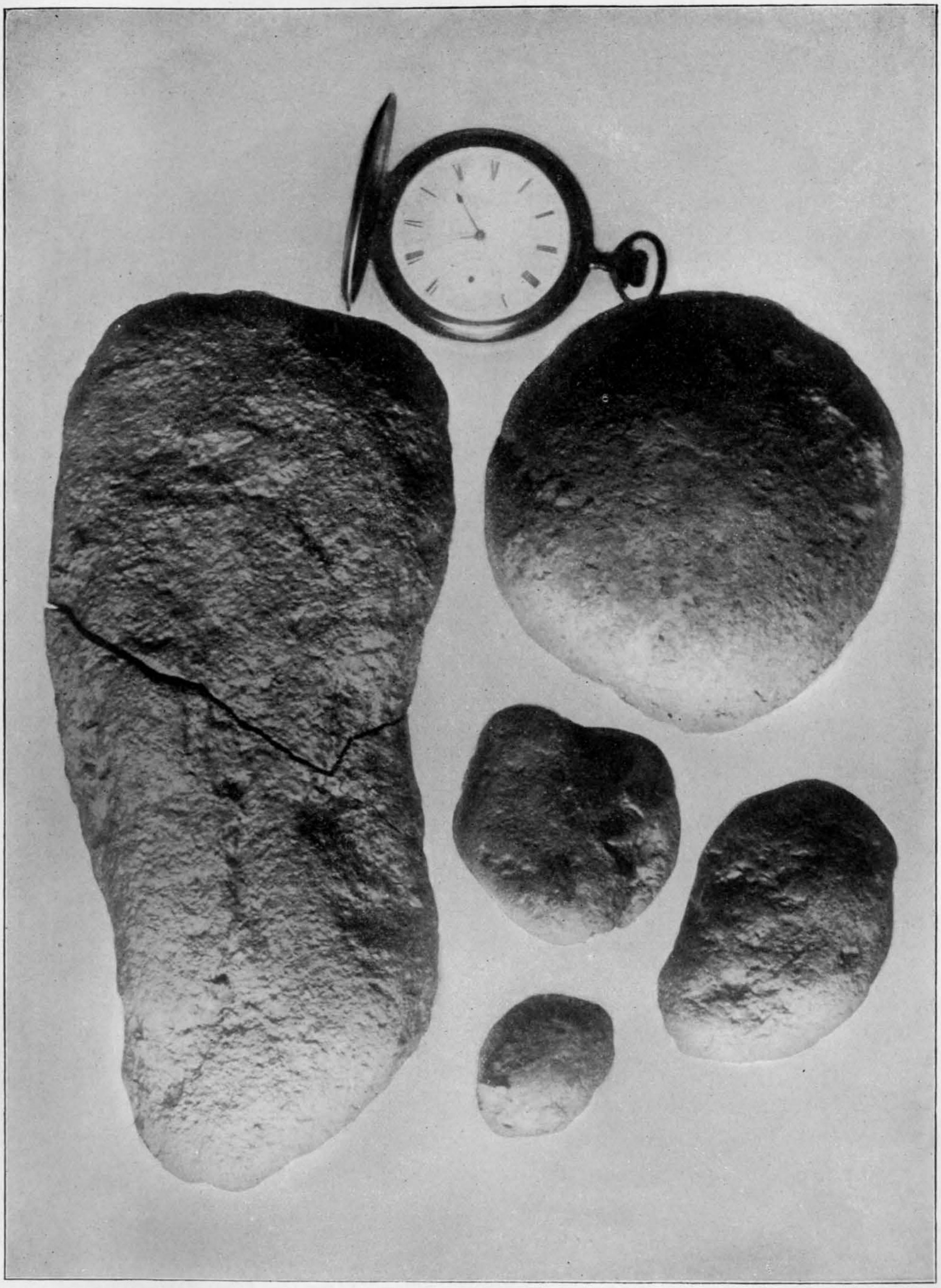
Prof. Geo. H. Williams in speaking of this old Piedmont land surface says:[1] "The general outlines of its structure indicate that it represents the remains of a vast and very old mountain range, the eastern half of which has sunk along a great fault beneath the sea, and thus buried by the comparatively recent Coastal Plain deposits. What we now see is the western flank of this range, composed of early Paleozoic strata which become more and more crystalline as they approach the centre cone where they are altogether replaced by still more ancient rocks, a large portion of which are of igneous origin."

Along the western margin of this old Piedmont land surface was added at the same time a narrow fringe of land extending from Alabama to New York. To the northwest, this same newly made fringe of land continued along the border of the Archean land as far west as Wisconsin. The emergence of large islands in Ohio, Kentucky and Tennessee, partially dividing the Greater Interior Sea into two divisions, above referred to, completed the epeirogenic movements closing the lower Silurian Era.

We have thus at the beginning of the Upper Silurian not only an increase in land surface, but also at the same time an increased elevation of the pre-existent land surface, conditions preeminently

[1] U. S. Geol. Surv., 15 Annual Report, p. 658.

favorable to rapid erosion and deposition of sediment. That these conditions did actually exist, is abundantly attested by the nature of the sediment. The first deposits laid down, subsequent to the continental disturbance above described, was a shallow water deposit, the Oneida conglomerate, made up chiefly of quartz pebbles and sand. Such a deposit can form only near the shore and along a recently elevated coast, supplied by sediment from rapidly flowing streams. The Oneida conglomerate was followed by the Medina sandstone, consisting mainly of thin bedded fine grained, vari-colored sandstone, often somewhat argillaceous. This deposit was also a shore deposit, as shown by its ripple and rill marks, and the coarseness of the material. The character of the material, however, being of a finer nature, indicates that surface erosion was less active, and that the streams were probably, in many cases, overloaded, or they had reduced their beds nearly to base-level in the lower part of their courses. Following the deposition of these two inshore deposits with their coarse-grained sandstones and conglomerates were laid down the more argillaceous beds of the Clinton formation with its thin beds of limestone and fossil iron ore. This transition of sediment from conglomerates and sandstones to shales and limestones, is the natural consequence of the lowering of the land-surface. Streams, which formerly bore large quantities of pebbles and sand to the sea to be distributed along the shore by tidal currents, had so reduced their grade by erosion that they were now apparently able to carry only the fine sands and clays. These rivers, judging from the extent of the land surface, during this time were all short, none probably reached a length of more than two or three hundred miles before emptying their waters into the Great Interior Sea. What they lacked, however, in length, was probably made up in number, as the conditions appeared to have been especially favorable for small hydrographical basins. The topography of the land during the deposition of the Clinton rocks seemed to have been approaching that of old age. The strong relief of hills and valleys, which so prominently characterized the landscape during the deposition of the Oneida conglomerate, now apparently gave place to a somewhat featureless plain with a low, broad coast line.



WATER-WORN BOULDERS FROM THE FOSSIL IRON ORE BED ON DIRTSELLER MOUNTAIN, CHATTOOGA COUNTY, GEORGIA.

The land surfaces from which the Clinton rocks were formed were probably in a large measure granites and other igneous rocks, as shown by the character of rocks now making up the old crystallines of the Piedmont region along the Atlantic. These rocks were apparently chiefly of the acid type, however, the common occurrence of diorites and diabases throughout the region indicates that the basic rocks, with high iron contents, were also more or less abundant. Both of these classes of rocks appear to have formed enormous surface flows, as shown by the widespread remnants of ancient igneous material along the entire extent of pre-Cambrian land from Newfoundland to Alabama.[1] In addition to these eruptives, there was also bordering the coastline a narrow belt of ancient clastics, varying in age from early Silurian to Algonquin, which also furnished sediments for the Clinton rocks. Mineralogically considered, the character of the material which went to make up the Clinton formation does not seem to differ materially from the sediment now being brought down by the Atlantic and Gulf coast rivers, which obtain much of their sediment from the same ancient rocks.

With the exception of the beds of fossil iron ore, the entire series of Clinton rocks as seen in Georgia and Alabama, where they have been studied by the writer, seem to differ in no way from recent deposits laid down in comparatively shallow water during the slow subsidence of the sea floor. The sandstones which predominate along the eastern outcroppings, with their numerous ripple-marks and fossil rain prints, are gradually replaced further westward, largely by shales, which in turn still further westward pass into limestone, indicative of clearer and deeper waters. We must not infer from these general features of the formation that the Clinton rocks in the horizon of the fossil iron ores are of a uniform character throughout; on the contrary, the formation is pre-eminently noted for its rapid and numerous changes. At many points throughout northwest Georgia and eastern Alabama, the beds of sandstones and shales are often repeated more than twenty times in a section of as many feet. Less frequent, and at various horizons throughout the

[1] Jour. of Geol., Vol. II, pp. 1-34, 1894.

series, occur thin beds of limestone made up largely of shells and fragments of coral and crinoid stems. These three kinds of wholly different sediment so often repeated, indicate that the depth of the water in which they were deposited, as well as the force of the currents themselves, were quite variable. The sandstones, with their cross-bedding, ripple-marks and fossil rain prints, unmistakable evidence of shallow water, are a written history of an old shore line frequently swept by currents of the Great Interior Sea. The region, however, of this tumultuous Sea, with its rapid, moving currents, appeared to have been rarely of long duration, scarcely had the deposits of sand and pebbles been fairly inaugurated, when the work was brought to a sudden close by a deepening of the waters, or a change of the currents. With this change came also a change of sediments. The enfeebled currents were now enabled to carry only the finest sands and clays, the materials of which formed the innumerable layers of shales. The latter condition seems to have predominated throughout the entire Clinton epoch, but the frequent occurrence of sandstone marks intervals in which rapid currents again prevailed. At longer intervals of time, and less often repeated, the conditions favorable for the deposition of sands and clays gave place to conditions favorable to the deposition of limestone. The last named conditions point to the clearing of the waters, and probably also the deepening of the Sea. The thinness of the individual limestone beds would indicate that the conditions favorable for the deposition were of short duration. Yet at the same time the extended area over which they often occur shows that the conditions were widespread, and not confined to certain special localities. In the entire series of Clinton rocks, from the beginning to the end, we here see no evidence of sudden upheavals or tilting of strata. The character of the sediment points only to general oscillations of the sea floor, many times repeated.

The climatic conditions which prevailed during the deposition of the Clinton rocks appear to have been quite different from the climatic conditions which prevail in the same latitude at the present time. This is demonstrated by the sub-tropical character of the fauna revealed in the fossil remains found in such great profusion in the thin beds of limestone. Whether this climatic condition was due solely to the distribution of the land and water, or partly to the great abundance of carbon dioxide in the air, is not known. However, it seems to be quite probable that the direction of the ocean currents, as affected by the distribution of the land, was the main cause which brought about the warm climate. By an examination of the map, showing the distribution of the land, at the beginning of the Upper Silurian, it will be seen that the Great Interior Sea in which the Clinton rocks were deposited was cut off almost entirely from the Arctic regions by the old Archean continent to the northward. It appears quite probable, judging from the distribution of the land during the Clinton epoch, that the prevalent currents of the Interior Sea were warm currents entering by the narrow channel over Alabama between the southern prolongation of the Archean land and the recent emerged land in middle Tennessee. The northern course of this sub-tropical current, after traversing the Interior Sea, probably escaped to the northwest by the wide passageway over central Illinois and Michigan.

This Great Interior Sea, with its warm currents, appears to have been extremely favorable to marine life. Especially was this true during the deposition of limestones. The fossil remains of these calcareous beds show that during short intervals, when the waters were partially cleared, the sea floors teemed with a luxuriant growth of crinoids and bryozoans. Molluscan life, with its great variety, was also abundant, and the innumerable fragments of trilobites in some of the sandstone beds likewise attest the abundance of cretaceans. The scarcity of plant remains indicates a barren land surface. *Spirophyton,* a spiral-shaped seaweed, occurring in more or less abundance in the sandstones of the Rockwood formation of northwest Georgia, appears to be one of the most common plant remains found in the Clinton rocks. Lycopods, plant-like club mosses, and a few small ferns, together with lichens, probably completed the list of the land plants.

CHAPTER XIII

DESCRIPTION OF THE FOSSIL IRON ORES

The Clinton ores as they occur in Georgia, consist, commercially speaking, of two varieties, namely, the hard ore and the soft ore. The soft ore which forms the weathered outcrop of the hard ore, and which differs from the hard ore mainly in the loss by weathering of calcium carbonate, rarely ever extends more than a short distance beneath the surface. Where the beds are nearly perpendicular and the conditions are favorable for surface erosion, as in stream channels, the soft ore may be absent entirely, or reduced to a few inches in thickness, while, on the other hand, where the dip is at a low angle, and conditions are unfavorable for surface erosion, the soft ores may extend to a depth of many feet. Furthermore, any geological structure whatever, such as jointing and faulting, which may cause deep weathering and soil forming *in situ*, likewise will increase the depth of the soft ore. In other words the soft ore, being only the weathered outcrop of hard ore, any physical or chemical condition which tends to accelerate rock weathering, will, at the same time, be effective in increasing the depth of the soft ore. The free circulation of water carrying carbonic acid in solution is no doubt the chief agent which caused the alteration of the hard ore into the soft ore, however, the depth at which it has been possible for carbonated waters to freely circulate, has been conditioned largely by the geological structure as above pointed out.

THE SOFT ORE.—As the soft ore is derived from the hard by a loss of calcium carbonate, which frequently makes up as much as 20 per cent. of the unweathered ore bed, it necessarily follows that the thickness of the soft ore is not so great as that of the hard ore;

nevertheless, this difference in thickness is not usually so great as might be supposed, owing to the soft ore being more or less porous. A difference in thickness of something like 5 or 6 inches, would probably be about an average for a three-foot bed. It will readily be seen from the nature of the origin of the soft ore that it is not always possible to draw a sharp line, separating it from the hard ore. The change is rarely abrupt. The soft ore more generally passes into the hard by a very gradual change. Furthermore, the change scarcely ever takes place at equal depths throughout the beds, but it is generally more or less irregular, governed apparently by the degree of porosity of the different layers.

The physical structure of the soft ore is very variable. It is not always, as the name implies, a soft friable earthy unconsolidated material, but may consist of very hard, rather closely compacted mass. The latter, when taken from its natural bedding, frequently breaks into prismatic blocks, and is often spoken of by the miners as "block ore." The prismatic structure of these ores is due to a series of joints formed apparently during the folding of the rocks. A similar joint structure is also noticeable in the thin beds of sandstone, associated with the soft ore. In addition to the joint structure, the soft ore sometimes shows slickensides. This structure, however, is best developed in the hard ore.

A more minute examination of the soft ore shows the mass to consist largely of reddish iron oxide, replacing fragments of crinoid stems and bryozoans. Associated with these fossil remains, and frequently entirely replacing them, occur minute rounded, flaxseed-shaped particles of iron oxide, frequently showing a concretionary structure, a more detailed description of which will be given under the microscopic structure.

THE HARD ORE.—The hard ores, or the unweathered part of the ore-bed, differ from the soft ore as above stated, chiefly in high percentage of calcium carbonate, and also in being harder and of more compact structure. They form regular stratified beds occupying a position near the center of the Rockwood formation. In Georgia where these beds vary from a few inches to several feet in thickness, they attain an aggregate total thickness of something like 15 feet, which is about 10 per cent. of the thickness of that part of the Rockwood formation through which they are distributed. The workable beds are rarely more than three in number, more usually they are limited to only one, though at several places two have been successfully worked to a greater or less extent. The main workable bed, which varies from 18 inches to 4 feet in thickness, almost invariably has both above it and below it other beds, but these beds are usually small; or carry a low percentage of iron. It is not uncommon to find within three or four feet of the main workable bed, one or more of these small seams. They vary from three to fourteen inches in thickness, and are remarkable for their continuity, being traceable sometimes by their outcroppings for long distances. The chief commercial importance of such beds is the aid which they render the prospector in locating the main workable ore-beds. On this account they are often designated by the miners as the "leader." In addition to the beds here described there are also larger unworkable beds which frequently attain a thickness of several feet. Such beds are usually locally developed, and can rarely ever be traced more than a mile or so along their outcroppings, They generally partake of the nature of a highly ferruginous limestone, though in places they form low-grade ores. In general, these locally developed beds differ from the more persistent and workable beds in the character of the organic remains. In the former the remains consist chiefly of brachiopod shells, and in the latter bryozoans and crinoid stems are the main fossils.

The workable beds of hard ore usually consist of two or more layers separated from each other by partings of shale or sandstone, which may vary from a fraction of an inch to a foot or more in thickness. The shale partings, like the workable ore-beds themselves, are often quite persistent, and can frequently be followed long distances with but little variation in thickness. The sandstone partings on the other hand are not so persistent, and generally they change rapidly in thickness from place to place. The percentage of metallic iron in the unweathered workable ore-beds, as above noted, is quite variable. A like variation is also sometimes noticeable in the individual workable beds, such variations being generally most noticeable at points where the formations have been subjected to intense folding. In other words, the workable seams in Georgia are likely to carry a higher percentage of iron where they are nearly perpendicular than when they are horizontal or dip at a low angle.

In addition to the variation in percentage of iron here referred to, due apparently to geological structure, there are also at some points variations in the percentage of iron due to the presence of foreign material, such as grains of sand, pieces of clay and boulders of water-worn sandstone. The sand granules are present in nearly all of the ore-beds, and, like the other mechanical impurities above referred to, appear to increase in abundance, as the eastern lines of outcroppings are approached. The clayey mechanical impurities occur often as rounded pellets, varying from an inch to two or more inches in diameter. They have the appearance of being rounded by the action of water before their deposition in the beds of iron ore. When fresh and unweathered, they have not only the color and general appearance of the shales associated with the iron ore, but also appear to be of the same mineralogical composition.

The sandstone boulders, as far as my own observation extends, are confined to the ore-beds of Dirtseller Mountain and Taylor's Ridge. They are especially abundant and of unusually large size along the eastern side of Dirtseller Mountain, where they are found chiefly in the soft ore. The boulders, which vary from an inch to a foot or more in diameter, have the characteristic shape and smooth surface of water-worn boulders, as shown in plate XVII. In composition they are somewhat variable, but generally they consist chiefly of more or less rounded granules of quartz, cemented with lime and a limited amount of iron oxide. The latter mineral is also found scattered throughout the mass as rounded flaxseed particles, just as in the hard ores. In addition to these foreign materials there also occur in the ores in places, rounded, kidney-shaped masses of iron carbonate. The nodules of iron carbonate are quite common in the ores of Dirtseller Mountain, where they are often found associated with the water-worn sandstone boulders. When found in the soft ores, the carbonate nodules have a dark reddish-gray color. They are usually quite compact, varying from one-eighth to three or four inches in diameter, and can be readily recognized from the clay nodules and sandstone boulders, which they often resemble in external form by their high specific gravity. Occasionally pyrite is to be noticed, associated with iron carbonate nodules and also with the sandstone boulders. The pyrite seems to be confined chiefly to the outer surface or the periphery of the nodules of boulders where it appears to form a more or less continuous coating or layer, having a thickness of only a fraction of the diameter of the nodule.

A more minute examination of hand specimens of the hard ore shows a somewhat variable appearance, depending upon their purity. In general, the ore may be said to have a dark reddish color, often specked with white and brown, the former color being due to small flakes of calcium carbonate, and the latter to minute areas of limonite. The ore is usually quite compact, and when freshly broken generally shows innumerable shining cleavage faces of calcium carbonate. The main mass of the ore consists of iron oxide, either in the form of rounded oölitic flaxseed-like particles, or in the form of casts of fossils. The oölitic particles, which have an average diameter of about one-sixteenth of an inch, are usually somewhat flattened, the longer axis being at right angles to the bedding of the ore. In some of the beds these particles make up the greater part of the ore, while in other beds they are almost entirely wanting. They are also quite variable in the same bed from place to place, often occurring more or less in patches, or are confined to thin layers. The fossil casts, consisting largely of the fragments of crinoid stems and bryozoans, are present in nearly all of the ore; even the most oölitic beds contain them in greater or less numbers. As a general rule these fossil casts form the large part of the Georgia ores. In addition to the fossil casts of crinoid stems and bryozoans, shells of brachiopods and gastropods also occasionally occur in the ore, but usually these remains consist chiefly of carbonate of lime. In the leaner hard ores the calcite which is the main impurity, is sometimes found in thin layers, or as irregular masses distributed through the bed, giving to the beds a streaked or mottled

FOSSIL IRON ORE STRIPPINGS ON DIRTSELLER MOUNTAIN, CHATTOOGA COUNTY, GEORGIA.

appearance. The irregular masses or spots of calcite consist chiefly of pieces of coral or shell which have been only partially replaced by iron oxides. Traversing the ore-beds, usually at right angles to the bedding, are occasionally to be seen minute veins of white calcite. Such veins are confined largely to the places where the ore has been crushed or broken in the process of folding.

FOSSIL IRON ORE WORKINGS ON TAYLOR'S RIDGE, CHATTOOGA COUNTY, GEORGIA.

CHAPTER XIV

MICROSCOPIC EXAMINATION OF FOSSIL IRON ORES

A microscopic examination of thin sections of fossil iron ore shows it to consist of a matrix and the iron ore proper. The relative proportion of these two constituents is quite variable, depending upon the character of the ore. In the high-grade ore the matrix is reduced to a minimum, and the percentage of iron ore is correspondingly increased, while in the case of the lean ore just the opposite conditions obtain, that is, low iron percentage and high matrix percentage. The richer ores, in some cases, may run 80 per cent. or more of iron oxide, whereas the leaner ores may be reduced to 40 per cent., or even less. There appears to be every possible gradation in iron contents between the high-grade ores and the low-grade ores, and, furthermore, a like gradation between the low-grade ores and the ferruginous limestone. Any theory, therefore, which will explain the origin of the iron in the iron ores must, likewise, also explain the origin of the iron in the ferruginous limestones.

THE MATRIX.—The two main mineral constituents of the matrix of the fossil iron ores, are calcite and quartz, the former constituent usually being far more abundant than the latter, especially is this true of the hard ores which still retain their original calcium carbonate. The calcite matrix often seems to be of two or more generations. The oldest appears to be that forming the fossil, and which frequently shows a lamellar or fibrous structure, due apparently to the original structure of the shells. Another form consists of rather larger interlocking crystalline grains, often exhibiting beautiful polysynthetic twinning, while still another form occurs as small rhombohedral crystals, which are generally found along the margin of fossils or between the larger crystals which they frequently partially or wholly replace. The calcite of the fossils which still retain their original organic structure, often makes up a very large percentage of the entire matrix. This is especially true of the lean ore in which there seems to have been a minimum amount of replacement. In addition to the lamellar structure, which is the main characteristic of the older, or what is taken to be the original calcite, there is almost invariably present a granular structure, which appears to be the commencement of alteration or recrystallization. In advanced stage of granulation the original fibrous or lamellar structure of the calcite disappears, and is replaced by a fine-grained mass of calcite, the individual grains of which have ill-defined boundaries. The fibrous and laminated calcite seems to be confined largely to the fragments of bivalves, while in many other fossils the original calcite occurs apparently in the form of minute grains, filling microscopic cavities. Owing to the minute size of these granules, it is frequently difficult to identify their mineral composition, and it is more than likely that much of this granular material is silica. This is evidently true wherever iron oxide is present, for after the calcite and the iron oxide have been dissolved out by means of hydrochloric acid, there still remains a complete siliceous cast of the fossil in the form of a spongy, porous mass, often with a concretionary structure.

LARGE CALCITE GRANULES.—The large interlocking calcite crystalline granules above referred to are most abundant in sections showing but little iron oxide or fossil remains. They, therefore, appear to be most characteristic of the leaner ores; however, all sections have them in greater or less abundance. The majority of these large crystalline grains have a granular or clouded appearance which becomes so marked in many instances as to mask or entirely obliterate all twinning-planes. This granular or clouded condition appears to be due in part to the physical structure of calcite grains, and in part to the presence of foreign material in the form of microscopic inclusions. In some instances these inclusions appear to be iron oxide, in which case they have a brownish color in transmitted light, but where they are segregated along the margins of the crystals, they become nearly opaque, and are undistinguishable from the iron ore proper, which, in many instances, seems to entirely replace the calcite of the individual grains. Such replacement usually commences along the margin of the granule and appears to gradually pass inward until the whole crystalline grain is replaced by iron oxide. Occasionally the replacement seems to begin at the center of the calcite grain and work outward. These partially replaced calcite grains are almost invariably of a more or less rounded form, the original sharp and irregular angles being entirely replaced by iron oxide.

RHOMBOHEDRAL CRYSTALS OF CALCITE.—The calcite which occurs in the form of small rhombohedral crystals is quite abundant in some sections, while in others it is almost entirely absent. It seems to be especially abundant in sections having a high iron percentage and numerous fossils. The rhombohedral crystals are often well developed along the margin of shells, which they sometimes wholly or partially replace. They likewise occur between the larger calcite grains, which they also wholly or partially replace. The rhombohedral crystals are never closely packed like the larger and older calcite granules, but are nearly always separated from each other by an intervening layer of iron oxide which increases in thickness in reversed ratio to the size of the crystals. The individual rhombohedral crystals usually show numerous inclusions which, in some instances, appear to be iron oxide. A granular structure is also noticeable in some of the crystals, as well as cleavage lines. The latter structure is especially well developed in many of the larger crystals, while the former seems to be the best developed in the smaller crystals. These small crystals, like the larger crystalline grains, as well as also fragments of fossils, appear to be gradually replaced by iron oxide, the replacement generally passing from the exterior of the individual crystal inward, but in some instances, the change appears to begin at the center and work outward. In the process of alteration the crystals soon lose their rhomboidal shape and become more or less rounded, and, at the same time, clouded and opaque. Every stage of alteration can be easily traced from the fresh calcite crystal to the iron oxide in nearly every section in which they occur.

QUARTZ.—The quartz, which is quite abundant in some specimens and rare in others, may be divided for convenience of description into two divisions, namely, rounded grains and angular grains. The former, which are not so numerous as the latter, frequently attain a diameter of 1/16 of an inch, and have the appearance of having been rounded by the action of water. They occasionally show wavy extinction, and almost always inclusions in greater or less abundance. These inclusions are often bunched or arranged in bands, and appear to be the liquid inclusions characteristic of the quartz of granite and similar igneous rocks. Many of the larger grains are fissured by irregular cracks which are filled with iron oxide. In some instances the iron oxide appears to have pushed the individual particles some distance apart so that the several fragments present a Mosaic structure.

The angular quartz grains are found to be quite abundant in all of the ores, showing a high siliceous content; this is especially true of the ores from which the calcium carbonate has been wholly or partly removed by weathering. The grains are invariably sharp and angular, having the appearance of the minute quartz grains occurring in the shales intercalated with ore-beds. They, like the larger grains, show inclusions and wavy extinction, but only occasionally fissures filled with iron oxide. In most of the sections examined, these angular quartz grains are promiscuously distributed, but in some they are arranged along lines, giving to the ore a somewhat laminated appearance. In a few instances the angular quartz grains are derived apparently from the crushing of the rounder grains, while in other cases they are probably of secondary origin, the silica having been derived from some foreign source. Besides the rounded and angular quartz grains there is also more or less silica, so intimately associated with the iron ore that it is difficult to identify it under the microscope. It is best seen in the small rounded particles of iron ore, after the iron oxide has been removed by hydrochloric acid. This silica has a spongy or porous texture, often concentrically arranged, in which condition the laminæ can sometimes be peeled off in layers like the coating of an onion. The silica of the individual lamina as well as the silica in the rounded iron ore particles, not so arranged, always have an amphorous granular structure except in the center of some of the iron ore particles where it occasionally occurs as minute quartz grains, similar but much smaller than the angular quartz grains above described.

IRON OXIDE.—The microscopic appearance of the iron oxide in the Clinton ores is varied. One of the most striking characteristics is a tendency of the oxide to collect in the form of small spherical or ellipsoidal bodies, which vary from 1/20 to 1/40 of an inch in diameter. These spherules often consist almost entirely of iron oxide, but more generally they have as a nucleus, a grain of quartz or a fragment of a shell. The spherules with nuclei, and also those without nuclei, are frequently seen to be made up of a series of concentric layers forming regular concretions, consisting of alternate layers of iron oxide and silica or calcium carbonate. These layers are often loosely cemented together, and are easily separated from each other. Some of the spherules instead of showing a transparent nucleus of quartz or calcite, have a nucleus of dense iron oxide surrounded by a layer of calcite or silica, which, in turn, may be inclosed in layers of iron oxide. Again spherules are often seen, consisting entirely of iron oxide, either in the form of layers or as a solid mass. When the nucleus consists of a rounded fragment of a crinoid stem, as is often the case, the iron oxide frequently completely fills all of its original minute pore spaces, while the walls of the spaces themselves consist of calcium carbonate or possibly, in some instances, silica. Surrounding this organic core or nucleus, with its injected iron oxide, is almost invariably to be seen an opaque covering of iron oxide which increases in density from within outward.

Less frequent, but, nevertheless, present in great or less abundance, in nearly every section, are to be seen spherules with nuclei consisting of a somewhat granular mass, having a green or yellowish green color. This class of spherules be more abundant in the latter. Furthermore, these granules appear to increase in abundance as the distance from the outcrop of the ore increases. It has also been observed that the spherules with greenish nucleus increase as the depth of the ore increases from the surface. Owing to the minute size of these greenish nuclei, it is impossible to study satisfactorily their mineralogical composition; however, judging from their structure and mode of occurrence, they are probably glauconite or greenalite, a green ferrous silicate from which the Lake Superior iron ores have apparently been chiefly derived. A typical spherulite of this class consists of an outward dense layer of iron oxide within which is to be seen a more transparent core of apparently granular quartz generally showing the characteristics of secondary silica and passing into a central irregular-shaped mass of greenalite. Often these green nuclei are broken up into small spherules, each having a separate outer coat of iron oxide. This nest of smaller spherules is enclosed within a rather thick, dense coating of iron oxide, which may or may not show a concentric structure. The green nucleated bodies are not always found in the center of spherules of iron oxide, but are occasionally to be seen wholly or partly filling the cells of bryozoans, in which case the walls of the bryozoan are always replaced by iron oxide. Spherules of this class are again to be seen consisting of an outer coating of dense iron oxide with a nucleus of the same, but somewhat porous iron oxide. Separating this outer layer from the nucleus is a narrow band of greenalite, which along its inner and outer border shows reddish flakes of hematite. Still other spherules are occasionally noticed which differ from the spherule here described, in having a nucleus of calcium carbonate or quartz. When the nucleus consists of the latter mineral, it exhibits sometimes an almost fibrous structure apparently due to crushing; such spherules may or may not show a concretionary structure.

It must not be inferred from the description above given, that all of the iron oxide in the Clinton ore occurs in the form of spherules. It is true in some of the ores, the iron oxide is mostly in this form, but in other ores, the iron oxide is chiefly cavity filling. It seems to have filled every available cavity or pore space however small. It has been injected into the minute cavities and cells of the bryozoan and other fossils, until they resemble histological preparation for microscopic study. It has also found its way into the crystalline grains of calcite, where it has been deposited along the cleavage planes. The space between loosely-fitting grains of calcite or the fragments of fossils, appears to have been especially favorable for its deposition, and even the original quartz grains did not entirely escape its replacing action as shown by their iron stained peripheries and injected fissures. The crystalline grains of calcite and fragments of fossils exhibit every stage of replacement from a faint iron stain to a complete change into iron oxide. This replacement appears to commence usually along the outer margin of the grain of calcite or shell fragment, and gradually works its way inward, but in some cases the spherical replacement seems to be accompanied by a change within, revealed by the appearance of a network of minute brownish filaments, which give to the calcite nucleus an appearance of rutilated quartz. In the lean ores many of the rounded shell fragments are to be seen more or less completely replaced by iron oxide, but more often they consist of calcium carbonate, which has a somewhat granular structure. It is no uncommon thing to see a spherule of iron oxide entirely enclosed by a ground mass of calcium carbonate, and separated some distance from its nearest neighbors. In such instances the intervening round fragments of shells may contain little or no iron oxide.

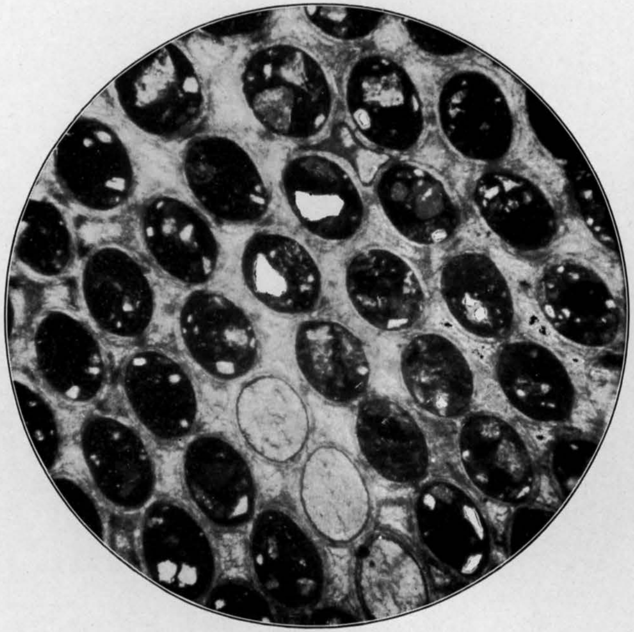


FIG. I. PHOTO-MICROGRAPH OF FRAGMENT OF CORAL THE PORE SPACES ARE FILLED WITH IRON OXIDE THE COLORLESS ANGULAR GRANULES IN THE PORE SPACES BEING QUARTZ.
Magnified 75 Diameters

FIG. 2. PHOTO-MICROGRAPH OF FRAGMENT OF CORAL PARTIALLY REPLACED BY IRON OXIDE.
Magnified 75 Diameters.

FIG. I. PHOTO-MICROGOAPH SHOWING NEST OF IRON OXIDE SPHERULES AND FRAGMENTS OF FOSSILS IN GROUND MASS OF CALCITE.
Magnified 75 Diameters.

FIG. 2 PHOTO-MICRHGRAPH SHOWING IRON OXIDE GRANULES HAVING A CONCRETIONARY STRUCTURE IN A MATRIX OF CALCITE.
Magnified 75 Diameters.

FIG I PHOTO-MICROGRAPH OF LARGE CRYSTALS OF CALCITE PARTIALLY REPLACED BY IRON OXIDE AND SMALLER CRYSTALS OF CALCIUM OR MAGNESIUM CARBONATE.
Magnified 75 Diameters.

FIG. 2. PHOTO-MICROGRAPH SHOWING FRAGMENTS OF A BRACHIOPOD AND A CORAL; THE FORMER BEING SPLIT AND FAULTED HAS ITS SMALL PORES INJECTED WITH IRON OXIDE.
Magnified 75 Diameters.

FIG. 1. PHOTO-MICROGRAPH SHOWING LEAN PIECE OF ORE WITH FRAGMENTS OF FOSSILS ONLY PARTIALLY ALTERED INTO IRON OXIDE.
Magnified 75 Diameters.

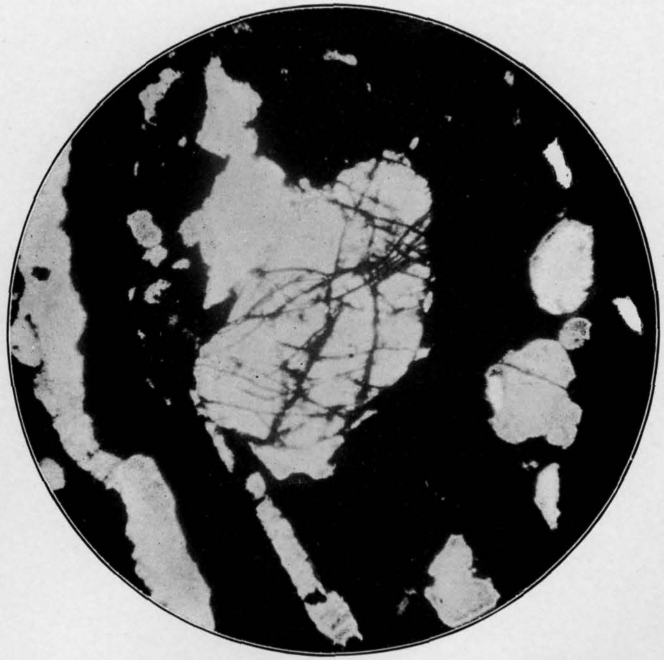


FIG. 2. PHOTO-MICROGRAPH SHOWING FRAGMENTS OF FRACTURED QUARTZ GRANULE IN IRON OXIDE MATRIX
Magnified 75 Diameters.

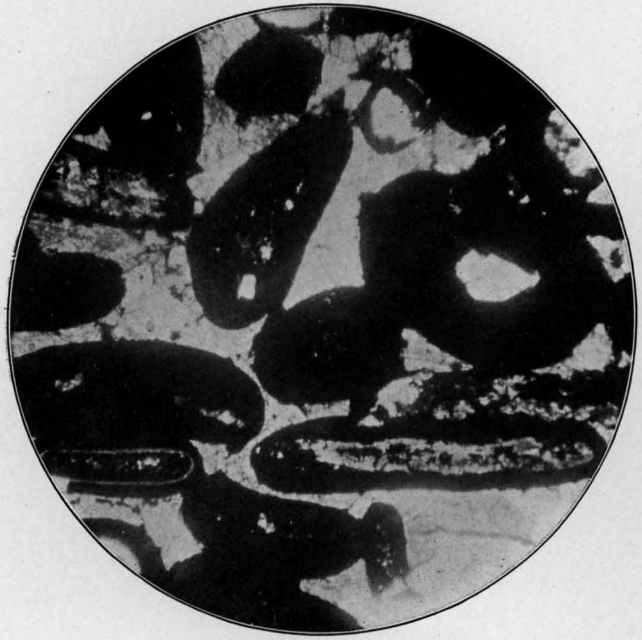


FIG. I PHOTO-MICROGRAPH OF FRAGMENTS OF FOSSILS WITH OUTER LAYER OF DENSE IRON OXIDE AND WITH NUCLEI OF PARTIALLY ALTERED GLAUCONITE. THE NUCLEUS IN THE LARGER SPHERULE TO THE RIGHT IS A QUARTZ GRANULE.
Magnified 75 Diameters.

FIG. 2. PHOTO-MICROGRAPH SHOWING NEAR THE CENTER A LONG FRAGMENT OF SHELL WITH ONE END COMPLETELY REPLACED BY IRON OXIDE AND THE OTHER CONSISTING CHIEFLY OF UNALTERED GLAUCONITE.
Magnified 75 Diameters.

CHAPTER XV

THE CHEMICAL COMPOSITION OF THE GEORGIA CLINTON ORES

The chemical composition of the Georgia Clinton ores is shown by the following analyses of samples taken from various parts along the outcroppings in the different counties where the ore has been either worked or more or less extensively prospected:

	1	2	3	4	5	6	7	8
H_2O at 100° C.	0.10	0.32	0.27	0.43	0.45	0.70	0.41	0.62
Loss on Ignition	2.04	0.87	0.75	3.01	0.90	2.40	1.75	2.01
FeO	2.65	4.03	2.05	none	0.90	1.00	1.70	1.00
Fe_2O_3	45.29	22.50	42.20	77.04	56.53	48.49	52.16	47.67
Al_2O_3	3.14	17.17	3.89	5.21	4.16	1.98	5.22	2.02
MnO	0.28	0.30	0.23	0.69	0.52	0.36	0.21	0.27
CaO	21.41	28.24	24.95	1.02	16.76	19.65	15.23	18.39
MgO	0.44	2.14	0.42	0.47	0.55	1.23	0.06	0.79
Na_2O	......	......	......	......	......	......	......	......
K_2O	....	....	......	......	......	....	......	......
TiO_2	....	....	......	......	......	.....	......	......
CO_2	16.50	16.60	19.40	none	12.01	15.60	11.01	15.06
S	trace	0.07	0.10	......	trace	0.09	0.06	0.06
P_2O_5	1.17	0.38	1.31	0.62	0.79	0.36	1.83	0.77
SiO_2	7.28	7.03	4.06	11.85	7.93	7.67	10.52	11.85

	9	10	11	12	13	14	15	16
H_2O at 100° C.	0.82	0.67	0.40	0.19	0.58	0.50	0.32	0.19
Loss on Ignition	2.41	0.83	2.02	2.04	3.20	2.00	2.22	1.70
FeO	0.65	0.56	none	2.00	0.10	none	1.25	3.15
Fe_2O_3	44.50	65.63	77.70	45.00	79.37	84.17	41.38	42.47
Al_2O_3	5.74	0.98	5.61	4.05	2.30	3.60	11.57	5.45
MnO	0.23	0.20	0.48	0.49	0.56	0.51	0.42	0.29
CaO	22.33	11.56	2.34	24.80	3.00	0.89	3.63	22.70
MgO	0.08	0.92	0.08	0.38	0.08	0.47	1.89	0.59
Na_2O	......	......	....	......	......	......	.....	0.01
K_2O	.....	.....	......	......	......	......	......	0.47
TiO_2	......	......	......	......	......	......	......	0.18
CO_2	18.00	9.04	none	15.00	none	none	3.60	15.20
S	trace	0.11	trace	0.25	0.12	none	0.12	0.02
P_2O_5	0.87	0.97	1.65	0.72	0.65	1.09	0.60	0.96
SiO_2	4.16	9.07	10.41	5.16	10.82	7.13	32.68	7.00

	17	18	19	20	21	22	23	24
H_2O at 100° C.	0.51	0.90	0.16	0.32	0.30	0.32	0.11	0.14
Loss on Ignition	2.77	1.89	3.56	1.96	3.29	3.51	0.80	0.85
FeO	0.07	0.07	1.94	1.34	none	none	3.75	0.90
Fe_2O_3	77.66	76.81	51.91	53.40	76.50	76.88	56.86	36.51
Al_2O_3	5.33	4.66	5.98	11.89	5.68	1.13	2.78	2.18
MnO	0.22	0.27	0.22	0.08	0.30	0.67	0.58	trace
CaO	1.25	2.33	16.82	14.89	0.28	0.30	14.40	29.84
MgO	0.33	0.16	0.05	0.16	0.24	0.17	1.95	0.14
Na_2O	0.06	0.16	0.16	trace	.....	.....	.....	.....
K_2O	0.34	0.73	0.16	0.38	.....	.....	.....	.....
TiO_2	0.18	0.12	0.12	0.12	.....		.....	.....
CO_2	none	none	12.34	8.42	none	none	12.40	22.49
S	0.01	0.02	0.04	0.01	0.11	0.12	0.06	0.06
P_2O_5	1.65	1.71	1.08	1.28	0.63	0.22	1.15	0.61
SiO_2	9.32	9.63	5.18	6.41	12.81	16.12	4.98	6.89

	25	26	27	28	29	30	31	32
H_2O at 100° C.	0.11	0.56	0.42	0.53	2.15	0.50	0.30	0.30
Loss on Ignition	1.20	1.90	1.82	1.49	4.84	1.75	7.00	1.90
FeO	0.18	none	none	none	none	none	none	1.85
Fe_2O_3	82.63	69.92	82.13	80.69	71.17	63.90	54.41	77.97
Al_2O_3	2.59	2.14	3.83	1.76	3.89	9.01	5.31	4.81
MnO	0.49	1.76	0.29	1.41	0.65	0.28	0.43	0.50
CaO	1.41	0.30	0.86	2.26	0.10	5.44	0.26	1.11
MgO	0.34	0.78	0.08	0.54	0.72	0.33	0.25	0.42
Na_2O	.....	.....	.....	.....	.....	.....	.....	.....
K_2O	.....	.....	.....	.....	.....	.....	.....	.....
TiO_2	.....	.....	.....	.....	.....	.....	.....	.....
CO_2	none	none	none	none	none	1.52	none	none
S	0.10	0.29	0.04	0.12	trace	0.10	0.09	0.08
P_2O_5	1.36	0.23	0.85	0.52	0.75	2.62	0.27	0.96
SiO_2	10.00	22.46	10.46	10.91	15.44	15.14	30.91	10.63

	33	34	35	36	37	38	39	40
H_2O at 100° C.	0.61	0.40	0.67	0.56	0.31	0.27	0.42	0.34
Loss on Ignition	2.76	3.15	2.40	1.74	1.14	4.05	4.73	5.40
FeO	none	none	0.25	0.10	0.05	0.75	none	0.75
Fe_2O_3	76.63	80.48	77.29	82.48	76.98	48.07	81.01	73.04
Al_2O_3	5.48	3.28	0.89	3.78	5.23	4.35	2.86	4.97
MnO	0.40	0.09	0.28	0.03	0.26	0.42	0.01	0.26
CaO	0.20	trace	1.09	0.80	1.21	9.81	0.04	0.15
MgO	trace	trace	0.13	0.11	0.17	0.55	0.59	0.73
Na_2O	.....	.....	.....	.....	.....	.....	.....	.....
K_2O	.....	.....	.....	.....	.....	.....	.....	.....
TiO_2	.....	.....	.....	.....	.....	.....	.....	.....
CO_2	none	none	none	none	none	8.00	none	none
S	0.12	0.10	0.03	0.07	0.06	0.06	0.01	0.07
P_2O_5	0.69	0.57	1.06	0.83	0.97	0.79	1.13	1.34
SiO_2	12.29	11.47	15.64	9.17	14.91	22.79	9.29	13.17

	41	42	43	44	45	46		
H_2O at 100° C.	0.25	1.26	0.54	0.85	0.40	0.18	......	......
Loss on Ignition	4.50	4.36	1.74	2.47	0.34	2.01	......	......
FeO	0.10	none	0.10	none	0.22	2.24	......	......
Fe_2O_3	80.03	59.49	82.48	85.24	68.02	27.76	......	......
Al_2O_3	0.52	6.65	3.78	1.57	3.84	4.90	......	......
MnO	1.77	0.30	0.30	0.35	0.28	0.12	......	......
CaO	0.24	0.21	0.80	0.08	10.21	27.34	......	......
MgO	trace	0.03	0.11	0.23	0.58	0.09	......	......
Na_2O	......	0.10	......	......	......	0.22	......	......
K_2O	......	0.32	......	......	......	0.56	......	......
TiO_2	......	0.23	......	......	......	0.10	......	......
CO_2	none	none	......	none	7.40	20.01	......	......
S	0.08	0.02	0.07	0.08	0.33	0.01	......	......
P_2O_5	0.90	0.87	0.83	0.92	1.32	0.23	......	......
SiO_2	11.40	26.39	9.19	8.58	6.84	13.92	......	......

WATER.—By an examination of the above table, it will be observed that the amount of water given off at 100° C. is comparatively low, only two samples running as high as one per cent. This low percentage of hygroscopic water is due in a large measure to the ores having been collected many months before and stored in a dry room previous to the analysis. The ores when shipped directly from the mines to the furnace, will always show a much higher percentage of water than above given; this is especially true of the soft ores, the porous and cavernous condition of which being quite favorable for the absorption and the retention of much water.

LOSS OF WATER ON IGNITION.—The loss of water on ignition, it will be noticed, is also low, the soft ores averaging about 2 per cent. and the hard ores about 3 per cent. The low percentage of loss on ignition shows not only that the ores contain but little sulphides or organic matter which would be affected by ignition, but it also shows that but little or no iron is in a hydrous condition. In a few instances, however, as in sample No. 32, where the loss by ignition is somewhat high, there is evidently hydrated iron oxide present, as shown by the brownish color of the ore. Such ores are always soft, and have usually been so altered that the organic remains are only partially preserved.

Ferrous Iron.—The ferrous iron oxide appears to be abnormally high in these ores, especially in the hard ores, or those carrying more than 10 per cent. of calcium carbonate. The general average of ferrous iron in such ores is found to be a fraction over 4 per cent. of the total iron contents, the maximum being 16 per cent. and the minimum 1½ per cent. On the other hand, the ferrous iron in the soft ores averages only 3/10 per cent., which is approximately 1/14 as much ferrous iron as that carried by the hard ores. In a few instances, as may be seen in No. 33, the ferrous iron in the soft ores runs as high as 1 per cent., but more frequently it is entirely absent or shows only a trace. The presence of the ferrous oxide in these ores is thought to throw some light on the origin of the Clinton ores, which will be discussed under a separate head.

Ferric Iron.—A like variation is also shown in the amount of ferric iron present. In the hard ores the average percentage of ferric iron is about 53 per cent., while the soft ores average about 74 per cent. of ferric iron, which is probably a little higher than like ores from the Birmingham district.

The Alumina.—The alumina is quite variable, running from less than 1 per cent. to 17 per cent. The ores running high in alumina always carry considerable clay in the form of thin layers or partings. When such partings become an inch or more in thickness, the shale can be easily removed by hand picking, and alumina percentage thereby reduced. In addition to these shale partings, there also occurs in some ore considerable clay intimately distributed throughout the mass. Such clay is probably all original clay laid down in the sea bottom with the other deposits, but in some instances clay has been introduced subsequently, in the soft ores by muddy waters flowing over the outcroppings where they are exposed along the hill-slope. The amount of alumina thus introduced, however, is practically small, and confined to the first eight or ten feet of the exposure.

Manganese.—The amount of manganese is rather low, ranging in the hard ores from a trace to .52 per cent., and in the soft ores from .01 per cent. to 1.77 per cent., the general averaging for the hard ores being .26 per cent. and for the soft ores being .45 per cent.

This rather marked difference in the percentage of manganese in the soft and the hard ores is probably due to manganese being introduced into the soft ores during the process of weathering. In which case, the manganese in the hard ores would probably represent more nearly the original manganese contents of the ores. Should the relative proportion of iron and manganese be compared in the two different ores, it will seem that the percentage of manganese to the iron in the hard and the soft ores is not so great as shown by the above figures; however, even then there is quite a discrepancy which could hardly be accounted for except by the introduction of manganese from some extraneous source.

Calcium Carbonate.—The great variation in calcium carbonate is mainly due to the leaching action of meteoric waters. There is, however, in the unleached ores, quite a variation in the calcium carbonate, which seems inherent in the ores themselves. This variation is to be seen not only in the different beds, but also in the same bed from place to place. The soft or leached ores, which never extend to more than a few feet beneath the surface, may vary from a mere trace of calcium carbonate to 10 per cent., depending upon the leaching action of the meteoric waters, while the hard ores in many instances, as seen in the above table of analyses, run nearly 30 per cent. calcium carbonate. From the great abundance of fossils in the hard ore, it would appear that all, or a greater part, of the calcium carbonate is an original constituent of the beds, although much of it has probably been crystallized over and over again.

The following table shows the theoretical combination of the calcium in the several analyses above given:

No.	$CaCO_3$	$Ca_3(PO_4)_2$	$MgCO_3$	CaO as Silicates.
1	37.50	.86	....	....
2	37.73	.83	....	6.68
3	44.09	.48	....	....
4	.....	1.35	....	.29
5	27.29	1.69	....	.55
6	35.09	....	.31	....
7	25.02	2.25	....	....

No.	$CaCO_3$	$Ca_3(PO_4)_2$	$MgCO_3$	CaO as Silicates.
8	33.84	....	1.16	....
9	39.87	....	.86	....
10	20.54	.11	....	....
11	.....	3.60	....	.39
12	34.10	1.57	....	4.85
13	.....	1.42	....	2.23
14	.....	1.64	....	....
15	6.58	.....	1.43	....
16	34.55	1.76	....	2.55
17	.....	2.31	....	....
18	.....	3.73	....	.31
19	27.14	2.35	....	.75
20	19.14	2.79	....	2.66
21	.....	.54	....	....
22	.....	.48	....	.04
23	25.71	....	2.07	....
24	47.48	1.33	....	4.13
25	.....	2.60	....	....
26	.....	.51	....	.02
27	.....	1.56	....	....
28	.....	1.13	....	1.65
29	.....	.18	....	....
30	3.44	6.62	....	.42
31	.....	.48	....	....
32	.....	2.05	....	....
33	.....	.37	....	....
34	.....	....	....	....
35	.....	2.01	....	....
36	.....	1.47	....	....
37	.....	2.11	....	.07
38	17.52	....	.55	....
39	.....	.07	....	....
40	.....	.27	....	....
41	.....	.44	....	....
42	.....	.39	....	....
43	.....	.14	....	....
44	16.82	1.45	....	....
45	.....	.07	....	....
46	45.48	.50	....	1.60

When there is insufficient calcium to combine with all of the CO_2 found the excess of the latter is calculated to $MgCO_3$.

Magnesia.—The small amount of magnesia present, shows that the ore contains but little or no magnesium carbonate. The general average of magnesium is only a fraction of one per cent. or less than is often found in our common limestones and marbles. The magnesium, together with the sodium and potassium present, no doubt comes, in part, from silicates contained in the shale and clays associated with the ores. Titanium, which is also present in some of the ores, is probably also derived chiefly from the shales.

Carbon Dioxide.—The variation in carbon dioxide bears a very close relation to the calcium carbonate, showing that the chief carbonate present is calcium. It will further be noted by examination of table No. 2, that there are also six instances in which the carbonic acid is in excess of the amount required to combine as the calcium carbonate, in which cases the carbonic acid has been calculated as magnesium carbonate.

Sulphur.—The sulphur of the Clinton ores is probably chiefly in the form of pyrites, as in some of the ores this impurity can often be seen as small irregular patches. The occurrence of the pyrites, more frequently in the soft ores, would seem to suggest that it is of secondary origin, having been deposited during the weathering of the hard ore.

Phosphorus.—The phosphorus is quite variable; however, in all cases it is far above the Bessemer limit. There seems to be no definite relation between the amount of the phosphorus present and the class of ore, the general average in the soft ores being about the same as in the hard ores. The ores in different localities, on the other hand, differ in the amount of phosphorus present. This is well illustrated in the ores of Dirtseller Mountain and Taylor's Ridge, which usually carry a higher percentage of phosphorus than the ores of Pigeon and Lookout mountains.

Silica.—The great variation of silica is due chiefly to the variation of sand, which occurs in all of the ores as an original constituent. The silica contents, it will be noted, vary generally inversely as the calcium. There are, however, a few exceptions to this general rule, as will be seen in sample No. 46, in which both the calcium and silica are high. The soft ore being derived from the hard ore by the removal of the soluble constituent, which is mainly calcium, it necessarily follows that the soft ores nearly always carry a high percentage of silica. In other words, usually the higher the ore runs in metallic iron, the higher it also runs in silica.

CHAPTER XVI

THE MOST PROBABLE ORIGIN OF THE CLINTON ORES

Having given in the preceding chapters, in some detail, what appear to have been the geological conditions under which the Clinton ores were deposited, together with macroscopic and microscopic description of the ores and the chemical composition of the same, we are now better prepared to take up the question of origin. At the outset, it might be well to state frankly that the facts so far collected are not by any means absolutely conclusive as to the true origin of the Clinton ores, nevertheless the fact seems to be strongly indicative that these ores are in a large measure only altered beds of glauconite or green sand, a hydrous silicate of iron and potassium. The geological conditions, the nature and character of the associated rocks, the microscopic study and the chemical composition of the ores themselves, all point to widespread beds of glauconite as the original source of the Clinton ores.

Glauconite, as shown by the Challenger report on Deep Sea Deposits, is not found in deep water, but chiefly along the edges of the continent where clays and silts are now being laid down. The deposition and the occurrence of this rather peculiar deposit, as given by Murray and Renard, in the Report of the Voyage of the Challenger, are as follows:

"It appears to be most abundant about the lower limit of waves, tides and current, or, in other words, in the neighborhood of what we have termed the mud-line surrounding continental shores. In the shallower depths beyond this line, that is to say, in depths of about 200 and 300 fathoms, the typical glauconite grains are more abundant than in deeper water, but glauconite casts may be met with in deposits in depths of 2,000 fathoms."

The same authors also make the following statement as to the origin of the material: "We are therefore inclined to regard glauconite as having its initial formation in the cavities of calcareous organisms, although we have admitted above that some grains, which may be regarded as glauconite, appear to be highly altered fragments of ancient rocks or coatings of this mineral on these rock fragments. It appears that the shells are broken by the swelling out or the growth of the glauconite, and that subsequently the isolated cast becomes the centre upon which new additions of the same substance take place, the grains enlarging and becoming rounded in a more or less irregular manner, as in the case of concretionary substance like silica for example, which forms molds of fossils."

Ehrenberg, in speaking of the glauconitic grains in limestone from Alabama, makes the following statement concerning the formation of glauconite. "The formation of the green sand (glauconite) consists in a gradual filling up of the interior space of the minute bodies with green colored, opal-like mass, which forms therein a cast. It is a peculiar species of natural injection, and is often so perfect that not only the large loose shells, but also the very finest canals of the cell walls and their connecting tubes are thus petrified, and are separately exhibited. By no artificial method can such fine and perfect injections be obtained."

Glauconite is said to cover approximately 1,000,000 square miles of the present sea bottom. It is now being laid down along the Atlantic coast between Florida and Cape Hatteras in depths varying from 100 to 1,000 fathoms. This zone of deposits corresponds to what Murray and Renard term the mud-line, which may be said to mark the outer margins of the continental shelf where the mechanical detritus and the organic matter seem to be so adjusted as to meet the requirements essential for the deposition of glauconite. Have we not here along our Atlantic coast conditions very similar to those which obtained along the eastern margin of the great Interior Paleozoic Sea, during the time of the deposition of the Clinton ores?

The rivers of the Atlantic sea-board are all comparatively small, none of them attaining a length of more than a few hundred miles.

Before pouring their waters into the Atlantic, these rivers with reduced currents traverse a broad Coastal Plain, where some of the coarser sediment is deposited along the flood plains, but most of the sediment reaches the coast and is chiefly deposited within a short distance of the shore line, where by the action of the waves it gives rise to a rather remarkable chain of low sea islands. A small portion of this river-born sediment in the form of fine clay or mud is carried further seaward and finally deposited in deeper water with more or less calcareous material in the form of tests and shells of sea animals, along the western margin of the warm Gulf Stream, where it forms a zone many miles wide in which the depth and the temperature of the water and the relative proportion of argillaceous and calcareous sediment seem to be especially favorable for the deposition of glauconite.

During the time of the deposition of the Clinton ores, as has been shown in the discussion of the geological conditions which prevailed at the time of the laying down of the Clinton rocks, the conditions appear to be almost identical with those here described along the Atlantic coast at present. The sediments which formed the Clinton rocks were derived mainly from the same ancient crystallines and borne to the coast by a system of short rivers, which probably, before reaching the Interior Sea, traversed a low coastal plain not unlike our present Atlantic coastal plain. Corresponding to the Gulf Stream which sweeps along the Atlantic coast with its warm water, was apparently a like current of warm water flowing from the south along the eastern margin of the Great Interior Sea, hugging the western margin of the Appalachian land area as far north as western New York. There probably occurred along this old Paleozoic shore line a chain of low sea islands like those now found along the Atlantic coast and at some distance off shore, along the mud line, existed favorable conditions for the deposition of glauconite. There appears to be no direct or indirect evidence, as some have supposed, that there existed along the western margin of the Appalachian continent during the Clinton Epoch any land-locked estuaries, lagoons or bogs in which the ores were deposited. The main deposits were probably laid down some miles off shore and in sufficiently deep waters to be only slightly affected by the action of the waves. The ripple-marked and rain-pitted sandstone, however, both above and below the beds of iron ore, distinctly shows that the glauconitic beds, from which the ores were derived, were at no time more than a short distance below the surface of the water. By reference to the geological conditions elsewhere given, which prevailed prior and subsequent to the Clinton epoch, it will be noticed that the Clinton iron ores occur in what may be said to be a transition stage between the shallow deposits of glauconite and sandstone, on the one hand, and the deep sea deposits of limestone on the other, just at such a position as appears to be most favorable for the deposition of glauconite.

The megascopic appearance of the ore in many respects is not unlike glauconite. Its occurrence in beds with clay partings, and its association with an abundance of calcium carbonate, in the form of organic remains, together with the frequent occurrence of innumerable small rounded bodies with smooth polished surfaces, all point to glauconite as the probable original form of the Clinton ores; but it is only by microscopic study of thin sections that the original source of the ores is most conclusively established. Elsewhere in the microscopic study of the ores, it was noted that in nearly every section examined there existed a greenish or greenish-yellow nucleus in some of the iron particles, which seems to be a remnant of the unaltered glauconite. Dr. C. H. Smyth, Jr., appears to have first noted the occurrence of the greenish nuclei in the Clinton ores. Later, they were noted by Dr. C. K. Leith, who makes the following comparison of the Clinton and Lake Superior ores:[1]

"In the Clinton ores two kinds of granules are numerous: (a) Normal concretions of silica and iron oxide or of silica and some greenish substance with a ferrous iron base, the further composition of which is unknown, about a nucleus of quartz. These are analogous to the few true concretions observed in the Mesabi district and to the concretions of the Penokee-Gogebic district. (b)

[1] Monograph U. S. G. S., Vol. XLIII, pp. 251-252.

Accretions of iron oxide about calcium carbonate shells and partial or complete replacements of the shells, in either case without or nearly without radial or concentric structures. The size is somewhat greater than that of the Mesabi granules. . . . . . . The shapes are almost identical with those of the normal greenalite[1] granules of the Mesabi."

"The similarity in shape is as close as between greenalite and glauconite. The crescent shapes, the gourd shapes, the much elongated ovals, and rods, which are seen associated with the round and oval forms in the Mesabi rocks, are also to be seen in the Clinton ores. . . . In both the Clinton ores and the Mesabi rocks a not uncommon feature is the accretion of a considerable number of granules into somewhat irregular pebble-like aggregates, which have been waterworn as a whole, and deposited parallel with the bedding. . . . . The Clinton ores, in their present form, may not be concretions or replacements subsequent to their deposition, for they have uniform composition in thin beds over great areas, which could not be the case were they subsequently concentrated through underground water or other agencies. They may well be compared with the fresh greenalite granules of the Mesabi, which also have undergone no concentration, rather than with the altered granules. If during the deposition of the Clinton ores the numerous minute shells had been surrounded and replaced by iron silicate instead of iron oxide, greenalite granules identical with those of the Mesabi district may have resulted." Leith here seems to have noted some of the most characteristic features of the Clinton ores, but, judging from the latter part of the above quotation, the idea that the ores were really altered beds of iron silicate or glauconite did not seem to possess his mind. He states that if during the deposition of the Clinton ores, the numerous minute shells had been surrounded and replaced by silicate of iron instead of iron oxide, greenalite granules identical with those of the Mesabi district would have resulted. The supposed conditions which he here assumes, apparently did actually take place, that is, the iron in the form of a ferrous silicate,

[1] Greenalite is a hydrous silicate of iron from which it is supposed the Lake Superior iron ores were derived. The mineral differs mainly from glauconite in the absence of potassium.

surrounded and replaced in a large measure the numerous calcareous organic fragments, forming glauconite, from which, by a process of change to be hereafter described, the iron ores were subsequently derived. His statement that the ores in their present form were not concretions of replacements subsequent to their deposition, on account of the uniformity of the ores over large areas, is in harmony with the theory of the glauconite origin. Furthermore this theory of origin fully explains the appearance of fragments of the ore occurring in the overlying rocks which constituted one of the main arguments advanced by Dr. Smyth in support of the theory that the original deposit of iron oxide was laid down simultaneously with the associated shales and sandstones. These displaced fragments were originally glauconitic, just like the beds from which they were derived, and they were afterwards altered into iron ores in the same manner as the glauconitic beds themselves.

The microscopic structure of glauconite, as described by Ehrenberg, is quite similar to the microscopic structure of the Clinton ores, as may be seen by an examination of thin sections. In the ores, as Ehrenberg notes, in the glauconite, every available pore space of shell fragments, however small, is injected by iron oxide. Occasionally the filling of the pore spaces consist of the original unaltered glauconitic material, and again this greenish material may be seen to be undergoing change to iron oxide along its margin. In some sections the various stages of alteration from fresh glauconite to iron oxide may be distinctly traced. The spongy porous mass of silica which remains after the treatment of the particles of iron oxides with hydrochloric acid, apparently represent the original, or a part of the original, silica of the glauconite, which becomes dissociated during the process of alteration.

The presence or absence of glauconite in the Clinton ores depends chiefly, as heretofore stated, upon the amount of weathering to which the ores have been subjected, therefore, other things being equal, the further the ore occurs from the outcrop the greater is the percentage of glauconite. This is well illustrated by samples of the ore from the Birmingham district, where the ore at the outcrop shows but little glauconite, but a diamond drill core taken a half-mile from the outcrop, and at a depth of about 800 feet from the surface, reveals a large amount of glauconite. Should this rate in the increase of glauconite continue, within a few miles at most from the outcrop, the beds of iron ores will pass into the unaltered beds of glauconite.

The chemical composition of the Clinton ores also bears out the same facts as revealed by the microscope. It was noted in the remarks on the chemical composition of the ores that the general average of the ferrous iron, the condition in which the iron occurs in the glauconite, of the hard ores, is found to be over 4 per cent. of the total iron contents, the maximum being 16 per cent. and the minimum 1½ per cent. On the other hand, the ferrous iron in the soft ores averages 3/10 per cent., which is approximately about 1/14 as much ferrous iron as that carried by the hard ores. It has been suggested that the ferrous iron which appears to be so abundant in the hard ore, as shown in the chemical analyses, possibly exists as a carbonate in the place of a silicate, as above assumed. This suggestion seems quite plausible on first view, however, an examination of the analyses shows that there is likely no iron carbonate present, owing to the insufficiency of CO_2 to combine with calcium, magnesia and iron. With only six exceptions, there is only enough CO_2 to combine with the calcium present. The presence of more or less potassium in the ore would seem also to indicate the presence of glauconite.

As to the original source of the iron prior to its deposition as glauconite, it was no doubt derived from the weathering of the crystalline rocks, which formed the old Appalachian land surface. Then, as now, in the usual process of rock weathering, the iron present seems to have been taken largely in solution by meteoric waters in the form of a carbonate, in which condition it was borne to the ocean, where, upon the loss of carbon dioxide, the ferrous oxide thus liberated, at once took up oxygen and was precipitated as a hydrated peroxide. This stable form of the oxide after reaching the sea bottom, in the presence of fine muds containing carbonaceous material undergoing decomposition, became reduced to a ferrous condition, in which form it appears to have combined with the colloidal silica present, to form glauconite. The original iron constituent of the muds themselves, was probably also drawn upon in this process of chemical change.

It seems to be quite likely, as noted by Hueppe, that iron forming algae or bacteria of the muds on the sea floor shared in bringing about the reduction of the hydrated peroxide, and indirectly in the formation of glauconite. Having thus followed the several changes through which the iron appears to have undergone from its original source in the crystalline rocks to glauconite, it now remains to explain the changes which it has otherwise undergone in assuming its present form. In other words, we must now assume certain other changes before the cycle is complete, and the ore is in the form of a stable oxide and so concentrated as to be of commercial importance.

Subsequent to the deposition of ore as a glauconite, it was buried beneath limestone, shales and sandstones, having an aggregate thickness of several thousand feet. Later the entire sea bottom along the western margin of the old Appalachian land area emerged, and at the same time the rocks were pressed into huge anticlinal and synclinal folds, and profound faults were produced. The newly made land was now attacked with vigor by atmospheric and aqueous agencies, and after a long interval of time the surface assumed its present form. During the cycle of changes, as here outlined, glauconite like the various other deposits, associated therewith, underwent greater or less chemical changes. The calcite, originally chiefly in the form of shells, crystallized apparently over and over again, and was often wholly or partly replaced by silica or ferrous oxide. In this process of change new minerals were probably formed and others were segregated. Meteoric waters carrying carbonic acid and free oxygen, which reached the deeply buried beds along fissures and fault plains were no doubt the main agents producing the chemical change. Such waters coming in contact with silicates of iron, such as glauconite, would readily take the iron into solution. The iron being thus brought into solution as a carbonate, was, as has been pointed out by Leith, either immediately oxidized and hydrated and precipitated as ferric hydrate, through the agency of oxygen carried by the solution, which brought about the carbonation, or the iron carbonate, may have been in part carried some distance until it met waters carrying an abundance of oxygen, and was thus precipitated. Simultaneously with the formation of iron carbonate from the glauconite, there was also set free silica, which appears to have largely become entangled and precipitated with the iron oxide, when it was thrown down in a ferric condition. In no other way does it seem possible to explain the intimate relation of the iron oxide and the silica in the small rounded particles of the ore.

The glauconite beds which afterwards became beds of iron ore, appear to have been, from the time of their emergence above the surface of the ocean, water carriers of greater or less importance. Their porous condition, due mainly to the presence of innumerable fragments of organic remains, their continuity throughout extended areas and the nature of both the overlying and the underlying rocks, all seem to indicate that these thin glauconitic beds have always been some of the most important water carriers of the whole series of Clinton rocks. This appears to have been especially true, subsequent to the decapitation of the anticlinal folds. Prior to this event, the glauconitic beds by reason of their porous nature, were no doubt always completely saturated with water, but as there was no free outlet to the surface, except probably by small tortuous fissures, there were but little or no currents in the imprisoned waters. The removal of the folds, however, by erosion, at once set up a free circulation, and thus the glauconitic beds became great trunk currents, so to speak, of underground water circulations. These currents would, from time to time, reverse their course as erosion in the adjacent valleys progressed. The lowering of the line of outcroppings of glauconitic beds in one valley to a lower level than the line of outcroppings of the same beds in an adjacent valley, would immediately set up a current to the latter, which would become at once reversed upon deeper erosion of the former. These reversions of currents or what may be called underground stream captures, were probably many times repeated as erosion progressed.

The ingoing waters, on the one hand, coming as they did immediately from the surface where they were taken up by the upturned edges of the porous stratum as they flowed from the hillslope, always carried abundance of oxygen, carbonic and other acids, the chief agents of chemical change in minerals and rocks. The outgoing currents in the adjacent valley, on the other hand, were poor in oxygen and carbon dioxide, but at the same time were probably more or less heavily charged with calcium carbonate, silica and other minerals, which are most frequently met with in underground waters. In addition to the currents from valley to valley, there were probably also local ingoing and outgoing currents from time to time along the same line of outcroppings in the same valley, conditioned by the variation of elevation of outcrops at different points; and, again, it is also possible as erosion deepened the anticlinal valleys far below the line of ore outcroppings, that ingoing waters on the hillslopes, after traversing the ore beds for some distance, gained the valley below by way of some underlying stratum whose outcropping occurred at a lower level. In the last instance, the distance to which the ingoing waters would traverse the ore beds, would depend upon the depth of the valleys, and the distance intervening between the ore bed and the underlying water-bearing strata. These ingoing meteoric waters, by whatsoever means the currents were produced, were the main agents no doubt which changed the glauconite into iron ores; however, we should not overlook the fact that they were probably also at the same time active agents in augmenting the iron contents of the original glauconite beds from extraneous sources. It is not at all improbable that part of the iron now forming the ore beds was originally in the form of sulphides or carbonates in the associated sandstones and shales, but was removed therefrom and precipitated in glauconitic beds by descending surface waters. Only by some such concentration, as here suggested, does it seem possible to account for the high percentage of iron in beds which were originally glauconite.

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