GENERAL FEATURES OF THE BROWN HEMATITE ORES OF WESTERN NORTH CAROLINA.[1]

By W. S. Bayley.

INTRODUCTION.

Within the last five years the continuous production of brown hematite in North Carolina has attracted attention to the State as a possible source of abundant supplies when the demand for ore of this kind becomes more pressing than it is at present. Since the beginning of 1917 about 126,000 tons of brown ore has been reported to the North Carolina Geological and Economic Survey as produced in the State. Most of it has come from Cherokee County, in the southwest corner of the State. Formerly a little came from Madison County, near Asheville, and from Gaston County, near Bessemer City, but the mines in these counties were abandoned several years ago.

As early as 1859 Lesley[2] referred to the existence of brown ores in Cherokee County and stated that they had been supplying bloomeries for many years before that date. Kerr,[3] 16 years later, declared that "there is no other county in the State which contains so much iron ore" as Cherokee, although he described large deposits also in Madison and Gaston counties. Of the Cherokee deposits he says: "Some rude mining has been done * * * recently, and much more * * * in ancient times by no one knows whom or for what purpose." Kerr described in a general way the geology of the deposits, and his description gave nearly all the information available on the subject before the publication of Keith's reports. Nitze[4] in 1893 gave a number of analyses of samples of all the brown-ore deposits in the State but added nothing to the description of the

[1] Prepared in cooperation with the North Carolina Geological and Economic Survey; Joseph Hyde Pratt, director.

[2] Lesley, W. P., Iron Manufacturer's Guide, pp. 449, 451–453, New York, 1859.

[3] Kerr, W. C., Report of the geological survey of North Carolina, vol. 1, pp. 217–271, Raleigh, 1875.

[4] Nitze, H. B. C., Iron ores of North Carolina: North Carolina Geol. Survey Bull. 1, p. 239, Raleigh, 1893.

geology given by Kerr. Hayes and Eckel[5] and Keith[6] discussed the origin of the brown ores and reached conclusions that are substantially those outlined in later pages of this paper. Keith also described in some detail the geologic conditions under which the deposits occur and mapped the distribution of those encountered in the course of his work but did not map the individual deposits except where they are scattered. The extreme southwest corner of Cherokee County was mapped by LaForge and Phalen,[7] but the positions of the individual deposits were not indicated.

The present study was undertaken to map the individual deposits and to gain some notion of the probable importance of western North Carolina as a future producer of limonitic ores. In this paper only the more general conclusions are outlined. A description of the individual deposits appears elsewhere.[8]

DISTRIBUTION OF THE BROWN ORES.

The brown ores of North Carolina occur mainly in the valleys between the mountains in the western part of the State and on the Piedmont Plateau region in its central part. (See index map, fig. 47.) There are other deposits in the Coastal Plain, but they are of little value.

The principal deposits in the mountain district are in Cherokee, Madison, and McDowell counties. Those in the Piedmont district are in Catawba, Lincoln, and Gaston counties. The Piedmont deposits are associated with schists, gneisses, marbles, and quartzites of pre-Cambrian age and in the main of doubtful origin; the mountain deposits are associated with Cambrian rocks that are of distinctly sedimentary origin, though more or less metamorphosed into schists and marble. Formerly the deposits in the Piedmont district were of considerable commercial importance, but in recent years only those in the mountains have been productive.

DEPOSITS IN THE MOUNTAIN DISTRICT.

CHARACTER OF ASSOCIATED ROCKS.

The rocks associated with the ores in Madison and Cherokee counties are Cambrian sediments that have been metamorphosed to

[5] Hayes, C. W., and Eckel, E. C., Iron ores of the Cartersville district, Ga.: U. S. Geol. Survey Bull. 213, pp. 239–242, 1903. Hayes, C. W., Geological relations of the iron ores in the Cartersville district, Ga.: Am. Inst. Min. Eng. Trans., vol. 30, pp. 403–419, 1901.

[6] Keith, Arthur, U. S. Geol. Survey Geol. Atlas, Knoxville folio (No. 16), Cranberry folio (No. 90), Asheville folio (No. 116), Greenville folio (No. 118), Nantahala folio (No. 143), Roan Mountain folio (No. 151), 1895–1907.

[7] LaForge, Laurence, and Phalen, W. C., U. S. Geol. Survey Geol. Atlas, Ellijay folio (No. 187), 1913.

[8] Bayley, W. S., North Carolina Geol. and Econ. Survey Bull. 31, Raleigh, 1922.

a greater or less extent by the great movements that occurred during Paleozoic time. They are folded and faulted to a marked degree. The general strikes of both folds and faults are northeasterly, but there are departures from this direction for short distances. As the dips on the sides of nearly all the folds are southerly and those on their northwest sides are the steeper, these folds are overturned toward the north or northwest. The faults usually appear on the northerly sides of the anticlines or southerly sides of the synclines. Most of the fault planes also dip toward the south.

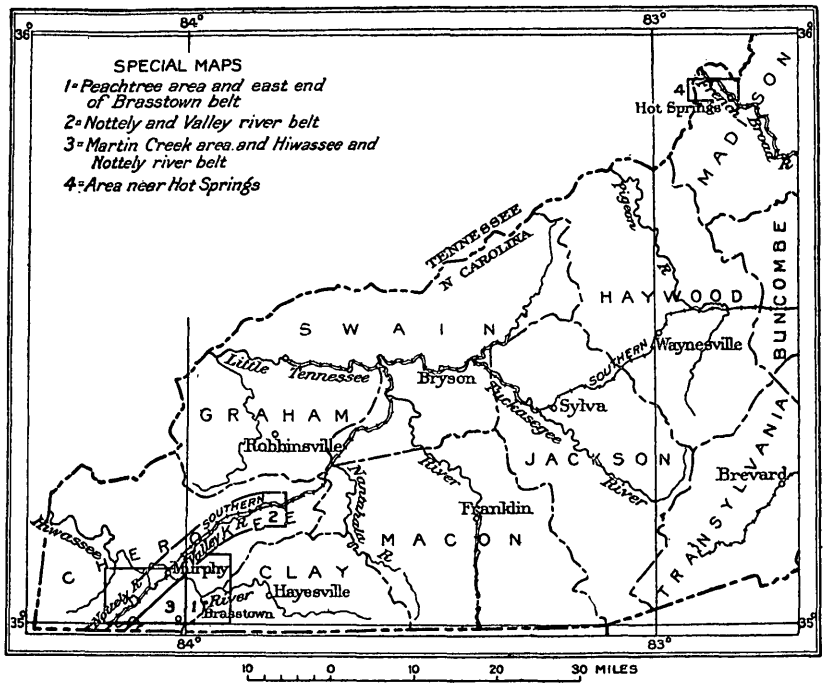


FIGURE 47.—Index map of western North Carolina showing location of areas containing valuable deposits of brown hematite.

Besides the folding and faulting produced by the compression of the sedimentary beds, the rocks composing these beds were broken by innumerable small cracks and were changed in composition by the growth of many new minerals, with their long directions approximately at right angles to the direction of greatest pressure. The strike of the schistosity thus developed is in general parallel to the strikes of the folds and faults, and its dip is steep, usually 50° or more.

The sequence of the Cambrian sediments in these two counties, as worked out by Keith,[9] is indicated in the following table, in which

[9] Keith, Arthur, U. S. Geol. Survey Geol. Atlas, Asheville folio (No. 116), 1904; Nantahala folio (No. 143), 1907.

Keith's names are used and approximate correlations are suggested. In Cherokee County metamorphism has been more pronounced than in Madison County and the present character of most of the formations is different, but there is a general parallelism in them, the differences being only such as might be exhibited by any two basins separated from one another at recurring intervals or even by different portions of a single basin if differently situated with respect to old shore lines.

Cambrian formations in Cherokee and Madison counties.

Cherokee County.	Madison County.
	Knox dolomite (Cambrian and Ordovician): Light and dark magnesian limestone with chert.
	Nolichucky shale: Variegated calcareous shales and thin limestone.
Nottely quartzite: White quartzite	Honaker limestone: Blue and gray limestone, thin
	Watauga shale: Purple, red, and yellow shales and sandy shale.
Andrews schist: Calcareous ottrelite schist, with beds of iron ore.	Shady limestone: Gray and blue cherty limestone, with marble beds near base.
Murphy marble: White and blue marble, with talc.	
Valleytown formation: Graywacke, garnet, and ottrelite schist and slate.	Hesse quartzite: Chiefly white quartz.
Brasstown schist: Blue and black ottrelite schist and slate.	Murray slate: Grayish slate and shale with sandy layers.
Tusquitee quartzite: White quartz	Nebo quartzite: Chiefly white quartz.
Nantahala slate: Black slate, with garnet-staurolite schist at base.	Nichols and Nantahala slates: Grayish slate and shale with sandy layers, metamorphosed to mica schist and ottrelite schist.
Great Smoky conglomerate: Conglomerate, coarse gray sandstone, and graywacke, with many beds of black slate and schist.	Cochran and Great Smoky conglomerates: Gray conglomerate with beds of slate, metamorphosed to schists in Great Smoky conglomerate.
Hiwassee slate: Bluish-gray banded argillaceous slate.	Hiwassee slate: Dark banded slate and schists, with layers of limestone and sandy beds.
	Snowbird formation: Light-colored quartzite and sandstone, with beds of slate, conglomerate, and arkose.

These formations lie on a basement of granites, gneisses, and crystalline schists of pre-Cambrian age.

ORIGIN AND AGE OF THE ORE DEPOSITS.

The limonite deposits of greatest value in the mountain districts are found in the residual clays of the Shady limestone or its equivalent, at the contact of this limestone with quartzites or schists, along or near faults separating the limestone or calcareous schists from other formations, and at contacts of quartzite and slate in the Brasstown schist. There are also small deposits at other places, but they are of no economic importance.

In general the deposits occur at such places as furnish the easiest channels for downward-traveling water and in the disintegrated products of rocks containing such ores.

Deposits of the first type appear as veins of varying width, from a fraction of an inch to 25 or 30 feet. For the most part they follow bedding planes or fault cracks (Pl. VI, *D*), but the smaller ones

may divide and coalesce in an intricate pattern, locally crossing the rock layers, swelling and thinning, and in some places wedging out. Few of the thicker veins consist of pure ore throughout. Most of them are mixtures of iron hydroxides and sand, which in some places occur as thin alternating layers and in others as uniform mixtures. In many deposits the vein material is coarsely porous and the ore lining the openings is mammillary. Mammillary surfaces are also common on the sides of veins (Pl. V, *D*), especially those in the bedding planes of the Andrews schist, and in manganiferous ores the portions richest in manganese are the outer layers of the spheroids. Thus the North Carolina ores are like some of those in the Cartersville district of Georgia, which are described by Hayes and Eckel[10] as consisting of geodal shells containing cavities with stalactitic and botryoidal forms, which have glazed surfaces.

The veins are nowhere single. They are almost invariably grouped in stockworks, which have the same general strikes and dips as the rocks with which they are associated. Those in faults may follow the fault planes for short distances, but they feather out into the bedding planes or into joints and other fractures of the faulted rocks and so may possess very irregular shapes.

Nearly all the ore of the veins in the Andrews schist contains sand grains and the remnants of decomposed ottrelite crystals. The calcareous cement of the original rock has been replaced by the iron compounds, leaving only the micaceous decomposition products of the ottrelite and little grains of sand to represent the original schist. Such ore may preserve the schistosity of the replaced rock in the arrangement of the sand and the decomposition products of the ottrelite.

As remarked by Hayes and Eckel,[11] in discussing similar ores in the Cartersville area in Georgia, the ores appear in part to have filled open fissures and in part to have replaced schists. These authors think it probable that the veins in the Cartersville district were formed by solutions ascending from a considerable depth and that the ore may change below the water level into a mixture of iron oxides, sulphides, and perhaps carbonate. In North Carolina there is practically no evidence as to the character of the ore below groundwater level. None of the mines have reached to so great a depth. It is certain, however, that the veins were formed after the deformation of the rocks in which they occur, as they exhibit no signs of slickensides or of true schistosity, and it is almost equally certain that they were produced by water percolating downward. They are best developed at the contacts of replaceable rocks with impervious

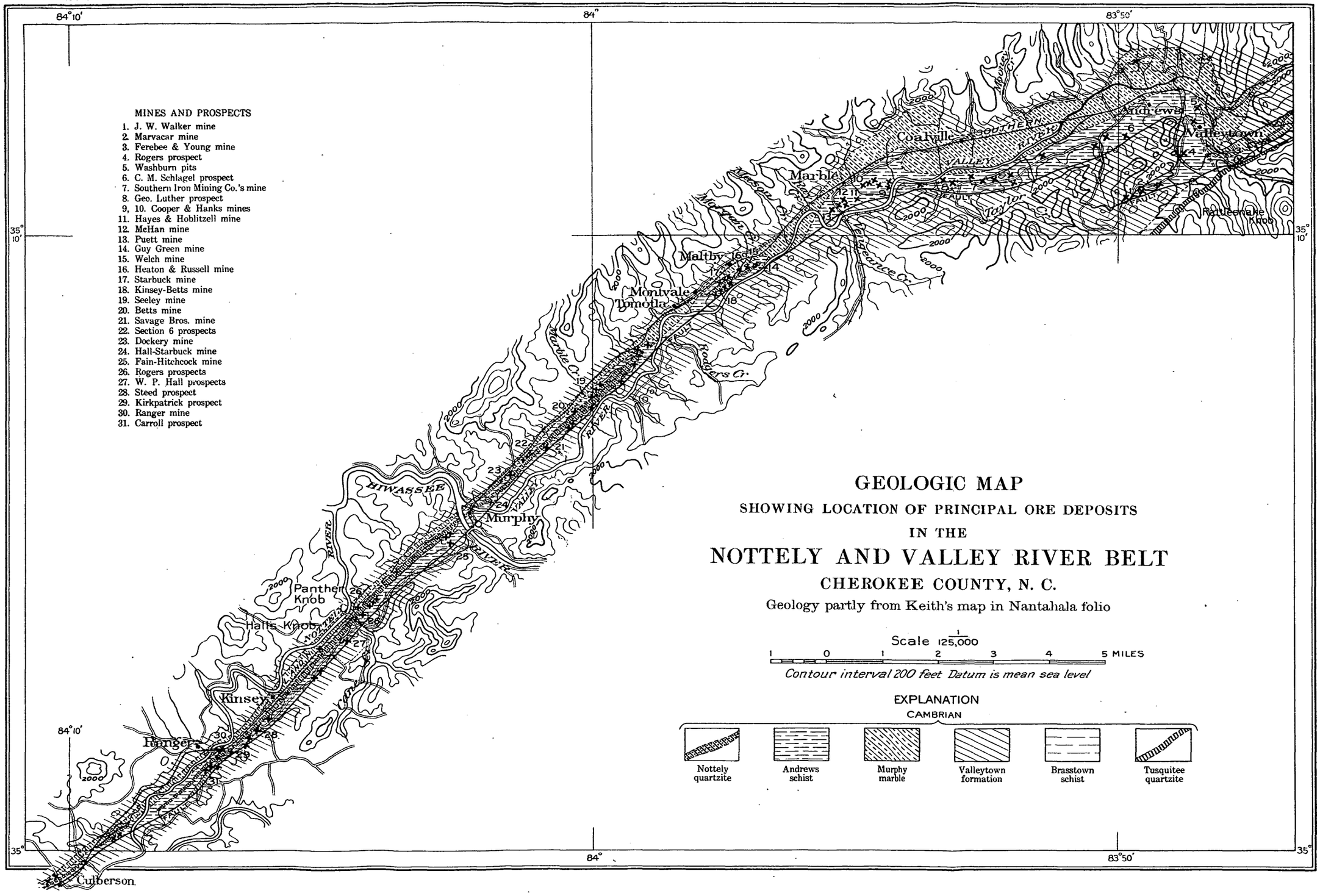
[10] Hayes, C. W., and Eckel, E. C., Iron ores of the Cartersville district, Ga.: U. S. Geol. Survey Bull. 213, p. 240, 1903.

[11] Op. cit., p. 240.

beds and in fault zones and are more abundant above the impervious beds than beneath them. In some places the veins are arranged as if in synclines and thus apparently follow a bed that is more easily replaced than others; but a glance at the maps (Pl. IV, figs. 48, 54–56) will show that they do not occur at any definite horizon. They may be present almost anywhere within the Andrews schist, for the rocks of this formation, because of their porous texture and pronounced schistosity, furnish abundant channels for percolating water. The veins are largest, however, at the contacts of the schists with impervious or nearly impervious beds, because these contacts furnish the best channels for the ore-depositing solutions. In rocks other than the calcareous schists deposits of brown hematite occur only at contacts or in faults.

The explanation of the existence of large deposits in the Andrews schist under the layers of quartzite in the Valley River belt is difficult, unless it may be assumed that the foliation planes of the schists near the contact were opened by shearing when the beds were folded and, naturally, thereafter became easy conduits for descending solutions. As the folds are overturned to the northwest, the foliation of the schists and their accompanying veins dip southeasterly under the overlying quartzite.

The source of the iron in the ores has not been determined. Keith believes it to be pyrite in the overlying quartzites, but there is so little pyrite in the quartzites in Cherokee County that this can not be the sole source of the iron in the deposits, though it undoubtedly contributed to the supply. There were, however, other rocks above the quartzite, and each of these may have furnished some of the iron. Deposits of ore were made whenever the conditions for concentration were favorable. In Madison and Cherokee counties the Cambrian beds furnished proper conditions for the deposition of ore, just as in other localities proper conditions were furnished by rocks of other ages. The source of supply was in the rocks above the deposits. These were not exposed to weathering until after the deformation at the end of Paleozoic time, and therefore they could not have furnished ferruginous solutions before this time. During the carving of the Mesozoic and Cenozoic peneplains, however, the Paleozoic rocks must have furnished a great deal of ferruginous material for concentration into ore deposits. Probably the deposits formed earliest were near the old surface. With lowering of the surface by continued erosion, the zone of ore deposits must have been similarly lowered, but it could not have reached the Cambrian beds until the surface had nearly reached them. It is probable that this did not occur earlier than the time of development of a Tertiary peneplain and therefore that the deposits in Madison and Cherokee counties



GEOLOGIC MAP

SHOWING LOCATION OF PRINCIPAL ORE DEPOSITS IN THE

NOTTELY AND VALLEY RIVER BELT

CHEROKEE COUNTY, N. C.

Geology partly from Keith's map in Nantahala folio

Scale 1/125,000

1 0 1 2 3 4 5 MILES

Contour interval 200 feet Datum is mean sea level

EXPLANATION

CAMBRIAN

Nottely quartzite	Andrews schist	Murphy marble	Valleytown formation	Brasstown schist	Tusquitee quartzite

have been formed since Tertiary time. If the blanket deposit on the Jenkins property and the Southern Iron Mining Co.'s land is a Pleistocene conglomerate, the veins in the Cambrian rocks must have been formed in early Quaternary time.

Deposits of the second type (those that have resulted from disintegration of rocks containing deposits of ore formed by descending water) need little discussion. They are most abundant above the Murphy limestone and the calcareous Andrews schist, because these rocks contain most of the deposits of the first type and because they dissolve rapidly, leaving behind only their insoluble constituents, which consist principally of quartz sand and fragments of the equally insoluble iron hydroxides. Thus comparatively small ore deposits in the calcareous rocks may be concentrated by weathering into fairly rich deposits. The richest residual deposits will be found near faults or near contacts with quartzites, because at these positions the largest original deposits occur. Deposits of this kind are shallow, rarely exceeding 20 feet in thickness. When the price of ore is high and labor is cheap, the larger fragments of ore may be picked from the soil and shipped at a profit. Usually, however, the deposits must be washed to obtain all the ore in them, and in many places even when this is done the depth to which profitable exploitation may go is only a few feet. Nearly all the brown hematite that has thus far been produced in North Carolina has come from residual deposits or from the disintegrated upper portions of mineralized Andrews schist which are in the process of forming residual deposits. (See Pl. V, *A*, *C*.)

CHARACTER OF THE ORE.

The brown hematites of Madison and Cherokee counties are hard, flinty dark-brown mixtures of goethite and limonite and soft yellowish-brown sandy limonites. As furnished in carload lots they are non-Bessemer ores, containing about 45 to 50 per cent of iron, 0.25 to 1.25 per cent of manganese, 0.3 to 0.7 per cent of phosphorus, and 8 to 18 per cent of silica. The sulphur content is rarely more than 0.1 per cent and is never large enough to be objectionable. The variations in iron and silica depend mainly upon the care taken in preparing the ore. The variation in the manganese is due to inherent differences in the ore. In a few deposits the manganese content is less than 0.25 per cent, in some it is greater than 2.25 per cent, and in a few the ore is a low-grade manganese ore.

MADISON COUNTY.

In Madison County (fig. 48) the principal deposits are accumulations of lumps and masses in the residual clays of the Shady limestone near Shut-in Creek at Tennelina, 3 to 4½ miles west of Hot

Springs. The ore in the clay varies greatly in amount. It is most abundant at the west end of a belt of limestone, where that rock lies in a synclinal basin surrounded by ridges of conglomerate and quartzite. Keith writes:[12]

> The hematite is most abundant near the contact of the limestone and the underlying quartzite and is found here and there along the entire contact. The upper portions of the limestone contain very little ore. Its presence in the lower layers near the quartzite appears to be due to downward concentration into these layers. The limestone itself contains little or no ferruginous material, so that the hematite is probably derived from the quartzite series, in which are found small accumulations of pyrite.

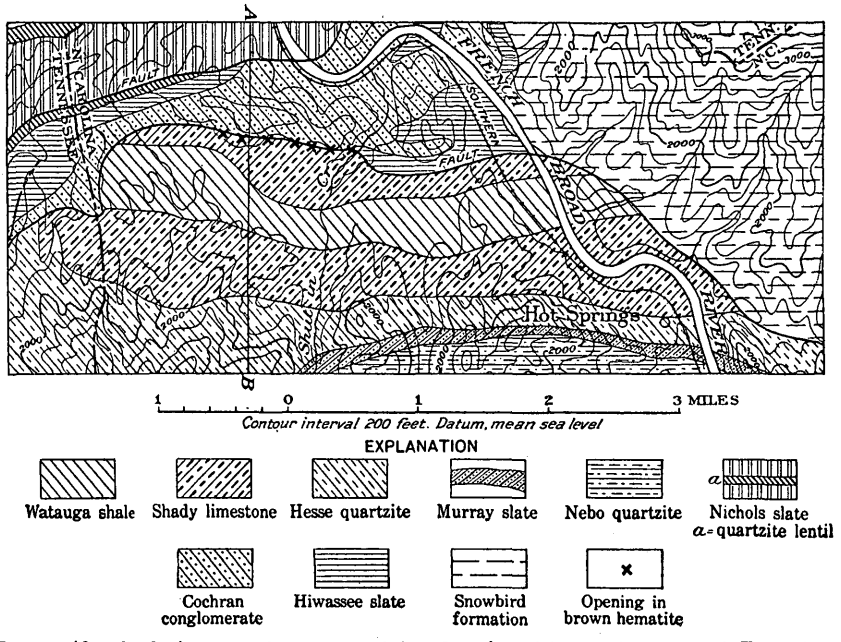
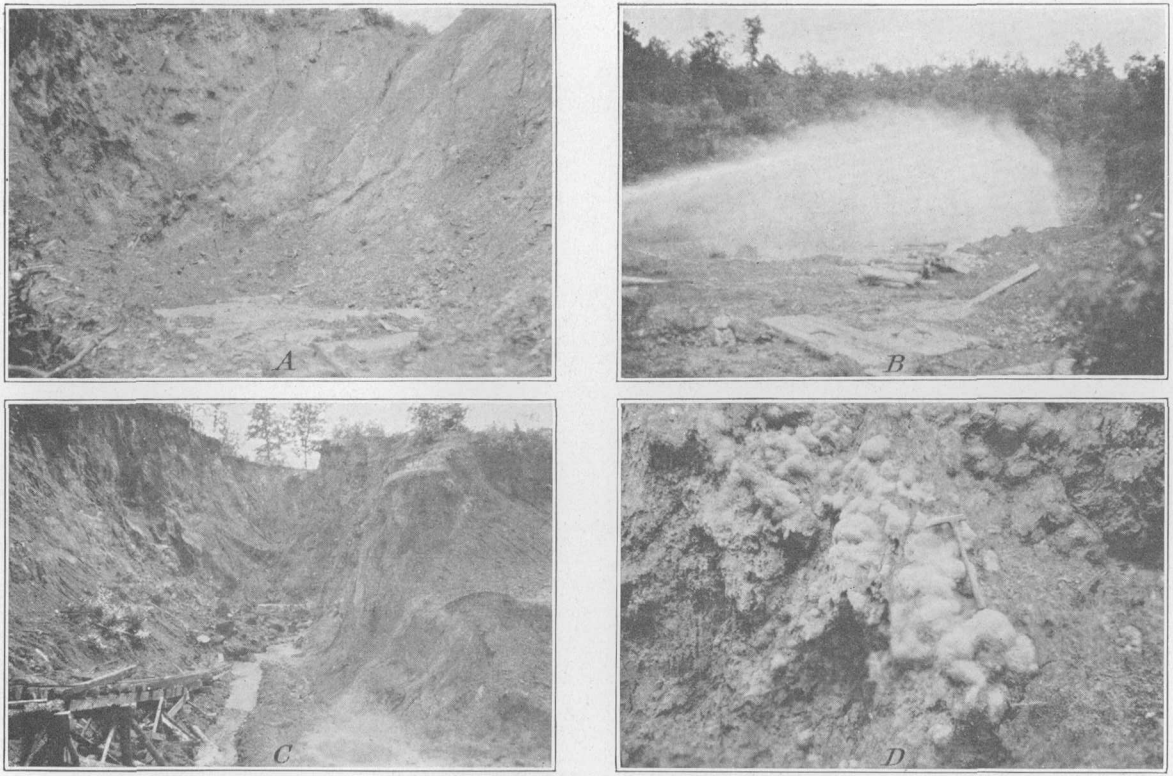


FIGURE 48.—Geologic map of area containing deposits of brown hematite at Tennelina, near Hot Springs, N. C. *A–B*, Line of section, figure 49.

The depth of the ore has been tested only by shallow pits, and, according to Keith, the clays containing the ore are probably not much more than 30 feet deep.

A map and cross section of the area showing the relation of the ores to the limestone are given in figures 48 and 49. They are taken from Keith's map of the Asheville quadrangle (Folio 116). The section is slightly modified, as Keith's section lies east of the points at which the ores are best developed. Just west of Shut-in Creek the rocks on the upthrown (north) side of the fault are members of the Cochran conglomerate and not of the Snowbird formation, as

[12] Op. cit. (Folio 116), p. 10.



VIEWS IN BROWN-HEMATITE MINES IN WESTERN NORTH CAROLINA.

A, View in Heaton & Russell mine, near Maltby; *B*, hydraulic jet in Heaton & Russell mine; *C*, Hayes & Hoblitzell mine, near Marble; *D*, mammillary ore in the Savage mine, near Murphy.

VIEWS IN BROWN-HEMATITE MINES IN WESTERN NORTH CAROLINA.

A, Ore bed in mine of Southern Iron Mining Co., near Andrews; *B*, west end of bed shown in *A*, showing parallelism with surface; *C*, general view of bed shown in *A*; *D*, ore vein in Heaton & Russell mine, near Maltby.

they are farther east, where the section was made. The ores are in or near the fault zone. Here weathering has been excessive because of the ease with which water could travel down the fault zone, and the limestone has been changed to sandy and clayey decomposition products to a greater depth than elsewhere.

The ore occurs nearly everywhere along the north side of the limestone. In some places it forms little streaks in the bedding planes of the limestone; in others it occurs as large dense masses in brecciated and massive limestone and clay; and in still others it is in veinlets cutting the limestone and to some extent the neighboring shale and conglomerate. The relations indicate that the ore has replaced the limestone along joints, small faults, and bedding cracks. As erosion proceeded the ore became shattered and dispersed through the clay and formed the productive ore mass that Keith describes.

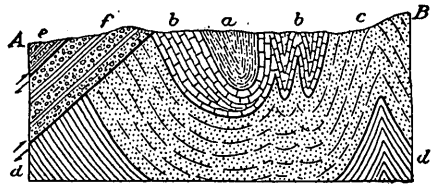


FIGURE 49.—Diagrammatic north-south section through area shown in figure 48. *a*, Watauga shale; *b*, Shady limestone; *c*, Hesse quartzite; *d*, Murray slate; *e*, Nichols slate; *f*, Cochran conglomerate.

The source of the iron in these deposits is problematic. It may have come from any one of the formations that have been eroded away above the Cochran conglomerate. Keith apparently ascribes its origin to pyrite in the Hesse quartzite; but after a careful examination of the old openings one can scarcely escape the conviction that at least some of the limonite came from the limestone itself.

The mines, which are on or near the fault, form a line extending westward from Shut-in Creek for about 1½ miles. Most of them are open pits that are now so filled with dirt that no rock can be seen in their walls. A few are tunnels in which small exposures are visible. It is said that several hundred cars of ore were shipped to Knoxville and other points when the mines were operated by A. G. Betts in 1917. Most of the ore was wash ore that yielded 1 part of commercial ore to 4 parts of material mined. In some places, however, the ore was hard and massive. Such ore was hand picked and shipped as lump, yielding a much higher average of ore than 1:4.

John Smith, who made an examination of the district for the North Carolina Geological and Economic Survey when the mines were in operation, in a report to the State geologist writes that "the ore was all worked from open cuts except the last attempt, in which the hydraulic process was used. * * * The concentration of the ore is accomplished by means of the log-roller process"

at the rate of 125 to 300 tons daily. "In all, there were six mines opened on this property, from which about 30,000 tons of ore has been taken."

Deposits have been reported by Nitze [13] from other points in the county, but his description is very brief and affords no information as to the conditions under which they occur. The ore in one deposit is said to be cellular and ocherous, and that in another botryoidal and compact.

So far as is now known, the only available ore in Madison County is along the fault at Tennelina. There is no means by which the quantity still remaining in the ground can be estimated. A consideration of all the facts seems to indicate that there may be as much as 100,000 tons left within 50 feet of the surface, but as a large part of it exists as boulders in sand the quantity of ore that might be mined profitably is much less. Considerable ore remains that might be concentrated on a small scale by log washers, but there is no promise of production on a large scale.

CHEROKEE COUNTY.

GROUPING OF THE DEPOSITS.

The most valuable deposits of brown ore in North Carolina occur in Cherokee County in the narrow belt of Murphy limestone and associated rocks along the Murphy branch of the Southern Railway from Valleytown to Murphy and its extension along the Louisville & Nashville Railroad to the State line, a distance of 28 miles (Pl. IV). The portion from Valleytown to Murphy is called the Valley River ore belt, and its extension southwest of Murphy is called the Nottely River belt.

Another series of deposits surrounds the area of marble near Peachtree, 6 or 7 miles west of Murphy (fig. 54, p. 195). Some of these are apparently large, but they have heretofore been so far from a railroad that it has not been thought wise to attempt to develop them.

A third series lies along the borders of a strip of marble extending from a point a mile southeast of Peachtree through Brasstown (fig. 54), westward through the valleys of the two main tributaries of Martin Creek, and southwestward along Gold Branch to Nottely River (fig. 56, p. 199). That portion of the series lying east of Martin Creek is known as the Brasstown belt of deposits, and the portion in the valley of Martin Creek as the Martin Creek deposits. None of these deposits have been worked since the Civil War, but

[13] Nitze, H. B. C., op. cit., p. 211.

at that time and earlier two or three of them were important sources of ore.

A fourth series follows the south side of a ridge of quartzite that runs S. 60° W., with a few interruptions, from a point near Hiwassee River 2 miles southeast of Murphy a distance of 10½ miles to Nottely River (fig. 56). Some of the deposits on this belt were worked many years ago to supply local forges, but they have long since been abandoned.

GEOLOGY OF THE ORE-BEARING DISTRICT.

The only Cambrian formations in Cherokee County that are closely associated with the ores are the Brasstown schist, the Valleytown formation, the Murphy marble, and the Andrews schist. All these have been sufficiently characterized for the present purpose in the table on page 160. Keith gives more complete descriptions of them in the Nantahala folio.

The Andrews schist, which is more intimately associated with the deposits than any of the other formations, consists of a series of beds of calcareous schist from 200 to 350 feet thick, flanking the Murphy marble on the southeast from Valleytown southwestward to the State line and bordering the marble at Peachtree on all sides but the north. It also occurs as a very narrow belt in some places on the north side of the marble in the Brasstown and Martin Creek areas. The schist is composed of a matrix of marble in which are embedded sand grains, muscovite and biotite flakes, and plates of ottrelite. At its base the Andrews schist grades into the Murphy marble by interbedding, and at the top it passes into the Nottely quartzite, as the sandy material increases both in separate layers and as grains in the body of the schist.

The Nottely quartzite appears in two small lenticular areas surrounded by Andrews schist near Tomotla. Farther northwest it is found in several small areas bordering areas of Murphy marble, and farther southwest it occupies an almost continuous narrow strip of country reaching beyond the State line into Georgia.

The general region of which the western portion of Cherokee County is a part consists of a great synclinal basin with a northeast-southwest axis, complicated by minor folds that have the same strike, of which one is a syncline following Valley and Nottely rivers. From Marble to the State line the syncline contains the youngest rocks in the region, but toward the northeast it rises and older beds are brought to the surface, the younger rocks having been eroded and with them most of the ores that they may have contained. (See Pl. IV.)

Moreover, the region is traversed by many faults. The Murphy fault follows the east side of the valley, bringing the Valleytown

formation into contact with the overlying Nottely quartzite, the Andrews schist, or the Murphy marble. Just south of Andrews the fault was probably folded, as it now crops out in a curved Z. The Murphy fault dips generally 20°–60° SE. in the valleys of Nottely and Valley rivers. Its maximum throw is about 5,000 feet in the neighborhood of Andrews.

A small syncline accounts for the Brasstown and Martin Creek areas of marble (fig. 55, p. 196), and an anticline for the outcrops of marble and Andrews schist at Peachtree (fig. 55). The Peachtree area, moreover, is bounded by two curving faults that separate it from the Valleytown formation on the north and east and from the immediately underlying Brasstown schist on the west. (See fig. 54, p. 195.)

DEPOSITS ALONG VALLEY AND NOTTELY RIVERS.

GENERAL FEATURES.

The largest belt of ore deposits in Cherokee County is that which extends from the State line near Culberson down the valley of Nottely

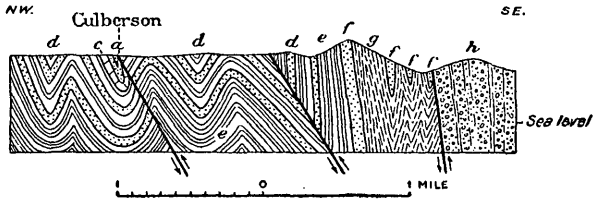


FIGURE 50.—Northwest-southeast section across Nottely River hematite belt at Culberson, N. C. *a*, Nottely quartzite; *c*, Murphy marble; *d*, Valleytown formation; *e*, Brasstown schist; *f*, Tusquitee quartzite; *g*, Nantahala shale; *h*, Great Smoky formation.

River and along the Louisville & Nashville Railroad to Murphy, up the valley of Valley River to its source at Topton, and beyond as far as Hewitts, in Swain County (Pl. IV). In this belt there are almost continuous deposits as far northeast as Andrews, but beyond that town, because of the rise of the syncline in this direction, the upper formations and the iron ores with them have been almost completely removed by erosion.

Throughout this belt extends a narrow syncline of Murphy marble, Andrews schist, and Nottely quartzite which is overturned to the northwest, as shown by the sections through Marble and Regal given by Keith (fig. 51), and through Culberson by La Forge and Phalen (fig. 50). The east side of the syncline is limited by the Murphy fault, which dips 20°–60° SE. As the downthrow of this fault is on the northwest side, the upper formations on that side have been preserved.

At Andrews the trough takes an abrupt turn to the south for about a mile and then south of Valleytown turns as abruptly to the northeast and resumes its original course. The Murphy fault is similarly folded.

Although deposits of brown ore are known to occur from Culberson to Andrews in an almost continuous belt, the most important ones, or at any rate those that have been mined and explored, are limited to the neighborhood of Murphy, of Marble, and of Andrews.

Between Culberson and Marble the deposits are at the contact of the Nottely quartzite and the Andrews schist, in some places only on one side of the quartzite, usually the southeast side, and in others on both sides. Between Marble and Andrews no quartzite occurs, and the ore deposits are in the Andrews schist near the trace of the Murphy fault, or in the sand arising from its decomposition at some distance from the fault trace.

The principal mines are at Murphy, at Maltby, near Marble, and near Andrews. At present only a few are being worked. Formerly

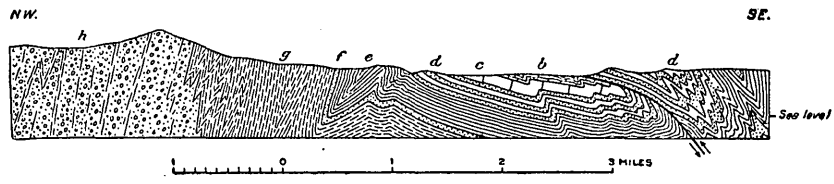


FIGURE 51.—Northwest-southeast section across Valley River hematite belt near Marble, N. C. *b*, Andrews schist; *c*, Murphy marble; *d*, Valleytown formation; *e*, Brasstown schist; *f*, Tusquitee quartzite; *g*, Nantahala shale; *h*, Great Smoky formation.

the number was much greater, but much of the ore shipped was separated by forking from the material that had been broken by pick from the walls of open pits. This was known as "hard" or "lump" ore, and the mines operated in this way were soon abandoned because of the increased cost of breaking down the ore as depth increased. In some mines the soil was so full of fragments of limonite that it was shipped without preparation of any kind, and after the supply of loose material was exhausted the mines were abandoned. Within recent years a large portion of the ore shipped has been washed in log washers to free it from the sand and dirt obtained by open-pit mining with the shovel and pick, steam shovel, or hydraulic jet. Most of the mines operated in this way have been profitable, even when worked on a comparatively small scale, and as a result nearly all the ore now produced is washed before shipment.

The first impression obtained by a rapid survey of the field is that failure has followed the attempts to exploit it. As a matter of fact, however, most of the operations have been successful financially, and

the mines have simply been abandoned when the cream of the deposits had been collected.

NOTTELY RIVER ORE BELT.

Location and general character of the deposits.—In the Nottely River ore belt as a rule the syncline is much narrower than it is between Murphy and Andrews, and the Andrews schist is not as well developed. The rock beds are closely folded, so that their dips are usually high. Moreover the Murphy fault traverses the fold nearly along its axis. The close folding and the position of the fault account for the narrowness of this portion of the syncline. (See Pl. IV.) Because the syncline is more depressed toward the southwest than toward the northeast (see p. 167) and because of the close folding the Nottely quartzite has been more completely protected from erosion here than farther northeast and has consequently been preserved as a low ridge flanking the Murphy branch of the Louisville & Nashville Railroad nearly all the way to the State line. West of the quartzite is a narrow strip of the Murphy marble, which at Kinsey was formerly quarried and at several places has been worked for talc. East of it is a comparatively narrow belt of the Andrews schist, and east of this the trace of the Murphy fault. In some places the fault trace passes very near the quartzite, so that the belt of Andrews schist exposed at the surface is reduced to narrow limits. In other places the fault passes through the Andrews schist and consequently there are wider patches of the schist between the quartzite and the members of the Valleytown formation. Opposite Ranger a very narrow strip of the Murphy marble lies between the Andrews schist and the fault line, but this is the only outcrop of the marble known on the east side of the quartzite.

The ore deposits in the Nottely belt are confined mainly to the neighborhood of the fault. A few pits have uncovered deposits on the northwest side of the quartzite, but they are small and unimportant. None of them have been developed into mines, but from a few openings in the neighborhood of Culberson small shipments have been made from time to time.

On the southeast side of the quartzite ridge, on the other hand, there are numerous evidences that the ore belt is nearly if not quite continuous all the way to the State line. Many pits and small exposures on or near the highway from Murphy to Culberson have shown the presence of deposits all the way. Only on the Fain-Hitchcock property, however, have any large explorations been attempted. (See p. 172.) Most of the openings are small pits that have not reached the solid ledge; consequently there is no means of learning whether the veins are large or small. Usually only soft

ore was encountered, and for this reason the openings were abandoned. No attempts have been made to test the material as a source of wash ore.

One of the most promising of these deposits is near the mouth of Cane Creek, where it crosses the quartzite ridge about 3 miles southwest of Murphy. Here ore appears to lie between the quartzite and the Andrews schist. The ore is yellow or yellowish brown and sandy and contains many little rhombohedral or cubical masses of limonite that represent decomposed ottrelite plates, showing that the ore is partly the result of a replacement of Andrews schist. Northeast of the pit near the railroad are five others that show the ore zone to extend about a quarter of a mile farther in this direction. Much of the ore is manganiferous, and some of the pits have yielded manganese ore of shipping grade. So far as could be seen, it is all loose ore that will require washing. There is now no means of estimating the quantity of ore in the deposits, but from the great size of some of the pits at the northeast end of the series it is evident that considerable ore must have been taken from some of them.

The only other promising deposits noted in this belt are on the branch road from the highway to Ranger, where there are two ore pits, one on the northeast side of the road near the highway, not far from the Murphy fault trace, and the other on its southwest side near the railroad. The latter is on the southeast side of the quartzite ridge at the contact of the Nottely quartzite and the Andrews schist. It is several hundred feet long and shows here and there in its walls small seams of sandy ore in very much disintegrated schist. These seams strike N. 40° E. and dip about 75° SE. The size of the pit indicates that it must have furnished a comparatively large quantity of ore.

Another deposit is exposed by a series of trenches and a tunnel in loose ore at the southwest end of the same hill, and here also the ore is on the contact of the quartzite and the Andrews schist. A little farther east, on the southeast side of the highway, are two other pits, likewise in loose ore. If the strip of country 500 feet wide between the two series of pits is everywhere as rich in ore as is indicated by the character of the material in which the pits have been sunk, it might contain a large quantity of ore suitable for washing.

No other deposits were seen between these pits and Culberson, about half a mile from the State line. Ore is exposed at Culberson just west of the railroad station, and there are several other exposures and a few pits uncovering loose ore about a mile southwest of the town, near the highway to Sweetgum, Ga. Much of the ore is highly manganiferous, and some is composed largely of pyrolusite. A few other evidences of the presence of limonite and man-

ganese oxides were seen near the borders of the strip of marble passing through the town, but none of the deposits appear to be of commercial importance.

Reserves south of the Fain-Hitchcock mine.—The reserve of ore in the Nottely River valley has not been estimated. There is unquestionably a large quantity of ore in the valley southwest of the Fain-Hitchcock mine, but it is widely scattered except in a few areas, and in these there has not been enough exploration to warrant an opinion as to the size of the deposits. At the mouth of Cane Creek and perhaps at a few other places washing operations might prove profitable, but elsewhere there is no evidence to encourage development.

Fain-Hitchcock mine.—The only mine in the Nottely River belt is about three-quarters of a mile southwest of Murphy, on the lands of Mr. Fain and Mrs. Hitchcock. It illustrates very well the manner of occurrence of the ore in the southern portion of the belt. The mine is on the southwest slope of a ridge, the crest of which is occupied by the Nottely quartzite. On the lower slope of the hill and to the southeast, nearly as far as the Louisville & Nashville Railroad, the surface is covered with fragments of sandy slate suggesting the Andrews schist, but near the top of the low hill beyond the tracks are outcrops and float of an ottrelite schist that is characteristic of the Valleytown formation. The ore consists of layers and loose boulders of hard limonite in a matrix of clay and sand. On the surface and near it the ore occurs as loose fragments and nodules in sandy clay, forming an excellent wash ore. At a greater depth it occurs in layers in a friable sandy schist dipping about 75° SE.

Such ore as can now be seen in place is in the main a mass of small and large veins cutting in a general parallel direction through much disintegrated sandy schists but in places crossing the schist and uniting into large veins. Some of the ore is coarsely botryoidal, with dense spherical masses measuring about 3 or 4 inches in diameter. (See Pl. V, *D.*) Other parts are brown sandy masses that fall apart when roughly handled. Many of these contain little scaly portions that represent the decomposed ottrelite plates in the original schist, and others are simply masses of sand and limonite. The veins evidently were formed by the replacement of the calcareous cement of the schist by iron hydroxides. In open spaces and in layers that were limestone dense ore was formed. In sandy layers sandy ore resulted. This sandy ore and that occurring in the plexus of small veins furnish the "wash ore," and the thick veins of dense limonite and the botryoidal variety furnish the hard or "lump ore." In this mine, as in most others in the district, the wash ore is much more abundant than the hard ore.

As the dumps contain a considerable quantity of conglomerate and breccia fragments it is probable that the geologic conditions are similar to those at Tennelina, in Madison County. The breccia probably marked the position of a small fault near the pit or of a crush zone of marble and schist at the apex of a closely compressed anticline. The presence of the great Murphy fault accounts for the absence of the Murphy marble between the Andrews schist and the Valleytown formation to the south, the position it should occupy if undisturbed by faulting. (See fig. 52.) Southwest of the pit hard ore crops out as rugged solid ledges for a length of about 2,000 feet and a width of 100 feet or more, and large boulders of ore cover a belt that is considerably wider. Some of the ore is distinctly botryoidal, as if deposited in an open crack. To the northeast the belt can be traced by float for 800 to 1,000 feet.

The workings of the old mine consist of an open pit about 400 feet long in a direction about N. 35° E., with a maximum depth of 65 feet.

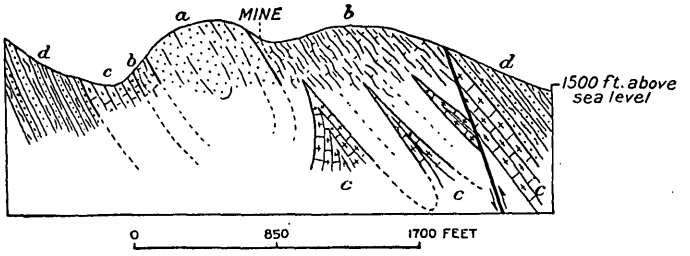


FIGURE 52.—Diagrammatic cross section through Fain-Hitchcock mine, near Murphy, N. C. *a*, Nottely quartzite; *b*, Andrews schist; *c*, Murphy marble; *d*, Valleytown formation.

The width of the opening is now about 20 feet, and the width of the nearly solid vein 12 to 15 feet; but the layer of productive wash ore must be much wider than this. The ore that was shipped is reported to have contained from 44.75 to 49.50 per cent of iron.

The northwest slope of the quartzite ridge is covered by quartzite fragments, but in the valley at its base are a few exposures of marble and a number of shafts from which talc has been taken. Across the valley are abundant ledges of the Valleytown formation. It is evident that the ridge is synclinal. On its southeast limb, however, the Murphy marble is lacking, owing no doubt to the presence of the Murphy fault, which at this place apparently intersects the Andrews schist. Nitze[14] gives a section through the ridge but does not indicate the existence of the fault. An ideal section through the hill is shown in figure 52.

[14] Op. cit., p. 198.

VALLEY RIVER ORE BELT.

It is not possible to determine without much work whether there is any ore on the northwest side of the syncline at the Fain-Hitchcock mine, but farther to the northeast ore is known to be abundant on both sides.

DEPOSITS BETWEEN MURPHY AND MONTVALE.

At the Hall-Starbuck mine, in Murphy, a deposit has been opened for 1,200 feet on the southeast side of the quartzite. There is also a little ore on its northwest side. Beyond it is the marble underlying the valley. Here also, as farther south, the structure is that of an overturned syncline, with dips on its southeast limb of 65°–70° SE. Moreover, this limb lacks the marble, the Andrews schist being brought into contact with the Valleytown formation by the Murphy fault.

About half a mile farther northeast, at the Dockery mine, ore was discovered in sufficient quantity on the northwest side of the quartzite to warrant its exploitation in a small way, but on its southeast side ore is absent or perhaps is present in small quantity. However, a little farther northeast apparently large veins of ore are developed on both sides of the quartzite, at openings in the district known as " Section 6 " and at the mine of Savage Bros.

The openings in Section 6 extend for nearly a mile on the northwest side of the ridge, thus continuing the vein system of the Dockery mine. Some of them are very large, but none are deep. Some are long trenches extending from points near the crest of the ridge down its west slope for 125 feet; others are large pits near the bottom of the slope. The long trench near the top of the slope exposes nearly throughout its length ore layers dipping 55° SE. One of these layers consists of almost solid ore 30 feet thick, and another of ore 15 feet thick. Besides these there are many small veins, aggregating a thickness of 10 or 12 feet. On the hill above the upper end of the trench boulders of ore are scattered abundantly over the surface, so that the inference is justified that the ore belt is even wider than the width exposed in the trench. Moreover, pits on the slope all the way from the lower end of the trench to the road at the bottom of the slope—a distance of 500 feet—show the presence of ore in the soil, but none of them, so far as could be determined, reached solid rock. It is probable that the ore on their dumps is all surficial material that has rolled from above.

About half a mile farther northeast other openings well up on the northwest slope of the ridge also show a series of limonite layers from 6 inches to 2 feet thick, dipping about 45° SE.

From the character of the ore layers seen in the few openings that reach undisturbed rock it is plain that there are here no great, thick layers of hard ore that can be mined and shipped without washing. On the other hand the abundance of boulders strewn over the upper slopes of the ridge for a distance of over a mile and the great quantity of ore fragments present in the soil and sand uncovered by the many pits that have been opened on its lower slopes indicate that this belt of country as far northeast as Marble Creek furnishes favorable conditions for an efficient washing operation.

According to Nitze [15] the ore contains 58.80 per cent of iron, 0.161 per cent of sulphur, and 0.391 per cent of phosphorus, and the "phosphorus ratio" (P: Fe) is therefore 0.664 per cent.

On the opposite (southeast) side of the ridge are the open cuts of the Savage mine. The property was worked by A. G. Betts during the first half of 1917 but later came into the possession of the Messrs. Savage, of Murphy, and was worked by them during the late war. The main opening, which is on the old Cooper property, is a large open pit about 500 feet long, 75 feet wide at the top, 30 feet wide at the bottom, and between 12 and 35 feet deep. It is well up on the slope of the quartzite ridge which separates the deposit from that in Section 6. The width of good ore is between 30 and 40 feet, of which 20 feet is solid black ore, some of it botryoidal (Pl. V, *D*), and 10 or 15 feet is soft ore. The ore bed is nearly vertical. In its general character the ore is similar to that in the Fain-Hitchcock mine. Only such hard ore as it was possible to cob by hand was shipped. The soft ore and small fragments were thrown on the dump. Mr. Betts shipped in all about 1,000 tons, and the Savage Bros. about 4,000 tons.

Analyses of carload lots of brown ore shipped by Savage Bros.

Iron (Fe)	47.08	45.10	49.54	48.81
Manganese (Mn)	.29	.58	.25	.49
Moisture	2.73	4.88	1.90	1.00

An inspection of the huge dumps at this place gives abundant evidence of the great quantity of ore that has been wasted. No estimate has been made of the percentage of ore present in the sand and clay that makes up the greater portion of the dump piles, but the material would doubtless warrant washing. Mr. Savage states that the width of the wash ore is at least 100 feet. As this estimate seems to be correct, the property deserves careful prospecting and testing with an efficient washing plant.

About 1,800 feet southwest of the Savage opening ottrelite-mica schists are exposed on the road. These are probably members of

[15] Op. cit., p. 199.

the Valleytown formation. Between these exposures and the mine there are no outcrops, but in the road, about 600 feet southeast of the mine, there is a clay with the characteristics of clays that are known to be derived from the marble. It is probable that the trace of the Murphy fault at this place passes through the upper portion of the marble very close to the old bin of the Savage mine. This is one of the very few places in the Valley River trough where marble is exposed on both limbs of the syncline.

Farther northeast, at Marble Creek, two ore belts are exposed. The creek cuts across the quartzite, which dips 45° SE. On the southeast side of the quartzite, near the mouth of the creek, ore crops out along the highway a few feet above the level of Valley River. Its dip is 75°–90° SE. Because of the low altitude of the outcrop, perhaps, the ore has not been explored, and consequently the thickness of the deposit is not known.

On the northwest side of the ridge the ore has been exploited by large open pits both south and north of the creek. In recent years the openings to the southeast were worked by A. G. Betts and those northeast of the creek by F. R. Seeley. Nitze [16] describes the southern deposit as consisting of a "solid ore bed 8 to 12 feet in thickness, dipping 50° SE. and underlain by decomposed shale and clay, beneath which there are several smaller seams of siliceous ore," containing 17.52 per cent of silica, 48.44 per cent of iron, 0.038 per cent of sulphur, and 0.295 per cent of phosphorus and having thus a phosphorus ratio of 0.609 per cent. On the north side of the creek the ore was 8 feet thick and was more siliceous than that in the southern opening.

West of these openings the Murphy marble is quarried by the Regal Blue Marble Co., and half a mile farther northeast it is worked for talc. Keith [17] describes the section through the marble as follows: "At the bottom are several feet of white marble with tremolite crystals; above this are 50 feet of pure white marble, 40 feet of blue marble, and 30 feet of white marble. After a small interval in which there are no exposures the ottrelite-bearing Andrews schist outcrops." Next follow the ore deposits, and above these about 150 to 200 feet of Nottely quartzite in the bed of the creek. The structure is a syncline overturned to the northwest. A reproduction of Keith's section is given in figure 51.

The large openings immediately northeast of Marble Creek extend for about half a mile, beyond which there are a number of small pits scattered on the northwest side of the quartzite for another mile, and here and there on its southeast side is a small exposure

[16] Op. cit., p. 200.

[17] Keith, Arthur, U. S. Geol. Survey Geol. Atlas, Nantahala folio (No. 143), p. 7, 1907.

of ore. The quartzite is not exposed between the small pits and Montvale, a distance of about 1½ miles. Through this stretch the Nottely quartzite has been entirely eroded, and with it any ore deposits that may have been developed along its contact with the Andrews schist. Here and there pits in the Andrews schist have opened small deposits, but these are of no commercial importance.

DEPOSITS BETWEEN MONTVALE AND MORGAN CREEK.

Just northeast of Montvale the Nottely quartzite reappears and constitutes another ridge, which extends as far as Morgan Creek, and here again it is flanked on both sides by ore. The deposits on its northwest side have been much more thoroughly explored than those on its southeast side, although on this side there are a few large but shallow pits and several promising exposures.

The principal opening is at the northeast end of the ridge, near Morgan Creek, where active operations are now being carried on intermittently by Ben Starbuck, of Murphy, under lease from Mrs. Kinsey, who owns the mineral rights. The main opening is about 325 feet long. Other openings on the strike of this one are small and shallow, but they are so distributed as to indicate a considerable width of mineralized rock, dipping about 35° SE. The mine is equipped with a pump and log washer. Most of the product is washed, yielding to the ton of rock about 800 pounds of ore, which on analysis shows in carload lots about 12 per cent of silica, 48 to 52 per cent of iron, 0.13 per cent of manganese, and 0.04 per cent of phosphorus. During the war the mine furnished several carloads of very porous ore to the naval station at Pensacola, where it was used for the generation of hydrogen.

The quartzite ridge is very narrow. On its southeast side near Morgan Creek are exposures and strippings showing 8 or 10 feet of hard ore, which it is proposed soon to work. Farther southwest are several large openings that were made by A. G. Betts. Mr. John Smith in his report to the North Carolina Geological and Economic Survey writes that on the "Dockery place" at Montvale, presumably the property worked by Betts, the ore vein is "made up of flat lenses stacked one on another and reaching a maximum of seven layers, width 1 to 8 feet, dip about 45°. This was worked for about three months and produced about 3,000 tons." He states that at the "Kinsey property," probably in the southern part of this area, about 7,000 tons has been produced since the opening of this mine some years ago, 1,200 tons of which was mined in 1918. The openings are spread over a width of about 150 feet, indicating a belt of ore at least 125 feet wide.

Mr. Starbuck declares that three engineers have estimated the reserve on both sides of the quartzite as from 1,500,000 to 2,000,000 tons, assuming a double belt of ore bodies to extend three-quarters of a mile. He does not know the data upon which the estimates were based but states that a shaft on neighboring property followed the ore to a depth of 85 feet. So little is known of the horizontal or vertical continuity of the veins in this locality and so vague is the information as to the proportion of ore to waste that the estimates have very little value. If the strip of ore-bearing rock on the east side of the ridge is 125 feet wide and that on its northwest side is equally wide, and if the rock can be worked profitably to the depth of 70 feet, then the quantity of concentrate that may be obtained from the two slopes of the hill within 2,000 feet of Morgan Creek is about 750,000 tons, provided the entire body of rock raised will yield 800 pounds of ore to the ton.

DEPOSITS BETWEEN MORGAN CREEK AND MARBLE.

Keith does not map the Nottely quartzite as extending to the northeast beyond Morgan Creek. There are, however, two small knobs north of the creek on which boulders of quartzite are thickly strewn. On the northwest sides of these knobs, well up on their slopes, are four or five large mine openings, some of which have distinctly defined quartzite to the east, while others are apparently not associated with any visible quartzite, although in line with those farther southwest which are so associated.

At the northeast end of the southern ridge, about a quarter of a mile from the Starbuck mine, is the large opening being worked by Heaton & Russell. The opening shows no unusual features. (See Pls. V, *A*, and VI, *D*.) The ore was originally cobbed but not washed, and consequently there was a great quantity of fine ore on the dumps. In the summer of 1920 this material was being raised by steam shovel and washed, yielding about a third of a ton of concentrate to the cubic yard. Shipments were being made at the rate of about 50 tons daily. The main pit around which the dumps have accumulated is an open cut about 175 feet long, 40 feet wide, and 40 to 60 feet deep, with an entrance at its northeast end through a cut 150 feet long. The vein as now exposed is 6 to 10 feet wide, but ore is so thickly scattered through the soil that the material as far as 100 feet down the slope from the outcrop will probably warrant washing. During 1921 water was piped to the mine and delivered at a nozzle under a pressure of about 100 pounds (Pl. V, *B*). It was hoped to use this water to break down the ore in the pit and to excavate the surface.

Southwest of the main opening of the Heaton & Russell mine a continuous trench about 1,200 feet long has uncovered, throughout its length, three sets of veins, ranging from 2½ to 5 feet in thickness, in which are sandy clay partings only a few inches thick. The veins dip 45°–50° SE. and are separated from one another by 10 to 15 feet of schist containing many small seams of ore. To the northeast the openings of the Welch and Guy Green mines seem to prove that ore occurs beyond the visible quartzite through a distance of 1,800 feet. There is a possibility, however, that ore has not been deposited between the Welch and Green mines; if not, the northeasterly extension of the vein beyond the Heaton & Russell mine is only 900 feet.

Southeast of the mine there is a narrow exposure of quartzite on the top of the ridge, but so far as known there are no ores on its southeast side, as there are at the Kinsey-Betts locality. Northeast of the mine the quartzite seems to disappear. It may extend to the Welch mine, 600 feet farther northeast, though no outcrops are to be seen on the hill near the opening and none are known farther to the northeast in Cherokee County. The brown ores northeast of the Welch mine occur in relations different from those to the southwest.

At the Guy Green mine, 1,000 feet northeast of the Welch mine, the quartzite is probably absent. The mine is on comparatively low ground, and there is no distinct ridge to the east. It may be that the quartzite was originally present in its usual position just over the ores but that it has been entirely removed by erosion, which, however, has not yet cut deeply enough into the underlying Andrews schist to remove the ores that were formed near the contact of the schist and quartzite.

The Welch and Guy Green mines are shallow cuts exposing a number of narrow veins, of which some are about 6 feet wide. At the Welch mine the thickest vein is broken down, and the ore is handled by forking. Thus nearly all the finer ore is lost. The mine is worked intermittently on a small scale.

The Guy Green mine has been abandoned for some time. It consists of a number of open pits and a stripping, which is about 150 feet long on the veins. The total length of "vein" that has been exposed by pits and stripping is 700 feet. The "vein" comprises for the most part a number of small veins, each about 1 foot thick, alternating with layers of sandy schist. Only the harder ore was saved. As the solid ledge has not yet been reached at either the Welch or the Green mine it is impossible to predict the conditions under the mantle of decomposed rock. A clean hand specimen of the ore from the Green mine gave 52.53 per cent of iron and 0.687 per cent of phosphorus as the result of a commercial analysis.

On the assumption of a continuous vein 2,100 feet long and a workable slice of ground 100 feet wide and 70 feet deep which will yield a concentrate of only half a ton to the cubic yard, the available ore in this strip will approximate 270,000 tons. That the yield of ore would be as great as half a ton to the cubic yard can not be doubted, as the yield of the waste left at the Heaton mine after the good lump ore had been picked out was, as has been reported by Supt. E. C. Palmer, a little greater than one-third of a ton to the cubic yard, during a week in August, 1920, when 778 cubic yards of dirt yielded 621,000 pounds of shipping ore. As much of the material that would be removed from the strip would consist of the vein ore, the yield of the entire strip would be much greater than that of the mine dumps.

On the further assumption that an equally productive ore belt extends continuously as far northeast as the Guy Green mine and that, because of the low altitude of the country, the deposits could be worked profitably to only 30 feet in depth, about 70,000 tons should be added to the figure given above, making the total available ore between Morgan Creek and the Green mine 340,000 tons.

DEPOSITS BETWEEN MARBLE AND VALLEY RIVER.

Beyond the Guy Green place for 2 miles there are no ore openings. The country is low, and erosion has exposed the Murphy marble the entire width of the syncline all the way to the town of Marble, where the Andrews schist reappears.

At Marble, however, begins another series of openings, some of which have been developed into profitable mines. The series begins with the Puett openings, about one-fifth of a mile south of Marble station. Formerly they were worked together with the openings on the adjacent McHan property by A. G. Betts, who produced about 1,500 tons, without screening or washing. Both properties are now abandoned, but the McHan mine was in operation very recently.

At the Puett mine, which consists of a number of holes extending in a comparatively broad band across the road from Marble up Vengeance Creek, the surfaces uncovered indicate the presence of an ore vein measuring 8 or 10 feet in thickness, striking about N. 20° E., and dipping at a very high angle. The dumps are so filled with fragments of ore and limonite sand as to appear to be worth washing. Other openings northwest of the larger ones suggest that the deposits are in a double belt.

At the McHan mine, which is immediately northeast of the Puett mine, the ore was shipped without screening or washing but was separated from sand by forking. After about 900 tons of material averaging 45 per cent of iron had been produced, work was discontinued in the early part of July, 1917. Analyses showed that

some cars contained from 2 to 3 per cent of manganese. Work was again undertaken in the early part of 1918 and stopped in May of that year after the shipment of about 75 cars, some of which contained over 52 per cent of iron. An average of analyses of 12 cars sent to the Roane Iron Co. as reported in August, 1918, gave the following result:

Silica (SiO_2)	10.86	Manganese (Mn)	0.58
Alumina (Al_2O_3)	5.30	Phosphorus (P)	.62
Iron (Fe)	49.90		

The present openings on the McHan property are some very large open pits uncovering a plexus of veins in a sandy schist. There is now visible no distinct massive vein, although it is currently reported that some of the veins opened up were 10 feet thick, but in the northeast hole, which is about 1,500 feet from the southwesternmost pit at the road, the veins are so crowded that they form a stockwork 20 feet wide which strikes about N. 40° E. and dips 35°–40° SE. There is no solid rock in sight. In the largest new pit, which is 300 feet long, 60 feet wide, and 50 feet deep, the upper 25 feet consists of sand containing no ore, except in boulders lying on the surface. Beneath this is the decomposed schist with ore veins running in all directions within the stockwork referred to above. In the entry northwest of the main pit a little light-colored clay is exposed. This may indicate the position of the southeast contact of the Murphy marble, and the material in which the pits are dug may be decomposed Andrews schist. Keith maps the whole width of the belt from the river to the railroad as Andrews schist, but it is possible that he has placed the contact of the schist and marble too far north, as no rocks were exposed here at the time of his visit. It was only by the stripping of sand from above the ore veins that the white clay was brought to light.

A few hundred yards farther northeast, on the ridge on which are the northern openings of the McHan mine, across a little valley from them, are the openings of the Hayes-Hoblitzell mine, which is one of the most productive in Cherokee County. (See Pl. V, *C*.) The principal open cut, which is at the northeast end of the hill overlooking the valley of Hyatt Creek, has walls of sand that are shot through and through with ore, forming a stockwork 50 feet wide. No well-defined solid vein was seen, though southwest of the main opening there are several crosscuts that prove the ore belt to extend in that direction for more than 50 feet, and about 125 feet southeast of the main cut is another small opening showing considerable hard ore. If this is the Morse property referred to by Nitze[18] there is an old shaft on it that at the time of his visit showed

[18] Op. cit., p. 202.

ore in its walls and on the surface for some distance northeast. A sample of this ore was analyzed with the result shown below in column 1. In the report of the Tenth Census (p. 327) the ore was said to be 8 feet wide and to have the composition given in column 2.

Partial analyses of ore from Morse property.

	1	2
Silica (SiO_2)	6.49	.....
Iron (Fe)	57.16	57.84
Sulphur (S)	.036	.....
Phosphorus (P)	.756	.021
Phosphorus ratio (P:Fe)	1.322	.036

The dip of the main veins is southeast, as usual, but the smaller ones dip to the northwest across the bedding, as if following joint cracks.

It is reported by Mr. Hayes that about 30,000 tons of ore was shipped from the present opening in the three years 1918–1920, all of which contained notable quantities of manganese. In 1921 mining was at a standstill, but the old dumps were being washed, yielding 2 cars of ore daily, at the rate of 100 tons of ore to 250 yards of sand. It is estimated that in the cut the proportion of ore to sand is 3:2.

Carload shipments during June, July, and August, 1918, are represented by four analyses of dried material, as follows:

Iron (Fe)	49.20	49.80	48.80	48.50
Manganese (Mn)	1.37	1.03	1.13	1.38

It is quite evident that the mode of occurrence of the ore in the region around Marble is very different from that of the ore farther southwest. From the Welch mine all the way southwest to the State line the ore veins occur in the Andrews schist on one or both contacts of the Nottely quartzite, which forms a ridge marking the axis of a syncline. In some places ore veins are found on one or the other side of the strip of quartzite; in other places they occur on both sides. Northeast of the Welch mine, however, the Nottely quartzite does not crop out, unless a small ledge about 900 feet from Valley River on the road that crosses the river at the mouth of Vengeance Creek represents a small remnant of the formation. In this northeastern area the ore is within the Andrews schist in the position it would have if the schist were synclinal and the ore belt lay in the axis of the syncline. In other words, the ore is apparently at the top of the schist, in the bottom of a trough from which the Nottely quartzite has been eroded. The ore

belt consequently is single, and it covers a broader area than it does farther southwest.

Ore of the same character extends about three-quarters of a mile farther northeast through the property of L. L. Jenkins. Here there are eight or nine small pits extending in a straight line about 1,500 feet and several larger ones on both sides of this line, all of which show many small veins in a mineralized zone in schists. In the southwesternmost pit the vein is 5 feet thick, and in several others it is reported to be from 7 to 10 feet thick, but in most of them the veins measure scarcely more than 6 or 7 inches. The mineralized zone is said to be in places 40 feet wide and to taper to 6 feet at the northeast opening. The ore in some of the pits is notably globular. Although it is reported that about 200 cars of unwashed ore, containing 48 to 49 per cent of iron, were shipped from this property during the war, it is clear that in the future the property will be profitable only through washing operations.

In the large open pit from which most of the ore was taken the lower portions of the walls show the usual plexus of small veins cutting sandy schists. Higher up the veins are truncated, and over their cut-off edges is a blanket of conglomerate formed of boulders, pebbles, and sand. Some of the boulders consist of ore. They may be of local origin like those on the slope of the quartzite hill at Section 6 (see p. 174), but here they are rounded and the deposit shows a rude bedding, as if worked over by water.

About 600 feet southeast of the main line of openings is another series of several shallow openings on the opposite side of the ridge. The ore has also been uncovered on the west bank of Valley River in a large opening about 60 feet above the stream and a smaller cut nearer the river. The latter shows 4 to 10 feet of ore dipping about 30° NE. Across the river on the right of way of the new railroad between Andrews and Hayesville are numerous outcrops of ottrelite (Andrews) schists, with which at several points are associated layers of limonite.

Fortunately Nitze visited the old mines when their openings were comparatively fresh and described the conditions as he saw them at that time. He states[19] that there are two series of outcrops trending nearly east on parallel ridges about 600 feet apart. The northern series was uncovered by trenches for a width of 175 feet, and at one point a shaft was sunk 38 feet in ore, without reaching the bottom of the deposit. The outcrops of the southern series had been explored by a shaft 55 feet deep, which penetrated to its full depth alternating layers of clay and limonite averaging about 4 feet in thickness. Drifts from the bottom of the shaft were driven 40 feet

[19] Op. cit., p. 203.

and 20 feet south in the same mixture of materials. A few yards east of the shaft the top of the ore had been uncovered for a width of 60 feet and had been found to be 8 feet thick. Farther east the ore had been again stripped and penetrated by a shaft and here also was only 8 feet thick. It lay almost horizontal just under the surface. At the river a large outcrop was exposed over a width of 48 feet and was 8 to 10 feet thick.

The deposit referred to above as dipping 30° NE., which is just a little steeper than the slope of the surface at this point, is probably the extension of the layer described by Nitze. It is evident that an almost uniformly thick layer of ore exists under the surface, following its undulations rather closely. (Compare Pl. VI, *A*, *B*, *C*.) It is overlain by 4 or 5 feet of sand and loose rock fragments, of which some are quartzite or granite and many others are ore boulders, and is underlain by sand and clay, representing a decomposed rock. This ore layer is in no way directly related to fissures in the underlying associated material, as the hard-ore veins are. Nitze[20] states that the ore bed near the river is "as a rule compact but in places porous; again it is nodular and extremely argillaceous, changing, in fact, into a hard, siliceous, ferruginous clay slate." Observations by the writer revealed a mass made up of rounded masses like boulders, in some places tightly cemented by limonite and in others loosely embedded in a mass of sand and limonite.

Partial analyses of samples of ore from Jenkins property.

	1	2
Silica (SiO_2)	3.32	10.70
Iron (Fe)	58.52	54.88
Sulphur (S)	.026	.072
Phosphorus (P)	.52	.273
Phosphorus ratio (P: Fe)	.888	.497

1. From shaft on northern belt.
2. From 30-foot shaft on southern belt.

It is plain that the blanket deposit, which slopes with the surface, has not had the same origin as the hard-ore veins, which are steeply inclined. The deposit seems to be a conglomerate or breccia, such as might be formed by cementing together into a mass the ore fragments so thickly strewn over the surface near the outcrop of ore veins and down the slope from them. It is possible that the thick layers of sand and clay below the ore represent decomposed marble and calcareous schist, and that the ore was originally in the débris on top of these rocks before they were so thoroughly decomposed, like the ore in the clay above the marble in Madison County (p. 164), or

[20] Op. cit., p. 205.

like the conglomerate above the sandy schists in the main pit on this property. Apparently the deposit was made and cemented after the general features of the present topography had been developed, the ore having been furnished by veins that cropped out near the apex of the ridge.

DEPOSITS BETWEEN VALLEY RIVER AND ANDREWS.

At the Jenkins place the ore belt crosses Valley River, and for the rest of its course it remains southeast of the river. Small exposures on and near the Andrews-Hayesville railroad where it crosses Taylor Creek mark the course of the main veins for a mile, and other exposures and pits show that it extends all the way to Andrews. Still other exposures and pits farther south, on and near the highway from Andrews to the mouth of Vengeance Creek, indicate the presence of deposits near the fault trace between the Andrews schist and members of the Valleytown formation. None of the explorations on any of these deposits have yielded promising results. Some of the deposits are moderately large, but none of them are large enough to warrant the installation of washing plants under present normal economic conditions.

Although the veins on the southeast side of the river are not promising sources of ore, the case is quite different with respect to the blanket deposits at the northeast end of the Jenkins property, already referred to.

Nitze's description shows that the conglomerate sheetlike layer of ore spreads over the northeast end of the hill on this property and dips down to the edge of the river. Whether it fills the river valley and the slopes on its opposite side is not known, as no exposures of it are seen for the next mile. A few rods northeast of Taylor Creek, however, it is again encountered, and from this point it extends at least three-fifths of a mile farther northeast, where it is mined by the Southern Iron Mining Co.

Two pits penetrate this layer of ore on the little hillock between the lower part of Taylor Creek and the river on the property of George H. Luther. The pits, which are on the southeast slope of the hill, pass through a flat-lying ore bed, which is exposed also in the road cut a few yards to the east. The bed is said to range in thickness from 6 to 8 feet. It is overlain by a mixture of ore fragments and sand.

On the northwest slope of the hill exposures and a few pits show the presence of an ore vein, but its size has not been developed. A clean sample of the ore from one of these pits yielded 48.93 per cent of iron and 0.766 per cent of phosphorus.

On the next hill to the northeast the conditions are nearly the same as at the Luther place. Here the main openings of the Southern Iron Mining Co. are at the southwest end of the hill, where an area at least 100 feet wide has been uncovered, showing a sheet of ore about 10 feet thick wedging to 5 or 6 feet toward the west and east (Pl. VI, *A*, *B*, *C*). On the top of the hill, farther north, are ditches and test pits, all uncovering ore over an area 250 feet wide and nearly a quarter of a mile long. Within this area a shaft is reported to have penetrated ore to a depth of 38 feet. The valley southeast of the hill is said to have been explored by several pits, now obliterated, and these exposed 5 or 6 feet of ore like that on the hill.

The ore sheet here has in most places a conglomerate aspect, although so compact that it forms a continuous and rigid layer. It is composed mainly of many boulders of limonite and a few of quartz and schist in a matrix of micaceous sandy limonite. In some places globular masses of ore are cemented by a dense limonite or goethite exhibiting no characteristic structure, or by crusts of fibrous goethite that were evidently deposited in open spaces between fragments. The structure of the layer is distinctly platy (see Pl. VI, *A*), partly because of the fact that many of the boulders are flat and partly because there are in it many lenses of decomposed schist, similar to that underlying the ore bed. Many of the quartz pebbles are fractured, and the cracks are filled with iron hydroxides. The cement of the ore is in general very porous. Some of the pores are now completely filled with soft limonite, and others are lined with fibrous goethite. The mica plates so abundant in the ore evidently represent the partly decomposed ottrelite plates that are so common in the Andrews schist.

Below the ore bed is a mass of sand that represents decomposed Andrews schist. It is thinly layered like the schist, and the layers are as a rule complexly distorted. Just under the ore, however, the layers of the schist become parallel to the ore bed, and many schist streaks are interlaminated with the ore, especially at its base. This parallelism of the schist layers with the ore bed is thought to be due to slumping occasioned by the weight of the ore. The underlying sand is almost free from ore particles. Here and there a little limonite vein occurs along a foliation plane, but the sand contains no large pieces of ore.

Above the ore is a 3-foot layer of an obscurely bedded mass of mixed sand, ore fragments, and pebbles of quartz. At its base, immediately over the ore, is a thin layer of pebbles and sand. This mass grades upward into a red sand, and this in turn into soil. Although the evidence is very weak, nevertheless it appears to indicate that the ore rests on an old erosion surface and that another old surface is just above it.

From the property, which when formerly active was known as the Lena Walker mine, 13 cars of float ore were shipped and 65 cars of ore were taken from the opening at the east end of the hill. The mine was reopened in November, 1919, and a steam shovel and washer were installed to recover the ore in the sand above and beneath the ore sheet as well as from the ore sheet itself. Between that time and April 21, 1921, when the mine was temporarily closed, active operations resulted in the shipment of about 70 tons of washed ore daily, containing an average of 48.5 per cent of iron and a moisture content between 2 and 4 per cent. The total shipments between October, 1919, and August, 1920, were about 11,000 tons. The overburden of loose material above the ore bed yields about a quarter of a ton of ore to each ton of material handled, and the ore bed a little less than three-quarters of a ton to the ton.

In Nitze's report[21] the "Sharp place" is described as being 3 miles from the point at which the ore belt crosses the river, but the description fits the Lena Walker place. If the two names refer to the same place, his statement that "in one of the prospect shafts marble was found at a depth of 32 feet below the ore by means of a sounding bar" is of interest. Keith does not map any marble in this vicinity, but as it is not exposed it may easily have been missed, and the south boundary of his marble area may have been placed a trifle too far north.

Between the Southern Iron Mining Co.'s plant and Andrews, a distance of 3 miles, there are no mines. The country is mapped by Keith as being underlain by a strip of the Andrews schist about half a mile wide all the way to Andrews. This strip is bounded on the south by the Murphy fault and on the north by the Murphy marble. As the country is flat and there are only a few exposures, it is probable that the mapping is only approximately correct. It is possible that the strip of schist is much narrower than half a mile, for a ledge of material resembling decomposed marble was noted on the highway 1½ miles west of Andrews in the area mapped as Andrews schist. No evidence of the presence of the Nottely quartzite was seen anywhere between the Lena Walker property and Andrews. At several points, however, ore has been uncovered near the highway to Andrews, but at no place has mining been undertaken seriously, though a number of carloads of ore fragments were shipped from several of the openings during the exploratory operations.

ANDREWS AREA.

Structural features.—West of Andrews the general northeasterly trends of the Murphy marble, the Andrews schist, and the Murphy

[21] Op. cit., p. 205.

fault are interrupted by a fold which bends them southward for about a mile, before they revert again to the northeast (Pl. IV). In the curved belt thus formed are some of the most promising deposits in the entire county. The belt is separated on the west and southeast from the underlying formations by the Murphy fault. Large deposits of ore have been disclosed in the Andrews schist near the western fault, others near the contact between the marble and the schist, and smaller ones within the schist. Evidently the conditions were generally favorable for the concentration of ore, possibly because of the shattering of the marble and schist at the turn.

After making the turn the Murphy fault runs south for a mile to the mouth of Snyder Creek, then southwest for three-quarters of a mile, where it is apparently cut off by another fault that trends northeast and continues the general fracture so prominent southwest of Andrews. Where it crosses Junaluska Creek it is joined by a short fault that extends for several miles in a little more northerly direction and then dies out. (See map, Pl. IV.) The triangular area inclosed by the three faults west, south, and southeast of Valleytown is occupied by a crescentic area of Murphy marble to the northeast and a surrounding crescent of Andrews schist to the southwest. The Andrews schist is bounded by faults that separate it on the surface from the Valleytown and lower formations. In the Andrews schist and along the faults that limit the area on the southwest are several mines and a number of prospects that are being seriously considered for exploitation in the near future.

Deposits on the east side.—The first openings southeast of the Washburn place (p. 192) are two pits on the property of G. W. Swan, near the junction of the road to Valleytown and that up Snyder Creek. The walls of the larger pit show a number of small veins dipping about 25° SE. No compact ore is now visible, though it is said that some ore was shipped without washing. A second pit a few hundred yards farther southeast is just east of Valleytown. It is a shallow opening measuring 70 by 40 feet, in wash ore. These two pits must be near the contact of the marble with the Andrews schist, as mapped by Keith, or within the schist near the contact.

The next openings in this direction are several at the Ferebee & Young mine, about three-quarters of a mile east and a little south from Valleytown, at the junction of the road from Valleytown to Topton and that leading northwest from Junaluska Creek. From one of these openings about 200 cars of ore were shipped. One of the openings is a small pit on the side of the road leading northwest of Topton, where there is a deposit of loose ore about 8 or 9 feet thick lying under calcareous schists that dip 45° SE. Most of the ore that was shipped came from a large pit 150 yards from the road, near the top of a little hill and just about on the trace of

the fault that bounds the Andrews schist on the southeast. This pit is 150 feet long in a direction N. 80° E., which is believed to be the trend of the vein. The rocks associated with the ore appear to be contorted and crushed, as if in a fault zone. The ore ledge in the bottom of the mine consists of many thin layers of limonite separated by sandy layers; the whole is about 9 feet in width and has a high dip to the south. The mining operations followed this ledge in a general way but were confined mainly to the removal of the overlying disintegrated material. The whole area of the pit was worked. Some of the material was simply scraped up and loaded into trucks without washing or even forking, but some was screened before shipment. When the harder rock under the mantle of disintegrated material was reached the place was abandoned.

It is reported that near the surface about half of the "dirt" was iron. Farther down the iron content diminished to 45 per cent, and at a depth of 12 to 15 feet the material became so poor in iron that it could no longer be shipped at a profit. A glance at the bottom of the pit shows that a great quantity of ore still remains, but that it must be washed to become salable.

Partial analyses of ore from Ferebee & Young mine.

	SiO_2	Fe	Mn	P	Analyst.
Ore as shipped, without washing or cobbing:					
March, 1917, 1 car	5.46	53.00	0.78	0.46	Virginia Iron, Coal & Coke Co.
October 3, 1917	11.90	50.40	.41	1.03	Intermont Coal & Iron Corporation.
March, 1918, 17 cars	7.93–10.93	46.08	.37–.92	.35–.65	Virginia Iron, Coal & Coke Co.
April, 1918, 6 cars	11.15	49.80	.49	.35	Roane Iron Co.
Selected ore:					
Road cut	12.48	46.70	3.37	1.008	Intermont Coal & Iron Corporation.
Do	3.63	50.01	.00	1.22	F. P. Drane, Charlotte.
Hill opening	3.23	58.11	Trace.	.90	Do.
Creek opening	.90	2.56	55.16	.113	Do.

The last sample was taken from a small hole on the creek south of the opening on the road and evidently came from a small vein of pyrolusite.

There are no other ore pits and no exposures of brown ore anywhere in the immediate neighborhood of the mine. It is reported, however, that trenches and pits have uncovered limonite in the Ingram field, which occupies the valley extending from the Ferebee & Young mine westward to Junaluska Creek. The limonite is probably underlain by the Murphy marble and the Andrews schist, for on the east bank of the creek, in an old pit for manganese, is exposed a broad expanse of contorted calcareous schist resting on a white marble that dips southeast.

Mines and deposits on Tatham Creek.—The road leading up Tatham Creek follows very closely the fault between the Valleytown formation and the Andrews schist, which forms the western boundary of the Andrews area. Near or on this fault are some of the largest deposits in the area. The most important are at the Marvacar mine and on the J. W. Walker property.

On the Marvacar Mining Co.'s property, about 2 miles south of Andrews, near the junction of the two faults that form the west and south limits of the Andrews area, is the only operating mine in the district. This mine was formerly worked by Cover & Porter and later by Griffith, Middleton & Co. In September, 1920, the Marvacar Mining Co. was incorporated. This company obtained the mineral rights on 201 acres of land and immediately began plans to operate on a large scale.

The present workings consist of an open cut 550 feet long, about 100 feet wide, and from a few feet to 50 feet deep. The opening follows a ledge of dark compact ore striking N. 50° E. and dipping about 65°–70° SE. There is an 18-foot vein of ore, of which 10 feet on the southeast wall is hard and compact, and this constitutes the principal source of the shipping ore, though the whole pit is in material that furnishes a satisfactory wash ore, as it is cut by smaller ore veins parallel to the large one. The footwall of the main vein is a micaceous sandy schist, and the hanging wall consists largely of red and white clay that may represent a fault gouge. The overburden ranges in thickness from 1 to 10 feet, and much of it contains enough ore to pay for washing.

Sandy schists containing ore veins extend for some distance to the west of the main vein, and prospect trenches in the hill 500 feet west of the pit indicate that the ore-bearing zone may cover a strip of country at least 600 feet wide. The westernmost row of trenches has uncovered ledges showing several veins from 2 to 3 feet wide and a number of thinner ones closely spaced through a width of 18 feet. The soil covering the ledges is only a few feet deep, but everywhere it contains numerous fragments of ore. It is said that six drill holes put into the bottom of the pit 30 feet northwest from the outcrop of the vein reached ore. On the assumption that the width of workable ore is 50 feet, there is present under the pit for every 30 feet of depth about 75,000 tons of merchantable ore. It is reported by the men in charge of the washing that under normal conditions the operations would yield 3 tons of washed ore containing about 50 per cent of iron to 4 tons of material excavated.

About 24,000 tons of ore was shipped from the property between April, 1917, and December, 1918. During a part of 1919 the mine was shut down, but in 1920 it was shipping about 50 tons a

day. During the summer of 1921 mining was again suspended, but a little work was being done to prepare the mine for more economical operation. It is interesting to note that this was the first iron mine in the State to make use of hydraulic methods for removing the overburden and washing the sand from the ore.

Partial analyses of carload lots of ore from Marvacar mine.

	Fe	Mn	P	SiO_2
Nov. 28, 1917, 2 cars	41.00	0.40	0.52	17.92
Nov. 28, 1917, 3 cars	49.60	.....	.....	7.34
Dec. 17, 1917, 4 cars	45.40	1.12	.54	10.10
April, 1918, 2 cars	51.90	.....	.....	8.91

About a third of a mile southwest of the Marvacar mine, at the junction of the two faults that form the east and west sides of the Andrews area, is the J. W. Walker property, which is under the control of the Southern Iron Mining Co. but is not now being worked. On this property five large openings and several small trenches expose ore for a length of 700 feet and a width of several hundred feet on the crest and east and northeast slopes of a hill that overlooks a branch of Tatham Creek. These openings were

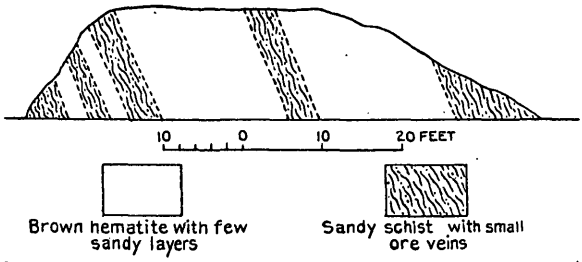


FIGURE 53.—Section across end of pit on J. W. Walker property, near Andrews, N. C.

made for purposes of exploration, but during the exploratory work about 60 cars of ore were shipped. The beds in most of the openings dip 55° S., but in the large pit that is farthest east the vein stands nearly vertical. The loose ore was separated from the sand of the decomposed schist by hydraulicking, forking, and screening. In addition, hard ore was broken from the steep quarry-like faces of some of the pits on the crest of the hill and shipped without further preparation.

At the large opening on the south side of the top of the hill there has been exposed a wall 60 feet long that shows about 30 feet of ore, in two veins 17 feet and 15 feet wide, separated by 3 feet of sand, and a number of smaller veins from 1½ feet to a few inches wide. Some of the ore in the wider veins could be shipped without washing, but much of it and most of that in the smaller veins and in the

sand between the veins (see fig. 53) would have to be washed to become merchantable.

The following analyses of shipments made to the Roane Iron Co. indicate the character of the product that may be furnished without washing and without further cobbing than the rejection of sand in the pit. For comparison the analyses of a shipment of 8 cars of unwashed ore and of a sample composed of quartered and washed material taken from the five openings on the property are added.

Partial analyses of carload lots of dried material, unwashed, from J. W. Walker property, 1918.

	July.		August.			September.	October.	
Iron (Fe)	46.50	43.30	46.70	45.90	47.90	42.80	40.50	44.10
Manganese (Mn)	.39	.45	.69	2.36	.98	.88	.34	.64

Partial analyses of unwashed and washed ore from J. W. Walker property.

	Fe.	Mn.	P.	Al_2O_3.	Insoluble.
Eight cars, unwashed ore, September, 1918	44.04	1.02	0.84	4.57	20.15
Sample of washed ore, from five openings	48.41	2.36	.349	.....	12.65

The southwesternmost openings in this area are several pits between Tatham Creek and the road on its southeast side, some of which are on the property of George Walker, about an eighth of a mile from the pits just described. They are now filled, but about 20 cars of ore were shipped from them before the place was abandoned. The rocks in their vicinity strike a little east of north and dip 85° E.

DEPOSITS BETWEEN ANDREWS AND TOPTON.

Northeast of Andrews only one deposit, belonging to the Valley River belt, was seen on the strike of those to the southwest. This was described by Nitze[22] as occurring on the Washburn place, half a mile north of Valleytown, on the south side of Valley River between the mouths of Tatham and Junaluska creeks, which is not far from the position of the contact between the Murphy marble and Andrews schist, as mapped by Keith. The occurrence is described as consisting of two outcrops, of which one exposed 18 feet and the other 25 feet of a compact, massive ore. This is the place which was later worked by J. Q. Barker and from which about 150 tons of ore was taken. There are three pits on the sides of a little hillock about 750

[22] Op. cit., p. 206.

feet east of the Andrews Lumber Co. plant. The vein is said by Mr. Barker to trend northeast and then to bend to the southeast, following in general the direction of the contact between the marble and the Andrews schist as it turns toward the south into the Tatham Creek area. The largest pit is about 150 feet long, and its bottom is from 10 to 15 feet below the water level. There was no evidence that the limonite was changing to pyrite with depth, as occurs where limonite is a surface oxidation product of pyrite deposits. During the operations some boulders measuring 30 by 40 feet were mined, indicating the existence of a large vein somewhere in the vicinity. None of the ore was washed, only the coarse, hard material being saved.

The syncline of marble and Andrews schist that is so marked a feature in the Valley River valley southwest of Andrews disappears a few miles northeast of Andrews, and beyond it to Topton there remain only a few patches of marble that represents its bottom. Elsewhere the entire syncline has been eroded and the great Murphy fault, already referred to, separates a strip of Valleytown formation from a strip of Tusquitee quartzite or Nantahala slate. Along this fault there are a few deposits, but none of them give promise of successful operation in the near future. Explorations have been made at only two points. One is on the crest of the little hill on the east side of the railroad track about 500 feet south of Rhodo station. Here there are three small trenches that uncover a little ore that appears to be a horizontal vein or a thin blanket deposit like that at the Southern Iron Mining Co.'s mine south of Andrews (p. 191). The other is about 1,600 feet north of Topton, on the east side of Red Marble Gap. Here the black Nantahala slate is mapped by Keith as being in contact with the Tusquitee quartzite, which lies above it. The ore occurs at this contact, where the conditions are somewhat similar to those farther southwest. In both places quartzite lies above a schist and ores were deposited at their contacts. Very little is known about the Red Marble Gap occurrence, and the openings have been nearly obliterated, so that it is impossible to get further information by examining them. Nitze[23] states that the deposit is 20 feet thick and that it dips toward the southeast.

RESERVES IN THE BELT ALONG NOTTELY AND VALLEY RIVERS.

If it were possible to determine the depths to which the ore deposits extend it might be possible to calculate the approximate quantity of ore contained in the rocks underlying the valleys of Nottely and Valley rivers between the Fain-Hitchcock mine and the Hayes mine. Much of this ore, however, would be unavailable for commercial exploitation, because it is not concentrated in sufficiently

[23] Op. cit., p. 206.

large deposits to be mined and washed cheaply enough to yield a profit. Much of the ore is in narrow veins or narrow zones of veins, so that large areas would have to be worked to supply the washer, large quantities of material would have to be raised to make room for mining, and long tramways would have to be constructed to carry the crude ore to the washing plant. Moreover, the character of the ore is such as to afford little encouragement to the view that it persists to great depths. No evidence is available to show that it extends downward more than 75 feet, and the theory that the veins were filled from above suggests that the deposits are shallow. Under present economic conditions the portions of the deposits lying below water level can not be worked profitably except in the few areas where the deposits are very large. If they are persistent to considerable depths, smaller deposits might become available if a number of them were consolidated under one management and worked together. At present only the ore that can be reached easily by open pits can be regarded as workable. On the assumption that under efficient management all the ore above a depth of 70 feet in areas that have been tested is available, the total is about 2,000,000 tons, the larger part of which is in the vicinity of Marble.

Between the Hayes mine and Andrews, in the strip of blanket ore, the indicated reserve is 1,500,000 tons.

Much of the ore in the area between the intersecting faults south of Andrews is unavailable. Some of the deposits might be worked on a small scale for a short time, but so far as is now known they could not be operated very extensively because in this area of low relief the underground water level is close to the surface. In the southern part of the Andrews area, however, conditions are different. Near the point where the faults limiting the area intersect concentration has formed larger deposits than occur in other portions of the area and the topographic conditions are more favorable for mining. The indicated available reserve in this portion of the area is about 1,350,000 tons of merchantable ore, on the assumption that all the ore above a depth of 70 feet might be removed.

PEACHTREE AREA.

The village of Peachtree, about 6 miles east of Murphy, lies in the concavity of a crescentic area of Murphy marble and Andrews schist produced by the erosion of an anticline that pitches toward the southwest. The fold involves only the two formations mentioned, and the Andrews schist surrounds the marble on all sides but the northeast. A fault separates the Andrews schist from the Brasstown schist on the west, and another separates it from the Valleytown formation on the south and east. Both faults are indi-

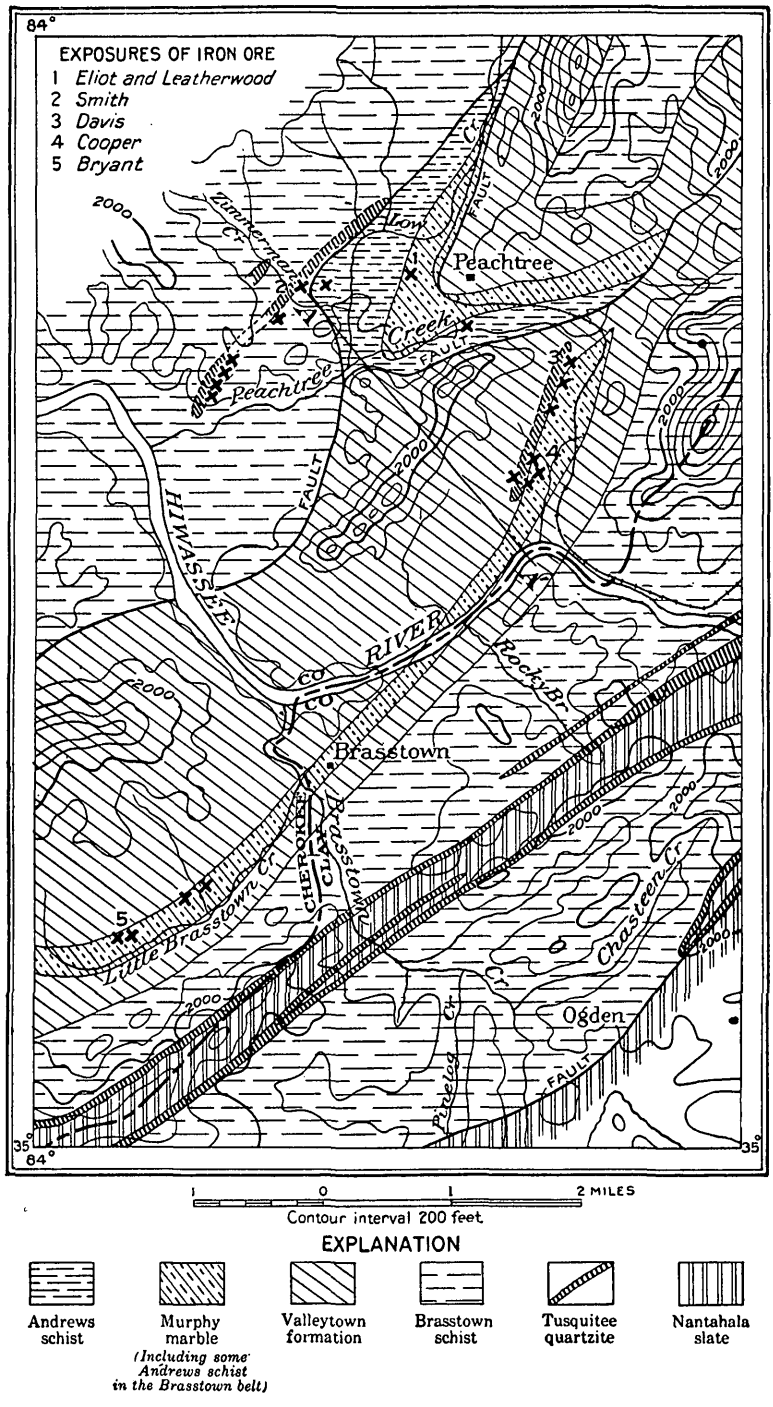


FIGURE 54.—Geologic map of the Peachtree area and the eastern part of the Brasstown belt, N. C. *A–A'*, Line of right-hand portion of section, figure 55.

cated by Keith as dipping at comparatively low angles to the southeast (figs. 54, 55).

There has been no development of ore deposits in the district, in consequence of the lack of transportation facilities. With the opening to traffic of the railroad to Hayesville a more thorough knowledge of the resources of the district will probably soon be available. Because of the lack of exposures in the vicinity of the village few deposits are known to exist within the area underlain by the marble and Andrews schist, but nearly a dozen are known outside of this area, a short distance from the village.

One of the most promising looking of all the deposits is just west of Peachtree, on the lands of Messrs. Eliot and Leatherwood, where two ledges about 20 by 30 feet rise a few feet above the general level of the valley. No other rocks are exposed in the neighborhood, but the deposits are near the mapped position of the contact between the marble and the Andrews schist.

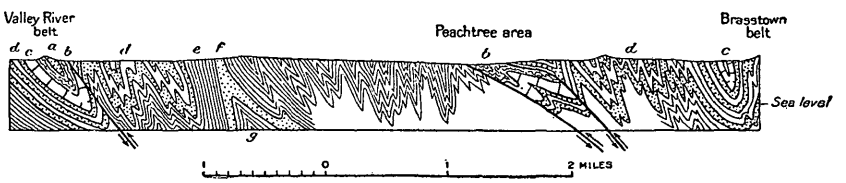


FIGURE 55.—Section across Brasstown belt, Peachtree area, and Valley River belt near Regal, N. C. (See fig. 54.) *a*, Nottely quartzite; *b*, Andrews schist; *c*, Murphy marble; *d*, Valleytown formation; *e*, Brasstown schist; *f*, Tusquitee quartzite; *g*, Nantahala shale.

There has been no attempt to discover the extent of the vein, nor, so far as known, any analysis of the ore. It is clear from inspection alone that much of the vein material could be shipped without washing.

The other evidences of ore in the area are a narrow ledge crossing the road about half a mile north of the Eliot deposit, another crossing Peachtree Creek about half a mile southeast of the Eliot ledge, and two openings in ocher, one near the junction of the Murphy and Zimmerman Creek roads and the other about half a mile from this junction on the road running north. The opening last mentioned is a large pit, known as the Paint mine, but it is so old that its walls are completely covered with verdure. All the deposits except one are near the faults bounding the south and west sides of the area. The ledge half a mile north of the Eliot deposit is near the contact of the marble and Andrews schist as mapped by Keith. None of the deposits are large enough to offer promise of much ore.

The Paint mine is also on the side of a quartzite ledge, which farther southwest becomes a low ridge that is flanked by ore deposits on its southeast side. This quartzite is not mapped as a separate formation by Keith. It may be a thick bed in the lower portion of

the Brasstown schist, but from its massive character it appears more likely to be a strip of the underlying Tusquitee quartzite brought up by folding. The belt of ore on its southeast side is indicated by small ledges and an almost continuous train of float, suggesting that the vein is likewise continuous. At two places only, however, does the ore show in such quantity as to warrant any expectation of profitable exploitation. One of these is on the property of W. P. Smith, near the junction of the road to Peachtree and that down Zimmerman Creek. Here on a low hill are a ledge and many loose fragments of hard ore that would seem to indicate a vein 6 or 7 feet wide. As it has not been explored no estimate of its value as a source of ore can be made. The other place is about a third of a mile north of the junction of the Peachtree road with the Murphy road. Here also there is a ledge of hard ore about 7 feet wide on the east side of a rough layer of quartzite which forms the crest of a little ridge.

The Peachtree area, so far as can be discovered from exposures alone, offers little promise for the development of large mining operations, though several of the deposits in it may furnish fair quantities of ore.

BRASSTOWN BELT.

Beginning at a point a little south of east of Peachtree is a narrow belt of the Murphy marble, nowhere more than half a mile wide, that has been mapped as passing through the village of Brasstown and extending westward for 7 miles to the west border of the Nantahala quadrangle and perhaps beyond. At the Monteith mine, on the divide between Little Brasstown and Martin creeks, no evidence of the presence of marble was seen; consequently it may be assumed that the Brasstown belt terminates at this point. Another belt starts at the headwaters of Martin Creek, a mile farther west, but this is described separately. The marble strip passing through Brasstown is the exposure of a closely compressed syncline overturned to the northwest about 15° from the vertical. (See figs. 54, 55.) It is bordered on both sides by the rocks of the Valleytown formation, and along its margins it contains ore deposits.

DEPOSITS NORTH OF HIWASSEE RIVER.

Among the most promising deposits in this ore belt, north of Hiwassee River, are those on the west side of the marble near its contact with a quartzite that is mapped by Keith with the Valleytown formation. If Keith's mapping is correct, the deposits are in the Valleytown formation at the edge of the quartzite. The topography, however, suggests that the marble or the calcareous Andrews schist may extend as far west as the ore ledges, and if it does the deposits are in their usual position—that is, at the contact

of the quartzite with the calcareous rock. At all points where observed the ore is hard and comparatively dense and apparently is present in large quantity. At the J. van Davis place, about 1 mile southeast of Peachtree, and at the A. E. Suddeth place, a quarter of a mile farther southeast, pits have been dug and some ore has been removed.

At both of these places the ore is at the east side of the quartzite, which, if Keith's interpretation of the structure of the area is correct, is a bed near the top of the Valleytown formation. The quartzite is persistent for several hundred yards to the northeast and appears at intervals for a mile to the southwest. The ore was not seen in place at either locality, but on the Davis property it forms a great heap of large boulders, and at the Suddeth place there is a pit from which ore was taken. Between the two places narrow ore veins crop out in the road.

The largest and most promising ledges in this portion of the district are about half a mile south of the Suddeth property and west of the residence of Cyrus Witte, across a little valley which is underlain by marble. There are here two ledges that are the outcrops of parallel veins about 300 feet apart. The eastern ledge is exposed in a little cliff, which apparently marks the western boundary of the marble. The vein can be traced continuously for 500 feet as an almost solid ledge about 15 feet wide. It is admirably situated for mining. The western exposure is an accumulation of large fragments and rough ledges that indicate a vein about 15 feet wide at the surface. This has been traced southwestward by float for a distance of about 1,000 feet. It is everywhere flanked on the west by quartzite. The rock between the two veins is covered, but the character of the covering indicates the presence of calcareous schists beneath.

DEPOSITS SOUTH OF HIWASSEE RIVER.

South of Hiwassee River ore has been found at Brasstown on the southeast side of the marble and at two points near the village on its northwest side. Farther west there are several exposures on the road leading to Martin Creek, and near the road on its southeast side are several pits and shafts from which small quantities of ore have been taken for local forges. They show that the ore belt is persistent and nearly if not quite continuous all the way to the Monteith mine. Near the road corner about 1¼ miles north of Sheep Knob, in the Murphy quadrangle, on the top of a ridge of white sandy rock that is probably partly disintegrated Andrews schist, is a large pit in a black porous manganese ore that is composed mainly

of pyrolusite. All other occurrences on the belt are small veins cutting sandy schists near their contacts with the Valleytown formation.

Marble ledges occur in some of the springs south of the ore exposures, and the Valleytown formation appears in the bed of Little Brasstown Creek and a short distance south of the creek.

MARTIN CREEK AREA.

The only mine in the Martin Creek area that was ever of importance was the old Monteith mine, about 3,500 feet west of the road corner north of Sheep Knob. This is on the headwaters of Martin Creek about 5 miles south of Murphy. The Brasstown belt of Murphy marble may end at the divide between the headwaters of Little Brasstown Creek and those of Martin Creek, and another area beginning near the Monteith mine may extend down the valley

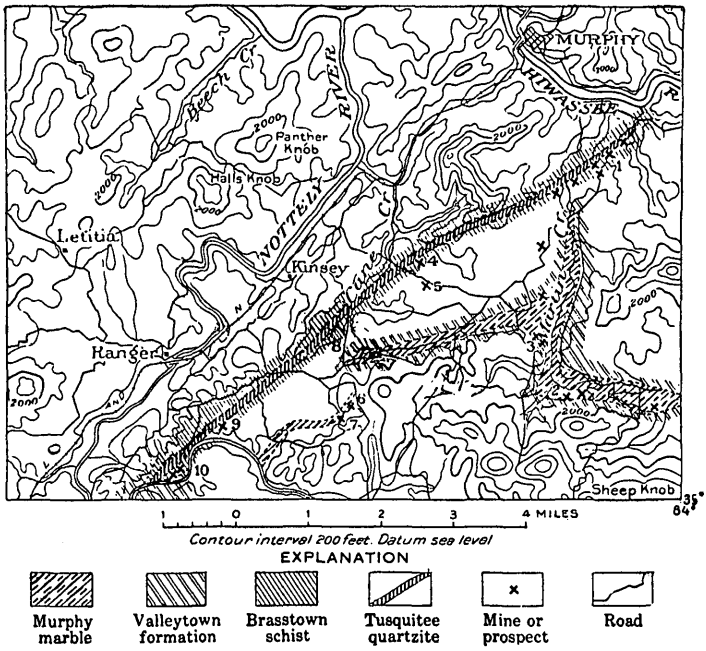


FIGURE 56.—Map of Martin Creek area and Hiwassee-Nottely River belt, N. C., showing location of deposits of brown hematite.

of Martin Creek and up its west branch. It is possible, of course, that the two areas are continuous, as all the rock between the headwaters of the two creeks is covered by sand. For the purpose of the present report the marble on Martin Creek is regarded as a separate area (fig. 56).

The larger part of the Martin Creek area of marble occupies the valley of the main creek from a point near the Monteith mine to the junction of the two roads along its sides 4 miles farther north. A

narrow extension follows the principal western tributary to its source, then an eastern tributary of Cane Creek for a mile, and then down Gold Branch to its mouth. Few exposures of the marble are seen. The best are at the bridge crossing Martin Creek about half a mile north of the Monteith mine. A small exposure in a stream a few yards farther north, a ledge in Mr. Elliott's spring, some shallow cuts made by the tributaries of Martin Creek in which white clay is uncovered, and a few sink holes are about the only data, aside from topography, by which the main area can be outlined. The strip extending down Gold Branch is traced by sink holes east of Martin Creek Church, by an exposure in the bed of Gold Branch near the crossing of the old road from Ranger to Belview, and finally by fragments of talc plowed from the fields near the mouth of Gold Branch.

Limonite deposits have been discovered along the west side of the marble area in the valley of Martin Creek and on the north side of its western extension. At one or two points the deposits are large enough to have furnished ore to local forges, but none are thought to be worthy of exploitation at present. All are at the contact of the marble with the Valleytown beds. The Monteith mine is at the southeast corner of the area, and if the ledge of ottrelite schist exposed in the bed of Martin Creek, about 1,800 feet northwest of the old pits, is a member of the Andrews schist series, the mine is on the southeast side of the marble at or near its contact with the slates of the Valleytown formation.

The old mine is now represented by a series of very old pits in a line striking about N. 70° E. The width of the ore was stated in the Tenth Census report to vary between 4 and 10 feet. Its better parts were hard and flintlike; the softer parts were more siliceous, grading into a brown clay. The analysis of a sample taken from one of the cuts showed 56.45 per cent of iron and 0.691 per cent of phosphorus, and the phosphorus ratio was therefore 1.224.

The most westerly point in the valley of Cane Creek that is reached by the marble is about half a mile east of the junction of the Ranger and Belview roads. The marble reappears as another very narrow strip at the Belview road about half a mile southeast of the junction, runs about due southwest, crossing the road down Prices Creek at the old sawmill, and continues down Gold Branch to its mouth.

A few hundred yards southwest of Mr. Suit's house on the new Belview road is a sink hole, and just south of it a small trench in soft ore. On Gold Branch at the old bridge crossing, about a quarter of a mile to the southwest, is a large pit and trench on the south side of the stream, and a few feet downstream is a small ex-

posure of brecciated talc and marble in the creek bed. The pit, which is so old that it shows nothing in its dumps, is on the south side of the marble at its contact with micaceous slates. It is reported that a number of tons of ore was removed from it and shipped to local forges, but no definite figures concerning the quantity can now be given. No other evidences of the presence of ore were seen along Gold Branch to its mouth, and the only other evidence of the existence of marble in the valley is the talc that is occasionally plowed up in the fields. It is stated by Mr. L. E. Mauney, of Murphy, however, that near the mouth of Gold Branch ore exists in its channel and ore and marble in the hill to the right.

The general impression produced by a study of the deposits occurring in the Brasstown and Martin Creek areas is that they are scattered and small. The conditions that exist at the contact of the marble and the schists of the Valleytown and Brasstown formations are not as favorable for ore concentration as those at contacts with quartzite or those along fault planes. In fault planes and at the contacts of the marble or the calcareous Andrews schist with quartzite concentration is more complete because these places afford more competent watercourses than contacts with the schists—at faults because the continuity of the rocks is broken by shattering, and at quartzite contacts because quartzites are more impervious to solutions flowing downward than steeply dipping schists. In the schists the solutions are more likely to pass downward through numerous channels; at the quartzite contacts they sink to the quartzite and are directed along its surface.

AREA BETWEEN HIWASSEE AND NOTTELY RIVERS.

The fourth belt of deposits here described is on the southeast side of the quartzite ridge that stretches from Hiwassee River about 2 miles above Murphy in a general direction S. 35° W. to the bridge crossing Nottely River 1½ miles northeast of Culberson. (See fig. 56.) The quartzite is nearly continuous through this distance, but at some places the outcrop becomes very narrow. On the road running south from Murphy up the valley of Martin Creek the quartzite is in contact on the south with black slates that are probably members of the Brasstown formation. It has not been determined whether the quartzite is also a bed in this formation or whether it is a narrow strip of the Tusquitee quartzite on the crest of an anticline. The series dips about 70° SE., and the principal ore deposits are near its southeast contact with the slates. At the northeast end of the belt a second line of deposits is about 300 yards south of the main line. The ore here is also on the southeast side of a quartzose layer. In some

places the quartzose layer is in contact with black slate, and in others with a clay that resembles a decomposed calcareous schist. Some of the deposits on both lines were worked years ago and furnished considerable ore; others have simply been explored. As a rule the ore is more porous, more ocherous, and much more sandy than that in the Nottely and Valley River belts. Moreover, much of it, especially that in the more southerly line, apparently contains some hematite and much more than the usual quantity of manganese. Some of it is so rich in pyrolusite that it would pass as an ore of manganese.

The most northeasterly point in this area at which ore is known to exist is about 1½ miles southeast of Murphy, on the northeast corner of a hill overlooking Hiwassee River. At this point there is a fairly large opening on a vein about 34 feet wide dipping southeast. The hanging wall looks like a shaly limestone cut by quartz veins. The footwall was not seen, but quartzite appears to the northwest, on the crest of the hill. About 2,000 feet southwest of this is another opening near the crest of the quartzite ridge, in which only about 10 feet of good ore is exposed. The hanging wall is a black slate.

Other pits and ledges give evidence that ore is continuous all the way to the road leading from Murphy up Martin Creek.

On the east side of the road there is a deep trench 64 feet long with a shaft at its northeast end. According to Mr. Mauney, the owner of the property, the shaft, which is said to be 60 feet deep, was sunk in 1855. The cut is in thinly layered rocks striking N. 45° E. and dipping 45° SE. On the road northwest of the cut, about 100 feet distant, are road cuts in quartzites and graywacke schists, and between these and the opening of the trench is an exposure of clay that seems to be a decomposed slate. No rocks but a few black slates were seen near the ore on its southeast side, but 800 feet distant in this direction there is a tunnel 110 feet long, running into the slope from the northeast side of the road. This tunnel cuts about 20 feet of ore and for the rest of its length is in quartz schists. South of the ore black slates reappear. About 60 feet northwest of the tunnel other quartz schists occur, and about 50 feet southeast of it there is another trench. This also shows a little ore underlying a blue slate which is on its southeast side.

A quarter of a mile southwest of the trench on the road there is another opening on the south side of the main quartzite ridge. Here the ore is said to be 49 feet wide, but of this width 6 feet is black clay. The dip is 70° SE. On the hanging wall is fissile black slate, and south of this are a few thin layers of quartzite, which are apparently beds interstratified with more slaty members of the Valleytown formation. South of this quartzite is about 200 feet of

black fissile slate, which includes layers of ore aggregating about 10 feet in thickness. A trench 200 yards to the southeast exposes a sandy slate that has been strongly impregnated with limonite and hematite. This represents the last deposit of brown ore on the southern line. About a mile farther southwest a small deposit of manganese ore was opened on the top of a little hill near the main highway from Murphy, and this also is on the edge of a quartzose bed, but beyond this there are no exposures of the quartz rock and, so far as known, no ore deposits.

Other deposits in the same position with reference to the main quartzite ridge have been opened on the top of a knoll about 1,200 feet northwest of the bridge over Martin Creek, where 30 feet of ore is said to have been exposed, and about 1½ miles farther southwest on the land of R. R. Owensby, on the road from Martin Creek down Cane Creek to its mouth. At the Owensby place three trenches were dug on the slope of the quartzite ridge north of the highway, but they uncovered only about 5 feet of ore. This is reported to contain more than 2 per cent of manganese, but no records of its analysis have been seen.

On the south side of the highway a little farther east is probably the best deposit of manganese ore in the district studied. The ore is a shattered mass of quartzite about 20 feet wide that is cemented by almost pure pyrolusite. It occurs near the contact of the quartzite with schists. A great deal of material has been taken from the three trenches cut into the ore body, but unless the material was crushed and washed it can not have had much value. Other openings about 200 yards southeast of Mr. Owensby's residence also uncovered manganese ore, but in what quantity is not known.

For the next 1½ miles to the southwest the hills have been unexplored, but about half a mile north of the residence of J. H. Headon, on the Martin Creek road, is a pit in soft ore on the south slope of a hill that is covered with quartzite boulders.

There are two other points beyond this place at which explorations have been undertaken, and although they are on the south side of a quartzite belt that is on the trend of the quartzite ridges along which so many evidences of the existence of ore have been noted, nevertheless it is possible that they may be in a different line of deposits, as the ridge is not known to be continuous with that at the Headon place. However, it is probable that they are on the same line, because the ore uncovered by them is richly manganiferous.

One of the largest of the explorations is a deep trench and small pit on a tributary of Gold Branch, about 1½ miles southeast of Ranger. The openings are in a sandy slate 200 to 250 feet south of a ledge of quartzite that crops out on the hill slope above. The ore is soft and black and is highly manganiferous.

A little over a mile farther to the southwest, on the land of B. L. Fox and his neighbors to the southeast, are four other pits and trenches on the south side of the same quartzite ridge, which is continuous all the way from Gold Branch. All the openings show the presence of ore, but otherwise they exhibit no interesting features. The outermost openings are about half a mile apart, and through this distance there is a continuous line of float.

DEPOSITS IN THE PIEDMONT PLATEAU.

Although brown hematites are known to occur at many places on the Piedmont Plateau in North Carolina, only those in Catawba, Lincoln, and Gaston counties are of prospective importance. Of the deposits in these three counties only those described below are large enough to be considered even probable sources of ore.

CATAWBA AND LINCOLN COUNTIES.

The deposits in Catawba and Lincoln counties are described by Nitze[24] as occurring in a belt passing 2 miles east of Lincolnton. They are said to be in mica schists lying above a limestone, which may be of Cambrian age.[25] Search was made for some of the old pits mentioned by Nitze, but none were found. They have been abandoned for many years and are now obliterated. The belt is said to cross the Carolina & Northwestern Railway 2½ miles south of Lincolnton, but a traverse along the railway revealed nothing but micaceous schist cut by pegmatite and fine-grained quartz veins, many of which contain tourmaline. No iron ores were seen, but some of the schists are very red.

GASTON COUNTY.

In Gaston County brown hematites are found in two belts, one in gneiss and schist immediately east of a belt of limestone, which may be the continuation of that in Lincoln County, and the other in quartzite about three-fourths of a mile still farther east. Both belts are short, and each is notable for one mine. Both mines are within a mile or a little more of Bessemer City. The Ormond, which is on the western belt, was at one time one of the best-known mines in the State. The other—the Little Mountain mine—was noted because of the fanciful forms assumed by its ore.

The country has not yet been mapped geologically, and until this is done it is useless to speculate upon its structure. There are practically no exposures in the neighborhood of the Ormond mine. At

[24] Op. cit., p. 87.

[25] Cf. Keith, Arthur, and Sterrett, D. B., Tin resources of Kings Mountain district, North Carolina and South Carolina: U. S. Geol. Survey Bull. 660, p. 126, 1918.

the Little Mountain mine the only rock exposed is the quartz schist that is associated with the ore.

ORMOND MINE.

The Ormond mine is about 1½ miles west of Bessemer City, in a series of talcose quartz schists. The mine openings and exploration pits extend for three-quarters of a mile in a direction about N. 20° E. At present the old shafts are inaccessible and the open pits so overgrown that their walls are invisible. The mine has been worked intermittently since before the War of the Revolution and has produced much ore. Nitze, who visited the mine when it was last working, states[26] that the ore was in overlapping lenses with a general northwesterly dip. They occupied a belt from 50 to 100 feet wide and were connected with one another by small streaks of ore, along which there was a flow of water. The most interesting feature of the deposit is the occurrence of a thinly bedded gray and white, very sandy limestone on the western drifts of the lower level of the most prominent shaft (No. 4). This limestone is reported by Nitze to dip about 45° W. and to show "signs of erosion" where in contact with the ore. The limestone is nowhere exposed on the surface, but just west of the pits there is a little ridge of very friable white quartzite.

Analysis of the ore from two of the lenses and of a sample from a carload of washed ore from three lenses that were being worked at the time of Nitze's visit are as follows:

Analyses of ore from Ormond mine.

	SiO_2	Fe.	S.	P.	Phosphorus ratio.
Block ore from 28 foot lens	.....	64.40	.....	0.036	0.055
Block ore from 12-foot lens	.....	63.52	.....	.033	.051
Sample from carload of washed ore	9.72	52.39	0.048	.079	.150

As the shipping ore was imperfectly washed in a trough, it is probable that with more careful manipulation in a log washer it might be raised to Bessemer grade. This probability seems reasonable in view of the fact that the specimens of the block ore, which must have constituted a large proportion of the shipping product, were well under the Bessemer limit.

Nitze gives several figures of sections through the mine at various places, but they are so unlike that they apparently have little significance. None of them show any of the quartzitic talcose schist that

[26] Op. cit., p. 97.

is said to be associated with the ore bodies, nor is there anything to show that the deposits are in overlapping lenses. The impression gained from a study of the sections is that the ore bodies are very irregular masses lying in the schistose planes of foliated rocks, or at the contacts of pervious and impervious layers. The erosion of the lower contact of the limestone in No. 4 shaft suggests corrosion by water. It may signify that the origin of the ore at the Ormond mine is analogous to that of the ore in the mines in Cherokee County, and that at the Ormond mine the source of the iron was in the limestone.

The belt in which the Ormond mine is situated has not been traced beyond the old mine workings in either direction. There are probably a number of lenses in the mine property that have not yet been discovered, but whether the belt extends to the northeast or southwest is not known.

LITTLE MOUNTAIN MINE.

The Little Mountain mine, or the Devil's Workshop, is about 1 mile southwest of Bessemer City station, on the crest of a little hill of quartzite or quartz. On the ridge of the hillock are outcrops of fractured quartz, cemented by quartz. In some places the quartz is broken by gashes, in others it is crossed by quartz veins, and in still others sharp-edged fragments of quartz lie in a quartz cement. In many places the cement is porous or cavernous, and the walls of the holes are lined by quartz crystals. The ore is in the cracks and caverns.

Willis in the Tenth Census report (p. 321) describes the ore as limonite altered from siderite or calcite, because many specimens show pseudomorphs after rhombohedra. "It incloses large crystals of quartz, sometimes 3 inches through, whose surfaces bear the impressions of rhombic crystals. Associated with this limonite is an earthy friable ore, which also shows pseudomorphs after rhombohedra but has a dark-reddish streak, and it is apparently manganiferous." Some of the ore was described as containing also large apatite crystals. Analyses of two varieties showed the following results:

Analyses of ore from Little Mountain mine.

Iron (Fe)	61.00	58.37
Manganese oxide (Mn O)	1.00	4.11
Phosphorus (P)	.009	.005

Nitze,[27] who examined the mine after it had been more extensively developed, says that the ore consists of limonite, goethite, and

[27] Op. cit., p. 102.

turgite and that the beds strike N. 37° E. and dip from 75° NW. to vertical. At the time of his visit the outcrop had been explored by a trench 270 feet long, 3 to 10 feet wide, and 3 to 20 feet deep. Two shafts had also been sunk, one at the southwest end of the trench and the other about 175 feet farther northeast. In the northeast shaft the vein matter was "profusely mixed with quartz" to a depth of 30 feet, below which the proportion of quartz diminished, until at its bottom (60 feet) the shaft was in pure ore, 10 feet wide. Drifts proved the vein to vary in thickness between 10 and 27 feet. At the 50-foot level a crosscut into the quartz hanging wall passed through 17 feet of quartz into a second vein of ore. Analyses of the ore from the bottom of this shaft (1) and from across the vein on the 50-foot level (2) are quoted below. Analysis 3 represents a sample taken from a stock pile of 50 tons of ore raised from the southwest shaft.

Analyses of ore from Little Mountain mine.

	1	2	3
Silica (SiO_2)	6.67	7.90	11.96
Iron (Fe)	54.32	53.75	52.70
Manganese (Mn)	.45	.....	.....
Sulphur (S)	.....	.011	.....
Phosphorus (P)	.017	.045	.022
Phosphorus ratio (P:Fe)	.031	.083	.041

When the writer visited the mine it had been abandoned and the trench had been partly filled, so that access to the vein was impossible. However, good exposures were found on the walls of the trench and good outcrops on the hill near the trench. The quartz is crushed, and the fragments are cemented by quartz. Thus the quartz is in many places crossed by quartz veins, many of which contain vugs lined with quartz crystals. On the strike of the trench and on its walls, however, the cementing quartz appears to be replaced in part by ore, and the walls of open gashes and of vugs are coated with ore material. The ore is mainly in crusts lining the walls of crevices and in botryoidal and stalactitic forms in vugs. In many places it incloses quartz crystals and coats them concentrically. Usually there is a mass of earthy or porous limonite next to the walls, or a mass of platy limonite in which the plates are thin and arranged parallel to the walls. Next to this and surrounding quartz crystals that penetrated the vug spaces are layers of fibrous goethite about half an inch wide. Here and there the goethite does not entirely close the space and its exposed mammillary surface is covered with a lustrous black enamel.

An analysis of a sample of compact ore, made by E. T. Erickson in the laboratory of the United States Geological Survey, yielded this result: Fe_2O_3, 81.84 per cent; MnO, 0.15 per cent; FeO, none;

H_2O above 105°, 11.81 per cent. Goethite (FeO(OH)) contains 10.1 per cent of water, and limonite ($Fe_4O_3(OH)_6$) contains 14.5 per cent. The sample is a mixture of approximately 60 per cent of goethite and 40 per cent of limonite.

Ore of another type is a cellular mass of goethite, made up of thin plates inclosing cells of rhombohedral shape, as if the iron hydroxide had developed in the cleavage cracks of some rhombohedral mineral. Where massive rather than cellular the mass is of a reddish-brown color, and much of it exhibits a rhombohedral cleavage. The writer saw none of the impressions of rhombohedral crystals on the quartz described by Willis. However, the rhombohedral cleavage of some of the massive goethite and the rhombohedral cavities in the cellular varieties suggest that some rhombohedral mineral was present in the crevices before the iron hydroxide was introduced. It is possible that this was siderite. If so, it was oxidized to iron hydroxides, and later supplies of iron hydroxide coated the surfaces it found, whether they were surfaces of the hydroxide that had replaced the carbonate, surfaces of quartz crystals that extended into cavities, or surfaces of cracks that had contained no carbonate.

The sequence of events seems to have been (1) the shattering of the quartz; (2) the introduction of silica, forming quartz veins and the crystals in the vugs; (3) the introduction of a carbonate; (4) the introduction of iron hydroxide that replaced the carbonate and formed the fibrous coatings of goethite. The iron hydroxides may have been brought from some outside source or, if the carbonate was siderite, a part might have resulted from the oxidation of this carbonate in place and a part from the oxidation of a solution of some iron-bearing mineral higher up in the deposit. The carbonate certainly originated elsewhere. There is no marble in the series of rocks near the Little Mountain mine, but the layer found in the Ormond mine, if it keeps its strike to the southwest, can not be more than a mile distant on the surface.

The vein of the Little Mountain mine has been traced for several miles to the southwest by its outcrop of ferruginous quartz, and two small pits about 1½ miles from the mine have uncovered conditions similar to those near the surface at the mine.

AVAILABILITY OF THE ORE.

The Ormond and Little Mountain mines may contain fair quantities of ore, but they are so much more expensive to operate than the deposits in Cherokee County or similar deposits farther northeast in Virginia that they are not likely to be able to compete with these in the near future.