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RECONNAISSANCE

OF SOME

GOLD AND TIN DEPOSITS OF THE SOUTHERN APPALACHIANS

BY

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WITH

NOTES ON THE DAHLONEGA MINES

BY

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RECONNAISSANCE OF SOME GOLD AND TIN DEPOSITS OF THE SOUTHERN APPALACHIANS.

By L. C. Graton.

INTRODUCTION.

FIELD WORK AND ACKNOWLEDGMENTS.

That part of the Carolinas which lies immediately to the southeast of the Blue Ridge, in hat is known as the Piedmont region, has long been of both scientific and commercial nportance, largely on account of the variety and abundance of its minerals. In 1904 the riter was detailed to make a brief preliminary study of the mineral resources of a portion f this area, under the direction of Mr. Waldemar Lindgren. The work began October 5 nd ended November 25, being thus favored by the delightful autumn of the South. Near he close of October the writer enjoyed the advantage of Mr. Lindgren's active supervision 1 the field for about five days and was also privileged to accompany him on a trip of a few ays to the Dahlonega gold region of Georgia, where interesting comparisons with the Carona deposits could be made. Mr. Lindgren kindly consented to publish in this bulletin a rief description of the Dahlonega mines. A few hours were spent in November at the 'ash tin mine, in Rockbridge County, Va., to ascertain if this deposit is related to those of he Carolina belt. Early in May, 1905, the writer made a three days' visit to the tin belt to arn of later developments.

During the course of the field work assistance was rendered and information furnished by nany persons residing in the area traversed. Especial thanks are due to Mr. E. A. Thies, nanager of the Haile mine; Mr. O. J. Thies, manager of the Blackmon mine; Mr. J. L. Daniels, superintendent of the Ross mine; Mr. John F. Jones, of Blacksburg, and Messrs. I. M. Carpenter and A. R. Rudisill, of Kings Mountain. The writer is glad of this oppor-unity to acknowledge his indebtedness to Mr. Lindgren, whose constant and inspiring nterest in the work and willing criticism and suggestion have been of great value and ssistance.

SCOPE OF REPORT.

A complete study of the area would have resulted in a thorough understanding of the eneral geology, as well as in detailed information regarding the mineral resources. But veral things conspired to make it very difficult to obtain an accurate and comprehensive lea of the geology. The area to be covered in the time at the writer's disposal made it ecessary to confine effort almost entirely to visiting mines and mineral localities. No pographic or other thoroughly reliable maps of this particular district have been pub-shed—a lack which made accurate locations of particular points impossible and reduced ie amount of ground which could be covered. Finally, decomposition of the rocks is so rofound that it is, in general, only by careful and repeated examination of the altered prod-cts and extended search for exposures of fresh material that safe conclusions as to lithology in be reached.

The following report, therefore, deals principally with the mineral deposits, but the broader geology will be described and its bearing on the economic features indicated so far as possible.

LITERATURE.

This portion of the United States has been long settled and was one of the earliest mineral regions in the country to become of economic importance. It has, therefore, attracted much attention from geologists, particularly before the civil war, and many of the leading scientists of their time have studied and described it. It is interesting to note that the North Carolina Geological Survey, established in 1824, with Prof. Denison Olmsted at its head, was the first organized effort of the kind on this continent. South Carolina followed next, in 1826, with its survey under Vanuxem. Through these surveys Tuomey, Lieber, Ebenezer Emmons, Kerr, Hanna, and Nitz made contributions to the geology of the Carolinas that have become well known.

The preliminary nature of this report does not properly admit the inclusion of a complete bibliography of this general region, but throughout the report there are many references to articles or portions of works which deal with the area here described.

GEOGRAPHY.

LOCATION AND GENERAL FEATURES.

The area under consideration lies between meridians 80° and 82° west and parallels 34° 30′ and 35° 30′ north. It centers at about the middle of the North Carolina-South Carolina boundary line and includes parts of Cleveland, Lincoln, Gaston, and Union counties in

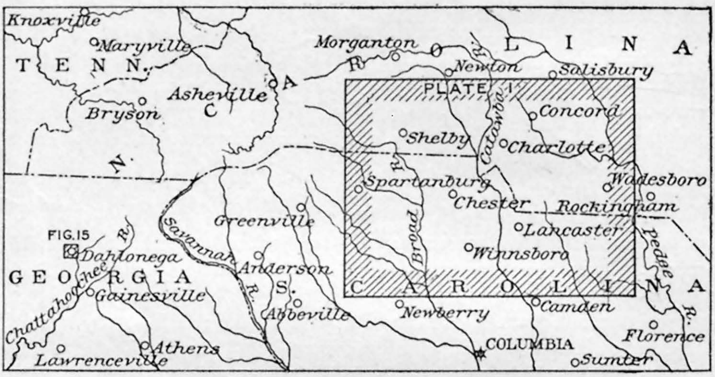


FIG. 1.—Index map showing location of area.

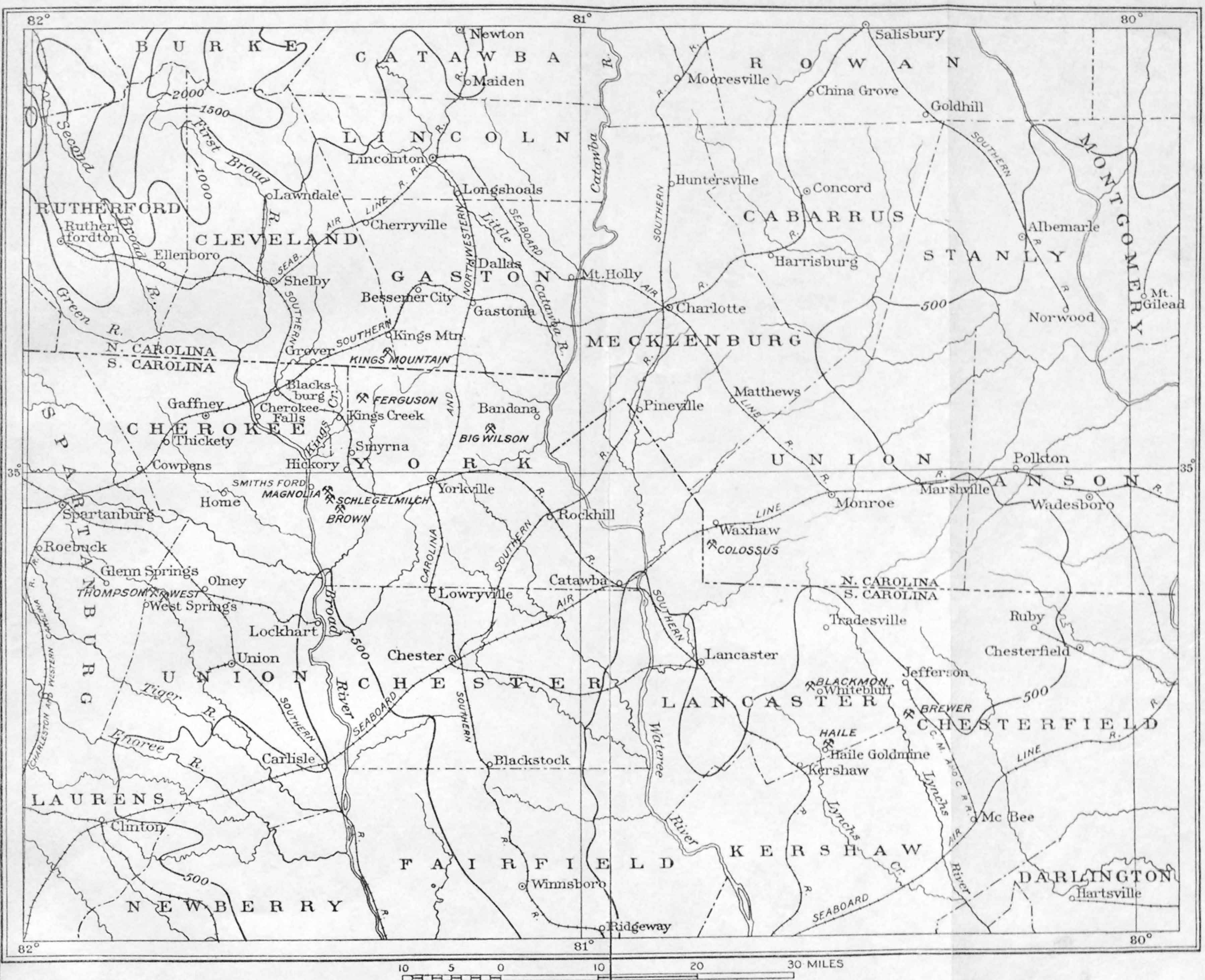
North Carolina, and of Union, Cherokee, York, Lancaster, and Chesterfield counties in South Carolina. (See fig. 1.) Outside of the many small towns, the country is rather thinly populated, but roads are numerous and generally good. Transportation is facilitated by a number of railroads. Two branches each of the Southern Railway and the Seaboard Air Line and one line each of the Carolina and Northwestern, the Lancaster and Chester, and the Charlotte, Monroe and Columbia Railroads cross the district.

TOPOGRAPHY.

GENERAL OUTLINE.

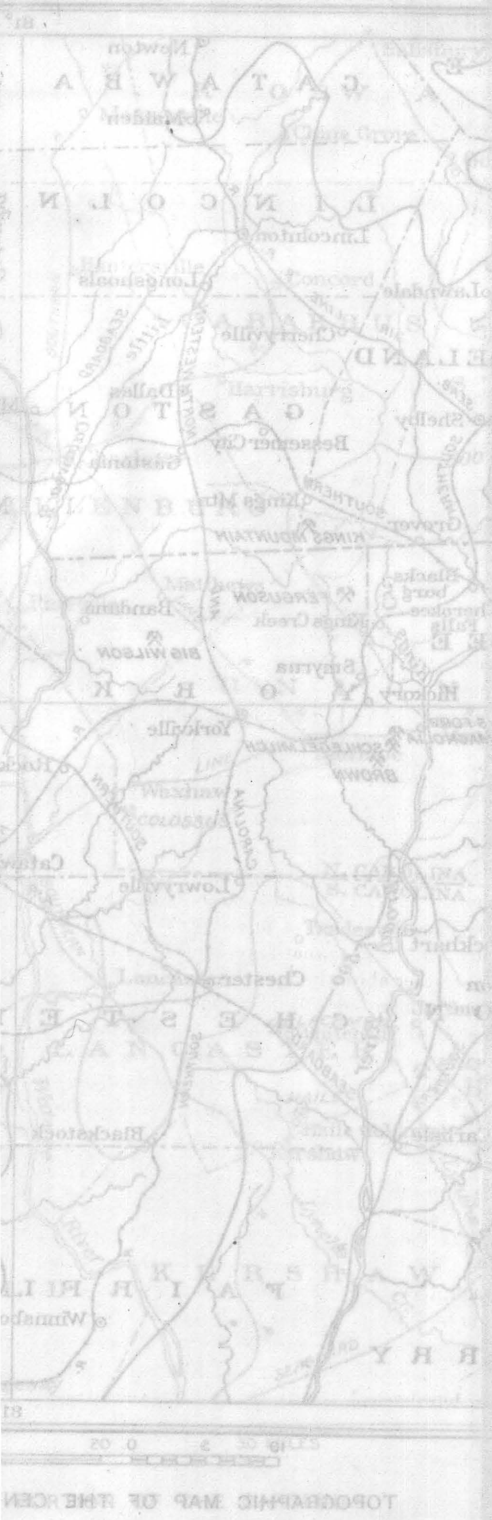
The topography of this area is so largely dependent on its geology and on the geology and topography of the surrounding region that it will be of advantage to consider the latter features briefly before endeavoring to describe the local topography.

The territory embraced by the Eastern States from Pennsylvania to Alabama is commonly divided, on the joint grounds of topography and geology, into three zones trending northeast and southwest and approximately parallel.



TOPOGRAPHIC MAP OF THE CENTRAL PORTION OF THE CAROLINAS.

Showing, by crossed hammers, locations of principal gold mines in the area described.


Newton
Lincolnton
Longshoals
Lawndale
Cherryville
Dallas
G A S T O N
Shelby
Bessemer City
Gastonia
Kings Mtn
Grover
Bandana
Kings Creek
Smyrna
Hickory
Yorkville
Lowryville
Chester
Blackstock
Winnsboro
TOPOGRAPHIC MAP OF THE CEN

On the northwest is the mountain belt of the Appalachian system, made up of sedimentary and accompanying igneous rocks, much folded, metamorphosed, and dissected. For most of the distance the Blue Ridge is the easternmost range of this mountain zone.

Skirting the eastern flank of the Appalachians lies the Piedmont Plateau. Although composed of older rocks, it is structurally similar to the mountains; but it is now so worn down by erosion that, viewed broadly, its surface is a plain which bevels the edges of the upturned strata composing it.

On the southeast the Piedmont rocks are concealed by the overlying unconsolidated sediments of the Coastal Plain.

The particular area which is the subject of this study forms a part of the Piedmont Plateau and extends on the east approximately to the boundary of the Coastal Plain. Its geological structure conforms with that of the mountains and of the other portions of the Piedmont belt; the rocks are much folded, usually dip at large angles, and almost invariably have a northeasterly strike.

RELIEF.

DESCRIPTION.

Standing upon any slight elevation the observer remarks the generally flat character of the country. The level sky line is almost unbroken until the foot of the Blue Ridge is reached. This fact is indicated by the map (Pl. I), on which this area is represented almost entirely between the 500- and 1,000-foot contour lines. For this reason features of relief which would otherwise be of small significance become conspicuous and are often assigned an undue importance. Almost every elevation which may be seen at a distance of more than a mile or two is dignified by the name mountain.

The most noticeable topographic feature is a chain of disconnected ridges extending southwestward across Lincoln, Gaston, and Cherokee counties and part of Cleveland and York counties. Crowders, Kings, Whitaker, Draytonville,[a] and Thickety mountains are the culminations of the ridges of this chain, which is commonly designated as the Kings Mountain Range, both because of the prominence of that elevation and because of the historical significance [b] attached to the name.

Although rising only a few hundred feet above the surrounding plain, these hills form noticeable landmarks for miles around. Kings Mountain, which is the highest, is said to be about 1,700 feet above sea level, and its summit is probably 600 to 700 feet above the plateau at its base. Crowders Mountain is somewhat lower, and the other hills are much less prominent. All these hills rise rather abruptly from the plain, and some of them, as Kings Mountain, are bounded on one or more sides by steep cliffs.

With a few unimportant exceptions, such as Henry Knob and Nannies Mountain, in York County, the topography is otherwise diversified only by depressions below the general level of the plain. These depressions are the valleys of present or past streams and give a rolling or undulating surface to the country. The monotony of the ordinary plain is thus relieved and a pleasing aspect given to the landscape.

DEVELOPMENT.

The prevalent explanation of the origin of the Piedmont topography may be summarized as follows: It is supposed that the Piedmont Plateau was once a mountain region, much like the present Appalachians. During long intervals, in which this region was subjected to erosion, very little elevation or depression took place. This constant stand of the land gave the rivers opportunity to lower the surface gradually toward sea level. By a continuation of this process the greater portion of the region was degraded to a very slightly undulating plain, called a peneplain, which sloped gently toward the ocean. The streams

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[a] Sometimes called Gelky's Gelkey's, or Gilkey's.

[b] A stone shaft marks the site of the battle of Kings Mountain, one of the decisive engagements of the Revolutionary war, fought October 7, 1780.

then occupied extremely shallow and broad valleys and flowed sluggishly, with little degrading power. Areas of rock particularly resistant to the agencies of denudation partially withstood this otherwise general planing down and remained as monadnocks, somewhat elevated above the general surface of the peneplain.

Before these last remnants could be reduced to the common level the whole region was elevated to approximately its present height. With their grade thus increased, the streams took on new vigor and again began active cutting. Up to the present time they have been unable to remove these conspicuous residuals of the former topography, but have produced the other variations in the surface as it appears to-day.

The monadnocks of the area concerned in this report are the hills above described—Kings, Crowders, Draytonville,[a] and other mountains. All these eminences are made up of hard and resistant rock, in most cases quartzite. To this fact, as has been shown, they owe their commanding position.

DRAINAGE.

DESCRIPTION.

A well-developed system of drainage is established in this region about three principal channels—Lynchs, Catawba, and Broad rivers. All these rivers flow across the area in a direction slightly east of south, turn more to the southeast on the Coastal Plain, and empty into the Atlantic.

On the east Lynchs River, formerly called Lynchs Creek, rises in the southern part of Union County, N. C., and forms the boundary between Lancaster and Chesterfield counties, S. C. It flows into the Pedee, which is the lower part of Yadkin River.

Catawba River drains the central part of the area. Rising in the western part of McDowell County, N. C., it takes a course slightly north of east to the northwest corner of Catawba County, and then flows almost due south, forming the eastern boundary of Lincoln and Gaston counties. In South Carolina it crosses York County and separates Chester and Lancaster counties. It there becomes known as Wateree River, and farther south joins the Congaree to form Santee River, which continues to the coast. Little Catawba River, one of its principal tributaries, rises in the northern part of Catawba County, crosses Lincoln and Gaston counties, and reaches the Catawba just north of the State line.

Broad River heads in the western part of Rutherford County, N. C., flows southeastward nearly to the State line, and then turns almost due south, crossing part of Cherokee County and forming the eastern boundary of Union County, S. C. At the edge of the Piedmont Plateau it unites with the Saluda to form the Congaree, which in turn joins the Wateree to form the Santee. Two tributaries within the area are of sufficient size to be mentioned, viz: Broad River rises in the northern part of Cleveland County, flows southward and empties into Broad River just north of the State line. Pacolet River heads in the northeastern part of Spartanburg County, forms the southern limit of Cherokee County, and reaches Broad River at the corner of Cherokee, York, Chester, and Union counties, S. C.

Each of these rivers has numerous minor tributaries, of which the greater number flow in a southeasterly direction.

Nearly all the streams are rather swift and flow over innumerable rapids, commonly called shoals, and at some places over considerable falls, thus furnishing power for many mills. The water is generally yellow and muddy, owing to the large amount of material held in suspension. The valleys are, as a rule, not deep, but have rather steep sides. Most of the streams, particularly the upper tributaries, have noticeably straight courses.

DEVELOPMENT.

Only a glance at a large-scale map of the area and of the surrounding region is needed to show that the general direction of the streams is southeasterly and that their disposition corresponds rather closely with the drainage that would be expected if a plain, tilted in

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[a] Cf. Tuomey, M., Geology of South Carolina, 1848, p. 101.

that direction and composed of homogeneous material, had been exposed for a considerable time to erosion. It is known that the elevated peneplain slopes to the southeast, and the drainage of this area is therefore largely consequent—the result of the initial slope of the plain. But it has been shown that this plateau is composed of rock beds tipped on edge and striking northeasterly. These various beds of rock are of dissimilar composition, and hence possess different degrees of hardness and resistance to corrosion and corrasion.

The natural result when streams flowing down a slope cross a discordant structure is adjustment to that structure, finally causing them to flow along the strike of the rocks. When such a result is not reached, as it is not in the present case, other conditions must have entered.

The explanation which first suggests itself is that after planation the Piedmont Plateau was submerged, covered with a layer of sediments, and then elevated to its present stand. Consequent drainage established on its slope would cut through this mantle and be superimposed on the transverse structure of the ancient rocks below. There is, however, no evidence preserved of such a submergence or of such a deposit, and this explanation may therefore be abandoned.

A second explanation involves much the same principles as the first. It has been shown that the region now occupied by the Piedmont Plateau was eroded nearly to base-level. When this process, whose effect gradually lessened, had reduced the land well toward a peneplain, the rate of erosion became so slow that decomposition of the rocks—perhaps aided by the peculiar conditions existing at such a stage [a]—proceeded faster than degradation. That decomposition has actually exceeded denudation is evidenced by the fact that many of the streams have not yet cut down to fresh rock; but the rate at which the streams are now cutting, when compared with that in other regions, is almost certainly greater than that of decomposition—an indication that decomposition could have exceeded denudation only when conditions were different from those at present.

During the interval from the time when decomposition began to proceed faster than its products could be carried away until the streams were finally rejuvenated by uplift, atmospheric alteration of the rocks had opportunity to extend far below the surface of the peneplain. It is probable that all the rocks of the region, including the quartzites (which, as will be seen later, are impure, holding much mica, and hence readily susceptible to disintegration), were, at the surface where decomposition was greatest, reduced to soil. But, under the sluggish action of the streams, which had almost attained base-level, this soil remained in situ and still retained the structure of the rocks from which it had been derived. Here, then, was a layer of soft and relatively unresistant material to serve as a mantle to the hard rocks below. In appearance it possessed a decided structure of its own; in essence it was at the surface almost structureless.

The drainage consequent on the establishment of the present Piedmont slope began to trench this covering of soil and soon incised considerable valleys in it. As the streams wore down the beds of rock more resistant to weathering were discovered and eroded, but, in general, less rapidly than the surrounding beds. In this way the rapids and falls were formed. These barriers tended to divert the streams and adjust them to this new-found structure, but the valley walls already formed held the streams closely to their initial consequent courses. At present a number of streams have cut down to and into solid, fresh rock, to whose structure they show very little adjustment.

Such streams appear to belong in a subdivision of superimposed rivers. They have courses "quite out of accord with the underlying structures on which they have descended,"[b] but the relatively thin overlying mass through which they have first cut, instead of being an unconformable deposit, as the usual definition of this class of rivers requires, is the irregularly decomposed zone of the deeper lying rocks.

Other factors have doubtless helped to maintain this unadjusted condition of the streams. The principal one of these is steepness of slope to the southeast—i. e., across the structure.

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[a] Cf. Campbell, M. R., Erosion at base-level: Bull. Geol. Soc. America, vol. 8, 1897, pp. 221-226.
[b] Davis, W. M., Rivers of northern New Jersey: Nat. Geog. Mag., vol. 2, 1890, p. 82.

Although the Piedmont Plateau appears approximately level, its slope is considerable when compared with the average profile of streams in soft material. This slope prevents an overloading of the streams, and consequently, by preventing meandering, induces the fairly straight courses which have already been alluded to in the description. The slope also causes headward cutting of the tributaries, which likewise results in straight courses. Such courses are less easily brought into adjustment with discordant structure than meandering courses.

Some adjustment has, however, taken place, as shown by a number of the smaller, and hence younger, tributaries, whose courses are parallel to the strike of the rocks. Such subsequent tributaries of some of the larger consequent streams have been able in certain instances to capture weaker consequent streams which were perhaps held up by the temporary base-level of a hard rock barrier.

An interesting evidence of the planation of this region is shown on the map, where it is seen that the railroads are enabled to follow the present watersheds or divides, whereas in most regions of equally diversified topography they are forced to follow the more circuitous courses of the stream valleys.

GENERAL GEOLOGY.

DESCRIPTION OF THE ROCKS.

OUTLINE.

The rocks of this area belong to three great classes—igneous, sedimentary, and metamorphic. Sedimentary and igneous rocks of great age have been much contorted and folded. The forces producing and attendant on these movements have extremely metamorphosed the rocks, converting them into schists. Volcanic rocks, mainly represented by bedded tuffs, covered these metamorphosed rocks in places and were themselves subjected to a part of the metamorphosing influences. Into these metamorphic rocks later igneous material has been intruded. Granite is the most abundant of these igneous rocks and the numerous dikes of pegmatite are probably closely connected with it. Diabase dikes cutting all the foregoing rocks are the last representatives of intrusion. On the eastern border of the area the solid rocks are covered by thin beds of sand, which probably belong to the Coastal Plain formations.

METAMORPHIC ROCKS.

The metamorphic rocks of this district have resulted from the action of the tremendous forces of mountain building. They are usually extremely metamorphosed, and may be placed in that perplexing group, the crystalline schists. In many places nearly or quite all traces of their original character have been removed; but here and there the former nature of the rock can be seen, and by comparison and analogy the more altered varieties are correlated. These schistose rocks are derived from both igneous and sedimentary formations.

SCHISTS OF IGNEOUS ORIGIN.

AMPHIBOLITE.

The most common and abundant rock under this head is hornblende schist or amphibolite. In some places, as in central York County, the gradation from this rock into fairly unchanged gabbro can be traced with certainty. It seems probable, however, that much of it has resulted from volcanic as well as from plutonic rocks, for its exact intercalation with the sediments in many places would indicate that it had been in such cases a surface rock, probably occurring as basaltic flows or tuffs. On subjection to shearing and other metamorphosing processes these igneous rocks were foliated and otherwise altered, becoming schistose amphibolite.

These amphibolites are fine-grained rocks, of dark, greenish color, generally possessing a definite structure in one direction, or "grain." In some of them the foliation is sufficient to allow a very easy parting in thin plates. Under the microscope the rocks are found to have a surprisingly large amount of feldspar, in consideration of their very dark color. They are typical "greenstone schists." The feldspar occurs in small, rudely polygonal grains, in many specimens built up zonally, commonly untwinned, and perfectly clear. It belongs mainly to the variety albite, with a less amount of oligoclase. Epidote is often found in abundance, both in irregular interstitial grains and as lath-shaped prisms poikilitically penetrated by other constituents of the rock. Zoisite occurs in a manner similar to epidote and is on the whole more common. These two minerals may occur together and in many cases can be distinguished only in polarized light. Calcite likewise occurs in numerous specimens, in irregular grains and in lath-shaped individuals, and was undoubtedly present when the recrystallization of the rock took place. Calcite is usually not abundant in those specimens which contain much of the calcium silicates epidote and zoisite, or, if it is, it occurs principally in bands or zones in which they are sparingly present. Quartz, either formed by the removal of bases from some of the silicates or introduced by the waters producing metamorphism, perhaps also in part primary, forms mosaics of small clear grains which are distinguishable from albite only in convergent polarized light.

The dark constituent is the typical amphibole of the "greenstone schists" and is probably uralite. It occurs in well-formed prisms and in irregular, elongated grains, but in no case was it seen developed as a pseudomorph after pyroxene. As a rule, it is rather strongly pleochroic in bluish and brownish greens and has a not very strong double refraction.

Black iron ore is generally abundant and is associated particularly with the amphibole. The most common occurrence is in irregular grains, but in some cases it is present as crystals of definite outline, usually too small to be accurately determined as to form, but sometimes showing a pair of predominant parallel faces that give the crystal a flattened appearance and suggests ilmenite. Many of the grains are surrounded by borders of sphene, and in some cases the change to this mineral has been complete. In a few instances a mineral which is probably rutile accompanies the titanite. The iron ore is therefore titaniferous in most or all cases. Small broken grains of zircon are present in a few specimens.

In those specimens which contain considerable calcite, epidote, or zoisite it is not uncommon to find irregular grains, turbid and decomposed but still showing the twin lines, of a moderately calcic plagioclase, usually labradorite. The rocks free from calcite, epidote, and zoisite have in general a cleaner, better-defined appearance than those which are not. It appears probable that the crystallization of these secondary lime-bearing minerals is only an intermediate step in the complete metamorphism of the original rock, the ultimate result being their solution and removal, leaving a rock decidedly less rich in lime than the original.

These amphibolites thus present a typical example of the original metamorphism of a rather basic igneous rock, probably having the composition of a gabbro, with the production of a wholly recrystallized and altered schist.

Rocks of this character are extremely common in the western part of the area examined and probably are the most widely developed variety in that part. In central York County, as has been said, the degree of metamorphism which they have suffered is not so great. There they possess a more granitic texture and pass gradually into gabbros. In the eastern part of the area amphibolites were less commonly observed, although a study of the areal geology might reveal them in abundance.

QUARTZ-SERICITE SCHIST.

Dense, siliceous rocks, usually of rather light gray color, more or less schistose, occur in several portions of the area and may have a considerable extent. A peculiar silvery, mottled luster, frequently seen on the planes of schistosity, has won for these rocks the very suggestive name applied by the miners, "fish-scale slate." The appropriateness of this name is especially apparent when the rocks are wet and viewed by the flickering light of the miner's candle.

In their common development it would be a very difficult matter to determine the nature of the rocks from which these have been derived, but fortunately a clue is given in a few localities, where enough of the original character is preserved to aid in arriving at a fairly definite conclusion.

The least altered of these rocks are well-bedded, fine-grained, and not very much indurated tuffs, made up of irregular fragments of a rock which if massive would have been a porphyry. Broken grains, some of them rounded, of quartz and feldspar, representing original phenocrysts, are embedded in an evenly fine-grained matrix of quartz, feldspar, and mica. The porphyries from which these fragmental rocks were derived therefore correspond to granite porphyry and quartz-monzonite porphyry and were probably related to the porphyries which occur in the vicinity of the Brewer mine in Chesterfield County and the Blackmon mine in Lancaster County.

The quartz appears in many cases to have existed in the massive rock as sharp double pyramids without development of prism faces. The character of the feldspar varies in different localities. In the neighborhood of the Ferguson gold mine, in the northwest corner of York County, for instance, most of the determinable individuals of feldspar appear to belong to the varieties oligoclase and andesine. At the Colossus mine, in the southwestern part of Union County, N. C., microcline is most abundant, while microperthite is rather common. At the Haile mine, in the southern part of Lancaster County, the character of the feldspar could not be determined. Both biotite and muscovite are present, and while it seems probable that the former at least was an original constituent of the rock, the evidence is not conclusive and the mica may have been introduced by the contact metamorphism to which the rock has plainly been subjected. The biotite is present in small ragged flakes, usually exhibiting a parallelism of arrangement and indicating the direction of foliation of the rock. It is of a clear brown, and shows fairly strong absorption and rather strong polarization. In many cases it has been changed to a dirty greenish chlorite. Muscovite is doubtless secondary in all cases, having been derived both from the biotite, by the common but poorly understood process known as bleaching, and from the feldspars by decomposition. In the less foliated rocks it can be seen in process of formation from both these minerals. Compact, fibrous muscovite or sericite occurs commonly in the more schistose rocks and is especially abundant along certain planes which are planes of greatest movement and hence of greatest weakness—in other words, planes of schistosity. It is the silvery sheen of this muscovite, exposed when the rock is cleaved along these planes of fissility, which gives rise to the term "fish-scale slate."

It is possible that these soft tuffs cover a considerable area, but do not outcrop conspicuously, and are in consequence overlooked. The localities where they were found, however, are in the immediate vicinity of gold deposits, and there, owing to their physical make-up, being rather porous and in fine particles, and possibly also to their chemical constitution, they were easily attacked by the mineral-bearing solutions which produced the gold deposits and were very greatly altered. This alteration has been for the most part a silicification with attendant recrystallization. Feldspar, biotite, and sericite have all been attacked and more or less completely replaced by quartz. Since these silicified tuffs are closely connected genetically with the gold deposits which occur in them they are more fully described in the section dealing with gold (pp. 78–79).

These granite-porphyry and quartz-monzonite-porphyry tuffs have been observed in the vicinity of the Haile mine in Lancaster County, the Colossus or Howie mine in Union County, N. C., and the Ferguson mine in York County. They doubtless belong in the group of ancient volcanic rocks whose distribution in the eastern part of North America has been set forth by G. H. Williams.[a]

GNEISS (SCHISTOSE GRANITE)

Much-foliated rocks which show by their texture and composition that they were origially granites are found in isolated localities throughout the area. They are usually of rather

[a] Jour. Geol., vol. 2, 1894, pp. 28 et seq.

fine grain and light color and exhibit by the position of the dark biotite flakes a decided foliation. When greatly weathered it is not always possible to distinguish them from granite.

Viewed under the microscope quartz is seen to be fairly plentiful and shows crushing and strain shadows. Microcline is very abundant in many specimens, intergrown micropegmatitically with the quartz. A little plagioclase is present and probably is albite. Small broken plates of brown biotite and of muscovite occur somewhat sparingly. Fragments of apatite crystals are sometimes seen and more rarely broken grains of zircon. Crushing seems to have taken place, especially along certain zones.

The gneisses are most common along the Kings Mountain Range, but probably occur also at places in the eastern part of the area, as in the western part of Chesterfield County.

As is shown on page 20, it is probable that these gneisses have a close genetic connection with the massive granites.

SCHISTS OF SEDIMENTARY ORIGIN.

QUARTZ SCHIST.

Foliated or schistose rocks made up principally of quartz are common and conspicuous throughout the western part of the area. Original sandstones, arkoses, and quartz-pebble conglomerates have been changed into quartzitic rocks, which usually retain enough of their former structure to make their derivation a matter of certainty.

The finer grained or sandstone members are made up of small polyhedral grains of quartz, in most cases combined with minute yellowish scales of mica, muscovite, and a little biotite, but in some cases composed of quartz alone and then very friable or "sugary." The mica-bearing varieties usually have a decided schistosity dependent on the parallel arrangement of the mica flakes. In some localities the scales of mica serve to bind the quartz grains together, and, being flexible, allow a slight movement of the quartz grains, producing the flexible sandstone or itacolumite described at length by Lieber.[a] In these micaceous quartzites magnetite is commonly present and by its oxidation stains the rock pink, red, or brown. Under the microscope the polygonal outline of the quartz grains penetrated by foils of mica, usually muscovite, the numerous small octahedrons of magnetite, and the occasional crystals of garnet indicate that recrystallization has been considerable.

Some varieties, perhaps different in original composition or possibly subjected to different conditions of metamorphism, have fresh microcline instead of muscovite and hold numerous small, irregular grains of garnet.

The conglomerates are made up principally of quartz pebbles varying in diameter from a few millimeters to several centimeters, but most commonly 1 to 1½ cm. These pebbles have been almost everywhere much flattened and drawn out by pressure, and in many places the resulting mass can be determined as a conglomerate only by observing the gradual change into more typical facies. The matrix of the pebbles is in some places a green, slaty, sericitic, and chloritic material, rather abundant as compared with the bulk of the pebbles which it contains and wrapped around the pebbles in a manner recalling the flow lines of a porphyry. In other places the pebbles, large and small, compose nearly the whole of the mass and the cementing material is mainly silica, probably derived from partial solution of the pebbles.

Were it not for their flattening due to pressure, the pebbles would in most cases be well rounded. Surface specimens, however, frequently show a peculiar faceting of the exterior pebbles and sometimes suggest a rude approach to crystalline form; but large exposures show that this faceting is due to solution. The surface of the conglomerates is covered with pits and depressions exactly similar to those produced by solution in many limestones. The very decided solution which is thus evidenced probably has some relation to the conditions existing in a region near base-level already referred to (p. 13).[b]

[a] Survey of South Carolina, vol. 3, 1859, pp. 75-106.
[b] Campbell, M. R., erosion at base-level: Bull. Geol. Soc. America, vol. 8, 1897, pp. 221-226. Cf. also Hayes, C. W., idem, pp. 213-220.

The quartz pebbles are now a granular aggregate of quartz grains, but whether they are portions of clastic rocks or have been derived from the breaking down of quartz veins, in which the rocks abound, and have been given their granular structure by crushing, it is impossible to decide, although the latter view is perhaps more plausible.

These quartz-rich metamorphic rocks are particularly abundant along the Kings Mountain Range, but also occur in places, isolated so far as known, farther east. They are more resistant than the surrounding rocks and hence outcrop conspicuously, forming the ridges of which Paysour, Crowders, Kings, Draytonville, Whitaker, and Thickety mountains are the highest portions, many smaller near-by ridges or mounds, and the elevations Henry Knob and Nannies Mountain. Notwithstanding this apparent resistance, these quartzitic rocks are in many places so rich in minerals like mica and magnetite, which are more susceptible to atmospheric decomposition than the quartz, that they crumble to soil with considerable readiness and do not form conspicuous outcrops. This variation in composition from place to place undoubtedly has had much to do with the unsymmetrical and irregular shape and distribution of the quartzite ridges. Conglomerate occurs along Kings Creek and makes up the greater part of Draytonville Mountain in Cherokee County. At the latter locality the surface of the rock is strewn with unevenly rounded pieces of quartz—the conglomerate pebbles which have been released by the decomposition or solution of their matrix. On the summit of this hill the conglomerate is exceedingly well exposed. This occurrence was noted by both Tuomey [a] and Lieber.[b]

QUARTZ-SERICITE SCHIST.

Closely related in composition to the quartzitic rocks described in the preceding section are certain schists which, when unaltered, are gray, glistening, micaceous, and much foliated. As generally seen, they are colored various shades of red by the oxidation of the magnetite which they contain. Some specimens hold an abundance of small red garnets. On disintegration they form a soil which gives little indication of the amount of mica which they held.

The microscope reveals in the thin section abundant quartz in rudely polygonal grains surrounded and enmeshed by shreds of fibrous muscovite or sericite. In places it appears as if numbers of these fibers had been so rearranged as to crystallize into an irregular flake of muscovite. Octahedrons and irregular grains of magnetite are rather common, and furnish, on decomposition, most of the coloring matter of the stained rocks. In a few cases turbid decomposed remnants of feldspar grains are being replaced by sericite. It seems probable that these rocks represent arkoses richer in feldspar than those from which the quartz schists were derived.

Quartz-sericite schists of this kind were not seen at many places in the area, probably owing in large part to the ready disintegration which they undergo. An occurrence of unknown extent was found in the northeastern part of Gaston County.

QUARTZ-BIOTITE SCHIST.

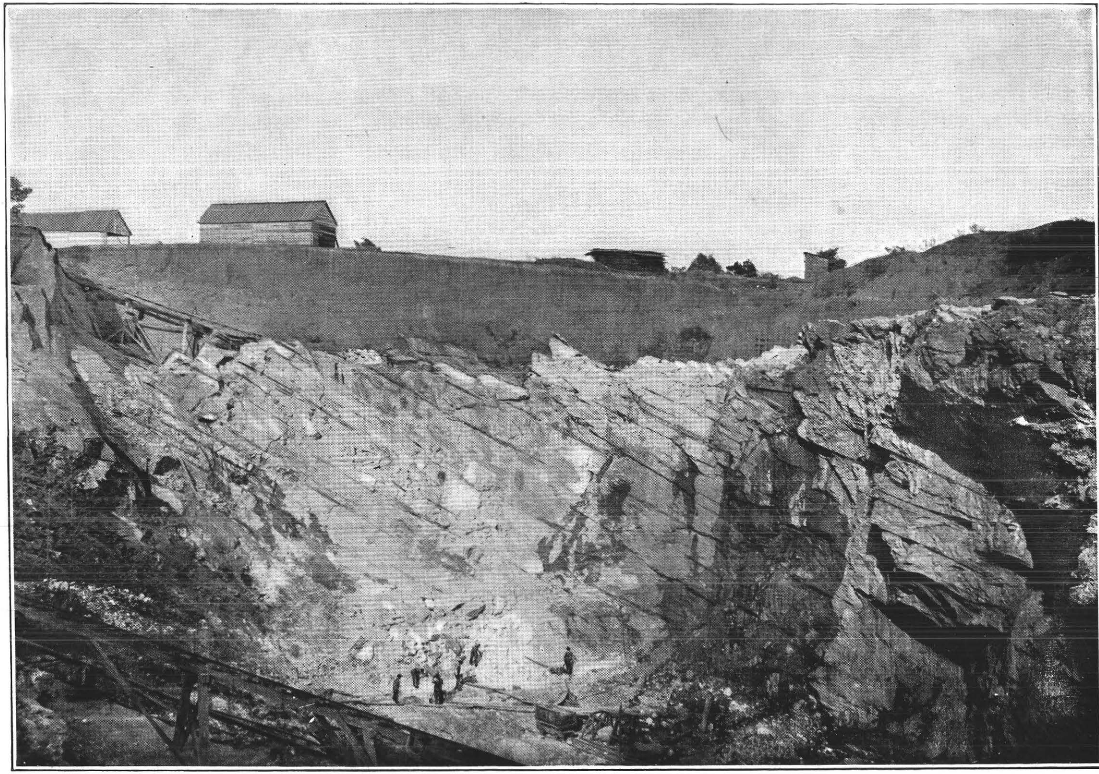
Dark-brown fine- and even-grained micaceous rocks are found at numerous places along the Kings Mountain belt. They consist of small grains of quartz, a little rather turbid feldspar, mostly oligoclase, and abundant brown biotite in small scales. Muscovite is present in some cases, and grains of carbonate are not unusual. Schistosity is well developed. They have probably been derived from impure feldspathic sandstones.

These rocks are found generally in close association with the limestone beds, though it is of course possible that they have a more extended development. They have been encountered in the limestone quarries at Gaffney and Blacksburg, S. C., and a similar rock is found at the Thompson mine, near West Springs, Union County, S. C.

SERICITE SCHIST.

Compact grayish or bluish-gray rocks, with a characteristic lustrous sheen on their parting planes, are known at various places along the Kings Mountain Range. They are made up almost wholly of sericite, and have probably resulted from the metamorphism of

[a] Rept. Geol. and Agr. Survey South Carolina, 1844, p. 18; Geology of South Carolina, 1848, p. 77.
[b] Survey of South Carolina, vol. 2, 1858, pp. 40-42.



LIMESTONE QUARRY AT GAFFNEY.

Showing stratification and soil derived by decomposition of rock in place. Dolomitic beds above to right.

shales or other argillaceous rocks. They are associated with beds of manganese oxide and graphite and may represent deposits in comparatively shallow water.

A beautiful deep-green rock, which resembles a talc schist, forms the wall rock of the Blackmon mine in Lancaster County. In places the green color gives way to a silvery gray and pink, suggesting mother-of-pearl. This rock is almost completely made up of exceedingly fine fibers of sericite and contains, in addition, a few small dark-red garnets. It is probably a sediment much altered by regional metamorphism and by an intrusion of porphyry which has penetrated it.

LIMESTONE.

The limestones of this area can hardly be called schists, but they have been subjected to the same forces of metamorphism as the surrounding rocks and in many places, particularly near the limits of the beds, they are foliated and composed of other minerals in addition to calcite; in such places they possess a truly schistose appearance. These limestones are rather magnesian; the upper portion of the beds is in places too high in magnesia to make lime, and is practically a dolomite. The dolomitic portions are usually light gray to white in color and the more calcareous varieties are generally blue. The quarrymen are pleased to find "blue rock," while the white they speak of as "dead." Below are given the analyses of some typical limestones of this area, which the writer owes to the courtesy of Dr. Earle Sloan, State geologist of South Carolina:

Analyses of typical limestones.

	1.	2.	3.
SiO_2	0.71	1.28	1.16
Al_2O_3	.23	.23	....
Fe_2O_3	.47	.47	.96
MgO	1.16	5.60	25.48
CaO	54.24	48.66	30.50
Na_2O	.02	.08	....
K_2O	.01	.01	....
H_2O at 100	.02	.06	.03
TiO_2	Trace.	Trace.	....
P_2O_5	Trace.	Trace.	....
CO_2	43.27	43.52	....
Loss on ignition	.11	.12	....
	100.24	100.03	....

All these specimens are from near Gaffney. No. 1 represents very pure limestone; No. 2 indicates a rock that is somewhat less pure, but makes very good lime; No. 3 is a partial analysis of a magnesian or dolomitic phase, which is not burned for lime.

Mineralogically, these rocks consist principally of granular carbonate, whether calcite or dolomite can not be told by means of the microscope. Small lenses and bunches of quartz, probably introduced at the time of the metamorphism of the region, occur in some specimens. A little colorless amphibole, probably actinolite, and thin blades of a colorless or whitish mineral, presumably wollastonite, are rather commonly observed. At the edges of the limestone masses the rock passes over within a short distance, yet by gradations, into the adjoining rock—feldspathic quartzite in some places, quartz-biotite schist in others.

The limestones are known to occur at numerous points through practically the whole extent of the Kings Mountain Range. A good view of the limestone in one of the quarries at Gaffney is shown in Pl. II.

IGNEOUS ROCKS.

The rocks described under this section are those which were intruded and reached their present position after most or all of the metamorphism which affected the rocks described in the foregoing pages had taken place. They exist at the present day, therefore, in practically the same state in which they crystallized from their molten magmas. These rocks have a small areal extent as compared with the metamorphic rocks. They appear either as dikes or as elongated bodies, whose shape was influenced by the structure of the rocks which they penetrated.

GRANITE.

Granite is the most abundant of the massive igneous rocks. It is of light color, medium grain, and typical granitic texture. Exposures of large size sometimes show the rock to be almost structureless—that is, devoid of any foliation—but in most places a more or less distinct gneissic structure is observable, in spite of the fact that hand specimens may appear nearly or quite massive. This granite is rich in the lighter-colored constituents, which include muscovite, and contains a rather sparing amount of brown biotite.

The microscope shows the presence of abundant quartz in clear grains, holding numberless fluid inclusions of the ordinary kind. Microcline is the predominant feldspar, followed in decreasing amounts by orthoclase, oligoclase, and albite, all fresh. Muscovite is plentiful in broad, thin foils. Deep red-brown biotite is not very abundant. By its bleaching, some of the muscovite may have been formed. Some of it has been changed to chlorite. Scattered garnets, a few crystalline grains which are probably epidote, one or two small zircon crystals, and numerous prisms of apatite complete the list of constituents.

A comparison of this description with that of the granitic gneiss (pp. 16–17) in the section on metamorphic rocks shows that the two types of rock are practically identical mineralogically. While the field relations are not very distinct and have not been carefully studied, it is believed that they likewise favor the view that the foliated granite or gneiss and the massive granite were derived from a common magma and belong to the same general period of intrusion. If this is true then the eruption of the granite must have marked the closing stage of the regional metamorphism of the country; otherwise, all the granite would be foliated. The difference in amount of foliation of the granite and the gneiss may partly be explained by the reasonable supposition that these last metamorphic movements were not equally intense in all portions of the area. It seems probable, however, that other conditions were largely responsible for this difference in foliation.

It has just been stated that the granite and the gneiss probably belong to the same general period of intrusion. This does not mean, however, that all the masses of these rocks were intruded at the same absolute time. It is doubtful, indeed, if instances of such kind are at all common. On the other hand it is reasonable to suppose that successive intrusions took place and that the interval from the beginning to the end of eruptive activity was considerable. Since this epoch of eruption probably began just as the great movements of compression and folding were dying out, the first of the granitic intrusions would suffer more or less squeezing and shearing and would be converted into a granitic gneiss, while successively later portions of the granite magma to be forced up into the metamorphosed rocks would be subjected to less and less dynamic action, and the last of the granite would appear after metamorphic movements had ceased, and would thus remain massive.

PEGMATITE.

The dikes of pegmatite which abound in the western part of the area studied form one of the most interesting geologic features of the region. Several varieties of pegmatite may be distinguished, although it may be that all are members of a series in which certain varieties are most common or abundant. Of the types established several exhibit a considerable variation in mineralogical composition, so that it is not at all improbable that a further slight change would result in a passage to the neighboring type. Although these rocks are of various appearances, they all possess features which at once characterize them as pegmatites. In composition they are all closely related to granite. In the following paragraphs the four most common varieties are described in the probable order of their formation.

The first variety is usually of light color and not very coarse grain. It occurs in small contorted lenses and dikes in the granite and surrounding rocks. Microcline, quartz, oligoclase, orthoclase, and muscovite are present in decreasing amount. Small red garnets are numerous in some specimens and ilmenite is a prominent constituent of some of the small masses. Crushing can be seen to have taken place in much of the rock. In some cases it appears as if contortion had gone on while the pegmatite was unsolidified.

The pegmatite of the second variety is a light-colored rock, much of it somewhat foliated or gneissic, whose chief constituent is feldspar. The microscope shows large individuals of orthoclase with well-developed cleavage, some of them with microperthitic intergrowths of albite. Numerous smaller grains of albite also occur near the periphery of the orthoclase individuals. Narrow tongues of quartz appear to be eating into the feldspars and are surrounded by small grains of micropegmatite—a granophyric intergrowth of quartz and feldspar. Small shreds and scales of brown biotite are plentiful in some parts of the section, and associated with the biotite particularly are small prisms of monazite. In thin section this mineral is pale yellow, and has a high index of refraction and apparently rather low double refraction. In many places the dikes contain flakes of graphite, whose origin is undoubtedly primary.

Dikes of this kind are rather common in the western part of Cherokee County, where they are injected into gneiss and amphibolite, and where, on sufficient decomposition, they are sometimes worked for monazite.

The third variety of pegmatite is very light colored and fairly coarse grained. In most places quartz and feldspar are the only constituents visible in the hand specimen, but in some places muscovite is present and locally cassiterite becomes an essential constituent. It is rather easily decomposed and weathers to a soft mass chiefly made up of kaolin.

Microcline is abundant in large individuals penetrated by grains of albite and by long, narrow tongues of quartz, which look as if they had eaten their way into the feldspar. Along the borders of these larger quartz individuals are small grains of different orientation. The quartz is crowded with fluid inclusions. Much of the muscovite is converted into the fibrous variety, sericite, by crushing. Cassiterite, when present, occurs as crystalline grains of dark color and pleochroic under the microscope. This kind of pegmatite is known only in the vicinity of the Ross tin mine, near Gaffney, Cherokee County, S. C. In some respects it resembles the monazite-bearing pegmatites from the western part of Cherokee County, and the occurrence of a notable amount of monazite in the bed of the stream which crosses the dikes of the Ross property may be an indication that this variety also is monazite bearing. Neither biotite, monazite, nor graphite has been found in the Ross dikes, however.

A slight change in composition of the pegmatite of this class would probably result in the production of the fourth variety.

The fourth kind of pegmatite consists very largely of quartz and muscovite. It is coarse grained, some of the mica flakes attaining a width of 10 cm., and in this way merits the name "giant granite" sometimes given to it.

As a rule feldspar is absent or only sparingly present, but in certain cases good-sized crystals of feldspar are rather abundant. Where these dikes penetrate the metamorphic rocks they seem in general to contain much mica and little or no feldspar. Where they cut the granite or granitic gneiss, on the other hand, they usually hold a plentiful amount of feldspar and decidedly less muscovite. Cassiterite is in some places an important constituent and seems to be most abundant in the mica-rich varieties. Among other minerals which have been found in these dikes are large but imperfectly terminated crystals of spodumene, violet-blue or bright-green apatite, and a brownish or yellowish-brown lithia-manganese phosphate, probably lithiophilite. These dikes are in some places so resistant to atmospheric agencies as to outcrop conspicuously. Many of them are very friable, however, and hence disintegrate and are concealed by soil. This variety of pegmatite is described at greater length in the section devoted to the occurrence of tin (pp. 31–32). Dikes of this rock appear or have been exposed in many places along the Kings Mountain Range. They extend in a belt which crosses Lincoln, Gaston, Cleveland, and Cherokee counties, and passes beyond the limits of the area concerned in this report.

The possibility that the various types just described may be members of a continuous series has already been stated. Whether such is the case or not, it seems probable from the amount of foliation which each has suffered that the types appeared in the order described. The first variety is almost always considerably crushed. The others are progressively less affected and the fourth variety only here and there gives evidence of having been deformed.

In the description of the granite (p. 20) the opinion is expressed that the gneiss and granite belong to the same period of intrusion, were derived from the same magma, and differ only in having suffered unequal amounts of squeezing consequent on being erupted at somewhat different times. It is here proposed to extend this hypothesis still further to aid in explaining the origin of the pegmatite.

Pegmatite of the first variety cuts the granite and suggests at once the conclusion that it was a part of the granite magma. The other varieties of pegmatite were nowhere found cutting massive granite. In the northwestern part of Gaston County, however, pegmatite dikes of the fourth type are abundant in the somewhat gneissic granite, and the impression conveyed by the appearance of these dikes is that they are related to the rock which they cut. If the granite were not foliated, it might be said without hesitation that the pegmatite dikes represent the last phase of the eruption which resulted mainly in the production of granite. The fact that the granite is rather gneissic, however, while the pegmatite is practically uncrushed, indicates that considerable time has elapsed between the intrusion of the two rocks. This would, in general, be sufficient to prove that the two could not have been derived from the same magma. In this case, however, it is believed that a particular combination of circumstances accounts for the seeming paradox of pegmatite cutting its parent granite after the latter had been rendered gneissic.

If the gneiss is really the earliest portion of the granite magma, which happened to be caught in the grasp of expiring dynamic metamorphism, and if the last of the granite was late enough to escape nearly all the squeezing—in other words, if the granite and gneiss are related—it is conceivable that pegmatite and gneiss can bear exactly the same relation to each other as pegmatite and granite.

It is believed, in short, that the pegmatite—the residuum from the solidification of the granite, the last of the material to be ejected in a molten state from the magma reservoir—appeared after almost all regional metamorphism had subsided, and, coming from the heated interior, where the effects of surface folding were not felt, cut the gneissic and the massive granite indiscriminately, except that the gneiss, having been subjected to pressure and stress, was probably weaker and allowed an easier access of the material than the massive granite. Such a hypothesis, if true, would account for the relation of the pegmatite to the foliated granite and for its greater abundance in that phase of the rock. It is realized that this theory is open to the criticism that it is based on an artificial and perhaps unwarranted grouping of favorable conditions. But the intimate lithologic connection between gneiss and granite and the close relation of pegmatite and gneiss, added to the fact that the pegmatite is almost certainly related to some mass of granite, have favored the acceptance of this hypothesis.

PORPHYRY.

In a few places masses of rock with porphyritic texture intrude the surrounding schists. These masses are in all known occurrences closely associated with gold deposits and are in consequence much altered. In general they are light-grayish, granitic-looking rocks, of moderate grain. Phenocrystic grains of quartz are visible in many hand specimens. In the least altered rock from the Brewer mine crystalline individuals of an unknown mineral (see p. 90) are easily recognizable.

Under the microscope the rocks are seen to consist of good-sized individuals of quartz, some of which are developed as bipyramids, and very turbid crystals of orthoclase and oligoclase, decomposing into kaolin, sericite, and epidote. In the rock from the Brewer mine large individuals of the unknown mineral are being slowly converted into sericite. The matrix for all these individuals is a fibrous mass of sericite. Magnetite is present in some specimens and is probably secondary. Pyrite is abundant in places. A little rutile has probably been formed by the decomposition of some original titanium-bearing mineral. There is no indication that dark silicates were ever present.

These porphyries have been found at the Brewer mine in Chesterfield County and at the Blackmon mine in Lancaster County. It is probable that they are closely related to the tuffs found at the Haile, Colossus, and Ferguson mines. While it is difficult to determine the original character of these rocks, because of their altered condition, they probably belong in the quartz-monzonite-porphyry group. At the Brewer mine the porphyry shows in places the effects of brecciation.

Keith[a] has described a series of volcanic rocks from the Cranberry quadrangle, about 80 miles northwest of the area embraced by this report. The rocks there are considered to be altered rhyolites, andesites, basalts, and diabases, and are thought to be of Algonkian age. Keith believes that the porphyritic rocks in the two localities are similar.

DIABASE.

Dikes of diabase occur at many places through the area studied and represent the last phase of eruptive activity experienced here. These bodies range from a few to 200 or more feet in width, and cut any or all of the other hard rocks of the district. The material of the dikes ranges from moderately to very fine grained and is of greenish-black color. Individual minerals can with difficulty be determined by the unaided eye. The rock is fairly resistant to weathering and, although seldom outcropping, furnishes much float which marks the course of the dikes. It weathers in the concentric layers characteristic of diabase.

In thin section the rock is found to be a typical olivine diabase. Plagioclase, a calcic labradorite, in long, narrow laths, was the first mineral to form. Olivine is generally abundant and occurs mainly in automorphic crystals, but here and there in irregular grains. On decomposition it changes into the mineral called iddingsite, which, in these rocks particularly, seems certainly to be a micaceous mineral. Less commonly it alters to a material which is of almost identical appearance in ordinary light, but which is isotropic. In a few places serpentine results from the olivine. Augite is abundant, usually as irregular interstitial individuals, but locally in crystals of fairly good form. It is slightly pleochroic in colors suggesting a small content of titania. Cleavage is very well developed. Some of the pyroxene may be diallage. Closely associated with the olivine and commonly included in it are numerous small octahedral crystals of perofskite. The exterior of the crystals is nearly opaque, while the interior is a rather dark brown. Small crystalline grains of black iron ore, probably titanic, are especially associated with the pyroxene. The ophitic texture is beautifully exhibited.

SEDIMENTARY ROCKS.

Sediments which have been deposited since the cessation of regional metamorphism and which are, in consequence, present in the state in which they were laid down, are of unimportant extent in this locality.

"MONROE" BEDS.

Extending for a considerable distance about Monroe, Union County, N. C., are horizontal or slightly tilted beds of fine-grained material, well stratified. They were seen by the writer only to the southwest of Monroe, and the following description applies only to that part of their area. They are considerably affected by decomposition, and colored yellowish or

[a] Geologic Atlas U. S., folio 90, U. S. Geol. Survey, 1903.

pinkish by the oxidation of the iron which they contain. Along the joint planes thin films of limonite have been deposited.

The appearance of the rock at once suggests that it is a tuff. No conclusive evidence has been found to prove this assumption. Porphyritic crystals have not been observed and the microscope shows only very minute grains of quartz and of some other mineral much obscured by limonite stain. The fact that fossils have never been found in these rocks is a negative evidence in favor of their being volcanic tuffs.

SAND.

In places along the eastern part of the territory traversed are areas covered with a clean, loose quartz sand. This is the country of the "long-leaf" or turpentine pine. This deposit is in most places known to be thin, resting on the Piedmont rocks, and is doubtless a part of the Coastal Plain formations. It is regarded by Doctor Sloan as probably of Quaternary age.

CLAY.

Comparatively small bodies of clay, like that near Grover, N. C., occur in isolated localities. They probably represent deposits, in small basins, of material derived from the decay of the other rocks.

ALLUVIUM.

Along some of the streams small flood plains have been formed. They are built up of the detrital material which the streams have been forced to deposit and consist principally of sand and gravel. These plains are, of course, the most favorable localities in which to search for placer deposits of valuable heavy minerals, such as gold, monazite, cassiterite, etc.

EFFECTS OF METAMORPHISM.

REGIONAL METAMORPHISM.

As may be gathered from a statement of the relative extent of the three great classes of rocks, this is a region characterized by the presence of metamorphic rocks. The principal effects of the agencies which caused the changes from their original to their present form have been described in the section dealing with the metamorphic rocks (pp. 14–19).

In structure the changes have been from the stratified sediments, bedded tuffs, and massive igneous rocks to the wholly crystalline and generally much foliated schists. It appears probable that these mechanical changes have not been accompanied by marked changes in chemical composition; but in some cases, as that of the quartzites, there has been pronounced silicification, while in the amphibolites some lime has doubtless been removed. The molecular or mineralogical changes, however, have been great. Feldspars have been changed to sericite or to epidote, zoisite, calcite, and a less calcic feldspar. Pyroxene has been changed to amphibole. Impure kaolin has become sericite and biotite. Garnet is a common product in many of the rocks.

CONTACT METAMORPHISM.

The changes induced in the surrounding rocks by the intrusion of igneous masses are of much less extent in this portion of the Carolinas than those produced by dynamic forces. Nevertheless the heat, pressure, solutions, and vapors caused by or accompanying the molten material have in this region had a very noticeable effect along the contacts of the igneous bodies. In most cases the structure of the original rock has not been altered, but has instead impressed itself on the new minerals developed, so that the change is a pseudomorphous replacement. In only a few instances has a new foliation been developed parallel to the contact of the intruding mass.

Unlike the effects of regional metamorphism, the results at the contact of igneous bodies have been accomplished by more or less intense chemical and consequent mineralogical changes. The nature of the intruding rock, however, has had much to do with the degree of metamorphism. The diabase dikes effect in the wall rocks very little change beyond a rather slight induration. Granite, on the other hand, has produced very pronounced changes. Little opportunity was found to examine the effects of the large granite masses, but in the case of some of the smaller dikes the results can be well studied.

In amphibolite the secondary, uralitic hornblende is generally converted into a biotite which under the microscope possesses the clear, chestnut-brown color characteristic of mica of this origin. In a few cases a lavender amphibole, related to glaucophane, accompanies this secondary biotite. It appears in long, slender prisms of amphibole outline, with cleavage not so perfect as is common in hornblende. A transverse parting is also present. The plane of the optic axes is the clinopinacoid and the maximum value of the angle $\mathfrak{c}:\dot{c}$ is 16°. It seems probable that this orientation of the axes of elasticity is somewhat variable, for most sections give a much smaller extinction angle. The character of the double refraction is positive. Pleochroism is noticeable, as follows: $\mathfrak{a}$=pale yellow to colorless, $\mathfrak{b}$=very delicate lilac, $\mathfrak{c}$=lavender; $\mathfrak{c}>\mathfrak{b}>\mathfrak{a}$. Some of the amphibolite is tinged with a border of a green, strongly pleochroic mineral, of fairly strong double refraction, which may be another amphibole intergrown with the lavender variety. Small red garnets are developed in some abundance, tourmaline and magnetite are introduced in certain cases, and not uncommonly small grains of sulphides, pyrite, pyrrhotite, and chalcopyrite, many of them intergrown, impregnate the wall rock. These changes become less prominent away from the contact, but the secondary biotite has been found more than 10 feet from the granite.

The effect on rocks other than amphibolite has not been carefully studied. The principal result seems to be the development of the brown biotite.

Pegmatite as a rule acts in a similar way to granite, except that its action is in most cases much less pronounced. In a few instances, however, tourmalinization of the immediately adjoining wall rock has been exceedingly intense. Garnets and sulphides are seldom seen at the contact of pegmatite dikes.

The metasomatic replacement effected by quartz-vein solutions in their wall rocks is in these southern deposits strikingly like that produced by contact metamorphism. This feature is dwelt on at greater length under the heading "Gold" (pp. 63–64), but it may be said at this point that tourmaline, garnet, magnetite, and sulphides characterize the wall rocks of many of the quartz veins and the resulting products are in some cases almost indistinguishable from those caused by granite or aplite dikes. Porous rocks, like the acidic volcanic tuffs, have in many places been subjected to intense silicification.

All these results of contact metamorphism bear evidence that they were produced at great depths and have been exposed only by profound erosion.

HYDROMETAMORPHISM.

Throughout the southern Piedmont region the effects of weathering are very prominent. In many places marked decomposition of the rocks has extended over 100 feet below the surface. It is believed that the physiographic history of the region has allowed this weathering to proceed to so great a depth. With the slow rate of erosion as base-level was attained and the help of those conditions which are supposed to exist at such a stage, decomposition of the rocks exceeded erosion of the products of decomposition and in consequence extended to very unusual depths. This decomposition seems to have been, except perhaps within a few feet of the surface, much more a hydration than an oxidation—a fact which probably indicates that there was sluggish circulation of the waters that caused this change. So far as they have been studied, the principal products of this hydration are kaolin and chlorite. Magnetite is oxidized to limonite near the surface and colors red or brown all the rocks which contain it. The amphibolites thus produce a very red soil, while much of the magnetite-bearing itacolumite is stained red or pink. The quartzites become friable, partly from solution of the cementing silica and partly from decomposition of the mica which helps bind the grains together. The limestones are dissolved, leaving a small amount of red residual soil at the surface. (See Pl. II.) The granites and gneisses are much less affected than the more schistose rocks, but are somewhat decomposed near the surface, the principal change being the conversion of feldspar into kaolin. Those pegmatites which are poor in feldspar are fairly resistant to decomposition, and some of them outcrop distinctly; but the feldspar-rich varieties are readily affected by weathering. In most cases where observed, the porphyritic and tuffaceous rocks have been sufficiently silicified to enable them to resist extreme decomposition. The diabase dikes very commonly outcrop in the characteristic "nigger-head" fashion, showing that the rock has not been greatly decomposed.

STRATIGRAPHY AND STRUCTURE.

The broadest features of the structure of this area and its relation to the rest of the Appalachian province have been outlined on pages 10–11. All the foliated or schistose rocks strike in a northeasterly direction, varying from N. 20° E. to N. 65° E., and dip at high angles, usually between 45° and 90°, either to the northwest or to the southeast, but probably most commonly to the northwest.

Undoubtedly the best place for studying the structure within the area described is along the Kings Mountain Range, particularly in the vicinity of Blacksburg, S. C. The stratigraphic relations are much more evident there than elsewhere and furnish the necessary key for deciphering the structure. Moreover, the intimate dependence of the distribution of the tin deposits on the structure of the Kings Mountain belt warranted the expenditure of more time on the examination of the geology of this particular locality than was possible in other places. Yet even here the study was so hasty that the writer does not feel justified in attempting to enumerate, in exact order, the formations which occur, nor to represent their respective attitudes in a sketch. The Kings Mountain belt will be first described and remaining portions of the area will be considered later.

KINGS MOUNTAIN BELT.

RELATIONS OF THE ROCKS.

The Kings Mountain Range is made up of nearly all the schistose rocks described in the preceding pages. A broad view in the field confirms the idea that many of these rocks are of sedimentary origin by revealing a stratigraphic succession characteristic of sedimentary formations. Impure quartzites, biotite and sericite schists, and partially marmorized limestones, representing original sandstones, conglomerates, shales, and limestones, are bedded with true sedimentary regularity. At the limestone quarry south of Gaffney, S. C., the limestone is seen passing upward into impure quartzite, which is exposed in typical development along a road not far to the northeast. On the west bank of Kings Creek, near the point where it enters Broad River, a quartz-rich conglomerate with a chloritic matrix is exposed. It probably represents a transition into the quartzitic beds which occur just above, capping the bluff on the eastern side of the creek. On the summit of Draytonville Mountain is a similar occurrence of much-metamorphosed conglomerate passing into quartzite.[a]

Intercalated with these several rocks are layers of iron and manganese ores and bands of graphite or graphitic schist. As might be expected, these beds are less persistent and regular than the strata which inclose them. It is believed that the iron, manganese, and graphite beds represent localized deposits in bogs or swamps, while the sandstones, shales, and limestones were deposited in much more extensive basins, possibly in the ocean itself. It should be stated here, however, that not all the iron deposits of the Kings Mountain belt are attributable to such an origin.

[a] Cf. Tuomey, M., Rept. Geol. and Agr. Survey South Carolina, 1844, p. 18; Geology of South Carolina, 1848, p. 77; and Lieber, O. M., Survey of South Carolina, vol. 2, 1858, pp. 40–42.

From evidence furnished by the structure which is described in the next section, a succession has been determined which is probably fairly correct. Beginning with the lowest member the rocks are biotite schist, limestone, biotite schist, sericite schist, conglomerate, quartzite, graphite, or graphic schist, sericite schist containing a bed of manganese ore, beds of iron ore, sericite schist. The thickness of the beds was not determined. These strata are penetrated or separated by layers of amphibolite lying in parallel position. It seems probable that part of the amphibolite represents intercalated intrusions into the sediments, while part represents interstratified deposits of basaltic tuff or flows of basalt lava. Ancient bodies of granite, now converted into a more or less foliated gneiss, are likewise intercalated with the other rocks. More recent intrusions of granite, pegmatite, and diabase have also penetrated these strata.

STRUCTURE.

The strike and dip which are most prominent in these rocks are dependent on the direction of schistosity or foliation induced by movement. But it is found that the foliation is parallel to the bedding of the rocks. There may be in some cases a slight divergence of the plane of schistosity from that of sedimentation, but such was not observed. A determination of the strike and dip of the foliation will therefore throw light on the structure and position of the sedimentary strata and hence will indicate what changes have taken place since the beds were deposited in their originally horizontal position.

A traverse across the Kings Mountain Range in the vicinity of Blacksburg shows that the ridges are composed of the hard, resistant quartzites and that the valleys between mark the position of the softer schists and the limestone. Starting near the North Carolina boundary and passing along a southeasterly line through the town of Blacksburg, the observer encounters the upturned edges of the beds enumerated above, beginning at the top. These rocks dip steeply to the northwest; in places they are nearly vertical. To the southeast from Blacksburg the same rocks are observed but in the reverse order and generally dipping very steeply to the southeast, although in some cases—for instance, the quartzite of Kings Mountain—the dip is steep to the northwest.

It is evident that the rocks are, in general, symmetrically arranged with respect to an axis which lies between the two layers of limestone.[a] While the evidence is not so conclusive as would be desirable, it seems probable that the dips on the opposite sides of this axis are, in general, away from each other. In other words, this strip of country is probably an anticlinal fold, with its axis running northeast and southwest. Blacksburg is situated just northwest of this axis. Because of their comparatively small extent, the beds of iron and manganese ore and the conglomerate do not always form continuous outcrops and are not always present on both sides of the fold. With these exceptions the repeated succession in reversed order is very distinct. Local variations in the dip between the exposures of limestone and quartzite on the southeast limb of the fold indicate that minor folding has taken place and has formed a part of the main anticline. Another deviation from exact symmetry on the two sides of the axis is the fact that the dips on the southeast are rather steeper than those on the northwest limb of the fold, with an actual reversal to northwesterly dip in some places on the southeast side. This indicates an approach toward isoclinal structure with dip to the northwest.

If the results of this folding had not been modified by erosion, a steep-sided ridge much higher than Kings Mountain or Whitaker Mountain would be present to-day. But after the folding had taken place, erosion wore away the highest parts, so that the crest of this fold has now been completely cut down. The rate of erosion has been slowest on the resistant quartzite, which therefore remains higher than the surrounding rocks. Viewed in this way it is probable that the two beds of limestone were once parts of a single, continuous, flat stratum and that the quartzite of Whitaker Mountain and of the ridge extend-

[a] Cf. Tuomey, M., Geology of South Carolina, 1848, p. 76. Only one of these limestone outcrops was seen by the writer. Old pits are said to have been made on the other limb and now to be caved in and filled.

ing southwest from Kings Mountain were similarly connected when in their original horizontal position. The schist which appears between the two limestone beds is the lowest member of the series exposed, and the schist overlying the quartzite is the highest member which can with certainty be assigned a definite geologic position.

In some places along this belt only one bed of limestone has been found; in other places three or four layers are said to occur. It may be that two strata of limestone are present; if so, four outcrops would normally occur wherever erosion has extended sufficiently deep to cut the lower stratum. If the lower stratum is barely exposed, then three bands would appear on the surface, while if erosion had cut down only to the upper bed but one band would be exposed on the surface. On the other hand, it may be that faulting parallel with the axis of the fold has caused a repetition of some of the beds by uplift or a disappearance of some by depression. However, since the limestone outcrops are generally obscured by coverings of clay and other detrital material, it is easily conceivable that outcrops actually present have never been discovered. Since limestone is the one member of the series by which the details of structure are at all readily deciphered, and since the data which it furnishes are not conclusive, it is impossible without further study to decide the direction and amount of pitch of the fold and whether or not faulting has taken place.[a] Both Tuomey[b] and Lieber[c] recognized this anticlinal structure.

The foliation of the igneous masses, the amphibolite, and the gneiss is of course parallel with that of the sedimentary rocks, since both were subject to the same forces.

Granite, pegmatite, and diabase have been intruded since the folding and foliation took place, and hence are massive and almost unchanged. The form and distribution of the granite and pegmatite bodies were largely influenced by the structure of the rocks which they invaded, and hence they are elongated masses striking with the surrounding rocks. The pegmatite of course occurs as dikes. The diabase also is in the form of dikes, but more commonly cuts across the formations than runs parallel with them.

The general trend of the Blacksburg anticline is northeasterly, but certain irregularities are worthy of mention. At Gaffney, S. C., the rocks and the axis of the fold strike about N. 45° E. From a short distance northeast of Gaffney to Kings Mountain the strike is about N. 55° E. Thence into Lincoln County the strike is about N. 20–25° E. This jog or bend in the fold near the State line corresponds on a reduced scale with the similar change of trend of the Appalachians to the northwest.

An interesting side light on the structure of this region is the behavior of the well which supplies the water for the town of Gaffney, S. C. This well, about 550 feet deep, is said to be wholly in schistose and gneissic rocks. With the exception of such minor elevations as Draytonville and Thickety mountains and slight ridges and valleys occurring here and there, the country is practically level for miles around. In spite of this fact, the well for some time after completion was of the artesian type, a steady flow of water rising several inches above the top of the pipe. This phenomenon may possibly indicate that Gaffney is located on a syncline, but is probably to be explained by some other peculiarity of structure.

OTHER PARTS OF THE AREA.

Interpretation of the structure in other portions of the area is much more difficult, principally because of the lack of distinctiveness in the formations exposed. Quartzite is known in isolated localities, as on Henry Knob and Nannies Mountain, but definite stratigraphic relations have not been found outside of the Kings Mountain Range, where the limestone is the main factor in solving the problem.

Nevertheless, it is believed that the general conclusions reached in the Kings Mountain belt may be applied to some extent to other portions of the region. It is probable that a fold so marked as the Blacksburg anticline would be accompanied by—would, in fact, be

[a] Lieber, O. M., Survey of South Carolina, vol. 3, 1859, pp. 112, 116.
[b] Rept. Geol. and Agr. Survey, South Carolina, 1844, p. 16; Geology of South Carolina, 1848, p. 99.
[c] Op. cit., vol. 1, p. 92, Pl. V. Cf. also Nitze, H. B. C., Bull. North Carolina Geol. Survey No. 1, 1893, map opp. p. 85.

only one of—many other similar folds. In regions of intense movement isoclinal or overturned folding is very common. It seems probable that almost or quite the whole of the area has been subjected to repeated folding, with axes trending in a northeasterly direction. Prevailing isoclinal folds would account for the predominant northwesterly dips, while southeasterly dips could be explained by the presence of more nearly symmetrical folds, like the Blacksburg anticline. Thrust faulting may also have taken place. Such an explanation accords with the accepted idea of structure elsewhere in the Appalachian province, where conclusions can be more safely drawn. Careful and detailed study will be required to prove the truth or falsity of this hypothesis.

At one place the structure is worthy of mention. The "Monroe" beds, southwest of Monroe, N. C., are very well bedded and in most places have only small dips. In several places cuts along a new road expose a structure illustrated in fig. 2. The beds are bent up as if by a thrust from below and are broken and crushed. The material in the crushed zone is of the same character as that of the beds. This structure resembles the products of some of Willis's [a] experiments in the folding of sediments. It is a fold-fault produced by compression, and probably results from expansion of the beds due to atmospheric alteration.

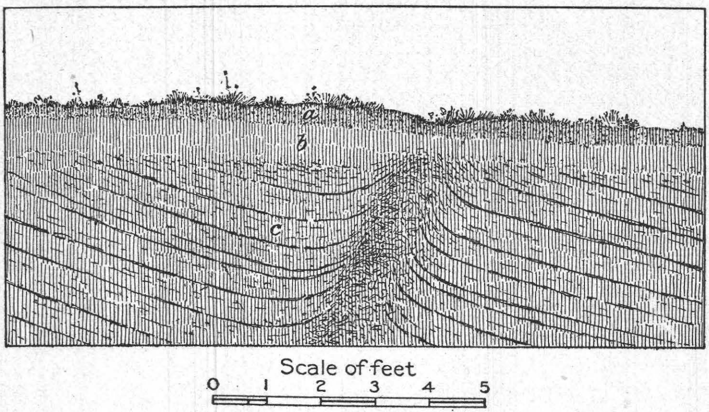


FIG. 2.—Sketch of exposure along road west of Monroe, N. C., showing disturbance of "Monroe" beds. *a*, Soil; *b*, disintegrated tuff; *c*, volcanic tuff.

AGE OF THE ROCKS.

Almost from the beginning of geologic study in this region the age of the rocks has been the subject of much investigation and speculation. The earlier workers found slight encouragement in the results of their labors, and it must be admitted that our views have advanced very little beyond theirs. It used to be supposed that practically all the ore deposits of these Southern States were contemporaneous in origin with the inclosing rocks. Attention was therefore directed principally to the metamorphic rocks, in which most of the deposits of economic value occur.

METAMORPHIC ROCKS.

From their crystalline structure and the absence of organic remains these schistose rocks were first supposed to represent part of the original crust of the earth and were called primitive or primary. Emmons [b] in his report of 1856 considered these rocks as the oldest sediments of the globe and placed them at the base of the Paleozoic, in what he called the Taconic system. On the basis of what he supposed to be fossils, he concluded that

[a] Willis, Bailey, The mechanics of Appalachian structure: Thirteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1893, Pls. LXXV, a′; LXXXII, e.
[b] Emmons, E., Geol. Rept. Midland Counties of North Carolina, 1856, pp. 41–45, 60–64.

these rocks contain the first record of life on the earth. It was later shown that the specimens which he supposed to be fossils were not of organic origin. Lieber, working in the late fifties, regarded the Kings Mountain series as Silurian.[a] Kerr [b] in 1875 placed the Kings Mountain series in the Huronian system and considered the other rocks of the area as Laurentian. Becker [c] and Nitze[d] concluded that the metamorphic rocks of the central Carolinas were of Algonkian age.

From the description of these rocks and their structure Dr. C. W. Hayes favors the view that they are Cambrian, and hence that the Blacksburg fold is a syncline—one of a series to which belong several others known in the region farther west.

Acquaintance with the rocks occurring to the northwest of this area leads Mr. Arthur Keith to believe that the schistose rocks here described belong somewhere between the beginning of the Cambrian and the end of the Carboniferous; that the metamorphism which affected them took place in or at the close of the Carboniferous, and consequently that the unfoliated igneous rocks are post-Carboniferous.

Satisfactory proof of the presence of fossils in these rocks has never been made, although the discovery of organic remains has been several times reported.[e]

It seems unlikely that the age of these rocks will ever be determined by biologic evidence, because it is doubtful if such evidence, even if it has ever been present, is preserved. It is conceivable, however, that some place in the limestone may be found where there has been so little alteration that fossils may remain and be identified.

It is far more probable that the age of the rocks will be determined only by stratigraphic methods. Extremely careful study, consisting in tracing formations and gradations in character from rocks of known age continuously up to these very rocks, will be required to reach final conclusion by lithologic or structural correlation. Any opinion based on no more definite stratigraphic relation to known rocks than has yet been found can at best be only tentative.

These metamorphic rocks are in some places on the east overlain by beds of the "Newark" system, now regarded as Triassic, showing that these rocks must have been formed and rendered schistose before Triassic time. The last intense metamorphism which affected the rocks of the eastern United States took place in the Carboniferous period. These rocks must therefore be Carboniferous or older.

Several facts point to pre-Cambrian as the probable age of these rocks. The seemingly entire absence of fossils is such an indication. So far as known to the writer, proved Paleozoic rocks in the Southern Appalachians are by no means so much metamorphosed as the schists here described. As stated by Mr. Lindgren, also (p. 120), granite is nowhere known in the South intrusive into rocks proved to be Cambrian or younger. Yet the metamorphic rocks here described are cut by granite which in many places is little or not at all foliated. In the Cranberry quadrangle, about 80 miles to the northwest, folded sediments, somewhat metamorphosed in places, and, assigned by Keith to the Cambrian, unconformably overlie gneisses, schist, and intrusive granite which appear to correspond in a general way to the rocks of the area here concerned. Keith shows that the underlying rocks were much metamorphosed previous to the deposition of the Cambrian.[f] It seems probable that the rocks of this central Carolina region belong to the same pre-Cambrian complex as those in the Cranberry district. In support of this view, the porphyritic rocks here described certainly cut some of the schists, and corresponding tuffs are interbedded with the schists. As has been stated on page 23, Keith considers the porphyries of this region similar to the volcanic

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[a] Lieber, O. M., Survey of South Carolina, vol. 3, p. 149.
[b] Kerr, W. C., Geology of North Carolina, 1875, p. 133.
[c] Becker, G. F., Gold fields of the Southern Appalachians: Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 260.
[d] Nitze, H. B. C., Bull. North Carolina Geol. Survey No. 3, 1896, p. 44.
[e] Cf. Lieber, op. cit., vol. 2, pp. 87-88; vol. 3, p. 149; Emmons, E., Geol. Rept. Midland Counties of North Carolina, 1856, pp. 60-64; Marsh, O. C., Am. Jour. Sci., 2d ser., vol. 45, 1868, p. 217.
[f] Geologic Atlas U. S., folio 90, U. S. Geol. Survey, 1903.

rocks in the Cranberry quadrangle which he considers pre-Cambrian. These porphyritic rocks have likewise been regarded as pre-Cambrian by others.[a]

From all the facts available it seems most reasonable to regard these rocks, and the metamorphism which affected them, as probably of pre-Cambrian age. While a more conclusive statement can not now be made, the writer believes that later detailed study will confirm this view.

IGNEOUS ROCKS.

The igneous rocks which are now represented by granitic gneiss and amphibolite first cut the sediments and then were metamorphosed with them. The massive granite, some of the pegmatite, and the diabase are later than the metamorphism which formed the schists and are of course older than the planation of the region, which probably took place in Tertiary time. As has been stated, Paleozoic granite is not known in the South, and the granite and pegmatite are therefore probably pre-Cambrian. It has been shown on page 20 that the granite intrusion probably marked the end of the metamorphism; and this furnishes another evidence in favor of the belief that the great movements resulting in metamorphism took place in pre-Cambrian time. The porphyries and volcanic tuffs are likewise considered to be of pre-Cambrian age, appearing probably near the close of the metamorphism.

The diabase dikes are certainly the youngest of the igneous rocks, and have certainly escaped regional metamorphism, but more definite evidence as to their age was not obtained in this area. The writer is informed by the State geologist of South Carolina, Hon. Earle Sloan, that the diabase cuts Juratrias sediments and is probably of that age.

SEDIMENTARY ROCKS.

The comparatively small amount of induration, alteration, and contortion of the sediments occurring in the vicinity of Monroe, N. C., has already been described. It is difficult to believe that these soft rocks could have been present when metamorphism of the schists took place. On the other hand, they are older than the Triassic deposits of the "Newark" system. Fossils have not yet been found in the "Monroe" beds and their age remains a matter of uncertainty. The sands of the Coastal Plain formation which are included in this area are regarded by Doctor Sloan as probably belonging to the Columbia group of the Quaternary.

ECONOMIC GEOLOGY.

In the number of its mineral species North Carolina is said to excel any other State in the Union, and a great variety of minerals has been found in South Carolina. These minerals have long been prominent among the resources of the Carolinas, and the particular area described in this report has been one of the important localities in this respect.

Mining in this general region dates back before the time of the settling of America, and early Spanish and English accounts of the discovery and recovery of metals are numerous.[b] The principal mineral resource of this Carolina area is gold. Iron has been mined to a considerable extent, and within recent years the monazite industry has attained some importance. Tin is now creating considerable excitement. Besides these materials, copper, lead, manganese, pyrite, mica, barite, corundum, clay, limestone, and granite are or have been found and worked to a greater or less extent.

TIN.

The use of tin is steadily increasing and the demand for it is constantly growing. While new localities are being discovered from time to time, and while certain of the districts already known are increasing their output, some of the important tin-producing regions of the world are on the decline and others do not give promise of long maintaining their present

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[a] Williams, G. H., Jour. Geol., vol. 2, 1894, pp. 28 et. seq. Becker, G. F., Gold fields of the Southern Appalachians: Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 260.

[b] Cf. Becker, G. F., Gold fields of the Southern Appalachians: Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, pp. 253–257.

production. The reserve stocks held in various parts of the world are accordingly being greatly depleted and the price of tin is gradually rising.

For these reasons the discovery of a new tin locality is of much interest to mining men, and to many who are more or less directly connected with the metal industry, as well as to investors. The fact that the United States consumes over 40 per cent of the world's output while contributing an inappreciable amount makes of especial interest any information regarding a tin locality within the borders of this country which gives the least promise of becoming economically important. Previous waves of excitement have arisen on several occasions, only to wane and finally die out because of the failure to demonstrate the presence of valuable tin deposits. South Dakota, Missouri, California, Virginia, and Alabama afford notable instances of this and the Carolina tin belt itself has once risen to prominence and then almost passed from memory. Within the past couple of years interest has been revived in this region and it is now attracting a good share of attention from the outside, while within the tin-bearing territory considerable excitement prevails.

It was mainly with the idea of studying these tin deposits and satisfying a demand for information concerning them that the reconnaissance of this region was undertaken. For this reason chiefly the description of the tin deposits is placed before that of the intrinsically more important product of the area, gold.

HISTORY OF TIN MINING IN THE CAROLINAS.

Tin was first mentioned in this region in 1875 by Kerr,[a] who stated that it occurred in a micaceous slate in Gaston County, associated with garnet and columnar topaz (pycnite).

The first authentic discovery of the metal was made some years later at the village of Kings Mountain, Gaston County, N. C. Mr. Robert T. Claywell, of Morganton, N. C., who is by all accredited with the first collection of specimens from this locality, communicated with the writer on this subject and the substance of his statements is here repeated. While a student at the Kings Mountain high school in 1881, Mr. Claywell found in a street of the town a number of pieces of a dark-colored mineral of noticeable specific gravity. Although he was an amateur student of mineralogy at that time, he was unable to identify this mineral. It appears that this mineral was added to a collection which he was making and remained unidentified for some time. In 1883, at the request of Col. S. McD. Tate, who was making a collection of North Carolina minerals for the American Exposition at Boston, this mineral collection, including the cassiterite, was sent to Boston. It is said by Mr. Claywell that this specimen before being sent was marked by Colonel Tate "Tin(?)."

So far as is known, the first published statement, aside from the one by Kerr, noted before, regarding tin in North Carolina, is said to have appeared in the Commercial Bulletin of Boston, October 13, 1883. In the list of minerals from North Carolina given in that issue occurred the following paragraph:

"Cassiterite, pure tin oxide. Found massive and semicrystallized in the western part of North Carolina. Sp. grav., 6.8; hardness, 7; 70 per cent tin."[b]

Mr. Hidden claims the credit of the identification of this mineral, and states that he labeled it;[c] the foregoing paragraph was obviously a copy of the label.

In an article dated February 14, 1884, Dr. C. W. Dabney, jr.,[d] stated that a specimen collected by Mr. Claywell was sent to him by Colonel Tate marked "No. —, tin?," but he does not tell when it was sent. He says, however, that he received other specimens in July 1883, which also doubtless came indirectly from Mr. Claywell, and he visited Kings Mountain and instituted some explorations for the mineral. This is evidently the first signed article dealing with the discovery of the mineral. In a recent letter Doctor Dabney states that so far as he knows he was the first to identify Mr. Claywell's mineral as cassiterite.

[a] Geology of North Carolina, 1875, p. 291.
[b] Hidden, W. E., Jour. Elisha Mitchell Sci. Soc., 1889, pt. 2, p. 66. The writer regrets that he has been unable to obtain this number of the Commercial Bulletin.
[c] Loc. cit. and personal letter to the writer.
[d] Science, vol. 3, February 22, 1884, p. 217; also Jour. Elisha Mitchell Sci. Soc., vol. 1, 1883-84, pp. 79-81.

The writer has endeavored to give here a plain statement of such facts as are available and to abstain from passing judgment on the question.

The news of the discovery of tin soon spread in Kings Mountain and throughout the country. Everyone in the town, men, women, and children, began to hunt for tin. All over the eastern part of the town they found crystals of cassiterite, which they sold as curios at 5 or 10 cents each. Early in 1885 a development company was formed by several prominent men of Kings Mountain and prospecting was begun. They read that tourmaline commonly accompanies tin, so they directed their attention to masses of tourmaline and black hornblende, which they encountered near the place where the float tin was found. Several pits were sunk and a 100-foot tunnel was driven south of the town, but no tin was found in place. The company disbanded and excitement subsided; but cassiterite crystals were still found in the streets of Kings Mountain.

In 1886 John H. Furman, a miner from Georgia, came to Kings Mountain to prospect for gold. He found bands of rock which he called "greisen," containing a black mineral supposed to be cassiterite. He took specimens of the material to Dr. A. R. Ledoux, of New York, who verified this supposition. Returning later under the direction of Ledoux, and with the assurance that the tin-bearing rock had at last been located, Furman began quietly to bond all the land which he considered promising. Prospecting was renewed on a broader scale; pits, trenches, shafts, and tunnels were started, and a considerable amount of ore was taken out for testing. At first small lots were sent to Ledoux's laboratories in New York, but it was found that samples of this kind were unreliable. Ledoux and Dr. James Douglass then came to the tin region, presumably in the interest of Phelps, Dodge & Co., of New York City. A stamp-mill test of 100 tons and returns from two carload lots of hand-picked ore shipped to England were fairly encouraging. In 1890 Furman sailed for England with specimens of ore and options on a large acreage in the hope of interesting capital there. The result of this mission is not known, but it was probably unsuccessful. An effort was next made by the Ledoux party to ascertain the extent of the ore bodies. The shafts were deepened and considerable diamond drilling was done. By these operations it was learned that the tin-bearing rocks were very irregular in extent and in their content of cassiterite, but the results were considered to justify the erection of a plant for treating the ore on the spot. A 10-stamp mill was erected about a mile and a half south of Kings Mountain station. After crushing, the ore passed through slatted sluices over burlap. Several tons of ore were tested at this plant, but the results were not gratifying, and work was stopped in the early nineties. It is said that clogging of the stamp mortars by the abundant mica of the tin-bearing rock and excessive loss of fine tin had more to do with the cessation of operations than a conclusive demonstration that the deposits were too small or of too low a grade to be profitable.

The work of this company had been directed mainly to the territory just south of the town of Kings Mountain. In the meantime other parties had been prospecting north of the town. Pits and shafts had been sunk and some machinery installed, but little or no success attended these efforts. By 1892 interest had abated, and very little work was being done.

About 1894 another company was formed, called the Kings Mountain Mineral and Development Company (Incorporated). The sum of $5,000 was raised by subscription and work was begun on Chestnut Ridge, a short distance northeast of the village of Kings Mountain. It was the intention to sink a shaft 150 feet deep and thus reach below the zone of decomposition. At a depth of 40 feet a crosscut from this shaft showed a decomposed "vein," holding considerable cassiterite, but it received no attention, since fresh rock only was being sought. Water was encountered in considerable amount, and the cost of pumping rapidly depleted the available funds, so that at a depth of 130 feet the capital was exhausted and work was stopped.

After this new failure an interval of several years witnessed only casual prospecting by M. M. Carpenter and A. R. Rudisill, of Kings Mountain, who had been connected with the enterprise almost since its beginning and who had purchased or leased considerable land along the tin belt.

Interest was revived early in 1902, when Capt. S. S. Ross, of Gaffney, S. C., found cassiterite float on his farm 1½ miles northeast of Gaffney, considerably farther southwest than tin had been known before. The tin-bearing formation was located and found to contain a promising amount of the metal. The actual shipment of a carload of concentrates to England in 1903 brought the Ross mine into prominence and served to stimulate prospecting in other parts of the region. Carpenter and Rudisill again took up prospecting and soon sold what is now the Jones mine, near Bessemer City, to the Carolinas Tin and Development Company, of Gaffney, S. C. Early in 1904 this property was again sold to the present owners, the Carolina Tin Company, of Charlottesville, Va. In June, 1904, prospecting was undertaken by agents of the American Sheet and Tin Plate Company, who obtained options on about 5,000 acres for a sum reported to have been very large. Their attention was directed chiefly to Chestnut Ridge, northeast of Kings Mountain, and the Faires mine, just southwest of the village; but their operations appear not to have been sufficiently thorough or extensive to prove very much, and after several weeks they forfeited their options. During the late summer of 1904 the Jones, Ross, and Faires mines were being worked and active prospecting was going on in the northern part of Gaston County and in Lincoln County. In the fall the Faires mine was closed.

At the present time the Ross mine is in operation and Messrs. Carpenter and Rudisill are engaged in proving up their properties in the northern part of the area.

The history thus shows that tin mining in the Carolinas has been marked by a succession of failures ever since the discovery of cassiterite in 1881. It is hoped, however, that some of the operations at present under way will open a new page in this history upon which success shall be written.

GEOLOGY OF THE TIN BELT.

LOCATION.

The Carolina tin belt, as at present explored, extends from near Gaffney, Cherokee County, S. C., across parts of Cleveland and Gaston counties, N. C., to a point about 4 miles east of Lincolnton, Lincoln County, N. C., a distance of about 35 miles. In a general way it follows the Kings Mountain Range throughout that distance.

TIN-BEARING ROCKS.

From the discovery of tin-bearing rocks by Furman in 1886 until the present day cassiterite has been found in situ in this region only in dikes of pegmatite. The "greisen" of Furman[a] and Pratt,[b] the "feldspathic shale" of Sloan,[c] and the clay or kaolin in which the cassiterite occurs at the Ross mine are all in reality pegmatite. It is probable, also, that the term "feldspathic beds" of the writers before the existence of tin was known was applied to these pegmatite dikes.

DISTRIBUTION.

The position of the tin belt and the distribution and structure of the tin-bearing rocks are intimately connected with and dependent on the general geology of the area. In a preceding section (pp. 26–28) it has been shown that the country along the Kings Mountain Range is a belt of ancient metamorphic rocks folded into an anticline, invaded later by igneous rocks such as granite, pegmatite, and diabase, and then greatly eroded. It has also been shown that the pronounced structure of the metamorphic rocks exerted a marked influence on the distribution and structure of these later intrusives. The result of this influence has been that the invading rocks occur as sheet or dike-like bodies, whose upturned

[a] Trans. N. Y. Acad. Sci., vol. 8, 1888–89, p. 137.
[b] Mineral Resources U. S. for 1903, U. S. Geol. Survey, 1904 p. 340, or p. 10 of the extract entitled "The Production of Tin."
[c] The State, Columbia, S. C., August 22, 1904, p. 2.

edges furnish elongated outcrops, generally, though not everywhere, conforming in dip and strike with the surrounding schists.

Fig. 3. indicates the distribution of pegmatite, the tin-bearing rock. Passing through the northwestern part of Gaffney, S. C., the tin belt strikes about N. 60° E. to the vicinity of Kings Mountain station, N. C., thence turns more to the north (about N. 25° E.), and continues across Gaston County and into Lincoln County, about 4 miles east of Lincolnton, N. C. It thus corresponds closely with the axis of the Blacksburg fold; but the correspondence is not exact, for at Gaffney the pegmatite dikes occur on the southeast side of the axis and hence dip to the southeast, while from Blacksburg northward they occur where the rocks dip to the northwest, indicating that the belt crosses the axis of the fold at some intervening point. The relation of pegmatite to the structure of the metamorphic

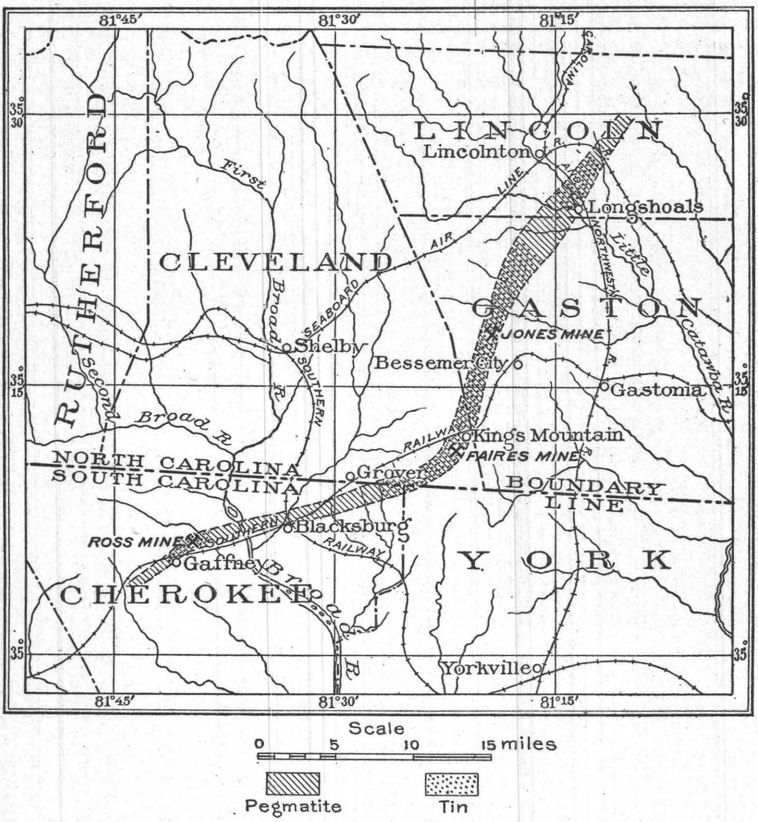

FIG. 3.—Sketch map showing distribution of pegmatite and tin in the Carolina belt.

rocks in the northern part of the area is not so readily discerned. The pegmatite belt is known to continue to the southwest beyond Gaffney and to the northeast beyond the center of Lincoln County, but authenticated discoveries of cassiterite have not been made outside of the limits mentioned. The width of this belt varies considerably; it comprises in some places a few narrow, closely spaced dikes, in others many dikes distributed over a belt as much as 2 miles wide. This maximum width is reached in the northern part of Gaston County.

STRUCTURE.

The masses of pegmatite range from numerous small streaks a few millimeters wide injected into the country rock, and collectively forming what may be considered a single body, to bands probably 30 or more feet wide. One of the wider bodies occurs about a mile southeast of Kings Mountain village.

While conveniently designated as dikes, these masses are in many cases much more irregular than the form commonly implied by that name. In strike, dip, width, and extent individual bodies exhibit great variations. Forking or branching is rather common. Many of the dikes pinch out completely, in some places being succeeded by other lenses farther along in the same plane or in a near-by, parallel plane, while in others no continuation is found. These variations take place both horizontally and vertically. For instance, a dike which has a considerable continuous extent on the surface may pinch out at a comparatively small depth, perhaps to be found again directly below or at one side, or not at all. Conversely, a dike which is short horizontally may extend downward for a long distance without interruption. On the other hand, a few dikes appear to be fairly regular and persistent so far as explored, but some of these will probably exhibit irregularities at greater distance or depth.

A few exceptions to the general rule of conformity of the pegmatite dikes to the structure of the inclosing schists are worthy of notice. Exploration has not been sufficient to admit of very extended generalizations concerning most of the features of these tin deposits, and especially is this true in regard to structure, on which conclusions can be reached in no other way than by a large amount of development. Such observations as have already been made, however, point to the conclusion that those comparatively few dikes which fail to correspond in strike and dip with the surrounding rocks, but instead cut across the structure of the schists, are fairly persistent and regular.

An explanation of the irregularities of those dikes which conform with the foliation of the country rock might be found in the supposition that faulting or shearing had divided originally continuous bodies into a number of irregular masses and lenses. But the field evidence is against such a supposition. Slight faulting since the introduction of the pegmatite has occurred in some places, and some of the pegmatite shows that it has been subjected to very moderate crushing, but no great amount of movement can have taken place. Moreover, any faulting which would affect those dikes which parallel the schistosity would also affect the cross dikes; but the cross dikes are fairly regular and can not have suffered much dislocation.

One is therefore forced to the conclusion that these pegmatite masses owe their present form to the nature of the original cavities which they filled, or at least to that of the planes along which they forced their way and ascended. It will thus be necessary to consider the character and origin of these planes in arriving at an explanation of the forms which the pegmatite bodies possess.

We have here a region of rock beds of heterogeneous composition so folded that the form of any single bed may be likened to that of a piece of corrugated iron. This folding was produced by an enormous compressive stress acting during a long interval approximately at right angles to the axes of the corrugations or folds which were produced. The fold, however, is only the end product of a complicated process. To accomplish it there had to be movement among the beds and portions of the beds. This movement was a slipping or gliding, generally parallel to the bedding planes, and is evidenced to-day by the schistosity or foliation of the rocks. That these planes along which cohesion was overcome so that movement could take place are planes of weakness is proved by the cleavability of the rock along planes parallel to the schistosity. But, as may be seen from an examination of a specimen of these schists, the planes of weakness are not uniform; some are more prominent than others, and even the most prominent ones are irregular and not continuous, but instead give way to others which then themselves become prominent as such planes of weakness.

It thus appears that the directions or the loci of greatest weakness—those places which would determine the position and the form of intrusion—are not simple planes, but are instead comprised of series of parallel planes of irregular extent, arranged more or less stepwise, in some places branching, in others overlapping, and in still others almost separated by the intervention of localities where the rock is stronger; *i. e.*, of greater cohesion between the two walls of the plane of movement.

Material forced by hydrostatic pressure from a reservoir below would follow these directions of weakness, force the walls apart, and occupy the space which it thus created for itself. Where cohesion had been entirely overcome by the original movement, the expansive force would be most effective, the intrusive material would have the greatest thickness, and the dike formed on solidification would have the greatest width. (See fig. 6, p. 50.)

The explanation of the irregular form of the pegmatite masses which conform to the schistosity of the inclosing rocks lies, therefore, in the fact that the planes along which intrusion or injection took place were themselves of irregular extent and their walls offered varying resistance to being forced apart by the invading material.

The explanation of the form of those dikes which cross the structure of the surrounding rocks is somewhat different, just as their form is different. After the rocks of this region had been folded to their present structure and the forces which caused this folding had nearly or quite subsided new forces more or less transverse to the first became active. These new forces tended to produce folds transverse to those already existing. But the resistance of this folded belt to contortion across the strike was too great to be overcome, just as corrugated iron is rigid to deformation at right angles to the corrugations. Since the stress induced by these later forces could not be relieved by folding, fracture at right angles to the direction of force took place. This fracturing was sufficient to relieve the stress and little faulting or other movement followed.

Later, when the material of the pegmatite dikes began to exert pressure on the walls of its reservoir, it found, besides those irregular places of weakness parallel to the foliation of the rocks already described, definite, sharp fractures or cracks, offering a fairly uniform resistance to the passage of a fluid and hence capable of being expanded and filled fairly evenly throughout their extent. These cross dikes are in consequence regular and persistent. In some instances relatively small branches or offshoots from the main cross dike are injected into the wall rock parallel to its schistosity. This adds to the evidence that although the cross dikes occupy fissures of later formation than those filled by the interfoliated dikes, the two classes of dikes are contemporaneous. (Compare fig. 5, p. 47, and fig. 6, p. 50.)

From these considerations the conclusion may be deduced that in the exploitation of a dike which crosses the foliation of the inclosing rock the prospector, while proceeding by those cautious methods which should always attend the early development of a mining region, may reasonably expect to find the dike continuous and possessing a fair degree of regularity. In the case of the dike parallel to the structure of the country rock, however, he must be prepared to meet great and sudden variations in its form and position; but if he explores beyond the limits of one lens he may often be rewarded by the discovery of another.

So far as known at present, faulting has not been sufficient to affect in any important degree the position or extent of these dikes.

DESCRIPTION AND MINERALOGY.

The tin-bearing rocks embrace two of the varieties of pegmatite described on pages 20–22. As was there stated, these two varieties, the third and fourth, may be simply different facies of the same rock. At any rate, it is highly probable that they do not differ greatly in composition. The general petrographic descriptions of these rocks have already been given. It will here be appropriate to consider them more in detail and in the light of ore-bearing formations.

The third or microcline variety of pegmatite was at first thought not to contain cassiterite,[a] but recent developments at the Ross mine below the zone of extreme decomposition have shown that this rock is the one which carries the cassiterite. In several places in

[a] Bull. U. S. Geol. Survey No. 260, 1905, p. 191.

that mine the pegmatite is very much like granite in appearance, and there the cassiterite is in small grains and less abundant than where the rock is coarser. Mica is not an abundant constituent, but is present locally, probably representing a transition to the fourth variety, which is in general characterized by much muscovite and little feldspar. A little hornblende has been found. On weathering this microcline pegmatite becomes very soft and clay-like, owing to the change of the feldspar into kaolin.

The fourth variety of pegmatite is much more interesting mineralogically. While consisting generally of abundant quartz and large flakes of muscovite mica, with a small amount of orthoclase, microcline, and albite or oligoclase-albite, some of it varies decidedly from such a mineralogical composition. In places it contains little mica and much feldspar. The muscovite has been called a fluoric mica,[a] but an analysis by Mr. W. T. Schaller of typical muscovite from the Jones mine gave only 0.15 per cent fluorine, which is rather below the average amount for muscovite. It is generally colorless, but yellowish or light-green colors are not unusual. Some of the flakes are several centimeters across. In some of the dikes which contain other lithium minerals the muscovite is bordered by an extremely narrow zone of lepidolite or lithia mica. In no other case has lepidolite been found.

Spodumene, the lithium-aluminum silicate, is not uncommonly present, and in some dikes, particularly those rich in feldspar, constitutes a considerable proportion of the rock. It occurs in large and small individuals devoid of crystal outline but having well-developed cleavages intersecting at 93°. It is colorless to white and in some individuals has a silky luster. Under the microscope the mineral is perfectly clear and colorless. The index of refraction is rather high. The double refraction is probably not over 0.020. Extinction is inclined to the traces of cleavage in some sections and the maximum extinction angle observed was $\mathfrak{c} : \dot{c} = 24°$. The mineral is biaxial and positive. Before the blowpipe it fuses and gives a strong flame test for lithium.

A yellowish-brown mineral occurring at the Faires mine contains lithium, manganese, phosphoric acid, and probably iron, and is undoubtedly lithiophilite. Where it has been subjected to decomposition near the surface—that is, to hydration and oxidation—it is converted into a black or brownish-black material of pitchy luster and conchoidal fracture, which contains iron, manganese, phosphoric acid, and water, and is probably a definite mineral. In close association with the lithiophilite, occupying lenses and veinlets and in one specimen, occurring between the lithiophilite and its black oxidation product, is a purple mineral which has been found to be a new species and has been named purpurite.[b] The occurrence of this mineral indicates that it is a decomposition product of lithiophilite, and its chemical composition confirms this view. It is a hydrous manganic ferric phosphate of the formula $2\,[(Mn''', Fe''')\,PO_4]\,H_2O$, and is the only known case of a manganic phosphate.

The mineral is probably orthorhombic, but crystal outline has in no case been observed. Two cleavages, presumably at right angles and pinacoidal, are of unequal perfection. The cleavage surfaces are in many grains somewhat curved, as if adjacent particles of the mineral did not possess exactly the same orientation. It has an uneven fracture and is rather brittle. Its hardness is 4–4.5 and specific gravity about 3.15. In color the mineral is a rich deep red or reddish purple, and the powder and streak have a decided purple or deep-rose color.

Although purpurite is transparent in exceedingly thin pieces, giving beautiful red colors, the ordinary thin section of the mineral allows the passage of very little light. Parallel to the cleavage the color is a deep scarlet, inclining to rose-red, while across the cleavage the absorption is greater and the color becomes a rich purple. Extinction is generally parallel; an inclination up to 3° or 4° which has been observed in a few instances has probably been due to the orientation of the sections examined. It may be, however, that the mineral is monoclinic, with a very small extinction angle. It was impossible to obtain an interference

[a] Pratt, J. H., and Sterrett, D. B., Bull. North Carolina Geol. Survey No. 19, 1904, p. 48.
[b] Graton, L. C., and Schaller, W. T., Am. Jour. Sci., 4th ser., vol. 20, 1905, pp. 146–151.

figure on the material available. If the mineral is biaxial, as is probably the case, the intersection of the cleavages is parallel to $\mathfrak{a}$. This is also the direction of least absorption. The refractive index is probably between 1.60 and 1.65. The double refraction is high, probably in the neighborhood of 0.060. Analyses by W. T. Schaller gave the following average composition for purpurite:

Average analysis of purpurite.

Fe_2O_3	15.89
Mn_2O_3	29.25
P_2O_5	47.30
H_2O at 100°	3.31
H^2O above 100°	1.95
CaO	1.48
Na_2O	.84
Li_2O	Trace.
Insoluble	.52
	100.54

It is probable that the soda and lime exist as impurities, or inclusions of foreign material, in the mineral. The lithia is doubtless a remnant of that of the lithiophilite.

Black manganese oxide, probably also derived from the decomposition of lithiophilite, is present in many places as thin botryoidal coatings on the other minerals. Some apatite occurs in narrow vein-like masses of bluish color and was at first thought to be fluorite. In isolated crystals of small size it has a bright-green color.

The cassiterite, the constituent of these rocks which is important from the economic standpoint, may better be described under the head of the ores (pp. 41–42). In thin section under the microscope it is found to include, besides tiny flakes of hematite, numerous minute dark grains which resemble black iron ore. The fact that a carefully panned sample of tin concentrates gave Doctor Hillebrand decided reactions for iron and titanium indicates that this material is ilmenite. Wolframite has been reported as accompanying the cassiterite, but careful search has failed to reveal its presence. It ought readily to be distinguished in the pan by its dark color, even in fine powder, its good cleavage, and its specific gravity, which is greater than that of cassiterite. It seems probable that the tungstic oxide reported in early analyses[a] of Carolina cassiterite may have been confused with the rarer elements columbium or tantalum, which have been found recently, although it may be that tungsten does in some cases exist as wolframite, but included within the grains of cassiterite, as is the ilmenite.

Chalcopyrite[b] and arsenopyrite,[c] or mispickel, have also been reported from the pegmatites, but it is doubtful if they occur as original constituents of these rocks.

CONTACT METAMORPHISM.

A general idea of the changes induced in the surrounding rocks by the intrusion of pegmatite has already been given. A study of this metamorphism is, of course, futile in the zone of surficial decomposition. Unfortunately, at the only place along the belt where development has extended into the unaltered rock (the Jones mine), a dike of granite or aplite is in close connection with the pegmatite. The granite is probably older than the pegmatite and the changes at its contact have certainly been more intense. Its effect has therefore partly forestalled and partly overshadowed that of the pegmatite. The development of clear brown biotite and less commonly of garnet and pyrite in the amphibolite can in some places, however, be seen to result from the action of the pegmatite.

Quartz veins closely associated with dikes of both granite and pegmatite exhibit very remarkable metasomatic alteration in the adjoining rocks. These veins vary in width from

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[a] Cf. Dabney, C. W , jr., Jour. Elisha Mitchell Sci. Soc., 1883–84, p. 81.
[b] Furman, J. H., Trans. New York Acad. Sci., vol. 8, 1889, p. 144.
[c] Ledoux, A. R., Eng. and Min. Jour., vol. 48, 1889, p. 521.

the merest stringers to several feet, and the metamorphic action of even the smallest is intense. The quartz of the veins is rather finely granular and under the microscope the grains are found to interlock in the manner characteristic of the granitic texture of igneous rocks. Small, many-sided prisms of deep-brown tourmaline occur scattered and in bunches through the quartz. In thin section the zonal structure of these crystals is readily seen. The interior is usually pleochroic in blue and violet colors, while the exterior is brown. Flattened individuals of ilmenite are in some places abundant. Sulphides, of which pyrite is most common, but including also pyrrhotite and chalcopyrite and perhaps a little arsenopyrite, are common though not abundant constituents in certain of the veins. In many instances the various sulphides are intergrown. Careful assays have shown that some of these veins carry gold. Further reference to this subject is made on pages 69–70.

The metasomatic processes which these veins have induced in their walls resemble as closely those of igneous masses as they do those of fissure veins. The formation in the country rock of garnet, brown biotite, and probably some magnetite might be attributed to contact metamorphism, while the impregnation with sulphides and quartz is more closely related to vein action. Tourmaline is common to both.

These veins are later than either the aplitic or the pegmatite dikes, and induce in them changes which are somewhat similar to those caused in amphibolite. In the granite or aplite the tourmaline has so nicely replaced feldspar[a] that it might easily be mistaken for an original constituent of the rock.

The texture and mineral constituents of these veins and their effect on their walls indicate that they were formed at great depth, and their intimate association with the granite and pegmatite shows almost beyond question that they are genetically related to those rocks.

TIN DEPOSITS.

It may be well to state at this point that the tin deposits of the Carolinas can in no way be considered veins. They are, instead, dikes of an igneous rock—pegmatite—which have solidified from an originally molten state. Placer deposits of comparatively little importance have been derived from the breaking down of these dikes.

DISTRIBUTION OF CASSITERITE IN THE DIKES.

The tin-bearing mineral is an exceedingly variable constituent of the pegmatite. Probably in the majority of cases where pegmatite has been found no cassitertite can be seen in it, and while it is possible that the mineral is generally disseminated in minute grains throughout the rock, such is probably not the case

of tin ore are usually found to be simply lens-like portions of an ore shoot that are of especial width or richness. Development has not yet been sufficiently extensive to show whether or not there is any regularity in the position of these shoots in the dikes. They have as a rule a much elongated form, measuring only a few feet along the dike at a right angle to their greatest dimension. Some of the ore bodies, however, have a considerable extent in two directions and a few of them persist as far as present explorations have gone. In general they pitch steeply, though the angle of pitch may vary in the same shoot. In some places there seems to be a tendency for the shoot to occupy the full width of the dike, while in others it is confined to one side or the other or to the middle of the dike. Fig. 4 illustrates concentration near the middle of a narrow dike.

THE ORES.

The principal tin-bearing mineral in nearly all the tin-producing regions of the world is cassiterite, the dioxide SnO_2. This is the only tin mineral known to occur in the Carolina region. It is present in the pegmatite dikes in sizes ranging from tiny grains, barely visible to the unaided eye, to individuals weighing as much as 2 pounds. The mineral is crystalline, but only rarely possesses crystallographic outline. Where crystal faces are developed they are uniformly those of the low unit pyramid. Twinning is rather common, as shown both by the form of the crystals and by the behavior of sections under the microscope. An imperfect cleavage parallel to the prism face is often observed. Owing both to this cleavage and to some peculiarity of crystal development, many individuals of cassiterite are flattened. The fracture is uneven. The mineral is extremely brittle and friable, particularly where occurring near the surface, and on this account seems in many cases much lower in the scale of hardness than its actual value of 6–7. On account of its relatively high specific gravity, 6.8 to 7.1, it is rather easily separated by panning or other means of gravity concentration from most or all of the minerals which ordinarily accompany it. The color of the Carolina cassiterite is in most cases very dark, ranging from deep brown to black. Lighter colored or even colorless varieties have been reported, but none have been seen by the writer. The brown specimens have a resinous appearance; the blacker ones show a metallic luster. The streak and the powder range in color, depending on the intensity of color of the specimen, from nearly white to chocolate brown, and are in no case black. This fact serves to distinguish cassiterite from many minerals of similar appearance which occur in and about the tin region. Owing to the presence of included impurities which can not be mechanically separated, the Carolina cassiterite falls somewhat below the theoretical content of 78.6 per cent metallic tin. Probably 74 to 75 per cent would be an average for the carefully selected material.

In thin section the cassiterite generally gives evidence of imperfect crystal form, and in some specimens the effect of twinning is shown in the outline. Twinning is parallel to the pyramidal face (1, 1, 1) and is in some individuals repeated polysynthetically. Prismatic cleavage is readily discernable in some instances, and indication of a second cleavage parallel to the pyramid has been seen. The mineral is usually deeply colored, but the distribution of the color is uneven, giving a flaky or patchy appearance. The color is probably due to the solution, in the cassiterite, of a small amount of an iron mineral, possibly hematite, since the deeper-colored varities carry most iron. Dichroism is decided. The common absorptions are ε=deep red or red-brown, ω=light yellowish brown to nearly colorless. Sometimes ε= coffee brown, ω= bluish green. The refractive index and the double refraction are characteristically high. Some minute included flakes of hematite and grains of ilmenite are visible. Partial analyses[a] of specimens of cassiterite from Kings Mountain made in 1883 indicated the presence of about 1 per cent of tungstic oxide. A qualitative analysis of concentrates from the northern part of the tin belt, made by Dr. W. F. Hillebrand, fails to show the presence of tungsten, but reveals an appreciable amount

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[a] Dabney, C. W., jr., Jour. Elisha Mitchell Sci. Soc., 1883–84, p. 81.

of columbium, with possibly some tantalum. It is probable that these rare elements wer confused with tungsten in the early analyses.

The material which is mined as tin ore consists of the pegmatite rock, with its content o cassiterite. Within the limits of the ore shoots this mineral is in general fairly evenl distributed through the rock. Pl. III, *A*, reproduces a photograph of a specimen from th Henry Carpenter property near Long Shoals, Lincoln County, and gives a good idea o the common appearance of the ore. The black spots are the cassiterite. This particula specimen is rather rich, containing probably 10 per cent of cassiterite, which correspond to about 7 per cent of metallic tin. Pl. III, *B*, is a photomicrograph of this ore. In small dike in the Faires mine near the village of Kings Mountain the cassiterite is distribute as shown in fig. 4. The dark portion is cassiterite and the larger light areas are muscovit the remainder being a finely granular mixture of quartz, muscovite, and a little feldspa In the quartz-muscovite variety of pegmatite, cassiterite seems to be more common in th mica-rich rocks than in those which contain more feldspar. Very little tin has been foun in the spodumene-bearing dikes.

Much of the ore from depths to which superficial alteration has barely extended is coate along cracks and seams with black manganese oxide, probably pyrolusite, which ha doubtless resulted from the decomposition of lithiophilite. This manganese mineral is i many places deposited on and between the foils of the muscovite. It is scattered in patche over the surface of the ore, and when viewed at some distance is easily mistaken for cas siterite. The quartz-mica pegmatite is stained somewhat brown on weathering and become more friable. The microcline pegmatite readily decomposes into a white, soft kaolin, co taining small gritty grains of quartz. In this soft matrix the cassiterite remains practicall unchanged and can easily be picked out with the fingers. Some crystals thus obtaine have a roughened surface, as if they had been slightly etched. Whether this is actuall the explanation or not is unknown.

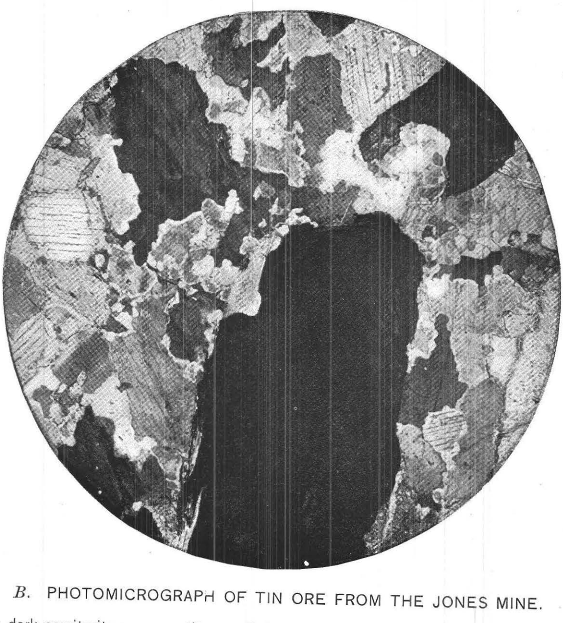
GENESIS OF THE DEPOSITS.

From the standpoint of the geologist the point which is perhaps of greatest interest co cerning the ore deposits of a region is their origin. To the miner as well this subject should b of interest, since it is of great importance. An understanding of the manner in whic the ore was formed and reached its present position is almost certain to throw light on i probable richness in unexplored places, the probability of its continuing with depth, a other vital questions which confront the mining man in the development of a new region

Throughout the world the most common occurrence of lode tin, that is, tin ore mined fro the rock in place, is in veins, which usually cut granitic rocks. These veins generally have gangue of quartz and are characterized by the presence of fluorine, boron, tungsten, lithiu and arsenic minerals associated with the cassiterite. Prominent among these minerals a topaz, fluorite, tourmaline, wolframite, scheelite, lepidolite, zinnwaldite, and arsenopyrit These materials are regarded as representing the final emanations from the granitic magma It is supposed that these comparatively rare elements are more and more segregated a concentrated as the solidification of the granite goes on, and at last, when fissures form, th are carried up in the form of vapors and solutions at high temperature and are deposited wi quartz in the veins. Although these are usually veins of filling, occupying fissures crevices, alteration and metasomatic replacement of the wall rock has in nearly all cases be considerable. The quartz of the granite has been little affected, but the feldspar and mi have been attacked, being partially converted into a mica which is usually lithia beari either lepidolite or zinnwaldite, and partially replaced by one or more of the foregoi minerals and by cassiterite. The resulting rock, composed largely of quartz and mica, designated greisen. This term can never be applied to any but an altered rock, a product this particular kind of vein metamorphism.

In contrast with this usual occurrence of tin in veins is the occurrence of cassiterite a primary or original mineral of igneous rocks, usually pegmatite. Tin has thus been fou in pegmatite in the Vegetable Creek district of New South Wales and in the Black Hills

A. SPECIMEN OF TIN-BEARING PEGMATITE.



B. PHOTOMICROGRAPH OF TIN ORE FROM THE JONES MINE.

Showing the dark cassiterite as a constituent of the quartz-mica pegmatite. Magnified 20 diameters.

South Dakota. Because of the unusualness of this mode of occurrence, tin deposits of this type have not been so thoroughly studied as the vein deposits. At many places the pegmatite dikes carry, besides the tin mineral, compounds of lithium and of phosphorus, such as spodumene, lepidolite, apatite, triphylite, and autunite. In these cases the cassiterite has crystallized along with or a little earlier than most of the other constituents. The pegmatite, being a product of solidification of molten material, is sharply defined from its walls, and in no case does the cassiterite replace portions of the country rock. On the other hand, the pegmatite produces at its contact metamorphism of the same kind as that produced by granite. Garnet is a rather common product in the wall rock; locally tourmaline is introduced and a chestnut-brown mica is developed in many places.

As in the case of the tin-bearing veins, these pegmatite dikes likewise are regarded as one of the final products from the granite magma, being succeeded only by vein formation. Like the veins, the dikes represent a concentration of those rare elements and the water which has been gradually excluded by the crystallization of the main body of the rock. In many respects, therefore, these two modes of occurrence are closely related.

Turning now to a consideration of the Carolina tin deposits, we find it evident at once that they belong to the second class, with cassiterite as an original constituent of pegmatite. In a preceding section (p. 22) it has been shown that the pegmatite dikes of this region are almost unquestionably related in origin to the granite and granitic gneiss which occur with some interruption all along the tin belt. Below the zone of surface decomposition these masses of tin-bearing rock exist in the same condition in which they originally solidified from the magma; they have suffered no alteration; they are not greisen. The effect of these dikes on the surrounding rock is characteristic not of veins but of igneous intrusions. Careful search for cassiterite in the wall rock has been made both by crushing and panning and by microscopic examination of thin sections, and in no case has tin been found, nor has it ever been reported as occurring outside of the dike proper. The absence of tourmaline, topaz, and wolframite and the extremely small amount of lithia mica in the tin-bearing rock, while, on the other hand, spodumene, lithiophilite, and apatite are present, go far in support of the view that the tin is of igneous origin. In one case a crystal of cassiterite was found adjoining a large crystal of orthoclase that is perfectly unaltered except for a slight amount of weathering. Such an occurrence would be extremely unlikely if the cassiterite had been deposited by replacement from solutions.

The unequal distribution of the cassiterite in the dikes is a subject difficult of explanation. Some combination of conditions or some process of differentiation as yet unknown has doubtless caused the segregation of tin in the ore shoots. A process of probably a similar nature has resulted in the formation of relatively large masses of quartz and of feldspar in the dikes, such as are seen in the Faires mine.

The complete cycle, beginning with granitic intrusion, followed by pegmatite intrusion, and brought to a close by vein formation, has been followed out in the Carolina region. The veins are closely associated with the pegmatites and in some cases with dikes of granite or aplite. They are quartz veins carrying pyrite, ilmenite, and in many places abundant tourmaline. Some of them, at least, carry gold. (See pp. 69–70.) Their walls also are in many places impregnated with tourmaline. They are usually parallel with and a short distance away from the pegmatite. In no place have they been found actually cutting the pegmatite, but at the Ross mine some of the pegmatite contains secondary tourmaline which was probably derived from one of these veins.

As has been previously stated (p. 40) these veins give evidence of having been formed at great depth and high temperature. It is probable that if the pegmatite had not been expelled from the magma reservoir, or had not carried all the tin with it, these veins would have received the tin of the magma, forming tin veins like those of most other tin deposits.

To summarize the origin of these tin deposits, pegmatite dikes genetically related to bodies of granite contain cassiterite as an original constituent unevenly distributed throughout their mass. The cassiterite was formed at practically the same time as the quartz, mica, feldspar, and other minerals of the dikes by crystallizing from the molten pegmatite magma.

In former descriptions of the Carolina tin deposits reference has often been made to th fact that the strike of the tin-belt, if prolonged, would just about pass through the ti locality of Rockbridge County, Va., and from this single fact some have gone as far as to stat that the two deposits are probably related. Largely with the idea of testing the correctnes of this view, the writer visited the Virginia locality. Owing to lack of time and the fact tha no work has been done at this place for a number of years, a thoroughly satisfactory idea c the deposits at the Cash mine was not obtained. But this much may be said. Cassiterit occurs there in quartz veins cutting a coarse granite. The veins are well banded and con tain, besides cassiterite, bands of pyrite and arsenopyrite. The granite walls are converte into greisen, being composed of quartz, fine scaly muscovite, and a small amount of cas siterite.

From the standpoint of mode of occurrence and genesis, therefore, the Virginia and Car lina deposits have almost nothing in common. Moreover, the geologic instead of geometr continuation of the Carolina tin belt passes far to the east of the Virginia deposits.

AGE OF THE DEPOSITS.

Since the granite and pegmatite are considered to be of pre-Cambrian age, the tin deposi are likewise pre-Cambrian. They have therefore been subjected to the various agencies disintegration and decomposition through an enormous length of time.

PLACERS.

The first cassiterite discovered in the Carolina region occurred as loose pieces unattach to any rock in place, and during the first five years that the existence of tin was know nothing but this float tin was found. Since the discovery of cassiterite in the rock in pla nearly all prospecting and primary development work has been guided by the occurren of pieces of float. In a few places, as at the Ross mine and the Jones mine, the amount cassiterite scattered through the soil has been sufficient to encourage efforts for its recover and a comparatively small return has been obtained. A little panning has been done the beds and flood plains of some of the streams, but the results have not been promisi

All this float or placer tin is directly traceable to the original deposits in dikes. As t rocks are decomposed and disintegrated, the cassiterite of the dikes, being very resista to alteration, is freed from the rock and on removal of the other materials is left behi because of its high specific gravity, being in this way gradually concentrated.

It is known that since the formation of the tin deposits this region has been subjected extreme degradation. All the phenomena of intrusion, contact metamorphism, and ve formation which have here been observed point to the fact that these porcesses went under great pressure and therefore far below what was then the surface. The physiograp evidence in the planation of this much-folded region is in the same direction. It t appears that extensive portions of the tin-bearing dikes have been removed. Mu cassiterite must thus have been liberated from the rock and remained close to the origi ore bodies as placer deposits. It is probable that more thorough prospecting of stre gravels along the tin belt will result in the discovery of small amounts of the mineral; such search as has been conducted leads one not to expect the presence of extensive plac The question then arises as to what has become of the large amount of tin which must h resulted from the disintegration and degradation of the tin-bearing rocks. It is belie that the answer to this question lies mainly in the fact that the cassiterite has been solved and thus carried away.

While from the customary standpoint of the laboratory chemist cassiterite is pronoun insoluble, it nevertheless does dissolve very slowly, even in pure water.[a] The oft-ci case of pseudomorphic replacement by cassiterite of the material of deer horns [b] sh that in a comparatively short interval of geologic time marked solution will take place.

[a] Doelter, C., Tschermaks Min. u. petrogr. Mittheilungen, vol. 11, p. 325.
[b] Collins, J. H., Trans. Roy. Geog. Soc. Cornwall, vol. 10, pp. 98–100.

eems probable that, subjected to the action of solutions during long geologic ages, the assiterite may have been in great part dissolved and carried away in the streams. It is ot unlikely that the peculiar conditions existing when the country was reduced almost to ase-level had much to do with this result. The streams, then being sluggish, could dis-olve greater amounts of chemical substances and thus become more powerful reagents han under ordinary conditions, and it is easily conceivable that under these circumstances he cassiterite was dissolved at a comparatively rapid rate.

It has been sought to test this hypothesis by examination of individuals of cassiterite the upper part of deeply decomposed dikes to see if they have suffered any etching or olution. The almost complete absence of smooth crystal faces and the uneven but not ery rough surfaces of the grains have made it impossible to decide this question with rtainty, but it seems probable that some solution has taken place.[a] The increased fria-ility of the mineral near the surface may be some indication of solution along cleavages minute cracks. Furthermore, this very friability may have aided in the removal of the n, both by exposing greater surfaces and in this way hastening solution and by subjecting e larger grains to comminution under moderate impact and thus allowing stream trans-ortation of the fine particles.

According to this explanation the float tin which has been found must be of comparatively cent derivation. Such seems certainly to be the case. No cassiterite is known at any eat distance from deposits in place, and that which has been found is usually rough and gular, often found adhering to pieces of the pegmatite rock, indicating that it has been ansported only a short distance, and that little decomposition has taken place.

In spite of these conclusions, more systematic and extended search for stream tin is vocated. Prospecting by means of the pan is so easily and cheaply accomplished, and nning of tin from placer deposits is so much less expensive than from veins, that a moder-e expenditure in search of such deposits seems to be worth the risk.

CONCLUSIONS.

From the foregoing remarks on the placers and the genesis of the ore, it is possible to aw certain conclusions which may be of interest and value to those engaged in the exploi-ion of these deposits. It has been shown that the present surface is, relative to the rocks, below the surface existing when the pegmatite intrusions occurred and hence exposes rtions of the ore bodies which were formed only at great depth. In other words, the osition of the ore now found is in no way related to the present surface and probably s only remotely connected with the original surface. No solution of the tin from upper rts of the deposits and redeposition in lower parts—the phenomenon known as secondary ichment—has taken place. The igneous origin of the ore and the fact that the deposits w known were themselves deep seated unite with the foregoing facts to establish the diction that the deposits will probably maintain their present characters and richness ond the depth to which economic mining is now possible.

MINING DEVELOPMENTS.

LOCALITIES.

condensed account of early development operations in the Carolina tin belt has been en in the section devoted to history (pp. 32–34). Time was not available for a careful mination throughout the tin belt and attention was directed chiefly to those places re a considerable amount of development work has been done. For the sake of com-eness, however, a list of properties on which tin is known to have been found is given . A more extended account of some of these occurrences is given in Pratt and Ster-'s bulletin on the Carolina tin deposits.[b] Prospecting has been rewarded by the discovery assiterite float at the localities or on the properties of the persons named in the following

[a] Cf. p. 42.
[b] Bull. North Carolina Geol. Survey No. 19, 1904, pp. 22–30.

list, beginning at the southwest: Capt. S. S. Ross, B. O. Jenkins, R. Patterson, Eph. Jackson, John Kester, V. Hambright, George Patterson, Dr. J. G. Horde, J. M. Smith, W. O. Ware, E. C. Faires, I. B. Falls, Mrs. Lizzie Falls, the streets and lots of Kings Mountain, Carpenter and Rudisill, J. J. Ormond, Arrowwood Brothers, R. A. White, M. V. Hovis, Ramseur Mill tract, John E. Jones, Mr. Weaver, Charles Byers, A. J. Rayfield, Sylvanus Beam, William Broom, William Carpenter, Sam Gardner, Katherine Vickers, Philip and Christy Jenkins, Norah Rayfield, John Carpenter, Eli Mosteller, Henry Carpenter, Monroe Reep, and Eph. Carpenter. A break in the general continuity of known localities occurs between the Ross property near Gaffney and the B. O. Jenkins place, about 1½ miles north-east of Grover, a distance of about 12 miles, although, as reported, a fragment of cassit-erite has been found in pegmatite on the place of William Martin, about 3½ miles northwest o Blacksburg, near the State line. Another break about 3 miles long occurs just south o Little Catawba River in the northern part of Gaston County. Pegmatite is found all along these intervals, however, and further search may reveal the presence of cassiterite.

DESCRIPTION OF MINES AND PROSPECTS.

Recent operations of anything more than a preliminary character have been carried on a only three places. These are the Jones, Faires, and Ross mines. Considerable prospectin in the way of trenches and pits has been done by Messrs. Carpenter and Rudisill in th northern part of the belt.[a]

JONES MINE.

The property known as the Jones mine, which was a part of the John E. Jones planta tion, is situated about 7 miles north-northeast of Kings Mountain and about 3 miles north west of Bessemer City, stations on the Southern Railway. The mine is owned and ope ated by the Carolina Tin Company, of Charlottesville, Va. Some work was done at thi place before the recent activity in tin mining, and several shallow workings have bee encountered, which probably date back to 1892 or 1893. In 1903 development was begu by the Carolinas Tin and Development Company, which held the property under optio Early in 1904 it was sold to the present owners, who have done the greater part of the work About a carload of concentrates has been obtained from the ore thus far mined and mille and one small trial shipment has been made.

The surface developments include a shaft house, boiler, and hoist. A mill for the extra tion of the cassiterite from the ore has also been erected. The workings consist of a vert cal shaft 175 feet deep, with levels at depths of 50, 100, and 150 feet, aggregating, perhap 500 feet of underground development. The 50-foot level connects with the bottom of shaft a short distance to the east of the main shaft. A few hundred feet to the south a a shallow pit and short drift.

The country rock of this mine is the typical amphibolite of the region and has a foliati which strikes about N. 30° E. and dips about 50° to 60° NW. Cutting this amphiboli is a dike of granite or aplite 2 or 3 feet wide and irregular, like the interfoliated bodies pegmatite. Two dikes of pegmatite are also intruded into the amphibolite. One, parall to the foliation, lies near and southeast of the granite dike. The other, which has bee traced on the surface for 1,000 feet, cuts across the structure of the country, striking 78° W. and dipping very steeply to the south. It is not yet definitely known wheth these two dikes unite or whether one cuts the other, but there is reason to believe that th are of the same age and do unite. While the evidence is not wholly satisfactory, the cro dike of pegmatite appears to cut the granite dike. This aplite or granite produces met morphism at its contact like that described in detail on pages 24 and 25. The pegmati also alters the adjoining amphibolite. Close to the aplite a narrow veinlet of quartz, whi carries a small amount of gold, impregnates the surrounding rocks with tourmaline, garn

[a] The writer has recently been informed that active work, attended with gratifying results, is bei carried on in this northern part of the district; and that considerable development work is bei done by a new company just north of the village of Kings Mountain.

ınd magnetite. There are present, then, in this mine representatives of the three stages of the intrusion of granite. On this account, as well as for the reason that the workings have reached below the zone of superficial alteration, the Jones mine is the most interesting and instructive place in the entire belt for the study of the tin deposits.

The pegmatite of the Jones mine is the quartz-muscovite variety, in general coarse grained, but in certain places rather finely granular. The mica is usually a prominent constituent. Both dikes contain cassiterite. A shallow pit and short drift on the interfoliated or inclined dike exposes a narrow shoot of ore pitching not very steeply to the northeast, so that it passes below the drift.

The principal workings are on the cross dike. The main shaft begins on the dike, but at some depth the dike bends to the south and the dike passes into the foot wall. It is estimated that the bottom of the shaft is at least 20 feet distant from the dike.

Although varying in width from a few inches to 4 feet, and having a strike and dip which are not exactly constant, this dike is regular as compared with the majority of pegmatite bodies of the region. Fig. 5 gives an indication of the structure of this dike. Little narrow offshoots are injected into the country rock parallel to its foliation. Slickensides are seen in places along the walls. An ore shoot was encountered on the surface and was prospected by means of a 40-foot shaft. The ore body was found to pitch to the west, so a

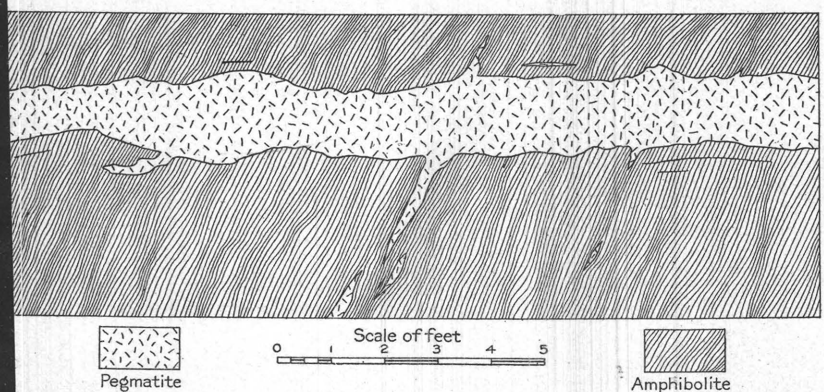


FIG. 5.—Diagrammatic plan showing structure of cross dike of pegmatite, Jones mine, 50-foot level.

drift was run westward from the bottom of the shaft. The main shaft was then begun still farther west. From a point about 50 feet below the surface and perhaps 50 feet east of the main shaft a stope has been made slanting upward and eastward to the surface. The horizontal extent of this stope along the strike of the level varies from 20 to over 50 feet. It is probably somewhat greater in this dimension than the ore body on which it is driven. A sublevel at a depth of 60 feet and the main 100-foot level disclose the dike, with the ore shoot still pitching westward. At the 100-foot level the dike is about 8 feet south of the shaft. A drift westward from the shaft is 45 feet long and is in the ore shoot, whose western limit has probably not yet been reached. On this level the cassiterite is present in smaller grains than usual, and more care is required in following the ore body than where the large dark "crystals" show plainly by candlelight. At the 150-foot level a crosscut to the south finds the dike much broken up. It appears here almost as if what has been cut is not the cross dike, but the interfoliated dike, which has been opened at the surface to the south. There seem to be irregular, lens-like bodies of pegmatite in the schist, and these carry some cassiterite. Some more crosscutting failed to find the regular dike as followed in the workings above, and, since very soft, caving ground was encountered, work was suspended in the bottom. It has been learned since the writer's visit that on the 60-foot level, 50 feet west of the shaft, a northeast dike, doubtless corresponding to the northeast dike known on the surface, was struck. The same dike was cut again on the 100-foot level, 75 feet west of the shaft, indicating a dip to the northwest, which also corresponds with the interfoliated dike. Here at the 100-foot level it would seem from the descriptions that the two dikes of pegmatite unite. It is not known how much cassiterite was present in the pegmatite encountered in this last work. Operations at the mine were stopped in the summer of 1905. Water was first encountered at 45 feet and has necessitated vigorous pumping since the shaft reached the depth of 65 feet.

The cassiterite occurs in the decomposed kaolin, mixed with mica near the surface, but at greater depth the ore becomes hard and fresh. Some of the fresh ore is comparatively rich, carrying, probably, over 10 per cent of metallic tin. The average of all the pegmatite broken in the mine is said to have been about 0.7 per cent metal. In joints in the fresh amphibolite little scales of yellowish sulphide with radial structure were found. It had been suggested that this might be a tin-bearing sulphide, but it proved to be simply pyrite. It may be that there is some connection between the ore shoot and the intersection or junction of the two pegmatite dikes. No relation was observed, except that the pitch of the two seems to be the same. The junction of the two dikes is apparently west of the ore shoot.

A little placer tin has been obtained in and near the small stream just east of the mine

FAIRES MINE.

The Faires mine is located on the property of Mr. E. C. Faires, about 1 mile southwest o Kings Mountain station. The Carolinas Tin and Development Company, of Gaffney, S. C. holds an option on it. Some work was done during the summer of 1904, but operations were suspended in the autumn. Besides numerous pits, the workings consist of a shaft 4 feet deep and about 200 feet of drifts and crosscuts at its bottom. Hoisting is done b means of a windlass and bucket.

The country rock here is a dark-colored schist, which is probably amphibolite, althoug decomposition has been so great that a final decision can not be reached. A few hundre feet east of the shaft is a prominent outcrop of quartzite. These rocks strike N. 20° to 30 E., and dip steeply to the northwest. Interfoliated with or cutting at low angles across th schist are several dikes of pegmatite. One of the largest dikes seen in the region occur not far west of the shaft, where it outcrops conspicuously and can be traced for a considerabl distance. Its actual width is not shown, but may be 20 or 30 feet. The step-like outcro of this dike affords a good illustration of the irregularity of these deposits. Faulting i suggested, but the true explanation is probably found in the presence of several near-b overlapping or en échelon lenses. A short distance east of the shaft are the croppings of quartz-tourmaline vein.

The pegmatite of the Faires mine is the quartz-mica variety, but in most places contai more feldspar than that of the Jones mine. The large dike above mentioned contains co siderable spodumene and small green apatite crystals along with albite, quartz, and musc vite. The smaller dikes contain no spodumene so far as known, but rather more feldspa Muscovite mica is abundant in nearly all the dikes. A considerable quantity of float tin h been found upon the surface in the vicinity of one of the narrower dikes. A rather perfe double pyramid, weighing about three-fourths of a pound, was found in 1904, and a lum part of a single individual, without crystal faces, was later found near by. It weighs abo $1\frac{1}{2}$ pounds.

A pit where the float was most abundant exposed a dike of pegmatite about 3 feet wid This dike strikes about N. 30° E. and dips steeply northwestward, being consequently near or quite parallel to the foliation of the schist. The dike appears not to be continuous, but be made up of narrow sections which pitch steeply to the northeast, and are separated by thin mass of foreign matter, presumably decomposed schist. This division into strips m be due to the faulting which in the underground workings is seen to have taken place. O of these sections exposed by the pit contains a promising proportion of cassiterite, es mated at 10 per cent.

The shaft was started just east of the outcrops of this dike. At its bottom, 40 feet bel the surface, a crosscut about 40 feet north-northwest cuts what is probably the same dik

Along this crosscut are seen several unimportant faults, probably of small throw. As the dike is approached the schist contains many narrow white streaks, a few millimeters wide, which prove to be decomposed dikelets of pegmatite injected parallel to the foliation of the schist. At the crosscut the dike is about 3 feet wide, but broadens along the drift to the northeast, and soon reaches a width of 13 feet. This is known as the west dike. A crosscut 21 feet east from the bottom of the shaft discloses another dike of pegmatite, 3 feet wide, nearly vertical, and striking about N. 5° E. This is called the east dike. A drift which follows it northward for about 55 feet shows that it widens to about 12 feet. At the north end of the drift the dike appears to be pinching out and pitching downward toward the north. At this poin a crosscut from the east to the west dike shows that they are 33 feet apart. A continuation of the northeast drift on the west dike discloses what appears to be the junction of the two dikes, but work was abandoned before this point was settled.

All the pegmatite seen underground is much decomposed. The feldspar and mica apparently both alter to kaolin and silica, causing the dikes to be soft and easily worked. The east dike contains several large masses of this mixture of kaolin and silica which represents feldspar. Remains of the feldspar cleavage are preserved in many places and show that some of the individuals were large, reaching a breadth of several centimeters. These masses were probably segregations of feldspar. They are balanced by lense-like masses of quartz, many of which are more than a foot in length and some of which reach a foot in width. This was apparently a very coarse-grained portion of the dike. The west dike contains many small black particles readily mistaken for cassiterite, but they are soft and can be easily crushed to a dark-brown powder. They are undoubtedly the alteration product of lithiophilite. Purpurite (see p. 38) is associated with the black material in some places.

Cassiterite is present in grains of small size sparingly scattered through portions of the west dike. Larger and more abundant particles of the mineral were found near the northeast end of the drift on the west dike. This richer portion appears to be a shoot pitching not very steeply to the northeast. It is probable that this is the continuation of the shoot exposed on the surface near the shaft. The percentage of cassiterite, even in the shoot, however, was not considered sufficient to warrant further expenditure, so operations were suspended. Water was never encountered in this mine.

To the south and southwest of the shaft several pits have reached pegmatite dikes. Some of these contain such a percentage of tin as to appear worthy of further development.

ROSS MINE.

This mine, located on the property of Capt. S. S. Ross, is about 1½ miles northeast of Gaffney, S. C. It is at present being worked by the owner. Fragments of cassiterite were discovered in the soil early in 1902. Search showed a considerable quantity present on the slope toward a small stream which crosses the property. Considerable of the soil on this slope was sluiced and much of the cassiterite saved. As progress was made southward up the slope tin ore was found in place in compact reddish clay, which changed to white a short distance below the surface. This clay proved to be the decomposed outcrop of a tin-bearing pegmatite dike and attention was then directed to the deposit. A trench showed the course of the dike to be N. 48° E. and its dip 60° to 65° SE. An incline pitching at a low angle was run southward for 135 feet. About 25 feet south of the projection of the bottom of this incline a vertical shaft was sunk on the hanging-wall side of the dike. This shaft cuts the dike at about 100 feet below the surface. At a depth of 75 feet a crosscut west from the shaft reaches the dike in 30 feet, and drifts about 30 feet long have been run along the dike in each direction. Sinking of the shaft is now being continued. The surface developments include a shaft house, two large boilers, and a steam hoist recently installed. A near-by stream has been dammed to furnish a sufficient quantity of water for washing and sluicing the ore.

The country rock of this mine is amphibolite. Decomposition has extended below the present workings, but the true character of the rock can readily be discerned from the freshest rock in the bottom of the shaft. In the bed of the stream to the north also fairly fresh amphibolite is exposed. A number of interfoliated pegmatite dikes are seen at the creek. They are narrow, usually not over a foot in width, and suggest simultaneous injection along planes of greatest weakness. This pegmatite is of the quartz-microcline variety, with only scattered small masses of compact muscovite. Near the bottom of the shaft the pegmatite becomes granitic in appearance.

So far as known the dikes contain no tin where exposed at the creek. It is not even certain that they are the continuation of the dike on which the workings are situated, but such is probably the case. The incline followed a southwestward-pitching ore shoot until the ground became so soft that the workings could not be maintained. Much of this ore was very rich, consisting of soft kaolin and a little quartz surrounding large and small masses of cassiterite. Groups of imperfect crystals and large irregular masses, some of which weighed as much as 100 pounds, were encountered. The drift from the 75-foot level of the shaft is on the extension of this ore shoot. Here the percentage of tin is probably less, but the distribution is more even, rich pockets giving way to disseminated grains from the size of a walnut down. Near the end of the drift to the southwest the shoot passes below the floor of the level. The dike where cut by the shaft, at about 100 feet, consists of a series of apparently disconnected lenses, many of them overlapping, which contain a little cassiterite in small grains. (See fig. 6.) It is the intention to sink the shaft somewhat farther and then to turn a level southward in the hope of picking up the continuation of the ore shoot encountered in the workings above.

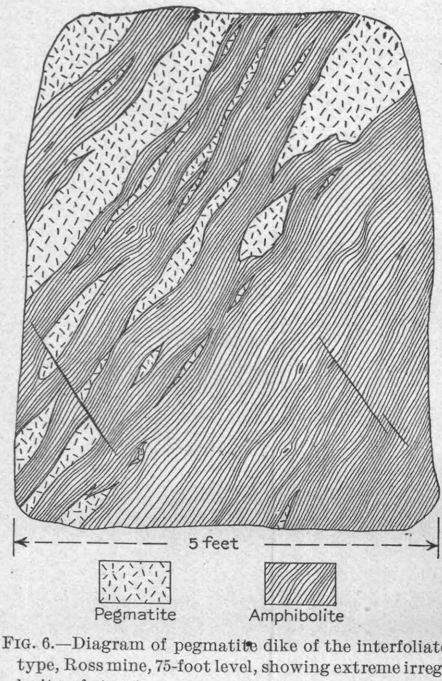


FIG. 6.—Diagram of pegmatite dike of the interfoliated type, Ross mine, 75-foot level, showing extreme irregularity of structure.

It is almost certain that the float tin found in the soil on the slope below the shaft was derived from the upper continuation of this ore shoot above the present surface. Its low angle of pitch would on degradation allow the liberated fragments of cassiterite to cover a considerable horizontal strip with but little lateral transportation. It is doubtful if the quantity of float tin found will be very great. In fact, it seems probable that the greater part has already been removed.

It is difficult to estimate the percentage of tin in the ore because of the variable content of cassiterite in different parts of the dike and the ore shoot. A 100-pound sample across the dike at the ore shoot on the 75-foot level was washed and gave 9 pounds of cassiterite, or about 6.5 per cent metallic tin. This is probably somewhat better than the ore shoot will average. Outside of the ore shoot the quantity of cassiterite in the dike is very small.

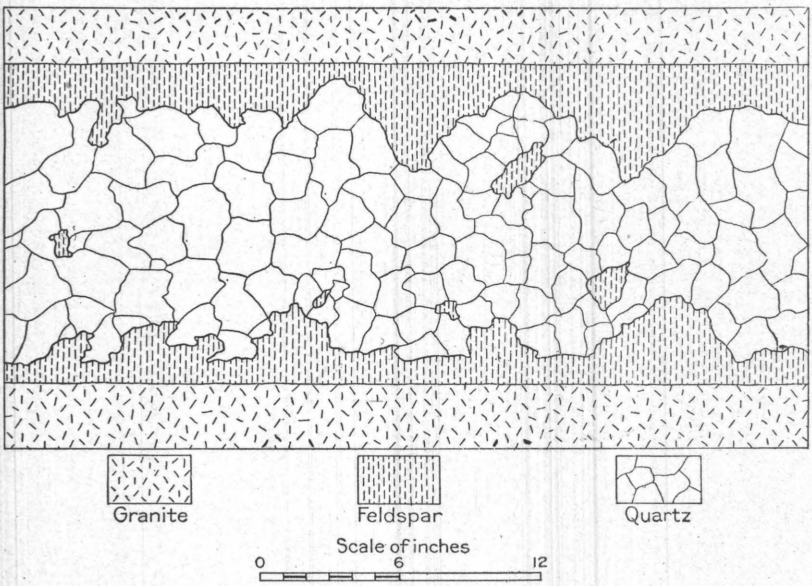
Water has been a troublesome factor in the sinking of the shaft and pumping is continued day and night.

One carload of nearly 20 tons of concentrates was shipped to England from the Ross mine in 1903. Another carload, bringing the total shipment to about 75,000 pounds, was sent out in 1904. Several thousand pounds are now on hand ready for shipment. The average content of these concentrates was about 66 per cent metallic tin.

OTHER PORTIONS OF THE BELT.

Considerable prospecting was done in the northern part of the area by Messrs. Carpenter and Rudisill in 1904. This work consisted in the excavation of trenches and shallow pits where the presence of float gave promise of tin in place. The results have been particularly successful, for in nearly every case they have located a dike carrying tin. On the place of William Carpenter, about 11 miles N. 20° E. of the town of Kings Mountain, the relation of the pegmatite to the gneissic granite is well shown. Here, particularly, spodumene is a prominent constituent of the dikes. A shallow pit on a dike just beyond the limit of the granite shows the pegmatite to contain more mica and cassiterite where it cuts the schist, probably amphibolite, than where it cuts the granite. A dike composed almost wholly of quartz and feldspar cuts the granite at this place. Its interesting internal structure is shown in fig. 7.

On property owned by Henry Carpenter, about 1½ miles northeast of Long Shoals, a pit exposes an irregular dike of pegmatite about 6 feet wide, striking N. 25° E. The normal



'IG. 7.—Sketch of pegmatite dike, showing internal structure. On property of William Carpenter, Gaston County.

uartz-mica pegmatite with some feldspar occurs on both sides and in the center is a band f quartz-feldspar rock of coarse grain. It is probably an illustration of the aqueo-igneous r veinlike character of pegmatite. The outer portions of this dike carry abundant cas-terite, probably 10 per cent or more. The specimen illustrated in Pl. III, *A*, p. 42, is 'om this locality.

About a mile farther northeast a number of pits have been put down on property belong-ig to Ephraim Carpenter. Together with natural exposures by streams, these workings iow the existence of what is probably a single continuous dike for nearly half a mile. The ineral course of the dike is N. 20° E. and the dip is about 80° W. The slight curvature f the line of outcrop is probably no more than is accounted for by the inclination of the dike id the contour of the surface. The dike is 5 to 8 feet wide, and in all the pits shows an nount of tin which ought to make working profitable. Whether this is an indication that e whole dike carries considerable cassiterite or whether the pits, located where the float as richest, struck an ore shoot in each case is impossible to decide without further develop-ent. The possibility that the dike contains an ore shoot conforming with the surface is so slight as hardly to deserve mention. The exposure at one of the streams, which is of course a fairer test than the pits, seems to show the dikes with less cassiterite and hence to indicate the unequal distribution of tin in the dike. In any event, this is one of the most promising prospects in the whole belt.

Numerous other less prominent prospects have been opened in the northern part of the tin region. The Piedmont Tin Mining Company, of Kings Mountain, N. C., has recently been incorporated to develop the promising properties in Lincoln County.

PLACERS.

As may be inferred, the importance of placer deposits in this region is very slight. Some little tin has been won from the soil immediately adjoining and surrounding the tin-bearing dikes at the Ross and the Jones mines, and a small quantity was obtained in the early days in the vicinity of Kings Mountain, but with these exceptions nothing of value has been found and little may be expected from this source.

METHODS OF MINING AND EXTRACTION.

MINING.

Where the rocks have withstood decomposition and are hard, the method of mining is similar to that employed in nearly all kinds of mining where the body to be extracted is narrow, inclined, and more or less tabular. Drilling is, up to the present time, done by hand. Such stoping as has been done has been mostly overhand stoping. Of the several shafts in the district, one is a very flat incline and the others are vertical. Little timbering is needed below the zone of surface decomposition. Near the surface the rocks are usually so decomposed that much timbering and constant attention are required to keep the ground in shape. Where water is plentiful, the walls run in like quicksand. Above the water level drifts can usually be run along the dikes by means of the pick, with only occasional blasting.

Since the present surface is in no way related to the origin of these deposits, a horizontal section of the dike is practically of as great instructive value as a vertical section. In other words, a surface trench 100 feet long reveals about as much as a shaft 100 feet deep. The trench has the advantages of being more expeditious and of much lower cost and of affording greater certainty in following the ore-bearing formation. In general, surface exploration in the way of pits and trenches should first be undertaken. If promising results are thus obtained—to be specific, if an ore shoot is thus exposed—a pit should be sunk upon it so that an idea of its extent, pitch, and richness may be obtained. Then, if the indications warrant, a shaft may be sunk to intercept the ore shoot at a desirable depth, it being borne in mind, however, that the dike and the ore shoot are liable to change direction or to pinch out before such a point is reached. In many respects an inclined shaft following the ore shoot would be the most effective means of development; but the possibility of change in direction of the ore shoot—necessitating either that the shaft be crooked, which is undesirable and uneconomical, or that the ore shoot be left, in which case an incline is less desirable than a vertical shaft—is so great that the risk is probably not justified.

By whatever method the mine is opened, the essential feature of development should be the following of the ore shoots.

TESTS FOR CASSITERITE.

Because of the dark color and metallic luster of the cassiterite from this region, numerous dark heavy minerals found along or near the tin belt have been mistaken for it. Of these the iron ores ilmenite and magnetite are most common. It may therefore be of use to note here one or two simple tests for cassiterite.

Magnetite can, of course, be identified by its attraction to a common magnet. Some ilmenite is also feebly magnetic and can be detected in the same way. If the material is not magnetic, the following test is in many cases of great service. The color of powdered cassiterite ranges from white to brown, but is never black. If a small piece of the mineral is question is ground to a very fine powder between two clean pieces of steel (the face of a hammer and a shovel will serve), it may generally be safely rejected as not containing tin if the powder is black. If brown or still lighter in color, recourse may be had to the blowpipe test, which is applied as follows: So much of the finely ground material as can be piled on an area one-fourth inch square is added to twice its bulk of powdered charcoal and to three times its bulk of pulverized sodium carbonate, or ordinary washing soda. These three substances are thoroughly mixed and then transferred to a little depression in a stick of charcoal, where they are moistened to a thick paste. The flame of an alcohol lamp is then directed upon them with a blowpipe, care being taken to envelop in the flame as much of the material as possible and at the same time to produce an intense heat. If the operation is properly carried out, the presence of tin will be indicated by the appearance of small globules, which seem darker or less highly heated than the surrounding material. By continued heating numbers of these particles can be made to coalesce into a bead of appreciable size. The formation of such metallic beads or globules is not, however, a proof of tin, but may be due to the presence of any one of a group of metals of which tin is a member. On being removed from the flame the globules often become oxidized on the surface and covered with a white layer which masks their metallic character; but if the melted mass is crushed after cooling the flattened pieces of metal may readily be observed. If a white insoluble residue results when the metallic beads are treated with concentrated nitric acid, it may be considered that tin is present.

EXTRACTION.

The typical tin ore of this region—that is, the unaltered pegmatite containing tin—must be crushed to obtain the tin mineral. Ledoux tried stamping, and erected a 10-stamp mill for his operations. He was met by two difficulties, however. The large foils of mica, being tough and elastic, resisted comminution and gave trouble by clogging up the screens and the mortars, and the heavy impact of the stamps served to crush the brittle cassiterite so fine that much of it could not be saved in the subsequent concentration operations. Since that time stamping has not been attempted.

The equipment of the Jones mill is supposed to be sufficient to handle 100 tons of ordinary material per day. Besides boiler and engine, the machinery consists of a jaw crusher, rolls, elevators, screens, a pair of mechanical two-compartment jigs, and a Bartlett table. The arrangement appears well adapted for economical handling.

Coming from the mine the ore passes through the crusher and goes to a revolving screen, where it is divided into eighth-inch and half-inch sizes. The smaller size goes to the concentrating table and the larger goes to the jigs, while the oversize goes to the rolls and then again through the screen. Considerable trouble has been experienced with the crushing machinery. The mica binds the rock together and makes it tough and springy, so that the crusher is continually being choked. When a stream of water is directed into the crusher the difficulty is slightly lessened, but clogging can be prevented only by frequent prodding with a bar. It is probable that the harder ore now being reached in the lower part of the mine will give less annoyance. The rolls are also subject to the same difficulties, but by the use of an abundance of water they can be kept ahead of the crusher. It is thought by Mr. Seamon, president and general manager of the company, that sluicing of the ore as it comes from the mine will remove a large amount of the mica and thus increase the capacity of the crushing machinery. This can be demonstrated only by experiment. It is believed that the best remedy would be the substitution of a rotary crusher for the jaw crusher now being used. The jigs make a very good product, although it is probable that an appreciable amount is lost by attrition, as the grains removed from the upper compartment are in all cases worn and rounded. It may be found advantageous to take some steps to save the fine material now carried away. Possibly a trap in the broad launder which carries off the tailings would accomplish this end.

To produce a clean concentrate it is necessary to run the material twice over the table. It is intended to reduce the size of the smaller screen and thus give the table a narrower range of sizes to handle. It is expected that in this way better results will be obtained and that the capacity of the table will be increased, while the jigs are relied on to handle with ease the increased amount of larger size. As the plant is operated at present, it is doubtful if the finest tin is being saved. If the tailings from the Bartlett table were carefully sized and the fines run over a Frue vanner, it is probable that an additional amount could be obtained, but whether the saving thus effected would compensate for the extra cost is not known.

At the Ross mine very little hard ore has been mined, most of the cassiterite thus far taken out being contained in the soft, putty-like kaolin which constitutes a large part of the upper decomposed portion of the dike. Sluicing does not succeed in removing this sticky material from the cassiterite. Some concentration in hand jigs has been done, but the process which seems most simple and effective is washing through a coarse screen and sluicing the material which passes through. Constant turning, with the shovel, of the material on the screen serves to remove the kaolin from the cassiterite. By shoveling over and over the material in the first box or sluice a very good concentrate is produced. This process is the same as that used for the concentration of monazite. Much of the float or placer tin has been recovered in this way, because scarcity of water and the small extent of the deposits have made ground sluicing impracticable.

PRODUCTION.

The only production from the Carolina tin belt of which there is accurate record is that from the Ross mine. This amounted to 38,471 pounds of cassiterite concentrates in 1903 and 35,925 pounds in 1904, a total of 74,396 pounds of concentrates. The actual total content of metallic tin is not known to the writer. The 1903 shipment is said to have run about 70 per cent tin and, according to assays by Ledoux & Co., the 1904 shipment averaged about 66 per cent. On the assumption that the entire output to date has averaged 66 per cent tin, the total amount of metallic tin shipped from the Ross mine has been about 50,000 pounds, or 25 tons. A few thousand pounds of concentrates are now ready for shipment at this mine and nearly a carload has been produced at the Jones mine. From these two sources perhaps at most 20 tons of metal may be obtained. Two carloads of ore sent to England by Ledoux in the early days of activity in tin mining are said to have averaged about 2 per cent metallic tin; the total amount could not have been over 1 ton of metal. If to this is added the amount of cassiterite that has been carried away as curios, specimens, and samples for assay, it is found that the total production of metallic tin from the Carolinas is probably not over 50 short tons. A considerable portion of this amount, probably over half, was derived from lodes, or at least from deposits in place.

ECONOMIC IMPORTANCE OF THE TIN DEPOSITS.

To the mining man and the investor the topic of moment is the prospective economic value of these deposits. Discussions as to geologic occurrence, origin, etc., may enable them to arrive at conclusions which can be reached in no other way, but what they most desire to know is, Will the deposit pay; and if so, how well?

A number of important factors, of which several are more or less interdependent, enter into the consideration of this question. The price of tin, the richness of the ore, the size of the ore bodies and their relation to depth, and the cost of mining, milling, and transportation—all these points demand consideration before final conclusions as to the commercial value of these deposits can be reached.

In a report of this scope, covering a region where so little development has been accomplished and where the production has been so scanty, several of these points can not be discussed satisfactorily. Certain facts which have a bearing on the question have, however, been learned and may be presented.

VALUE OF THE ORE.

Three ore bodies in the district have been prospected by underground workings. Results at the Faires mine were unsatisfactory. It is doubtful if the average content of the whole ore shoot at the Jones mine will reach 5 per cent of concentrates. At the Ross mine the percentage of cassiterite in the ore shoot may have been somewhat greater, but at the present level of working it is probably under 5 per cent. There is no reason to believe that the average richness of the ore in the deposits, considered collectively, will change with depth. On the other hand, decided fluctuations may take place in individual bodies.

The metallic content of the concentrates can only be inferred from one case. While small selected samples of cassiterite may reach 75 per cent metallic tin, the general run of the concentrates will fall considerably below that figure. Of the second shipment from the Ross mine, 1,860 pounds averaged 72.53 per cent tin, 29,376 pounds averaged 70.31 per cent, and 4,689 pounds averaged 36.50 per cent—in other words, about seven-eighths averaged over 70 per cent and the remainder about 35 per cent, the average metallic content of the whole shipment being about 66 per cent, which is a very good grade for lode tin. It is known that considerable care was exercised in the preparation of these concentrates, so it may be that this figure is rather above the average for the region. The almost entire absence of other heavy minerals in the pegmatite and the purity of the cassiterite itself, however, make it fairly certain that careful concentration will give a clean product of good grade. If the figure for the Ross shipment is the average for the region, it means that every 3 pounds of concentrates contain 2 pounds of metallic tin.

While subject to considerable fluctuations, the price of tin is slowly rising. The average price of metallic tin in the New York market during 1904 was practically 28 cents per pound. A ton of ore containing 1 per cent of concentrates, of which 66 per cent is tin, contains, therefore, about $3.70 worth of tin at the above price. A maximum of the average gross value of the ore from the shoots thus far developed in the Carolina belt is $18.50 per ton. If abundant spodumene is ever found in close association with tin ore of good grade it may add to the total value of the ore, provided it can be separated and saved.

SIZE AND EXTENT OF THE DEPOSITS.

The width of the ore bodies is limited to that of the dikes in which they occur and is in many cases narrower. The average width of those ore shoots which have been explored is probably not over 3 feet and more likely even less. The breadth of the shoots—that is, the dimension in the plane of the dike at a right angle to the pitch, or greatest dimension of the shoot—is less easily determined by a small amount of development. Twenty-five feet is probably a maximum for those already known. The pitch length—the greatest dimension of the shoots—is thus far unknown; but indications are that the concentration of tin in certain parts of the dikes is controlled by factors which are variable and rather easily influenced by surrounding conditions, so that the ore bodies may be expected to be of irregular extent longitudinally.

The fact that the ore bodies represent magmatic segregations from an igneous rock argues, on the other hand, strongly in favor of the probability that there is just as much cassiterite at a depth of 100 or 500 feet as at the present surface. It is not, however, certain, nor even likely, that the majority of ore bodies known at the surface will continue without interruption to great depth. Maintenance of a fixed output as depth is attained will therefore mean increasing cost of exploration, aside from the commonly increasing costs of hoisting, pumping, and other operations with depth.

FUTURE PRODUCTION.

An estimate of the total amount of ore which a mining region will produce must be based on long and careful study and is at best exceedingly uncertain. For a region where so little development has been effected as in the Carolina belt any prediction of this kind would be idle. Certain facts bearing on the probable output of the district may, however, be stated.

The prospecting that has been done during the twenty-five years since the discovery of tin in this region should furnish some idea of the extent and number of the ore deposits. While it is highly probable that some additional deposits will be found, there is no reason to expect ore bodies of much greater size or richness than those already known. If anything, the probabilities are that the best ore has been already discovered. Furthermore, it is reasonable to suppose that the ore shoots already explored are as good as, or—since mining usually begins at the most promising points—better than those whose existence is known but which have not been developed. In short, it seems justifiable to assume that 5 per cent of the total rock broken along an ore shoot is a generous figure for the average amount of cassiterite to be recovered. Finally, while the ore shoots will usually be found extensive in one dimension, in the other two they will probably be small, and the irregularity of their position and extent will make mining expensive and uncertain.

Glowing predictions that these deposits will soon supply the domestic demand for tin have of course been circulated, and while it is doubtful if they have made an impression on the minds of those acquainted with the region it is well to correct any false idea which such statements may give to others. A little consideration of the meaning of these statements will show their extravagance. The consumption of metallic tin in the United States, which is annually increasing, was 43,120 short tons in 1904. This is equivalent to about 65,000 tons of concentrates containing 66 per cent tin, or a production of nearly 200 tons of concentrates per day. If the ore contains 5 per cent cassiterite, 4,000 tons of ore would have to be raised each day in the Carolina tin belt. When it is remembered that the total production from the region has been about 50 tons of metal the absurdity of such a proposition is apparent.

COSTS OF PRODUCTION.[a]

Cost of mining.—The cost of mining is intimately connected with the position, shape, and size of the ore shoots. As work continues in this region, it is believed that attention will be directed more and more to following these shoots. Their small dimensions in two directions, their usually inclined and variable pitch, and their uncertainty of extent conspire to make their exploration costly.

At the Faires mine the material of the dikes was so decomposed that most of it could be broken down with a pick, and blasting was only occasionally required. Drifting in ground of this description, with a short underground tram and a hoist of 40 feet by windlass, is said to have cost $1 to $1.50 per foot. Sinking would cost more. At the Jones mine, according to reports, work in the hard rock is easier and cheaper than in the decomposed material. At the Ross mine, also, where the rock for the first 80 feet is so decomposed that it is extremely soft, the increased ease of "breaking" it is much more than offset by the care and the timber required to hold the ground. Shaft sinking below the water level under these conditions is exceedingly slow and expensive work. A contract for sinking the two-compartment shaft 50 feet from the 80-foot level, through ground which is rapidly becoming hard, has recently been given for $25 per foot, the company furnishing the machinery. Up to date the tin taken from the deposit in place has cost a little more than twice what it cost to extract the cassiterite from the surface gravels by placer methods.

If these deposits are to be extensively developed, the greater part of the mining will of course be in hard, undecomposed rock, such as is now being broken at the Jones mine. While the water problem may never be a very serious drawback to mining operations in the Carolina tin belt, the topography, geologic structure, and heavy rainfall of the region make it almost certain that the expense of continuous pumping, steadily increasing with depth, must be added to other items to make the total cost of mining.

Owing to the character and extent of the ore bodies, it is to be expected that the cost of exploration, development, and mining will increase with depth at a higher rate than the simple increase in cost of hoisting, pumping, etc.

Oak and pine wood for fuel cost $1.50 to $2 per cord delivered. Material for timbering is also cheap, and the price of lumber is reasonable. Good negro labor can be had for 75 cents to $1.25 per day. A team and wagon, with man, can be hired for $2 to $2.50 per day. Most other expenses are proportionately low, and the long open season is an advantage.

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[a] The writer is greatly indebted to Capt. S. S. Ross for most of the figures relating to costs.

Difficulty is experienced, however, in obtaining skilled miners, and inexperienced hands of course make mining much more expensive.

Cost of extraction and smelting.—The cost of extraction of the cassiterite from the surrounding rock, as now practiced at the Jones mine, is probably high. It is to be expected that longer experience will result in a considerable reduction of this cost.

At the present time there are no tin reduction works in operation in this country. A plant erected at Bayonne, N. J., a few years ago was never put into active operation. All the tin produced has accordingly been shipped to England. The cost of smelting per ton of concentrates is $24.75, or about $37 per ton of metal. This agrees closely with the statement that in 1895 the cost and profit of smelting all the tin ore produced in Great Britain was about $35 per ton of metal, or $1\frac{3}{4}$ cents per pound.[a] The freedom of the Carolina concentrates from such objectionable impurities as sulphur, arsenic, and tungsten ought to reduce somewhat the charges for smelting.

Transportation and miscellaneous costs.—The cost of transportation from the mines to New York is approximately $5 per ton of concentrates, or about 0.38 cent per pound of metal. The freight charges from New York to Haile, Cornwall, England, amount to $2 per ton of concentrates, or about 0.15 cent per pound of metal. To these figures must be added a small amount per pound to cover handling of the ore, sampling and assaying, commissions, etc.

CONCLUSIONS.

The foregoing considerations indicate that the future of the tin industry in the Carolinas is not yet assured. It is believed, however, that in the case of some of the deposits conservative, careful, and systematic mining will be attended with profit. There are a number of prospects of sufficient promise to warrant further development by cautious methods.

The profits made at the Ross mine, which were probably large compared with the expenditure, are not to be taken as a criterion, for a large part of the product of that mine required only washing, and most of the remainder has been derived from soft ground which required no blasting nor crushing.

SUMMARY.

Tin occurs along a narrow belt extending northeastward from the center of Cherokee County, S. C., across Cleveland and Gaston counties to the center of Lincoln County, N. C. This belt represents the distribution of pegmatite dikes and in its position is dependent on the general geologic structure of the region. The pegmatite is closely related genetically to the granite and granitic gneiss which occur along this belt and which are sometimes cut by the dikes of pegmatite. Most of the pegmatite bodies are very irregular in extent. Tin is present as the mineral cassiterite, which occurs only as an original or primary constituent of the pegmatite. This mineral is not evenly distributed through the dikes, but is generally segregated or concentrated along certain lines. The ore bodies or shoots thus formed generally pitch at a considerable angle and are of small cross section, but extend indefinitely along the pitch. They are probably irregular in extent, somewhat after the fashion of the dikes in which they occur. The percentage of cassiterite in the ore shoots may be high in places, but the average value will probably be under 5 per cent. This ore may be reduced to a concentrate of good quality. The cost of production of the metallic tin ought not to be excessive, but will certainly increase with depth. Placer deposits are unimportant. The necessity of shipping the concentrates to England for reduction is a serious handicap and may prohibit operations which would otherwise be successful. The production of the Carolina tin belt will probably always be very small as compared with the amount of tin consumed in the United States.

While the outlook, from the commercial standpoint, is somewhat questionable, it is believed that profit may be realized from a number of the deposits by careful methods of working.

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[a] Louis, H., Min. Ind., vol. 5, 1896, p. 573.

GOLD.

INTRODUCTION.

HISTORY AND PRODUCTION.

When the early Spanish explorers came to America they were shown by the Indians rich nuggets and ornaments of gold which came from the Southern Appalachian region. Some of this gold is supposed to have come from the area with which this report deals.[a] The Spaniards mined for gold in Georgia in the seventeenth century. During the eighteenth century very little attention was given to mining anywhere in the Appalachians, although it is supposed by some that gold was found in this section (Brewer mine) before the Revolutionary war.[b] Just at the close of that century placer gold was discovered in Cabarrus County, N. C., and from that time forward prospecting was carried on with considerable vigor. About 1825 vein gold was discovered in Montgomery County, and soon afterwards in Mecklenburg County, N. C.

The first recorded production from the particular area here described was $3,500 in 1829, and came from Lancaster and Chesterfield counties, S. C. In 1830 work was being done in many places and with profit. From that time until the civil war mining was an important industry of the region, and although the rich fields of California lured many from these deposits of lower grade, the indirect result of the California excitement was a stimulation of mining activity in the East. During the war, and for several years after, little mining was done in this area, but in the seventies, eighties, and nineties the condition of the industry improved. At the present time gold mining in this central portion of the Carolinas is not in a very flourishing state. On later pages the endeavor is made to show the causes for the lack of general success in this region.

Unfortunately, no reliable statistics of production from this area are available. The best records to be obtained are those from the United States assay office at Charlotte, N. C., but these, given by States and counties, have been carefully kept for but comparatively few years and hence are of little value. To judge from all available data, it seems probable that the total gold production of this region has been in the neighborhood of $10,000,000. A considerable but unknown proportion of this amount has been derived from placer deposits, but much the larger part has been won by hard-rock mining.

IMPORTANCE.

This area constitutes the southern part of the Carolina belt, one of the three principal divisions established by Becker in his excellent description of the Southern Appalachian gold fields.[c] The mines of this area are among the most important gold producers in the Carolina belt and, in fact, east of the Black Hills. Such mines as the Haile, Brewer, Colossus (formerly Howie), and Kings Mountain have been worked for years and have furnished a large part of the total output of the area.

Placer mining, which could be carried on at little expense, has undoubtedly been exceedingly profitable in many instances and has probably only rarely been conducted at a loss. With lode mining, which is at present by far the more important industry, the case is different. Although numerous rich strikes, with large profits, have been made, lode mining in this region has been on the whole unsuccessful. More has probably been put into the mines, considered collectively, than has ever been taken out. In those mines which are the exception to this rule profit has been realized in general only by constant and diligent care in the exploitation of the ore bodies and in the reduction of expenses.

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[a] Cf. Becker, G. F., Gold fields of the Southern Appalachians: Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 255.
[b] Geology of North Carolina, vol. 2, 1888, p. 234.
[c] Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, pp. 251-331.

GOLD DEPOSITS.

One great cause of the lack of success which has attended gold mining in this region lies in the fact that instead of one recognized and well-defined type of gold deposit, as is the case in most mining districts, there are various types exhibiting a very wide range in character, and individual mines present more and greater differences than similarities. Such conditions, whether they are appreciated or not, mean expensive mining. Advantage can not be taken of past experience to reduce the cost of exploitation. If methods which have proved successful in one mine are employed in another the chance is that they will be unsuccessful because they are not adapted to the dissimilar conditions of the second mine. Accordingly the owner is loath to apply to a new mine methods which have proved successful elsewhere, and is inclined instead to try new methods which may miss the mark as widely as those already in use.

Because of this absence of a single type of deposit the study of this gold region has been not wholly satisfactory. In most mining districts the geologist sees more and more clearly into the character of the deposits as a whole as his work progresses, nearly every mine adding evidence to aid in the explanation of the type of deposit. In this region, however, the student of the ore deposits is confronted on all sides by new and perplexing features, which, instead of uniting to explain the main problem of the region, result simply in a mass of uncorrelated and distracting facts. Especial and unusual attention has therefore been given to the mine descriptions, since nearly every mine possesses distinctive features and has an importance of its own.

OCCURRENCE AND STRUCTURE.

In spite of the apparently general dissimilarity in character of the Carolina gold deposits, there exist among them all certain close relations which indicate that the differences are the result of extraneous conditions—such as the structure and character of the surrounding rock—and that all the deposits have the same origin.

On the basis of the outward and readily perceived characters these deposits may be divided into two broad types—fissure veins and replacement deposits. These two are joined together by deposits which partake in part of the nature of each. Placer deposits will be considered later.

FISSURE VEINS.

The fissure veins which are essentially quartz veins with more or less pyrite are exceedingly abundant. They are present in nearly all parts of the area, conspicuously appearing because of their resistance to decomposition, wherever the soil is exposed. Many of the larger veins outcrop strongly. The veins occur principally in dense metamorphic rocks and seem to be most common in amphibolite or in the gabbro, closely related to it. They have been formed by the filling of fracture spaces and probably have in many cases pushed their walls apart both by the pressure from below, transmitted by the solutions and by the force of crystallization. In size they range from the merest stringers, a small fraction of an inch in width, to large, solid veins 20 feet or more wide. Most of the veins dip at steep angles. In the majority of cases they conform somewhat closely in strike and dip with the foliation of the inclosing metamorphic rocks, but here and there they cut across the schistosity of the country rock. The interfoliated veins are in general exceedingly irregular. They swell and pinch, turn and jog, split and unite in a most aggravating manner. It has repeatedly happened that a vein of good size and apparent persistency was found suddenly to break up into a mass of small stringers which could not be profitably worked. Conversely it is probable that sinking on groups of these narrow veinlets, which are too poor or too small or too scattered to be profitable, would show that in many instances they unite to form a single large vein or lens which may hold pay ore. (See fig. 13, p. 101.) Cross veins are much less numerous, but from what can be learned they are decidedly more regular and persistent than the conformable veins.

It will at once be noticed that there is a striking similarity in structure between these quartz veins and the pegmatite dikes of the tin belt. (Compare figs. 6, p. 50, and 14, p. 102.) It is believed that this similarity is due to the fact that, although the materials are different, the receptacle is the same. In other words, the form and position of both the quartz veins and the pegmatite dikes are almost wholly dependent on the structure of the surrounding rocks. The explanation of the structure of the quartz veins is therefore the same as that for the pegmatite, which has already been given at some length (pp. 35–37) and need only be summarized here. It is believed that the veins occur along planes which represented places of weakness in the rocks. The interfoliated veins, or those conformable with the sorrounding rocks, are irregular because these places of weakness, the planes of schistosity, were uneven, discontinuous, and irregular. The material from which the veins were deposited, because of its probably greater fluidity than that from which the dikes solidified, sought out even more irregularities, and consequently the veins are less regular than the dikes. In short, it is believed that the bodies of quartz which now exist did not solidify in open spaces of corresponding dimensions which were ready to receive the solutions; but that the solutions, pushing their way along what may in many cases have been the merest fractures, actually forced the walls apart and made the receptacles in which their load was deposited. The force of crystallization [a] may have aided somewhat in this expanding of the openings, but it is believed that the principal factor was the pressure under which the solutions reached this zone of deposition. This pressure, which must have exceeded that resulting from the weight of the overlying rocks, was transmitted from a greater depth, where the weight of the overlying rocks was greater than above. An idea of the structure of these interfoliated veins is given by figs. 12, p. 100, and 14, p. 102. The cross veins, though deposited at the same time as the others, are more regular than the conformable veins, since they occupy later fissures which are definite cracks breaking across the schistosity.

Faulting has not been important. Slight faults with throws of a few inches are sometimes seen in those portions of interfoliated veins which consist of many irregular stringers, but it is not certain in all these cases that the faulting has been later than the formation of the vien, for it is possible that the vein materials simply filled fissures which in places were faulted. In a few cases more important faults are known, but in general there is very little evidence of movement since the period of vein deposition.

As regards internal structure of the veins, it may be said that the quartz is usually dense and massive, but in a few places possesses a granular texture which has led to the miners' term "sugary quartz." In general, the ore minerals occurring in the quartz gangue are irregularly disposed, although in certain deposits there is a more or less decided tendency toward accumulation or concentration at or close to the walls. In a single vein only, the Little Wilson, has any indication of banding in the interior of the vein been seen, and even in this case the narrow streaks of pyrite parallel to the vein walls give little support to the idea of vein banding in the sense of successive deposition or crustification. Druses and comb structure of original formation have not been observed in a single instance in the mines of this region.

REPLACEMENT DEPOSITS.

Large bodies of ore wholly different in outward aspect from the quartz veins occur in several places in the eastern part of the area. While the fissure veins are more numerous, this type of deposit has been more productive. These deposits occur, with only one or two exceptions, in volcanic rocks of the quartz-monzonite-porphyry group and are most common in the fragmental varieties or tuffs. The porous nature and easy alterability of these volcanic rocks, particularly the tuffs, have allowed widespread penetration and replacement by ore-bearing solutions. While minute quartz veinlets are locally present, the great mass of the ore bodies has been formed by replacement of the country rock, chiefly by silica and pyrite; and it seems probable that many of the veinlets themselves are simply cases of extreme replacement and not deposits by filling.

[a] Dunn, E. J., Reports on the Bendigo Gold Fields, Victoria Department of Mines, 1896, p. 25.

These ore bodies are of generous proportions, ranging from 40 or 50 to hundreds of feet in length and from 20 to several hundred feet in width. Owing to insufficient development up to the present time their depth has not yet been definitely ascertained. Some of the ore bodies persist below present workings, which are several hundred feet deep, while others appear to give out at a depth of 100 feet or more. These ore bodies are not tabular and of irregular extent, as might be expected from the form of the rock masses in which replacement has occurred; they are instead large, rudely lenticular or elliptical bodies, whose longer dimensions correspond with the structure of the replaced rock. The reason for this peculiarity of form is not clear. The most plausible explanation seems to be that the deposition of ore was greatly influenced by the presence of cross fissures which contained either ore solutions themselves or different solutions which, mingling with the ore-bearing solutions near the intersection of the two channels, caused a precipitation of the ore. Cross fissures which may have accomplished such a result are known in some places—for instance, at the Haile and Colossus mines. At the Haile they are commonly supposed to have had an effect on the deposition of the ore, but in reality it seems probable that these particular fractures are later than the ore. The question of the form and extent of these ore bodies is therefore not wholly settled.

DEPOSITS OF INTERMEDIATE CHARACTER.

As has already been stated, all the gold deposits give evidence of a common origin. It would therefore be surprising to find among these deposits a sharp division into the two classes just described. As a matter of fact, the division is not sharp. The two types are in reality the end members of a series in which nearly all intermediate gradations are to be found. Few, if indeed any, of the quartz fissure veins fail to show some replacement of their wall rocks; and at the other extreme are the narrow quartz veinlets which represent the easiest channels for the passage of solutions and which gradually fade into the large siliceous replacement bodies. It is as unwise as it would be difficult to divide this series into a large number of types dependent on the amount of replacement along the veins. A few deposits, however, which seem to stand at about the middle of the series, are worthy of brief comment. The ore body of the Ferguson mine, in northwestern York County, is a good representative of this class. At that mine an interfoliated quartz vein penetrates a schistose volcanic tuff. Probably by the metamorphism and induration which accompanied foliation, this rock was rendered more resistant to attack by ore-bearing solutions than in most localities, but some alteration along the walls of the vein has taken place and has resulted in the production of a considerable zone of low-grade ore on each side of the richer quartz vein. The Blackmon, Kings Mountain, and Thompson deposits also appear to resemble in some respects both extreme types.

MINERALOGICAL CHARACTER.

The mineralogy of these gold ores is, on the whole, comparatively simple, but in some instances minerals rare in this association are present in considerable number. Owing to the different conditions under which they were deposited in the fissure veins and in the replacement bodies, the ores from these two sources exhibit certain mineralogical differences. But since the veins in nearly all cases exhibit some metamorphic influence on the adjoining rock, and since the two types of deposits are in a broad way closely related, it would be unwise to attempt to make a fine distinction between the vein minerals and the replacement minerals.

LIST OF MINERALS.

A list of the minerals known in this area which constitute or accompany the gold deposits is here given, together with the name of the mine where they are found and a statement as to whether they are original constituents of the fissure filling or products of replacement in the surrounding rocks. Names printed in italic indicate decomposition products. Those original components of the wall rocks which seem to have been unaffected by the ore-bearing solutions, such as feldspar, amphibole, etc., are not included here.

List of minerals constituting or accompanying the gold deposits. [a]

Name.	Locality.	Occurrence.
GANGUE MINERALS.		
Quartz	All the mines	Fissure filling and replacement.
Calcite	Kings Mountain	Replacement.
	Schlegelmilch	Do.
Sericite	Haile	Do.
	Colossus	Do.
	Brewer	Do.
	Blackmon	Do.
	Brown	Do.
	Schlegelmilch	Do.
	Ferguson	Fissure filling (?) and replacement.
	Kings Mountain	Replacement.
Biotite	Colossus	Do.
	Ferguson	Do.
	Brown	Do.
	Schlegelmilch	Do.
Chlorite	Haile	Do.
	Schlegelmilch	Do.
Apatite	Haile	Do.
	Ferguson	Do.
Rutile	Haile	Do.
Fluorite	Kings Mountain	Replacement (?).
	Schlegelmilch	Fissure filling.
Epidote	Kings Mountain	Probably secondary.
	Schlegelmilch	Replacement (?).
Graphite	Kings Mountain	(b)
Garnet (?)	Jones tin mine [a]	Replacement.
Tourmaline (?)	do	Do.
	Faires tin mine [b]	Fissure filling and replacement.
Pyrophyllite	Brewer	Secondary (?).
ORE MINERALS.		
Gold	All the mines	Fissure filling and replacement.
Pyrite	do	Do.
Galena	Kings Mountain	Fissure filling.
Sphalerite	do	Do.
Pyrrhotite	do	Fissure filling and replacement.
	Asbury	Do.
	Colossus	Replacement.
	Haile	Do.
	Jones tin mine [c]	Do.
Chalcopyrite	Kings Mountain	Fissure filling and replacement.
	Ferguson	Do.
	Mary	Do.
	Big Wilson	Do.
	Colossus	Replacement.
	Jones tin mine [d]	Do.
Covellite	Brewer	Secondary.
Chalcanthite	do	Do.
	Kings Mountain	Do.
Enargite	Brewer	Replacement.

[a] This list is based very largely on a similar list in Doctor Becker's report.
[b] Probably an original constituent of the wall rock.
[c] Vein is auriferous, but of very low grade.
[d] Vein said to be auriferous.

List of minerals constituting or accompanying the gold deposits—Continued.

Name.	Locality.	Occurrence.
ORE MINERALS—continued.		
Arsenopyrite	Kings Mountain	Fissure filling.
	Asbury	Do.
Leucopyrite	do	Do.
Tetrahedrite	Kings Mountain	(?)
Bismuth	Brewer	(?)
Bismutite	Asbury	Fissure filling.
Bismite	Kings Mountain	Secondary.
	Asbury	Do.
	Brewer	Do.
Tetradymite	Asbury	Fissure filling.
Nagyagite	Kings Mountain	Do.
Altaite	do	Do.
Molybdenite	Haile	Replacement.
Ilmenite	Ferguson	Fissure filling and replacement (?).
	Other quartz veins [a]	Do.
	Brown (?)	Replacement.
	Schlegelmilch (?)	Do.
Hematite	Quartz veins [a]	Fissure filling.
Magnetite	Jones tin mine [b]	Replacement.
assiterite	Brewer	Do.

[a] Deposit not known to be auriferous.
[b] Vein is auriferous, but of very low grade.

DESCRIPTION OF THE GANGUE MINERALS.

Quartz is of course the predominant gangue mineral. In the veins it is generally milky vhite, but in some cases is so clear that in large masses it appears dark. It is crowded vith fluid inclusions, some of which also contain gas and a solid. The mineral shows either fibrous structure nor crystalline faces. It occurs in irregular interlocking grains, howing a texture similar to that of granite. For this reason the quartz of many of the eins appears granular or "sugary," as if crushed. All the evidence points toward deep eated deposition of the quartz.

As a replacement mineral the quartz exhibits much the same characteristics as in the eins. It is more apt to be bluish and appears to hold fewer fluid inclusions. The grains re usually polygonal, presenting a mosaic appearance. In the wall rocks of veins the uartz appears most commonly as very small lenses, while in the large replacement bodies composes the greater part of the altered rock.

Sericite is probably next in importance. At the Haile, Colossus, and Ferguson mines occurs as minute needles and scales, especially along certain planes. It is probably rived from the original feldspar of the rock, and where silicification is extreme is replaced quartz. At the Brown and Schlegelmilch mines it is scattered through the wall rock. t the Brewer mine it appears to be forming from the unknown mineral already referred (p. 22). Sericite forms the great mass of the ore body at the Blackmon mine.

Biotite is nearly as abundant as sericite. It is absent at the Haile and Brewer mines, but the Colossus and Ferguson mines is sparingly present in minute scales of irregular shape. the other mines where it has been found it occurs as irregular flakes and clusters derived m the uralite of the amphibolite. In all cases the biotite possesses the clear brown color aracteristic of contact-metamorphic biotite. Minute shreds of a mineral corresponding clinochlore are plentiful in specimens from the Haile ore body. The mineral appears to ve been the result of vein action, but may possibly have resulted from the decomposition of biotite. Tiny fragments, a few of which show prismatic outline, are found in the replacement bodies at the Haile and Ferguson mines. This material is probably apatite and affords an interesting connection with the Dahlonega mines, where it occurs in the same habit in the midst of the veins. Rutile is found in minute yellow prisms in ore from the Haile mine. Fluorite in narrow veinlets cuts the quartz at the Schlegelmilch mine and appears to be of later formation than the gold vein. Its mode of occurrence at the Kings Mountain mine is not known to the writer. The association of fluorite with gold—particularly with tellurides such as occur at the Kings Mountain mine—is now well established by the deposits at Cripple Creek, Colo.

The concentrates from the Blackmon mine contain a "black sand" which proves to be a dark garnet. Whether it has any close relation to the gold is not known. Garnet has also been found at the Jones tin mine, where it occurs with biotite, tourmaline, and magnetite in amphibolite close to the quartz vein which carries a small amount of gold. The resemblance in this case to the occurrence of garnet at the Lockhart mine in Dahlonega is marked. It is reported that the tourmaline-bearing quartz veins at the Faires tin mine carry gold.

DESCRIPTION OF THE ORE MINERALS.

Gold occurs in all the deposits, both free in the quartz and inclosed in pyrite. At the Haile mine it also occurs closely associated with molybdenite in heavily pyritized bands, and at the Haile and Colossus mines as thin flakes on joint planes, probably from secondary deposition. Crystalline faces have not been seen. Grains of large size are not now abundant, but the size of nuggets which have been found in the placers indicates that they have been present in portions of the deposits now eroded away.

Pyrite is the most abundant of the ore minerals. It occurs as large and small masses, both well crystallized and of irregular form. It is about equally important in the quartz veins and in the altered wall rock; in some places it constitutes a considerable proportion of each. When crystallized it occurs most commonly as cubes; pyritohedrons are frequently seen, and in many cases minute octahedrons are abundant. Limonite is a common decomposition product of the pyrite, and a yellowish-green powder which results in some cases may be ferric sulphate. In a few places the pyrite on decomposition leaves cavities partly filled with crystalline native sulphur.[a] Mr. Buddell, foreman of the Brown mine, informed the writer that he has broken open large solid masses of unstained quartz and found cubical cavities containing nothing but sulphur. These always came from above the water level. Below the water level many of the cavities contained a yellow liquid (ferric salt ?) and a small amount of bright pyrite in fine grains, but no sulphur. The conditions under which these processes of oxidation took place were apparently unusual. At the Colossus mine much of the pyrite is decomposed below water level, presumably by ferric solutions or by sulphuric acid, and not by direct oxidation.

Pyrrhotite is not plentiful. It occurs both in the vein filling and in the replacemen bodies, much of it intergrown with pyrite and chalcopyrite. Chalcopyrite is likewis rather uncommon, and occurs in the veins and in the wall rocks. At the Mary mine it i fully as abundant as pyrite. Covellite and chalcanthite are decomposition products o the chalcopyrite, and at the Mary mine red coatings, which are probably cuprite, resul where the sulphide is partially decomposed. Enargite, present in small crystals in th ore of the Brewer mine, also decomposes to chalcanthite.

Galena, sphalerite, and arsenopyrite are not unusual associates of gold. The arsenic antimony, bismuth, and tellurium compounds found with gold at the Asbury and King Mountain mines, however, are interesting and uncommon in such relations. Molybdenit in close association with gold is now commonly recognized. Ilmenite occurs in tiny striate laths in the vein quartz of the Ferguson mine. Large flattened crystals of this mineral a rather common in quartz veins, not known to contain gold, in the vicinity of Home, Cher kee County, S. C. Irregular grains of ilmenite found in the wall rock of the Brown an

[a] Cobb, Collier, Sulphur from pyrite in nature's laboratory: Jour. Elisha Mitchell Sci. Soc., vol. 11, p 1, pp. 30-31. Tuomey, M., Geology of South Carolina, 1848, pp. 89, 93. Lieber, op. cit., vol. 1, p. 62.

Schlegelmilch mines may in part be due to introduction by the vein solutions. Hematite occurs plentifully in bands in quartz veins which have not been shown to contain gold. It is possible, however, that they are related to the gold veins. Magnetite occurs in the wall rock of a quartz vein at the Jones tin mine and has undoubtedly been formed by the vein solutions. This is another link between the Jones vein and the Dahlonega veins, in which magnetite crystallizes with the quartz. The occurrence of cassiterite at the Brewer mine is noted on page 91.

CONCLUSIONS.

The character and association of many of these minerals are unusual and nearly all indicate that the deposits are of deep-seated origin, having been formed under great pressure and at high temperature.

DISTRIBUTION OF THE GOLD.

GENERAL FEATURES.

The subject of the distribution of the gold in the veins and in the replacement bodies is of the greatest practical importance. It is regretted that information on this point is so meager. In many cases development has not been sufficient to furnish good evidence, and on the other hand deduction from the form, size, and position of stopes is not satisfactory, for they indicate the distribution of only such ore as could be profitably mined under conditions existing at the time they were made.

It may be said, however, that the distribution of gold in the deposits is in general irregular. Some veins or ore bodies seem to be of fairly constant grade, but pockets, pay shoots, and relatively rich lenses within the main deposits are the general rule.

In the veins ore shoots, usually of rather small cross section and of steep pitch, afford the most profitable places for exploration. Where the veins are richest the surrounding altered rock likewise generally contains most gold, but everywhere less than the vein, so far as known. Rich ore is usually accompanied by much pyrite, but there are numerous exceptions to this rule.

In the replacement deposits the bodies of pay ore are large lenticular or ellipsoidal masses, with gradually decreasing values toward the exterior. In a few instances the change from profitable to barren ground is so abrupt that the deposit may be said to have a wall. Within these large bodies the value is not uniform. The best ore generally occurs where most silicification has taken place, and this also in many cases corresponds with the degree of pyritization. At the Haile mine comparatively rich ore is generally found in those places, among others, where molybdenite occurs with abundant pyrite.

The cause of this concentration of gold in certain places or along certain lines has not yet been ascertained. In some cases it is believed that the presence of cross fissures has been influential, but definite proof can not be brought forward. In the case of the replacement deposits at the Haile and Colossus mines it has generally been considered that the diabase dikes which cross the ore bodies have been the controlling factors in ore deposition. This subject is further considered under "Genesis of the deposits" (p. 68), but it may here be stated that careful examination has failed to reveal any genetic connection between the diabase and the gold. Moreover, the fissures through which the diabase dikes were later intruded seem probably to have had no connection with the original deposition of the gold.

SECONDARY ENRICHMENT.

All students of ore deposits recognize that several of the metals are dissolved by surface waters and are reprecipitated in the upper portions of the deposits by the process commonly known as secondary enrichment. It is the general opinion, however, that in the case of gold the solubility of the metal is so slight that this process is of little consequence in enrichment from the commercial standpoint. The importance of secondary enrichment in certain gold deposits has recently been advocated by Weed,[a] and the consideration of the subject in this place seems to be justified. In the particular case of the Haile mine, moreover, certain facts appear to point rather strongly to such a possibility; and in anticipation of the detailed description of the mine these facts will be presented, so far as they bear on this subject. In view of the erosion which has certainly gone on since the formation of the diabase dikes it is unreasonable to suppose that any secondary enrichment of present importance took place before that event. Moreover, the facts that the diabase is known to be later than the deposition of the original ore, and that most of it is in a fresh condition, make it appear probable at first thought that secondary enrichment has not taken place to any important extent since the intrusion of the dikes. It is true, however, that the diabase is decidedly altered in its upper part, and that it has doubtless been protected from rapid decomposition at greater depth by the layer of clay-like, fairly impervious material produced by decomposition on the top. It is certain that, owing probably to the presence of many joints, which are absent in the diabase, decomposition and oxidation have gone on to a greater depth in the body of the siliceous ore than in the diabase. The absence of these joints may also account for the absence of gold of secondary deposition in the diabase. It should be borne in mind that the idea of secondary enrichment is now applied practically only to deposits of copper. The fairly distinct zones of different mineral composition and strikingly different appearance occurring in enriched copper deposits have unquestionably aided greatly in the recognition of the presence of this phenomenon. But the much simpler mineralogy of gold affords no aid in this respect.

Furthermore, the changes in the vertical distribution of values at the Haile mine are not so extreme or abrupt that they forcibly demand an explanation, as is the case with copper, for example. A little consideration will show also that if secondary enrichment of gold should take place, the results as regards vertical distribution of values might differ markedly from those commonly ascribed to this process. For example, a copper deposit which has experienced secondary enrichment may be divided on the basis of richness into three more or less distinct zones—(1) an upper impoverished zone from which most or all of the copper has been leached; (2) an intermediate rich zone in which the copper originally above has been added to that already existing in the primary deposit; and (3) a relatively low grade zone, of indefinite downward extent, which in value stands intermediate between 1 and 2 and which represents the character of the whole deposit originally. Owing to the extreme ease with which copper minerals are decomposed and the copper taken into solution, an instance is rarely found in which solution and reprecipitation at a lower level have not gone on to a marked extent, unless the gangue and the surrounding walls have been so impervious as to restrict decomposition to the uppermost portion of the deposit. In other words, where secondary enrichment of copper deposits has taken place appreciably it has reached a rather decided degree. With gold, on the other hand, the case is different. The metal is so slightly soluble that currents of oxidizing surface waters may flow around it and reach and decompose minerals far below without appreciably changing the relative position of the gold. But some solution of the gold is undoubtedly taking place and, given sufficient time, during which the process continues, the gold near the surface must ultimately be dissolved and carried to a greater depth, where without any question it will be precipitated, most probably by sulphides or other reducing agents. The difference between the behavior of gold and copper, therefore, is largely one of rate. Since the process in the case of gold requires a very much longer time to accomplish equal results, it is natural to expect that intermediate stages, showing less marked results, will be more commonly encountered than in the case of copper. The recognition that gold is dissolved and redeposited to a slight extent is a recognition of an early stage in this process. This action in the case of gold is so exceedingly slow, however, that it must be a comparatively rare combination of conditions when degradation by erosion will proceed so slowly that concentration of gold from higher levels may become an important determinant of the value of the ore.

[a] Weed, W. H., The enrichment of gold and silver veins: Trans. Am. Inst. Min. Eng., vol. 30, 1900, pp. 423–448.

At the Haile mine the ore values are distributed as follows: The uppermost portion of the deposits, which was worked as placer ground, was rich. Below this surface mantle the values have decreased, so far as known, rather steadily, although pockets of sulphide ore of better than average grade have been encountered, probably most commonly near the boundary of general decomposition. The limit to which economic mining can be carried appears to bear a pretty definite relation to distance from the surface, and that distance is not great and reaches not very far—usually less than 200 feet—below the limit of complete oxidation. Moreover, thin films and scales of pyrite and of free gold have been found in joint cracks which give every appearance of having been formed since the silicification of the rock and the attendant ore deposition. Thin films of free gold are commonly found on molybdenite associated with heavy pyrite bands. Finally, it is certain that the comparatively plentiful gold which was found at the surface of these deposits and which was derived from higher portions of the deposits now eroded away has remained in that place undisturbed for a long period—in fact, ever since the peneplanation of the region, which probably took place as early as Tertiary time. Erosion at these places has been almost at a standstill and the process of secondary enrichment of the deposits, slow as it is, has had time to be effective. The writer does not undertake to say that secondary enrichment has had much to do with the vertical distribution of the gold, but it certainly seems possible that it has. If such a process has gone on, the action has differed from that common in copper deposits, inasmuch as the copper is derived largely from the upper portion of the deposit in situ, while the gold is supposed to have been dissolved mainly from gold which rested upon what was then the surface of the deposits and which had been previously concentrated by mechanical means virtually as placers. (See pp. 74–75.)

Whether or not secondary enrichment has taken place, the present ore bodies of the Haile mine certainly represent original loci of more than usual concentration of the gold in the deposits.

VALUE OF THE ORES.

The value of the ores is of course dependent on the distribution of the gold. Gold is present in much greater quantity than the amount of workable ore would indicate. In the walls of the veins and as horses and outer zones of the large replacement bodies, as well as within many veins, there is much material carrying gold from a trace up to the minimum amount for which mining can be profitably conducted. Of the pay ores the values vary greatly, depending as much on the cost of winning the gold as on the absolute richness of the ore. Some shoots or parts of shoots have been found which carry ore valued at several hundred dollars per ton. The Kings Mountain mine had some very rich ore and ore of high grade has been taken from the Thompson mine. Small, very rich pockets have been found in numerous places. The ore mined from the fissure veins has on the whole been of considerably higher grade than that from the replacement deposits. This is probably due both to the concentration along narrow zones of the gold which the solutions held, rather than dissemination through larger masses, and to the fact that owing to their small size and irregularity in form and richness veins can not be profitably worked when below a certain value; while the large replacement deposits, of more regular outline and certain value, can be made to yield a profit when far below that value per ton.

The ores of this region must on the whole be classed as of rather low grade. While some few mines may always have raised ores of good value, the vein mines have probably produced ore running on the average not better than $8 to $12 and the replacement bodies have averaged from $2 to $12 or $15, the value of the ore in the second case depending rather on the extent to which mining was carried into the outlying leaner portions of the deposits than on the actual amount of gold present.

The values occur both as free gold and in pyrite. It is certain that original, native gold has been deposited from the vein solutions to some extent. At the Blackmon mine, for instance, below the general depth to which surficial alteration has reached, the greater portion of the gold occurs free. At the Haile mine also some of the free gold associated with pyrite and molybdenite was perhaps originally deposited as such. In most cases, however, it is likely that the gold which has been found in the metallic state, both in the deposits in situ and in the placers, has been liberated from pyrite by oxidation. Whatever the original condition of the gold may have been it is certain that nearly all the gold occurring in the oxidized portion of the deposits has been found in the metallic state, and that as the proportion of sulphides increased the amount of free gold has steadily lessened. To judge from statements of the value of these decomposed outcrops or gossans it appears that they were decidedly richer—in some cases several times richer—than the average grade of sulphide ore below. The solution and carrying away of portions of the vein material, leaving the gold behind in consequently increased proportions by weight, have been responsible for much of this added value which the gossans show. It is probable, also, that gold from overlying portions of the vein has gradually been left behind as the other lighter constituents were eroded away, and has settled down with the degradation of the country. This last kind of concentration is considered more explicitly in connection with the placer deposits (pp. 74–75). In spite of these two explanations of the greater richness of the upper portions than those found below, it is difficult to rid one's mind of the feeling that the upper portions were always richer. For this belief, however, there is little ground. Probably the greater proportion of the output of this area, exclusive of that from placers, has been from sulphides.

The fineness of the gold averages about 0.900, but ranges from 0.700 to nearly 1.000. Silver is the chief ingredient to lower the fineness.

Complaint has often been made that returns from shipments to southern smelters have not agreed with the actual value of the ore. The writer comments on this topic only to say that he heard of no case where careful, systematic sampling was done by the shipper and to point out how necessary it is that such sampling of the ore be done in order to determine its average worth and how nearly impossible it is even with absolute impartiality to choose from a lot of ore one or a few specimens which really represent the whole.

GENESIS OF THE DEPOSITS.

In the preceding sections it has been assumed that these gold ores have resulted from deposition by aqueous solutions. This assumption is so completely sustained by the vast array of facts available both here and in other gold regions that further consideration need not be given to this subject. Granted, then, that the ores have been deposited by solutions, the factors which enter into the consideration of the origin of the ores are the nature of the solutions, their source, and the manner of deposition of their dissolved materials.

It is regretted that a thorough investigation of these deposits could not be made. The reconnaissance character of the examination on which this report is based has not justified the devotion of such detailed and thorough study in the office and laboratory as a complete survey would demand. Moreover, while the deposits deserve careful and complete investigation because of their complexity, for that very reason it is difficult to obtain a fundamental comprehension of their character.

CHARACTER OF THE SOLUTIONS.

Without numerous analyses showing the changes effected by the solutions in wall rocks, much concerning the nature of these solutions is left to assumption. From the materials which constitute the fissure fillings, however, it is certain that silica was the most abundant of the dissolved substances. Metallic sulphides, chiefly pyrite, have also been important. The conversion of feldspar into sericite and of amphibole into biotite indicate that potassium has been taken from the vein solutions by the surrounding rocks and that sodium has been added to the solutions. The production of the micas and of chlorite may mean that the solutions carried aluminum. A small amount of calcium may have been carried by the solutions to form the apatite, or the calcium may have been derived from the replaced rocks. The presence of such oxides as ilmenite and possibly hematite, magnetite, and cassiterite point to conditions rather unusual in the formation of gold deposits. Besides the commoner sulphides of iron and copper, small amounts of arsenic, antimony, bismuth, and molybdenum sulphides and one or more tellurides were present in some cases. Fluorine and probably boron were contained in some of the solutions. A little phosphoric acid was present and allowed the formation of apatite. There is little or no evidence that carbon dioxide was present.

The nature of these materials deposited from solution, as well as the general effect on the wall rocks, an effect resembling that produced by contact metamorphism, points to the conclusion that the ore-bearing solutions were concentrated and at high temperature. The almost entire absence of banding in the veins and the widespread effect of the solutions in the replacement deposits, as shown by the large size of these deposits, may be taken as additional evidences of concentration of the solutions.

SOURCE OF THE MATERIALS.

The character of the minerals deposited, the metasomatic action on the surrounding rocks, the structure of the veins, and the amount of erosion which the region has undoubtedly suffered since the deposits were formed are grounds for the belief that the ore bodies now exposed were formed far below the surface of that time. The character of the solutions, moreover, points not only to deposition at high temperatures but to their derivation far below. The source of these materials was therefore at greater depth than their place of deposition, and the solutions were at even higher temperature at the beginning of their upward journey than when the dissolved materials were precipitated.

Such extremes of depth and temperature suggest at once a magmatic origin of the solutions. Such an origin can not be established with absolute certainty, but a number of facts appear to favor it. Granite is known in the vicinity of many of the mines. How large a body of granite exists below the present surface it is of course impossible to say, but it is probable that the areas exposed are small parts of a much larger mass. The absence of granite outcrops immediately around the mines does not, therefore, preclude the possibility that the veins or solution channels reach granite somewhere below.

The intimate association of granitic or aplitic dikes with the quartz-tourmaline veins of the tin belt and the close resemblance in many respects of these veins to the gold-quartz veins make the relation of the gold deposits to the granite rather probable. This probability was so apparent and the resemblance of some of these tourmaline veins to the auriferous veins of the Lockhart mine in Dahlonega was so marked that it was decided to have specimens of some of the tourmaline veins assayed for gold. Two samples were selected—one from the quartz vein, which occurs close to the aplitic dike at the Jones mine, the other from a quartz-tourmaline vein, reported to be auriferous, near the pegmatite dikes at the Faires mine. It should be stated here that the specimens tested were not collected in the field with the assay in view; otherwise more conclusive results might have been obtained. Very careful assays were made by Messrs. Ledoux & Co., of New York.[a] The results were as follows:

No. 1. Quartz vein, with tourmaline, Faires mine, 0.0003 ounce per ton.
No. 2. Quartz vein, with pyrite, Jones mine, 0.0111 ounce per ton.

No. 1, from the Faires mine, is of course valueless, and the assay doubtless means that no gold was present in the sample submitted. The writer is inclined to believe, however,

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[a] The method used in these determinations is here quoted from a letter from Ledoux & Co. to the Director of the Survey:

"To avoid possible contamination or salting the samples were ground to flour fineness in porcelain pebble mills, which had been cleaned by grinding clean quartz in them for several hours, followed by a charge of common salt.

"The pulp from the pebble mills was divided into lots of 2 assay tons, each of which were run separately by crucible assay. In the case of 'S. C. No. 7' [No. 1] eight charges, making 16 assay tons, were made, and in the case of 'S. C. No. 42' [No. 2] nine charges, making 18 assay tons, were made. In each case all of the sample was used.

"The buttons from the crucible assays were united and scorified to a size suitable for cupellation. An excess of silver (20 mg.) was added to the scorifiers for the purpose of preventing cupel losses of the gold. . . . The silver beads obtained were parted and washed in the usual way, and the gold weighed on a balance sensitive to one four-hundredth mg.

"Charges of flux equal in weight to those used on the ores were run through contemporaneously with them and treated in exactly the same way, but no visible amount of gold was obtained in the blanks."

that a specimen selected for that purpose would have proved more satisfactory. No. 2 indicates that gold is certainly present in the quartz vein at the Jones mine. While 23 cents per ton is of course very little, it must be remembered that it is not a negligible amount, since 50 to 60 cent ore has been mined in California and some of the ore now being milled at the Brewer mine is said to be not much above 50 cents.

The fact, therefore, that some of these tourmaline-quartz veins, which are almost undoubtedly of magmatic origin—derived from the granite magma—carry gold is a strong argument in favor of their being an intermediate stage in one complete cycle, and fairly well establishes the relation of the gold deposits of the region to the granite. It may be noted here that the gold deposits of Dahlonega are believed by Mr. Lindgren to have a genetic relation to a granite similar to, if not actually the same as, that occurring in this region.

In conclusion, it may be said that while the source of the solutions can not be definitely proved, the weight of evidence favors the view that the gold deposits represent the final products of the granite magma, the concentration of certain elements from an immense body of rock. The full geologic sequence is therefore doubtless as follows:

1. Intrusion of granite.

2. Intrusion of granitic or aplitic dikes causing the development of biotite and amphibole in their wall rocks.

3. Intrusion of pegmatite dikes, some of which carry cassiterite, impregnate the surrounding rocks with tourmaline, and cause the development of biotite and other metamorphic minerals in their walls.

4. Formation of quartz veins carrying tourmaline, ilmenite, sulphides, etc., and, in some cases, gold, causing in their wall rocks the development of tourmaline, magnetite, biotite, garnet, ilmenite, and sulphides.

5. Formation of quartz veins (and replacement deposits) carrying ilmenite, sulphides, and gold, and causing in the surrounding rocks the development of fluorite, biotite, sericite, ilmenite, sulphides, and gold.

It is necessary to consider more fully at this point a subject to which reference has already been made—namely, the relation of some of the large replacement bodies to the diabase dikes which cut them. In former descriptions of the Haile mine it has repeatedly been stated that the ore bodies were caused by the dikes of diabase, which occur in their midst. The same has been said of the Colossus mine, where similar conditions exist, and as an explanation of the formation of ore at the Brewer mine it has been stated that a diabase dike occurs close by. Particular attention was given to testing this hypothesis, especially at the Haile mine. The statements that the ores at this mine are richer in the vicinity of the dikes are frequent and fairly consistent. It is often stated, on the other hand, that the richest ore is not immediately surrounding the dike, but at a distance of several feet. This richness in the neighborhood of the dikes may be accounted for in four ways:

1. The ore may be the result of the intrusion of diabase, as commonly stated.

2. The deposition of the ores from the vein solutions may have been influenced by solutions from a different source that were present in the fissure later occupied by the dike.

3. Secondary enrichment, which was possibly a factor in the present distribution of the gold, may have been especially effective along the fissures at the sides of the dikes.

4. The unequal distribution of the gold may be in no way related to the dike or to the fissure occupied by it.

These possibilities will be considered in order.

1. If the diabase and the ore are genetically related, they came from the same source and through the same channel.

Development work outside the main ore lenses indicates the presence of no more gold or other materials of the ore at the contact of or near the dike than is found away from it. Both in and outside of the ore bodies the only visible effect which the diabase has had on the surrounding rock is a slight induration extending an inch or two from the dike. Where decomposition through weathering has taken place along the sides of the dike, a zone of alteration is present and is characterized by the softness of the rock, formation of limonite, and development along joints of minute crystals of gypsum. But this has nothing to do with the dike itself. Moreover, the diabase, with the exception of atmospheric decomposition, is perfectly unaltered where it cuts either the ore bodies or the barren rock. Little or no pyrite is present and no evidence of the action of vein solutions is seen. Such conditions would be almost impossible if the diabase were as old or older than the ore. The distribution of the ore bodies with respect to the dikes argues strongly against this hypothesis. Instead of being parallel to the dikes, as would be expected according to this supposition, they occur only at intervals, separated by lean or barren spaces, and have their long directions transverse to the dikes. The ore body at the Colossus mine is said to extend several hundred feet away from the dike on each side. In the Haile mine some of the best ore has been found at a considerable distance from the dikes. The writer is not aware that the ore is richer near the dikes at the Colossus mine; and at the Brewer, mining has not been conducted along or on the dike, if indeed a dike is present. Finally, the ore body at the Colossus mine is said to be faulted along an unsheared diabase dike, showing that the dike is later than the ore. There is also evidence of a fault in the vein along a diabase dike at the Wallis mine in York County, S. C.

At the Haile mine, furthermore, several narrow, decomposed diabase dikes, called by the miners "clay" dikes, are cut by and are consequently older than the large dikes which are commonly considered to have brought in the ore. It would be natural to expect, therefore, that these small older dikes would be converted into ore like the surrounding tuffs, or at least would show some effect of the ore-bearing solutions. But all the evidence obtainable indicates that these older dikes are themselves younger than the ore. Neither where most decomposed nor in the fresh cores, which can be found here and there, is more than a trace of pyrite present, and these traces are not ore—so far as the writer is aware they carry no gold whatever, even where in the midst of a large ore body.

It is apparent, therefore, that all these diabase dikes are younger than the ore, and had no connection with its formation.

2. Several facts argue against the theory that increased deposition of ore was caused by different solutions contained in the fissures now occupied by the dikes, at their intersection with the ore-bearing channels. Outside the ore bodies there is no evidence of the action of solutions along these dike fissures except the slight induration caused by the dikes and the later decomposition which has gone on in some places. The distribution of the rich portions, as noted in (1), is likewise against this supposition. Moreover, if these cross fissures existed when the ore was formed, the ore would naturally extend along them for at least a short distance beyond the general limits of the ore body, but such is not the case, and the fissures now occupied by the dikes are probably of later formation than the ore. Finally, it is an unwarranted assumption that a fracture existing in pre-Cambrian time, the probable date of vein formation, should still be a prominent plane of weakness when the diabase was intruded, probably in Jura-Triassic time.

3. Even if it is granted that there has been secondary enrichment of the deposits, the relation of the ores to the dike fissures is not decidedly marked and the tenor of the ore remains fairly constant for such distances away from these fissures that it seems improbable that they have exerted much more influence in the enrichment of the ore than have other fractures, crevices, and joints.

If it is true, as sometimes stated, that the ore within a few feet of the dikes is of lower grade than that a little farther away, it is possible that leaching of the gold has taken place along the decomposed zones bordering the dikes and that secondary deposition has gone on below. There is no satisfactory evidence of such phenomena, however.

4. The only alternative remaining is that the ore deposition, preceding the formation of the dike fissures, is in no way related to them. The only places where increased richness in the vicinity of the dikes has been noted is where the dikes cut across about the middle of the ore body. But that is just the place where a replacement deposit is apt to be

richest. The fact that in some cases the ore bodies pitch away from and leave the dikes ought to be good proof that the ore deposition was independent of the dikes and dike fissures.

DEPOSITION OF THE ORES.

In the consideration of this subject also the lack of analyses prevents the drawing of accurate and valuable conclusions. It has been shown that the ore-bearing solutions were probably under greater pressure and at higher temperature near their source than at the place of deposition. A ready explanation of the cause of deposition would be that the decrease in pressure and temperature lowered the solubility of the materials carried in solution and thus resulted in their precipitation. It has been pointed out by Mr. Lindgren,[a] however, that in general increasing temperature and pressure do not increase the solubility of ore minerals beyond certain maxima, and that consequently the effect of decreasing pressure and temperature on the deposition of ores has probably been overestimated. It is certain, on the other hand, that these changing conditions must have had some effect on the deposition of the ores, but there is no evidence by which to measure it.

It is believed by the writer that the deposition of the ores was brought about mainly by a change in composition of the relatively concentrated solutions. This change in composition would disturb the nice equilibrium which had been attained, and cause a decrease in solubility and consequent precipitation of some or all of the constituents. Such a change in composition of the solutions might be brought about in any or all of three ways: First, change in conditions of temperature and pressure. This would have some effect, probably not very great. Second, mingling with solutions from another source, such as atmospheric waters along cross fissures or channels. The intersection of such channels with the ore-bearing fissures may have fixed the location of extraordinary deposition, the pay shoots. While the vein solutions were doubtless under greater pressure than that which would be due to hydrostatic head, it is conceivable that solutions from the surface, which would be under hydrostatic head only, might mingle with them in spite of this difference of pressure, through the agencies of friction, capillarity, and diffusion. Third, the mutual chemical reaction of the solutions and the surrounding rocks. The subtraction of silica, potash, and possibly alumina from the solutions and the addition to them of soda and lime, which have taken place in nearly or quite all cases, would exert a very pronounced influence on the solubility of the remaining substances and cause their precipitation. It is believed that this third factor was the most important in the deposition of the ores.

The gold and sulphides in the veins have probably been precipitated in part mechanically with the quartz and in part chemically. These heavy metals have also been carried with the silica and lighter metallic elements into the wall rocks and there deposited, though less abundantly than in the fissures.

It has been stated (p. 61) that the fissure veins and the replacement deposits probably had the same origin. The occurrence of similar minerals in the two types of deposits and the presence of deposits of intermediate character sustain the conclusion that the nature of the solutions and the source of the materials were the same in each case.

In the mode of deposition of these materials from the solutions must lie an explanation of the differences which exist between the two classes. Briefly stated, these differences are as follows: The fissure veins are narrow and relatively rich; they effect a very marked change in their wall rocks for a short distance away from them; they occur in dense, usually basic rocks, already rendered resistant through profound regional metamorphism. The replacement deposits are large and irregular; they consist of altered country rock, and they occur in porous volcanic rocks of acidic character, easily susceptible to alteration.

The ore-bearing solutions, ascending at a high degree of concentration and temperature, would, on confinement to a narrow fissure, be able to exert intense action on the immediately adjoining, not easily pervious wall rock. The same solutions, reaching a body of porous, easily alterable material, would immediately disseminate through it, distributing

[a] Gold-quartz veins of Nevada City and Grass Valley districts, California: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1896, pp. 177-178, 183.

their heat and chemical energy through a large mass of rock. Such a dissipation of energy in the replacement bodies would account for the lower intensity of alteration in them than in the wall rocks of the fissure veins. The difference in chemical composition of the wall rocks in the two cases would explain the mineralogical differences in the two types of deposits.

This hypothesis assumes that the rock invaded by the solutions was at a lower temperature than the solutions. The solutions from lower depths and probably from the vicinity of recent intrusions can hardly have failed to transfer heat to the places of ore deposition more rapidly than could be accomplished by conduction from the same source through the rocks. The possibility that secondary enrichment has modified the original deposition of the ores has already been referred to (pp. 65–66).

CONCLUSIONS.

The gold deposits of this area are of two types—fissure veins and replacement deposits—with transitional members between these two extremes of the series. Concentrated solutions containing gold, silica, potash, sulphides, and oxides of iron and titanium ascended from great depth at high pressure and temperature. In the denser rocks they forced their way along crevices, forming veins, at the same time exerting so marked metasomatic action on the walls of these fissures that the result bears resemblance in many ways to the effect of contact metamorphism. Gold, pyrite, ilmenite, and other materials were deposited in the veins and in the wall rocks. In the more porous rocks the solutions permeated large masses and replaced the original rock fragments by quartz, sericite, gold, pyrite, apatite, etc. The mineralogical differences in these two types of deposits are due to the differences in chemical composition of the rocks invaded by the solutions and to the different degrees of concentration of action of the solutions. The source of the ore materials was at great depth below the surface of that time, but of unknown distance below what is the present surface. It seems certain that the vein solutions are genetically connected with the granite intrusions, representing the final product of the granite magma and bearing close relation to the tourmaline-quartz veins and the pegmatite dikes carrying tin, which were formed immediately preceding the formation of the gold veins. The deposition of these materials was probably due partly to decrease of pressure and temperature attained by the passage to a higher level, but was doubtless caused mainly by a disturbance of the nice equilibrium of solubility and concentration by the accession of substances dissolved from the wall rock.

These deposits differ markedly from the common western type of gold-quartz veins. From the amount of erosion which has taken place since their formation, as well as from the character of the deposits themselves, it is certain that they represent the deeply buried stumps of quartz veins which originally extended much higher. Whether or not the upper portions of these veins, now eroded away, more closely resembled the typical gold-quartz vein it is impossible to say.

The numerous nuggets of large size found in the placer deposits may be an indication that the upper eroded portions of the veins were richer than those portions now known. The ore has become too lean to be profitable or has pinched out at depths not exceeding 400 or 500 feet in so many cases that this may be considered the general occurrence.

It may therefore be that an uneven zone not many hundred feet below the present surface represents the lower limit of the gold—namely, the place of beginning of deposition. It is extremely doubtful, however, if the difference of conditions in this distance of a few hundred feet—a very slight distance compared with the original vertical extent of the deposits—could have caused so great a result. It is possible instead that ore exists far below the present surface, but that the individual bodies of pay ore known at present give out at comparatively small depths, to be succeeded farther down by other and still other ore bodies. Thus, while the ore may persist with depth, it is by no means certain that mining operations will succeed in finding the lower ore bodies. If secondary enrichment has had any marked influence on the value of the ore, the prospects for large bodies of workable ore occurring at depth are not bright

AGE OF THE DEPOSITS.

Concerning the geologic age of the gold deposits little direct evidence is obtainable. The deposits were formed after the greatest metamorphic movements had ceased, but the crushing and slight faulting which some of them have experienced indicate that they did not escape all movement. It seems probable that movements which did affect them were the last agents of dynamic metamorphism. This supposition is supported by the one that the gold deposits closely followed the granite intrusions. The ore bodies are cut by the diabase dikes, which are probably of Jura-Triassic age. All available evidence points to pre-Cambrian as the probable age of the deposits.

PLACERS.

It is said that the gravels of nearly all the streams of this area yield "colors" of gold when panned. Where the gold is sufficiently abundant these placer or "branch" deposits have been worked, often with profit. In the early days discrimination was not always made between the true placers and the loose, decomposed outcrops of deposits in place.

While placers have been of importance in this portion of the South, most of the placer mining was done in the early days of the gold excitement, and information is not easily obtained at present. The location of only a few of these deposits is now known.

A deposit from which much gold was taken was called the Martin or Enterprise mine, and is situated about 1 mile southwest of Smyrna station, in York County. The placer is said to have been discovered about 1836, and most work was done before the war along a shallow stream which has been "washed" several times. It is said that the workable gravels had an areal extent of 4 acres.[a] Much gold has also been picked up from the nearby fields after rains. It is reported that a nugget worth $44 and numerous others of less value have been found at this mine, and Lieber states that a piece of quartz containing 4,000 pennyweights of gold was found in the gravels.[b] One man took out $40,000 before the war, according to report. It is stated that a gold-bearing vein occurs close to the creek, and pits have been sunk there, but at the time of the writer's visit no indication of a vein was seen. The last work here was done four or five years ago.

Much work was done in the early days at the Brewer mine in what is known as the Tanyard pit. This was probably the first placer in the State. It is several hundred yards from the hard-rock workings and occupies a very slight depression below the surface of the peneplain, although a short distance away is a rather deep stream valley.[c]

A little work has recently been done a few miles south of Gaffney, S. C., but has not proved successful. Washing is being done on a small scale in a stream near the West mine. The Belk placer, in Lancaster County, east of Lancaster, the Austin placer near Gaffney, and numerous others were being or had been operated at the time Lieber wrote his reports.[d] Small nuggets have been picked up in the fields in many places, often not near any stream or depression nor in the neighborhood of any known deposit in place.

Two features concerning these placer deposits are worthy of note. The first point is the richness of some of the placers when compared with the usual low grade of the hard-rock deposits. In the second place, deposits, some of them rich, of waterworn gold have not uncommonly been found on elevations and divides away from and above present streams or valleys. This fact was observed as early as 1825 by Professor Olmsted,[e] and it is stated by Lieber that these placer deposits commonly occur on the foot-wall side of the near-by vein or hard-rock deposit.[f]

From these facts two conclusions may be drawn—namely, that the present streams have not been the only factor in the concentration of the gold and that much of the gold has been

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[a] Lieber, op. cit., vol. 1, pp. 75–76; vol. 3, pp. 154, 157.
[b] Op. cit., vol. 1, p. 76.
[c] Cf. Lieber, op. cit., vol. 1, pp. 66–67; vol. 3, p. 157.
[d] Op. cit., vol. 1, pp. 76–77; vol. 2, p. 71.
[e] Am. Jour. Sci., 1st ser., vol. 9, 1825, p. 13.
[f] Op. cit., vol. 1, pp. 157–158.

derived from portions of the veins which were once above the present peneplain level (cf. pp. 12–14) and owes part of its concentration to the old streams which accomplished this planation and are now extinct.

In the discussion of the tin placers it was shown that as the surface of the land was gradually lowered by erosion from pre-Cambrian time to the present the heavy resistant minerals were left behind in such depressions as existed, constituting placer deposits. In the case of cassiterite the friability and solubility of the mineral probably allowed most of this accumulation to be carried away when the rate of degradation became very slow. With gold, on the other hand, its toughness, high specific gravity, and resistance to ordinary solvents allowed such amounts of it as had accumulated to remain. In other words, it seems probable that the placer deposits of this region represent concentration of the vein gold from that vast amount of material which has been eroded away since the veins were formed. The finer particles of gold have probably been carried away mechanically and the coarser grains have doubtless been slightly reduced in size by solution, but a large proportion of the content of the hard-rock deposits between the present and the original surfaces is probably now in the placers. This hypothesis would account for the comparative richness of the placers. The redistribution of streams on the revival of drainage after base-leveling explains the independence of present topography which some of the deposits show.

MINING DEVELOPMENTS.

GENERAL STATEMENT.

EXTENT.

Mining has been going on in this region for seventy-five years, and much work has been done. The effort has been expended at many places, however, and there are no extensive mines in the area. A few mines, nevertheless, by a comparatively small amount of development work, have opened up large ore bodies on which extensive open cuts or stopes have been made. The deepest working in the area is at the Haile mine, where a winze extends 130 feet below the bottom or 350-foot level. The Kings Mountain mine is about 350 feet deep and the Colossus about 320 feet. Other mines having considerable workings are the Brewer and Blackmon, and it is said that there has been a relatively large amount of underground development at the West mine.

METHODS OF MINING.

The methods employed to obtain the ore from the deposits are varied in character. The placers were worked by panning, rocking, and sluicing; so far as known hydraulicking has been practised in this area only at the old Tanyard placer at the Brewer mine. The same methods were applied to the decomposed upper portions of many of the deposits in place, sometimes in conjunction with crushing. When solid rock was encountered, development was carried on by means of shafts and levels. In general, the flat character of the country does not make tunnels advantageous. One has been driven at the Brewer mine, however. Vertical shafts are much more common than inclines, although numerous inclines were sunk on the veins or on the ore shoots in the early days. The interval between levels is usually small, but ranges from 30 to over 100 feet.

In the large replacement bodies the best ore was mined by stopes from underground workings. In the best practice levels turned from the shaft were run along the hanging wall of the ore body and at intervals raises were driven to the level above. The ore thus blocked out was broken by overhead stoping, pillars and level floors and roofs being left to hold the workings intact. When the levels were no longer needed, these pillars could be taken out. This method of mining was successfully employed for many years at the Haile mine by the manager, Capt. Adolph Thies. An ingenious means of driving the raises economically was put in practice at that mine and well deserves description. The steep dip of the ore body made it necessary either to drive steep raises or to drive them partly in barren ground. The latter was not feasible, and the former necessitated timbering for the support of workmen and drills. It was found that in a raise driven at an angle of about 45° the broken rock would just serve as a foundation from which to work. The raises were therefore started from the levels at the hanging-wall side of the ore body and driven upward at 45° diagonally across the deposit. When the foot wall was reached the raise was turned to the right or left, first along the foot wall, then toward the hanging wall, and finally back again toward the foot wall, always being pointed upward at 45°. A spiral raise was thus driven, all in ore and without the use of timber. The cost of increased length of the raise was more than balanced by the saving in timber.

As the better grades of ore in these deposits were exhausted it became apparent that the shaft-level method of working when applied to the larger surrounding bodies of lower-grade ore would necessitate timbering and become too expensive. Since the workings were not very deep, it was found possible to extract the low-grade ore and take out the higher-grade pillars by means of open cuts. This method is now being used at the Haile and Brewer mines, has been used at the Blackmon mine, and it was announced as the intention of the management to put it in operation at the Colossus mine. No timber is required and the rock can be broken by quarrying methods. The result is that although in some cases considerable barren ground has to be broken, especially from the hanging wall, the cost of mining is greatly reduced. At the Haile the ore is hoisted in skips running on inclined tracks laid on the foot wall. At the Brewer a tunnel connects with the bottom of the pit or open cut and the ore is trammed out through it.

The depth to which open-cut mining can be carried with profit will of course depend on the strength and firmness of the walls, the size of the deposit, and whether it stands vertically or dips beneath the surrounding rock.

METHODS OF EXTRACTION.

The methods of extraction of placer gold have already been mentioned under the head "Methods of Mining." The same applies to the gossans of many veins. Hard rock containing free gold, either original or derived from oxidation of sulphides, is generally stamped and amalgamated. Sulphide ores containing also native gold are in most cases stamped, amalgamated, and concentrated, the concentrates being either shipped for smelting or else chlorinated or cyanided on the spot. At the Ferguson mine amalgamation has been discarded and the stamp-mill pulp is concentrated, the headings saved for roasting, and the tailings cyanided. At the Colossus mine a 500-ton mill nearly completed will crush the ore in rolls to 30 mesh and then cyanide direct. Both weak and strong solutions will probably be used. At the Haile mine stamping of the ores is followed by amalgamation of the free gold, while the concentrates are treated by the barrel-chlorination process, which was invented by Captain Thies, the former manager of the mine, and which is now in successful operation in the West, particularly on the ores of Cripple Creek, and also in Australia. The same methods have been employed at the Brewer mine.

Throughout the area much difficulty has been experienced in extracting the gold from sulphide ores by amalgamation, even when a considerable proportion of the values is free gold. From what can be learned of these operations, it seems probable that much of this lack of success may be attributed to lack of experience in the stamp milling of ores. Just the right combination of weight and drop of stamp, height of discharge, size of screen, and amount of water seems in many cases to have been missed, and in consequence the tailings were rich.

It is doubtful if the ores of this area can be successfully treated without concentration, roasting, and subsequent lixiviation of the sulphides.

COSTS OF PRODUCTION.

Little satisfactory information could be obtained on the subject of costs, as the mining companies are rather reticent about it. Labor and fuel are low in price and all kinds of operations can be carried on during almost the whole year. Pumping has to be done in nearly all the mines, but the quantity of water is not excessive.

At the Brewer mine, where loose, sandy ore is milled down into cars, trammed to the mill, run through stamps to insure uniform fineness, and then amalgamated, it is said that the total cost is under 60 cents per ton. These operations, however, can be carried on only for a short time before ore of this character will be exhausted, so the above figures have little significance. At the Blackmon mine underground stoping of a large ore body is going on, the ore being stamped and amalgamated. It is said that $2 ore gives a fair profit.

Accurate account is kept of all expenses at the Haile mine. Here large ore bodies, well developed, are mined by open cuts, the ore is stamped, amalgamated, and concentrated, and the concentrates are roasted and chlorinated. Considerable development work, particularly with diamond and churn drills, is being done. For the last two years the total cost of these operations has been under $1.60 per ton of ore mined. This, it will be admitted, is exceedingly low.

HAILE MINE.

The Haile (formerly called Hale[a]) mine is situated on Lynches Creek, 3½ miles northeast of Kershaw, in the southern part of Lancaster County, S. C. It is the property of the Haile Gold Mining Company, of New York City.

HISTORY AND PRODUCTION.

This mine has been worked more or less continuously since about 1830 and during all that time has been one of the most important mines of the region. In early days leases were given on sections 50 feet square, and open cuts were made on these claims by slave labor. This was of course disastrous to systematic, economic mining. The upper, oxidized portions of the ore bodies were rich and some of them yielded lumps of gold worth from $300 to $500.[b] Except during war time, open cutting was carried on until about 1880, when actual underground mining was begun and continued up to about four years ago. A return to the open-cut system has been made, on a much larger scale than formerly. This mine, said to be the only steady dividend-paying gold mine in the Southern Appalachians, owes its success in recent years very largely to the intelligence and persistent efforts of Capt. Adolph Thies, who for nearly twenty years was its manager. Mr. E. A. Thies, his son and the present manager, is following the same policy.

Spilsbury[c] gives the production of the Haile mine up to 1883 as over $1,250,000, and it has been said that the production since that time has been about $2,000,000, making the estimated total production about $3,250,000. As the company is a close organization, the amount of dividends paid is not known.

DEVELOPMENT.

The development of the Haile mine consists of a number of shafts, with drifts and cross-cuts, and of three large open cuts. (See fig. 8.) The deepest shaft is the No. 4 shaft of the Cross workings, 350 feet deep, with levels at depths of 200, 270, and 350 feet. The bottom of the No. 2 shaft connects at the 200-foot level. The drifting from these two shafts amounts probably to 3,500 feet. A 130-foot winze has been sunk from the 350-foot level, east of the No. 4 shaft. An old shaft at the Beguelin workings is about 180 feet deep and has two levels aggregating about 1,200 feet. No. 5 shaft, to the west of No. 4, is 100 feet deep, with short levels at 60 and 100 feet. The Chase Hill shaft is also about 100 feet deep. There is a 60-foot shaft on Red Hill, northeast of the Cross workings.

The principal open cut is the Haile pit, about 250 feet long and 200 feet wide by 180 feet deep. A diabase dike crosses the middle of this cut and, being barren, has been left in place to serve as a pillar. On the east side of this dike open cutting was carried down about 100 feet and then the cut was filled with waste. The west side, called the new Haile pit, is being worked at present at a depth of 180 feet, a chute connecting to a short intermediate level at 185 feet, and thence to the 200-foot level of the No. 2 shaft, where the ore is hoisted.

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[a] Lieber, op. cit., vol. 1, p. 60.
[b] Lieber, op. cit., vol. 1, p. 62. Lakes, A., Mines and Minerals, vol. 21, 1900, p. 56.
[c] Trans. Am. Inst. Min. Eng., vol. 12, 1884, p. 102.

The Bumalo cut, 300 feet long and 100 feet wide, lies just east of the Haile cut. It is about 100 feet deep, but is connected and practically continuous with large underground stopes which reach below the 270-foot level. The Beguelin cut, 1,500 feet northwest of the Haile cut, consists essentially of two pits, about 120 feet deep, separated by a wide dike of diabase. The eastern pit is 200 feet long by about 125 feet wide; the west pit is about 120 feet square. Considerable prospecting has been done by diamond drills and well-drilling machines, of which a fuller description is given on page 86.

Among the surface developments may be mentioned a narrow-gage steam tramway connecting mines and mills, a 60-stamp amalgamation and concentration mill, and a barrel-chlorination mill, in addition to shaft houses, office buildings, etc.

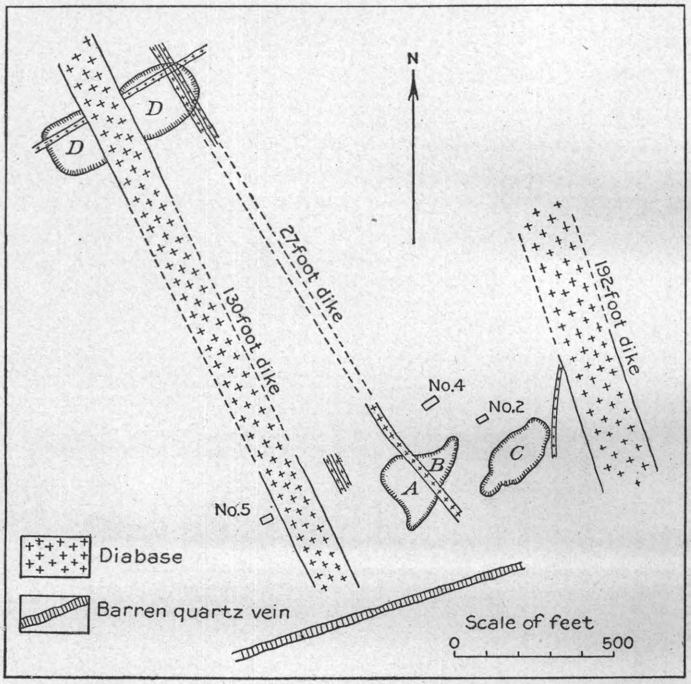


FIG. 8.—Sketch map showing location of the principal ore bodies of the Haile mine. *A*, New Haile pit; *B*, Old Haile pit; *C*, Bumalo pit; *D*, Beguelin pit.

GEOLOGY.

The geology of the Haile mine has often been described, but seldom in detail. Becker[a] and Nitze[b] give the best descriptions. The country rock is a quartz-sericite schist and is described petrographically on pages 15–16. The microscope shows it to have been derived by foliation from a porphyry tuff, probably granite porphyry tuff or quartz-monzonite porphyry tuff.[c] These tuffs were well bedded and this structure is preserved in some places. About 300 feet northeast of the chlorination mill the tramway cut exposes the tuff very plainly bedded in thin layers which on decomposition have assumed different colors, causing the banding to appear prominently. At this particular spot the rock has suffered only slight foliation, so that although it possesses a recognizable fissility the banding has been scarcely disturbed. Tiny cubical cavities lined with limonite indicate that pyrite was

[a] Gold fields of the Southern Appalachians: Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, pp. 306–308.
[b] Bull. North Carolina Geol. Survey No. 10, 1897, pp. 125–126.
[c] Cf. Becker, loc. cit.

once present. On the 60-foot level of the No. 5 shaft the same rock is seen in an unoxidized state. It is light gray in color, fairly soft, and exceedingly well bedded, so that thin layers can be separated from it. Under the microscope it is found to be somewhat silicified and pyritized. Remains of original bedding are easily recognizable in very siliceous ore from certain parts of the Haile and Beguelin cuts.

This tuff is composed of fragments of almost microscopic size. The assortment is nice, larger grains of quartz, feldspar, or mica being only rarely present, and it is in consequence natural to conclude that these are water-laid deposits. In this place in the No. 5 shaft some masses have almost entirely escaped shearing and the banding is perfect. From this extreme can be traced every gradation, through areas showing a slight disturbance of the bands and those in which remains of the banding is barely visible to dense rock with marked fissility or foliation and no indication of original bedding. In all places where bedding has been observed the foliation due to subsequent movement has been in general parallel to the original bedding planes. Minor local exceptions occur, the schistosity being oblique to the bedding. In several such instances the rock has a decided foliation across the bedding and yet the movement which produced this foliation was of so slight an amplitude that it requires a second look to be sure that the beds are faulted at all. Foliation or fissility is as well preserved in some of the silicified ore as in the less altered schist, but in general the soft sericitic rocks possess much more decided schistosity than the dense siliceous ores.

Of the few feldspar fragments which can be identified with certainty, no further classification can be made. Alteration has in most cases changed the feldspar fragments into sericite. When the rock has been foliated this fibrous mica gives a silvery luster to the cleavage surfaces and has led to the application of the name talc schists to these rocks. As a matter of fact, these rocks do not contain talc, as has been pointed out by Nitze,[a] who cites the following analyses by Baskerville:

Analyses of quartz-sericite schist from the Haile mine.

	1.	2.		1.	2.
SiO_2	44.61	61.02	Na_2O	6.96	2.19
Al_2O_3	31.57	25.54	K_2O	6.97	1.81
FeO	3.55	4.46	H_2O	5.80	4.20
CaO	.20	.60		100.04	99.96
MgO	.22	.14			
MnO	.16	....			

The difference in these two analyses is probably not to be attributed to initial dissimilarity of the rocks, but rather to the fact that the fairly unaltered sericite-schist, represented by analysis No. 1, has been silicified to the extent shown by No. 2. This silicification, which can be well represented by specimens and thus studied under the microscope, proves generally to correspond in intensity with the amount of foliation, although in the case of extreme silicification traces of former structure have been quite destroyed and the rock is simply a massive, siliceous "hornstone." Pyrite is a common constituent of all these phases of rock and in a general way corresponds in amount with the degree of silicification. This conclusion is reached only after microscopic study, for in the soft, less siliceous schists the pyrite occurs in crystals of a size readily detected by the eye, while in the hard silicified rocks it is present in abundance, but in such exceedingly minute crystals that they appear small even under a high power. These schists strike N. 40° to 60° E. and dip from 45° to 80° NW. (See Pl. V.)

Massive granite, similar to that in the tin belt farther west, is exposed about 2 miles northeast of the mine and may occur, covered by soil and sands, at a considerably less distance.

[a] Bull. North Carolina Geol. Survey No. 3, 1896, p. 34.

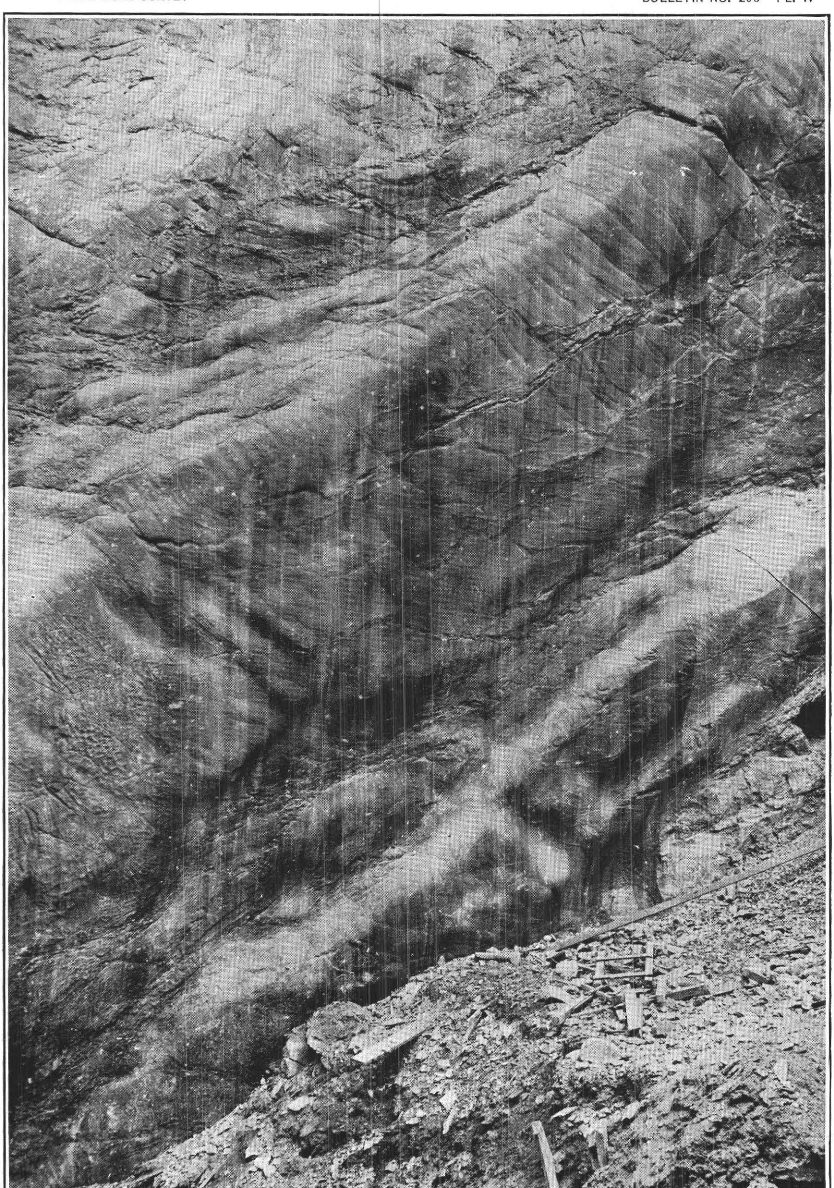
Several dikes of diabase close to the mine workings strike north-northwesterly across the foliation of the schist. (See map, fig. 8.) These are approximately vertical. A small decomposed diabase dike east of the Bumalo pit has a northerly strike and a steep dip to the east, and a narrow dike of diabase, also decomposed, exposed in the Beguelin cut, is parallel to the foliation of the surrounding rocks. (See Pl. VI.) In the description of the ore bodies, these dikes will be referred to and designated by their width, which is given on the map. In the Haile pit, as has been said, the ore has been mined away from the 27-foot dike, leaving it standing up as a partition between the two sides of the pit. In the new pit a side fully 150 feet square is exposed (Pl. IV). Near the surface this exposure affords a good example of the formation of residual soil. In the lower portion the dike has an uneven wall, the surface being billowed and looking shriveled or folded, much like an elephant's skin. The larger irregularities are rudely parallel corrugations and indicate the dip of the inclosing schists. The appearance of the dike suggests that it was intruded when the surrounding rocks were in a plastic condition, which certainly was not the case. Along the walls of these diabase dikes the miners find a layer of soft, muddy material which they term a "binder," and which doubtless represents an outer zone of decomposition. This binder is removed at the same time as the ore. It may be that the varying thickness of this decomposed portion has caused the irregularities in the surface of what remains, but if that is the case it is difficult to understand why these irregularities correspond with the dip of the schist. It seems more probable that the fracture through which the molten diabase came was influenced by the structure of the rocks in which it formed and hence did not develop along a perfect plane, but as an undulating crack. A petrographic description of the diabase of the region is given on page 23.

Where crosscuts and drifts penetrate these dikes away from the ore bodies, there is little alteration of the quartz-sericite schist at the contact with the diabase. The schist is baked or hardened a little for a few inches from the dike and shows a slight sheeting parallel with and close to the dike. Surface waters have been able to follow the crevice between dike and schist and have oxidized both rocks to a small extent. The diabase has usually suffered most in this respect. Small crystals of gypsum occur in the joints of both rocks where this oxidation has been moderate. Where the dikes cut the silicified schist of the ore bodies, the changes which they cause are even less marked and are practically negligible. There is no noticeable difference in the character of the diabase where it cuts the barren, unsilicified schist and where it breaks through the silicified rock of the ore bodies.

CHARACTER AND OCCURRENCE OF THE ORE.

The ore bodies of the Haile mine typify the class of replacement deposits previously described. They consist of large lenses of altered tuff which has been subjected to certain changes in composition. This alteration is of comparatively simple nature, consisting mainly of a silicification and pyritization of the porous tuffs. In most cases these two processes appear to have gone on simultaneously, so that although the pyrite is the mineral which carries the greater portion of the gold, the degree of silicification usually corresponds so closely to the degree of pyritization that it is commonly accepted as a rough measure of the richness of the ore. Soft, unsilicified schist is an unwelcome discovery, while rock so silicified that it will strike fire under the hammer is always looked on as a favorable indication. In general, the distribution of these replacing minerals is fairly uniform, producing a hard, bluish ore, usually with a lustrous fracture, due to the sericite, and containing disseminated pyrite, of which much is too fine in grain to be readily seen. Under the microscope this ore is seen to consist mainly of small polygonal grains of quartz with swarms of minute pyrite crystals, both cubes and octahedrons, scattered all through; sericite shreds and occasional fragments of biotite and remnants of a feldspar individual occur between the quartz grains. The rock which has suffered most intense silicification is a fine-grained aggregate of quartz and pyrite, with sparing fibers of sericite.

Here and there the replacement of the original rock has not gone on evenly. Light colored veinlets, occurring either singly or in numbers, closely spaced, probably represen



SIDE OF DIABASE DIKE EXPOSED IN THE HAILE PIT.

Major corrugations represent dip of ore-bearing rock which has been mined away. Vertical streaks due to water stains.

very narrow fractures which allowed an especially easy passage for the solutions and consequently the extreme silicification of the adjoining rock. In a few instances these crevices have been wide enough to allow the deposition of quartz filling in addition to the replacement which has occurred along the walls. A few of these quartz veins are outside the limits of the ore bodies and nearly all of them carry little or no values. It is possible that they were formed a little later than the general silicification which produced the ore bodies. A large, worthless vein of this sort outcrops strongly back of the stamp mill, and is shown in fig. 8. A smaller vein or lens, practically barren, is encountered in the Bumalo cut.

There are likewise places where the deposition of pyrite has been especially marked, producing masses which in some cases are nearly solid sulphide. These, too, are usually tabular in form, but can not be definitely referred to fractures, as can the quartz veins. Bodies of this kind, rich in pyrite, associated with molybdenite (heretofore assumed to be graphite) and carrying good gold values, occur near the hanging wall of the Haile ore body in the new Haile pit. The molybdenite occurs especially along narrow parallel bands in the pyrite and shows the effect of sliding motion, or slickensides. Gold occurs free on these smooth surfaces of the molybdenite in excessively thin flakes, which seem to have been deposited before motion ceased. Pyrrhotite occurs sparingly in some of the Beguelin ore. An irregular bunch of pyrite, said to contain a considerable proportion of zinc, but only a small amount of gold, was found at the northeast end of the Beguelin pit, at a depth of about 75 feet.

Gold occurs in three conditions in the Haile ores—native gold as originally deposited, free gold derived from the oxidation of inclosing pyrite, and gold in the pyrite. In either of the first two states the gold can usually be recovered by amalgamation, although the gold freed by oxidation is sometimes "rusty," i. e., covered with a thin film of resistant material, perhaps iron oxide, which protects the gold from the mercury and thereby prevents amalgamation. In the unaltered pyrite only a small proportion of the gold is attacked by mercury and another process is required in order to save the values.

There is possibly still another way in which the gold occurs. Some specimens from the Beguelin cut, now in the Haile office, show thin flakes of gold in narrow cracks or joints in blue unoxidized rock. These specimens give the impression that the gold has been carried and deposited in these crevices by solutions later than the original ore solutions—probably by surface waters which have obtained the gold by dissolving it from the original ore. Thin sheets of pyrite, many of them with a radial structure, occur similarly in narrow cracks and likewise suggest secondary deposition. The free gold associated with molybdenite may also have been deposited in this way. It has been impossible to determine whether or not secondary enrichment, i. e., solution from upper portions and redeposition at a lower level, has actually taken place; but the possibility that such has been the case seems rather strong and has already been considered on pages 65–67.

Broken pyritic ore lying exposed to the air very readily undergoes oxidation, with the production of so much sulphuric acid that, to save the plates from injury, such ore is not amalgamated, but sent to the concentrators direct. In this case a narrow string of the liberated free gold leads the headings down the Wilfley tables. Oxidation underground is also proceeding rapidly, and in nearly every drift iron-laden waters are depositing layers of limonite. The comparatively small amount of water which the mine makes is held at the 350-foot level by pumping.

VALUE OF THE ORE.

The Haile is essentially a low-grade mine. Although rich nuggets have been found in the decomposed upper portions of the ore bodies, as already mentioned, and these upper portions as a whole doubtless held good values, the great bulk of the ore has been of so low a grade that the utmost care has been demanded in the extraction of the gold to make the operations profitable.

In 1883 the average value of the ore, which had been mined down to a depth of 75 feet, was estimated at about $11 per ton.[a] In 1887 the values were said to average $5 to $10, with $6 as a fair mean.[b] By 1900 $4 was considered to be the average gold content.[c] At the present time it is probable that the average value of the ore that goes to the mill is little if any above $3 per ton.

This marked decrease in value may be attributed to several causes. In the first place, there can be little doubt that the actual richness of the deposit has steadily decreased from the surface down. Second, instead of mining along certain rich places or zones, as was done in the early days, with resulting irregular workings, the mining now takes everything as it comes, rich and low grade alike, down to a certain limit of value. Third, reduced costs have made it possible to work at a profit ore which twenty or thirty years ago was worthless, and in consequence work is now deliberately carried into what would then have been considered the walls of the deposits. In some respects, therefore, the decrease in value of the ore is to the mine's credit, indicating that much more material is available for treatment than there could have been under the early conditions. The fact that the comparatively rich ore has been exhausted and that mining operations have been forced toward the outer limits of the ore bodies, however, is of course a state of things which no company could desire.

As for actual values of any given mass of ore at present, little information is to be had. Assays are not commonly made, and as a general rule the value of the ore is measured only by the recovery on the plates and by chlorination. As the ores from the several ore bodies are generally run through the mill promiscuously, it is difficult to determine the value of any one lot. When it is found that returns run below the line that separates profit from loss, steps are taken to determine which of the several localities where ore is then being mined is the cause of this decrease in value, and when this is known material from that place is not sent to the mill.

It is not meant to imply here that these operations are conducted carelessly. The various processes—crushing, amalgamating, concentrating, and chlorinating—have in the past been so carefully studied and so nicely perfected at this mine that it is believed that increase in percentage recovery would cost more than the value of the extra gold saved. With the total cost charged against the ore standing at about $1.60 per ton, it is doubtful if ore running much less than $2 is intentionally carried to the mill. In the Haile pit certain zones carrying heavy pyrite, considerable molybdenite, and some free gold carry $12 to $14 per ton, and at a depth of 200 feet, just below the bottom of the Haile pit, some $40 ore has been found. These values, $2 and $40, probably represent about the extremes at the present day.

When mining was begun at the Haile practically all the gold was free, since oxidation was complete near the surface. As near as can be learned, the water level was at about 60 feet. From that point downward sulphides have been increasingly important. In the nineties a check on the value of the ore was kept by frequent panning, the amount of free gold being approximately proportional to the total value of the ores. As greater depths were reached the proportion of the total value occurring as free gold decreased still further, and is now about one-fourth; and much of the ore now worked profitably shows no color in panning. Visible free gold in the coarse ore is rare. It occurs most commonly as thin flakes on the molybdenite in the Haile pit.

Pyrite ranging in amount from 1 or 2 up to 30 per cent of the ore is saved by the Wilfley tables. The value of the tailings is not known to the writer, but the extreme fineness of the pyrite grains makes it probable that an appreciable quantity of pyrite is lost. The loss in concentration a few years ago was said to be 15 to 20 per cent,[d] and was doubtless attributable in large part to this small size of the pyrite grains. The ore is concentrated

[a] Spilsbury, E. G., Trans. Am. Inst. Min. Eng., vol. 12, 1884, p. 101.
[b] Idem, vol. 15, 1887, pp. 770–771.
[c] Lakes, A., Mines and Minerals, vol. 21, 1901, p. 56.
[d] Nitze, H. B. C., Bull. North Carolina Geol. Survey No. 10, 1897, p. 137.

HAILE ORE BODY NEAR BOTTOM OF HAILE PIT.

Showing foliation and dip. Looking northeast.

about 12 to 1 on the average, and these concentrates are very clean, seldom containing over 15 and often under 10 per cent of rock. The pyritic portion of the concentrates is practically pure iron sulphide, with only a slight amount of copper and occasional traces of arsenic. These concentrates range in value from only a few dollars up to $40 and more per ton. Between 90 and 95 per cent of their value is extracted by the Thies process of roasting and chlorination. It is probable that the total extraction is a little under 80 per cent of the assay value of the ore.

A point to which the miners unanimously hold, but for which an adequate explanation has not yet been found, is the decided influence of joints on the value of the ore. This feature seems to be best illustrated in the Haile ore body, but is said to apply also to the Bumalo and Beguelin deposits. There are three fairly well-defined systems of joints in the ore of the Haile pit. One system, approximately vertical and at a right angle to the strike, has little or no effect on the values except at the southwest end of the body, where the joints appear to be the boundary of the pay ore. Joints parallel to the foliation of the rocks likewise have little influence on the values. Joints of the third system, running from foot to hanging wall perpendicular to the dip and called "floors," are said to have a decided effect on the values. For a few inches on each side of them, particularly on the under side, the ore is said to be better than elsewhere, and there is also said to be a difference in value between any two. These floors are well shown in Pl. V. They have every appearance of being of later formation than the ore, and why they should so affect the value is not known, unless secondary enrichment has taken place along them, and that is probably not the case.

ORE BODIES.

The most remarkable feature of the Haile mine is its large ore bodies. Some idea of the size of these has already been given in the description of the developments. Roughly outlined on the surface by the presence of float gold the principal ore bodies were at once recognized. Subsequent work has resulted in the three large open cuts—the Haile, Bumalo, and Beguelin pits. As the grade of ore which could be profitably treated progressed lower and lower, these workings have been extended into the outer portions of the deposits. All these principal ore bodies, which are lenticular in form, are influenced in their position by the structure of the rocks in which they occur. In other words, their longest horizontal dimension lies in a northeast-southwest direction, and they dip to the northwest.

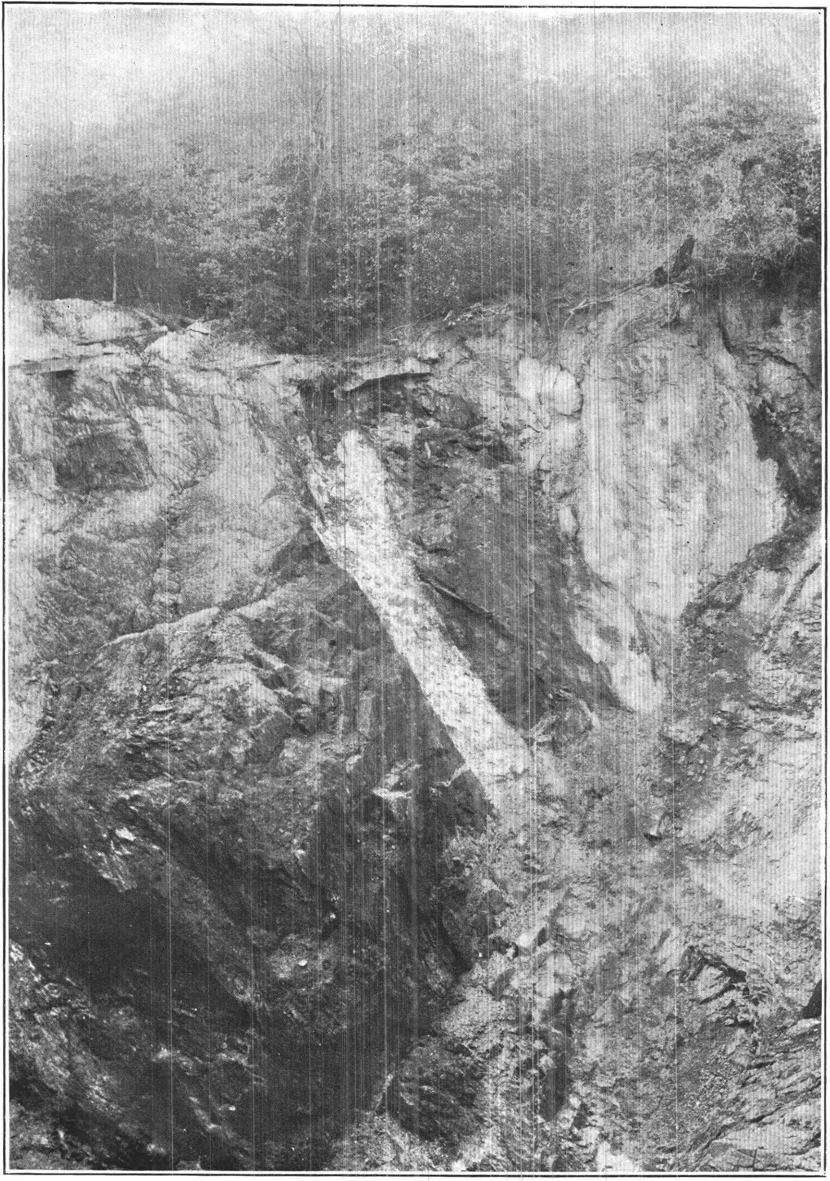
The Haile ore body is an irregular lens of altered tuff whose foliation strikes about N. 40° E., and dips on the average 55° NW. This foliated structure is preserved in the ore, as well as in the unaltered tuff, and is well shown in Pl. V, which is a view toward the hanging wall of the new Haile pit near its bottom. If the field of the photograph extended a little farther to the right, the diabase dike shown in Pl. IV could be seen. Pl. V also shows incidentally the method of breaking the ore, which practically amounts to quarrying. The ore body following this rock structure is about 200 feet long from northeast to southwest, and on the average 100 feet thick at a right angle to the walls. From a description of the old Haile pit, now filled in and inaccessible, and from what can be seen underground, the northeast end of the deposit seems to narrow up, lens-like, till finally pay ore practically ceases. At the southwest, however, at least for the upper 200 feet, the boundary between pay ore and rock of too low grade to be worked is roughly a plane running approximately vertically across the deposit. There is in some cases even a joint or break at this place, on one side of which ore occurs and on the other practically worthless rock. This suggests the possibility of faulting along a plane parallel to the 27-foot dike, but there is no other evidence of such an occurrence. It is difficult, however, to explain the sudden cutting off of the values and of the alteration which produced them.

About 100 feet below the surface, at the southwest end of the pit, a small bunch of quartz occurred holding some free gold. At 130 feet, about midway between the foot and hanging walls, at the same end of the pit, a horse of well-foliated sericite schist, soft in comparison with the surrounding silicified ore, juts into the pit, and continues with the general dip as far as work has gone. Just northwest of this, or toward the hanging wall, the ore is heavily impregnated with pyrite along a zone 2 or 3 feet wide. Narrow bands of molybdenite carrying free gold occur with the pyrite. This ore is said to run $12 to $15. Not far from the hanging wall is another similar streak.

The foot wall, exposed for practically the full width of the new pit, has a smooth, distinct surface with large horizontal waves or undulations. It is approximately parallel to the foliation of the rocks. Several crosscuts into the foot wall have demonstrated the absence of pay values beyond this surface. The line of demarcation between ore and waste is therefore rather sharp. Much of the hanging-wall rock has necessarily been broken to prevent its caving in. The nature of the transition from ore to waste is therefore not so well exposed as on the foot-wall side of the deposit. Crosscuts from the ore into the hanging wall give some idea of this boundary of the ore body, and while the change from ore to unprofitable rock appears to be less abrupt than on the foot wall, nevertheless the values decrease rapidly away from the present stopes. These facts mean that no matter how much the processes of winning the gold are cheapened in the future, the limits of this ore body are already set, so far as lateral extent is concerned. Similar conditions exist in the Bumalo and Beguelin bodies. Less satisfactory evidence leads to the same conclusion regarding the longitudinal extension of future pay values. In depth, too, it is plain that the various ore bodies are not indefinite. In the Haile body some very good ore, running as high as $40 per ton, has been found at the 200-foot level, a little below the present bottom of the Haile pit. Some stoping has been done between the 200-foot and 270-foot levels on the Haile ore body, and more ore from pillars and from the lower-grade periphery can probably be taken out profitably when the open cut reaches that depth. But below the 270-foot level the values are low, and unless relatively rich pockets or lenses are discovered the time must be expected when the ore will become so lean that with the increasing cost as depth is attained it will be impossible to mine with profit. A drift on the 350-foot level runs under the continuation of this ore body and encounters material carrying values that are appreciable, but too low to pay for mining. It appears, therefore, that the ore body has a greater extent downward than horizontally, but it seems likely that the limit of workable ore includes much less ground.

In the Bumalo ore body the principal differences from the Haile are those of dimensions. The main portion of the cut, about 250 feet long, is lagged over at a depth of about 100 feet, and thus separated from stopes which continue downward almost 200 feet farther. This ore body, striking about northeast and dipping to the northwest at a little lower angle than the Haile body, has a decided pitch north-northeast in the plane of foliation. It is narrower than the Haile deposit, averaging perhaps 40 feet perpendicular to the walls. A large quartz lens near the surface is inclosed in the ore body. It is practically barren, although the miners believe that the ore near it is a little richer than at a distance. At a depth of 45 feet a northeasterly drift was run from the end of the Bumalo cut. Low-grade ore was encountered as far as the 192-foot dike. The drift was continued through the dike, but no ore was found on the east side. A small diabase dike with northerly strike occurs just east of the main workings. It is much decomposed and does not carry values. A big stope on the 200-foot level is now inaccessible. On the 270-foot level uneven distribution of the values has resulted in irregular stopes, both steep and flat, separated by large and small pillars of lower-grade rock. Pay ore was found to stop about 25 feet below the 270-foot level. The pitch of the deposit has carried it to the 192-foot dike on this level. The 350-foot level explores the continuation of this ore body. Appreciable values are encountered where the ore would be expected, but nothing of workable grade has been found. Just west of the 192-foot dike a 130-foot winze has been sunk, inclined northward at 75°, in the hope of striking a new pay shoot, but only low-grade values were found. The 350-foot level continues on through the 192-foot diabase dike, but fails to reach ore. The position of the narrow diabase dike on the east side of the 192-foot dike shows that little or no faulting has taken place along the latter.

In view of the recumbent position of this ore body, necessitating the removal of much waste from the hanging wall, the extraction of the material remaining below the 200-foot



BEGUELIN ORE BODY, HAILE MINE.

Showing dip and interfoliated diabase dike now decomposed. Looking west.

level as pillars and as low-grade boundaries will be increasingly expensive by continuation of the open cut. Fig. 9 shows the distribution of values in the Bumalo cut.

The Beguelin ore body is in general character similar to the two already described. It is cut in two by the 130-foot dike without faulting. Ore extends along the strike of the schists about N. 60° E. for nearly 300 feet on each side of the dike. Near the northeast end of the ore body the 27-foot dike, which has split, crosses the ore. Just outside the ore body, in the hanging wall, a 3-foot dike of much decomposed diabase, called a "clay" dike, parallels the strike and dip of the ore. Pl. VI gives a view of this interfoliated dike as exposed at the southwest end of the pit. The average thickness of the Beguelin deposit is about 70 feet. In depth the ore reaches to about 170 feet, and there quickly drops off in value. Most of the richest ore was taken out to this depth by underground workings. Open cutting was then begun. The open cut east of the dike is 160 feet deep and has practically exhausted that end of the ore body. At the northeast end, perhaps 40 feet below the surface, were found the specimens showing free gold in the joints described on pages 63 and 64. About 50 feet northeast of this place and 35 feet deeper a small body of heavy pyrite, carrying some zinc, was struck, and 100 tons were shipped for the manufacture

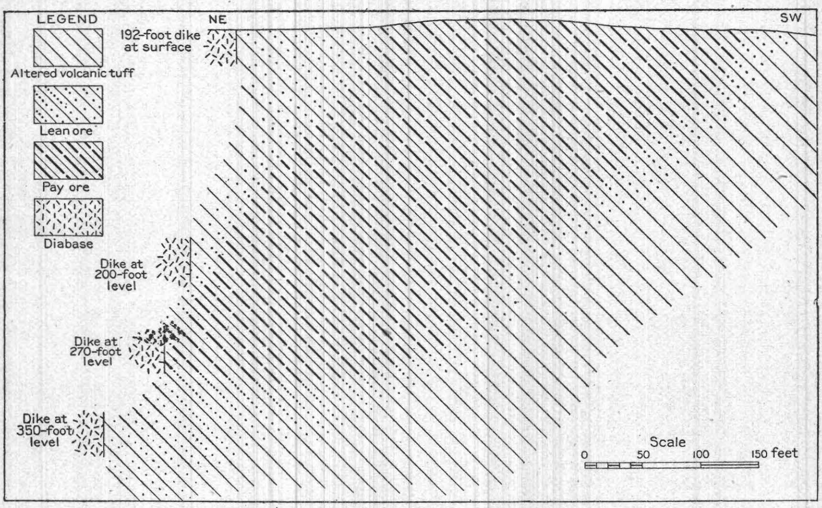


FIG. 9.—Longitudinal projection (approximate) on plane of deposit of the Bumalo ore body, Haile mine.

of sulphuric acid. On the southwest side of the dike the open cut had been carried to a depth of 120 feet at the time of visit, and had almost reached the southwestern limit to which underground mining had been carried. (See Pl. VII.) Still farther southwest of this point for over a hundred feet values are encountered, but they are so low that it is doubtful if mining can be extended there. The demarcation of this material from the surrounding rock, however, is such as to place it as part of the ore body, and it has so been shown in fig. 10.

Silicified and pyritized tuff carrying gold values is known in several other places. Assays have been obtained at several points northwest of the Beguelin pit, but up to the present time no further prospecting has been done in that locality. On a small elevation known as Chase Hill, several hundred feet northeast of the Beguelin cut, some shallow open pits have been dug on siliceous rock, with numerous quartz-rich streaks. Pyrite, once plentiful, has been mostly oxidized and carried away, leaving the rock crumbling and stained. The strike of these pits is in direct line with that of the Beguelin, and it seems highly probable that the two ore bodies are connected by a band of lower-grade material somewhere underground if not at the surface. The Chase Hill deposits, although explored underground as well as by surface workings, have never been important producers and are not now being worked. On Red Hill, 500 or 600 feet northeast of the Bumalo pit, considerable ore was once mined from open cuts reaching down to the limit of complete oxidation—about 60 feet. The body here, a lens which lines up well with the Haile deposit, has a maximum thickness of 100 feet. Considerable exploration in the way of diamond drilling and well drilling has been carried on here recently to determine if lower portions of this deposit would constitute profitable ore, but the writer learns from Mr. Thies that the values encountered were not very high and exploitation has ceased. It may be remarked here that 6- to 10-inch wells drilled by machines of the Keystone type have been found at this mine to be decidedly cheaper for holes down to 500 or 600 feet than diamond drills, and that the bailed drillings give a much more satisfactory indication of the values passed through than do diamond-drill cores.

About 150 feet northwest of the Haile pit the 185-foot level entered much jointed and fractured silicified rock which carried no visible free gold but averaged $8 per ton on assay. This body, about 30 feet in diameter, extended about 40 feet above and 25 feet below the level. A raise to this body from the 270-foot level passed through several streaks of $5 ore. Thirty feet west of the northwest corner of the Haile pit an old level 115 feet below the surface encountered $3 ore in amount too small to warrant extraction. On the 200-foot

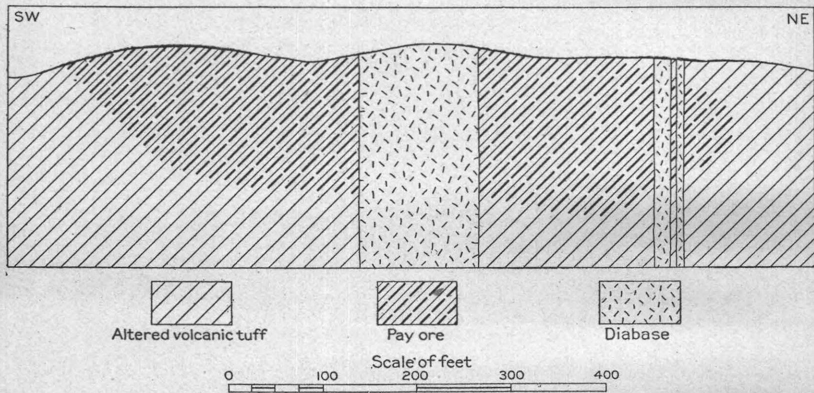


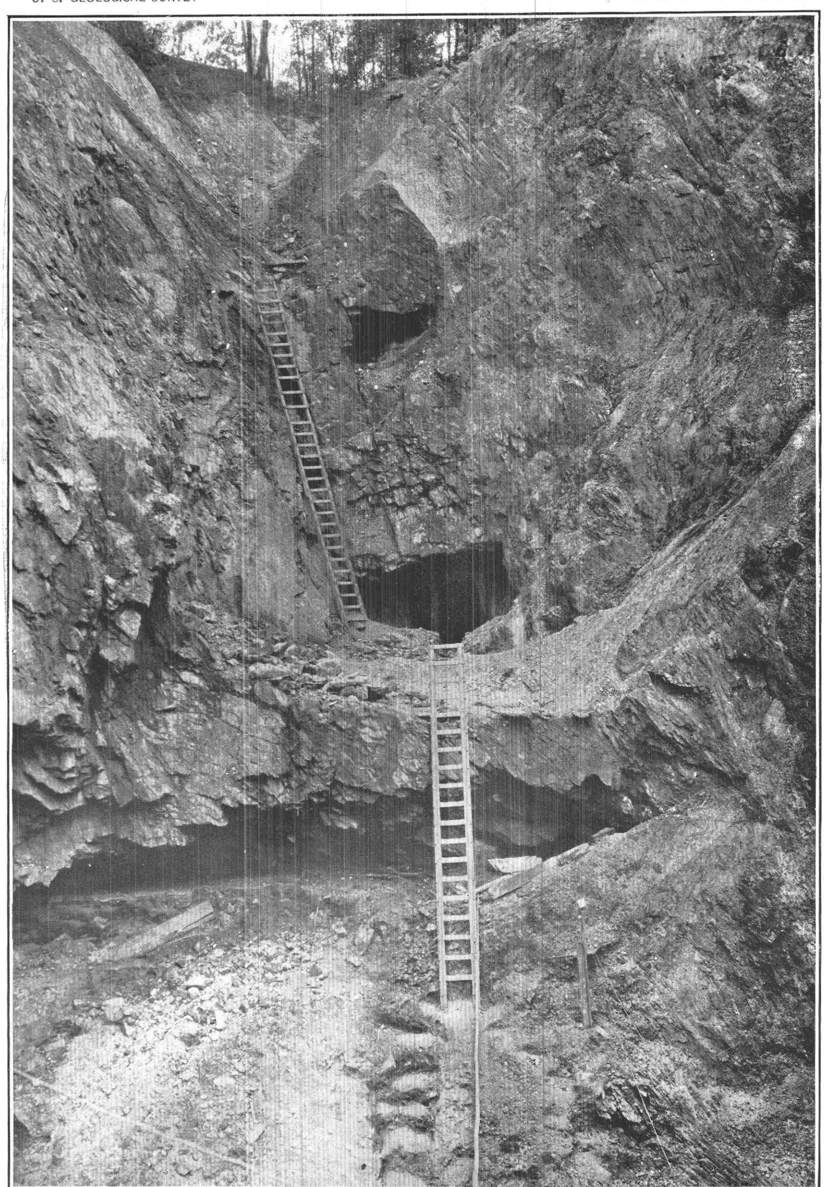
FIG. 10.—Vertical section (approximate) of the Beguelin ore body, Haile mine.

level, about 100 feet northeast of the No. 4 shaft, 75 tons of ore exhausted a small body occurring near but apparently not related to a quartz vein.

At a depth of 20 feet the No. 5 shaft reached ore assaying $4.50 per ton. This proved to be the top of a chimney-like body 15 feet in diameter, which ceased at a depth of 42 feet. A northeast crosscut from the bottom of the 100-foot shaft extends for 130 feet through material assaying 50 cents to $2 per ton and then reaches a practically barren hanging wall. The values are too low to warrant further development of this body. A well 400 feet deep about midway between the Haile and Beguelin pits gave evidence of quartz and silicified schist carrying pyrite with traces of gold.

A recent letter from Mr. E. A. Thies, manager of the mine, reports the discovery of a new ore body about 300 feet southwest of the 130-foot diabase dike on the continuation of the strike of the Beguelin deposit. Twelve holes have been drilled and indicate that the values rapidly decrease below 140 feet. Two hundred feet farther to the southwest drill holes indicate the presence of a large decomposed diabase dike cutting across the rock structure.

This new ore body, with the Beguelin and the Chase Hill pits, constitutes a zone almost 1,500 feet long, parallel to the foliation of the country rock and at a right angle to the main diabase dikes. This, it seems to the writer, is another argument against the existence of a



BEGUELIN ORE BODY, HAILE MINE.

Showing old levels and stopes exposed by open cut. Looking southwest.

genetic relation between the dikes and the ore. This subject is more fully discussed on pages 70–72.

While considerable ore of workable grade remains in the ore bodies now developed, the new deposit recently discovered and others like it must be looked to if the mine is long to continue as an important producer. It may be that ore bodies possibly of equal grade with those already known exist along the same general zone at greater depth, but it is not so probable that they can be discovered and worked at a profit. The possibility that secondary enrichment has effected the value of the known deposits is too uncertain to allow prediction as to the value of bodies below the surface. Of the bodies which reach the surface, it is probable that the richest are already known, but it is reasonable to believe that along the strike of these known deposits others of workable grade exist and might be discovered by careful surface prospecting.

COLOSSUS MINE.

The Colossus mine is situated in Union County, N. C., about 4 miles south of Waxhaw, on the Seaboard Air Line, and about 3 miles from the South Carolina line. Until recently it was called the Howie [a] or Huey [b] mine, and was once known as the Cureton mine. [c] At one time it was one of a group known as the Grand Union Gold mine. [d] It was worked certainly as early as the fifties and probably earlier than that. Before the war Commodore Stockton owned and operated the mine and it was sometimes known as the Stockton mine. Considerable ore was taken out at that time. About fifteen years ago the mine was again worked and the production considerably augmented. Some three years ago a company began to cyanide the amalgamation tailings from former operations. The Colossus Gold Mining and Milling Company now has control of the property and was working rather extensively at the time of visit, This company has its head office at Nazareth, Pa., and Mr. William B. Shaffer is manager.

No definite information is to be had regarding the production of this mine. Some say that a million has been produced, others half a million. In 1856 it was stated that the profit per month was $18,000 to $20,000 clear. [e] The cyaniding operation of a few years ago is said to have yielded $36,000.

The development consists of four shafts with rather short levels and several trenches. The Bull Face shaft was started as an incline, but fifteen years ago it was made vertical and carried to a depth of 160 feet. Later an incline was started from the 120-foot level of the vertical shaft and carried downward about 200 feet, so that the total depth of the shaft is about 320 feet. Only a small amount of drifting has been done. Active pumping had lowered the water to 220 feet in November, 1904. The Old Nettie and the New Nettie shafts, both sunk under former management, are nearly filled with water and are much caved. It is said that the New Nettie shaft is over 300 feet deep. The Pansy shaft, which was put down by the present company, is 104 feet deep and has perhaps 200 feet of drifting and crosscutting at its bottom. An old open slope or trench exposes the upper portion of the ore body.

In the way of surface development there is a small hoisting plant over the Pansy shaft, besides office buildings, assay office, etc. A 500-ton cyanide plant was well under construction at the time of visit. It is the intention of the company to work the mine as a large open cut, to break the ground by quarrying methods, raise and carry the ore in buckets by an aerial tramway reaching to the mill, dry crush by rolls to 30 mesh, and leach with cyanide in large vats.

The geology of the Colossus mine is very similar to that of the Haile. Foliated quartz-sericite schists retain enough of their original character to show that they were porphyry

[a] Emmons, E., Geol. Survey North Carolina, 1856, p. 133.
[b] Lieber, op. cit., vol. 1, p. 56.
[c] Kerr and Hanna, Ores of North Carolina (chap. 2 of Geology of North Carolina, vol. 2), 1893, p. 237.
[d] Kerr and Hanna, op. cit., p. 261.
[e] Lieber, op. cit., vol. 1, p. 43.

tuffs. Fragments of feldspar—microcline, microperthite, and plagioclase—and of brownish biotite are readily discernible in most of the microscopic sections of the rocks. The foliation of these schists, which appears in all cases to represent original bedding, strikes N. 55° to 65° E. and dips northwest at an angle of almost 90°. These schists have been silicified along certain bands which appear to represent shear zones. Where unoxidized, the resulting siliceous rock is dense and bluish, with lustrous cleavage faces almost identical with the Haile ore except that at the Colossus the banding is generally better preserved. A pronounced jointing has taken place, evidently since the silicification of the schists. These joints dip 80° to 90° SW. and strike about N. 35° W. Along these principal joints several dikes of diabase of similar character to that at the Haile mine have been intruded. They range in width from 5 to 8 feet. These joints and dikes often fault the ore body. One dike to the northeast of the principal mine workings is said to displace the vein 300 feet laterally. It is said that in the case of all these faults the northeastern side is thrown to the northwest. The "Monroe" beds, which are known to exist a few miles to the northeast, have evidently been eroded away in the immediate vicinity of the Colossus mine and certainly have no connection with the ore.

This mine is another excellent example of the replacement deposits of this region. The ore is decidedly similar to the Haile ore. It is hard, blue, siliceous rock, usually with decided fissility or cleavage, and contains pyrite. As at the Haile mine, ore is limited to the silicified portions of the schists. Small quartz stringers, usually parallel to the foliation, give the impression of almost complete replacement by silica of the rock adjoining narrow fractures. Pyrite is a little more abundant near these stringers than elsewhere. The zones of most intense silicification in general constitute the best ore. They exhibit a decided sheeting parallel to the original foliation and doubtless owe their existence to the fact that the ore-bearing solutions found readiest channels along sheeted zones. Oxidation is also more advanced along these sheeted zones than elsewhere, owing, without doubt, to the more easy penetration of solutions which they allow. Pyrite is less abundant and more evenly distributed through the ore than at the Haile mine and no molybdenite has been seen.

The condition of most of the gold is a matter not definitely established. It is said at the mine that the greater part of the gold is free and also that there is very little pyrite present. The fact that mining was carried on fully 200 feet below the water level when amalgamation was the only means of extraction employed would seem to strengthen this statement. The writer saw numerous specimens containing free gold, but all of them had suffered oxidation and in all the gold had the appearance of having been derived from pyrite. While it is true that pyrite is not abundant, it is present in tiny grains all through the ore, in amount ample to contain all the gold which the assays show. A possible explanation of the presence of free gold below the water line may be found in an occurrence near the bottom of the Pansy shaft. Joints and crevices along which water from the surface travels with more or less ease show the effects of oxidation; the adjoining rock is stained brown or red and a red slime oozes down the walls. The ore is usually better near these places than elsewhere. Away from visible fractures of any kind, the hard, unstained blue rock is often found to be porous, containing many minute cavities which correspond in form to pyrite crystals. Some of these cavities are partially filled with a light-colored crystalline substance which proves to be at least in large part ferrous carbonate. It is evident that some kind of solution, which probably means some kind of oxidation, has attacked the pyrite. It is equally evident that waters carrying dissolved oxygen, like the ordinary surface waters, have not been active. It is possible that the pyrite has been oxidized and converted into a sulphate by sulphuric acid, or ferric sulphate, or both. Such a reaction may have necessitated the liberation of free sulphur or of sulphur dioxide, although evidence of neither of these was seen. It was impossible to decide how widespread this phenomenon has been, and free gold has not been detected in the cavities originally occupied by the pyrite; but it is possible that gold could in this way be liberated from the inclosing sulphide and form a free-milling ore below the limit of ordinary oxidation.

The fact that of the ore milled during the former working of the mine a large percentage was not recovered is to the writer's mind an indication that considerable of the gold was contained in pyrite. On many of the numerous minor joints flat scales of pyrite occur, some of them with a rudely radiating structure. These fractures and the pyrite in them have almost certainly been formed subsequent to the principal deposition of quartz and sulphide. This occurrence of pyrite is rather common in or near the porous rock from which pyrite has been removed and is perhaps a redeposition of the actual material which constituted the original pyrite crystals. Where oxidation has been marked, small flakes of gold are frequently found on joint faces, only loosely attached to the rock and presenting the appearance of having been derived from this probably secondary pyrite. If such is the case it would seem to argue in favor of secondary enrichment, or at least solution and redeposition of gold comparable to the secondary enrichment of copper.

The ore which has been mined from the Colossus mine has probably been of higher grade than that taken from the Haile mine. That near the surface was rich, some of it running over $200 per ton.[a] In the later work the ore is said to have averaged about $15 per ton.[b] The tailings recently worked by cyanide had doubtless been subjected to some concentration by the action of the water which discharged them from the mill and by subsequent rains. They are said to have yielded from $3 to $15 of gold per ton. These values are not justly comparable with those at the Haile mine, for there the bodies of ore worked have been extended to the greatest possible size by including rock of lower and lower grade, while up to the present only the richer shoots, much smaller in size, have been mined at the Colossus. Assays made by the present company are said to run from $2 to $2,000. The rock broken in sinking the Pansy shaft is said to have averaged $8. As this is near the middle of what is considered the ore body, it is probable that the average value of the deposit will run somewhat under that figure. Lieber, writing in 1856,[c] states that the gold was worth 87½ cents per pennyweight, which, on the assumption that the accompanying material was silver, would make the fineness of the gold about 0.840. Of the $36,000 extracted by cyanide, about $1,100 is said to have been silver, making the fineness of the gold recovered from the old tailings about 0.435. It is stated by Professor Hanna, who made many assays of this ore, that the fineness ranged from 0.725 to 0.775.[d]

The old stopes are not extensive. A chimney-like ore shoot in the Bull Face workings was followed by the incline shaft. It pitches about 75° NE. At a depth of 140 feet the stope on this ore shoot is 20 feet wide and 40 feet long. From 140 down to 220 feet the stope ranges from 20 to 30 feet in diameter. Below that depth—the water level at the time the mine was visited—the size of the stope was not known, although it is said that when the old work was stopped there was ore in the bottom of the shaft and ore was left on the northeast side of the stope. The value of the rock forming the walls of this old stope was not learned by the writer. Of the stopes in the other old shafts practically nothing is known at present. They probably followed shoots similar to that in the Bull Face.

The Colossus Company has control of 10,000 feet along the strike of the deposit, and gold is known to occur at intervals throughout this extent, but adequate prospecting has been done on very little of the property. The portion which the company expects to mine at present is said to be 400 feet wide and perhaps 800 feet long. This body, approximately vertical, is parallel in its long direction to the foliation of the schists. At the bottom of the Pansy shaft crosscuts in each direction have been run about 100 feet. They show narrow strips of soft, almost barren rock, which separates zones of ore, but which are of so small bulk that it is the belief of the company that the whole may be mined and milled. In the writer's opinion—based, it is true, on a hasty and superficial examination of the deposit—exploration has not yet been sufficient to warrant so extensive preparations for milling as are being undertaken. It is questionable, moreover, if the straight cyanide process to be employed will sucessfully treat this sulphide ore.

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[a] Emmons, E., Geol. Rept. Midland Counties of North Carolina, 1856, p. 1314.
[b] Cf. Nitze and Hanna, Bull. North Carolina Geol. Survey No. 3, 1896, p. 105.
[c] Op. cit., vol. 1, p. 57.
[d] Kerr and Hanna, Ores of North Carolina (chap. 2 of Geology of North Carolina, vol. 2), 1893, p. 235.

BREWER MINE.

The Brewer mine is situated on a branch of Lynch River, in Chesterfield County, S. C., about 4 miles southwest of Jefferson, on the Charlotte, Monroe and Columbia branch of the Seaboard Air Line. It is about 10 miles northeast of the Haile mine. The property is being worked by Mr. B. J. Hartman, under lease from the De Soto Mining Company.

This was probably the first important producer in South Carolina,[a] and is even believed by some to have been worked before the Revolutionary war.[b] In 1830 and 1831 from 100 to 200 men were employed daily.[c] The first work was placer operations at what was known as the Tanyard deposit, which lies to the east of the present workings. Later, placer methods were applied to the decomposed portions of the deposits in place. Just before the civil war Commodore Stockton worked the mine and extracted the gold in Chilean mills and arrastres.[d] In the early eighties the Tanyard gravels were worked again, this time by hydraulicking. A 5-stamp mill was erected in 1885, in 1889 a 40-stamp mill was put in, and in 1892 a Thies chlorination plant was added, but continued in operation only a short time. It is said that the bringing of damage suits arising from tailings débris was one cause of cessation at this time. Spasmodic attempts, including some experimentation with the cyanide process, have since been made to resume active operations, but have brought little success. At present the mine is being worked on a small scale and the ore put through a 10-stamp mill with simple amalgamation. About half a dozen men comprise the force.

No idea of the production of this mine can be given. In the early days, when the output was probably at its greatest, no figures were made public. Probably several hundred thousand dollars have been taken from the mine.

The principal developments consist of two great open cuts. The old main pit is 140 feet deep and 200 to 300 feet in diameter. A tunnel extends eastward from the bottom 1,200 feet and leads to the mill near the river. Other tunnels or drifts have been run in various directions from the bottom of the pit. Several short levels, raises, and stopes make an irregular network underground, especially at the west side of the pit. About 500 feet southwest of this pit is another, more than 100 feet deep and about 150 feet in diameter. There is some thought of sinking this to the level of the bottom of the larger pit and connecting the two by a crosscut. In addition to these large cuts there are several shallow shafts and pits. The 40-stamp mill is in fair condition, but the chlorination plant has been demolished. The 10-stamp mill now being used is not well housed.

All geologists who have studied the Brewer mine have realized the difficulty of obtaining satisfactory knowledge of it. It is certain that porphyritic rocks, in part tuffaceous and brecciated, have been acted on by silica- and ore-bearing solutions. The rocks thus acted on differ so greatly from those which have escaped most of this action that it is difficult to decide if they were originally the same. The conclusion which seems most in accord with the facts is that all was once the same rock, but that intense brecciation, amounting almost to pulverization, affected some portions and left other masses only a little shattered. Then, when solutions sought to permeate this mass, they found easiest passage in the fragmental portions and there expended almost all their chemical and physical energy. The rock which remains least altered is a light-colored, fairly coarse-grained porphyry, with a small proportion of groundmass. The only recognizable original constituents are sparing grains of quartz and abundant phenocrysts of a mineral whose identity has not yet been established.[e] The quartz is penetrated by numerous prismatic crystals, apparently of secondary origin, possibly topaz, and the unknown mineral is in the majority of cases

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[a] Cf. Lieber, op. cit., vol. 1, p. 67.
[b] Kerr and Hanna, op. cit., p. 234.
[c] Becker, G. F., Gold fields of the Southern Appalachians: Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 257.
[d] Cf. Nitze and Wilkens, Bull. North Carolina Geol. Survey No. 10, 1897, p. 145.
[e] Dr. W. F. Hillebrand is now working on the analysis of this mineral. The purest material which has been separated has the maximum specific gravity of topaz, 2.57. Analyses of less pure portions show that the mineral has the same percentage of silica and alumina as topaz, but appears to contain less fluorine. In addition to this chemical disparity, the optical properties differ markedly from those of topaz. It may very well be, therefore that this is a new mineral. It is hoped that definite information on this point will soon be obtained.

much decomposed into sericite. Dark grains of a nonmagnetic titanium mineral are closely associated with this fluorine mineral. They may be ilmenite. Pyrite is present in crystalline grains impregnating both constituents. These less altered portions are practically valueless and have been left in place as the ore has been mined away from them. They are known as dikes. In all cases observed, however, they have no distinct walls, but gradually pass by increase of shattering and silicification into the dense bluish rock which constitutes the ore. On the surface this silicified ore is stained red from oxidation of the iron and well shows its brecciated character. Narrow veinlets of quartz, carrying a little pyrite, cut both the highly silicified and the little altered rock. In the former they seem to fade off into the surrounding rock; in the latter their walls are distinct, and along with and close to the pyrite they hold radiating masses of pyrophyllite. It certainly appears as if the three minerals—quartz, pyrite, and pyrophyllite—were contemporaneous.

Granite is known to occur about three-fourths of a mile to the west. It is said that a diabase dike passes near the mine.

From the standpoint of the miner the Brewer ore is similar to that of the Haile and Colossus mines. It is a dense blue siliceous ore, carrying finely disseminated pyrite and a variable amount of free gold. The ore of these other mines, however, is a replacement of bedded tuffs, while the Brewer rock is a replacement of what is probably only a massive igneous rock brecciated in place. There is consequently no evidence of bedding nor banding, and the only structure which the deposits show is a number of rather irregular systems of joints. The most prominent jointing strikes about N. 70° E. and dips steeply to the northwest. The Brewer ore is also more siliceous than that from the Haile and Colossus. Although pyrite occurs in the unsilicified rock, it carries very little gold. The pyrite in the blue, silicified rock, which averages about 7 per cent of the total mass,[a] carries, on the other hand, both gold and copper. When the pyrite decomposes it leaves cavities lined with an iridescent film of limonite. A black copper arseno-sulphide, enargite, is also present in small crystals and separates in the gold pan as the so-called "black sand." Where oxidation has taken place, this arsenical sulphide is decomposed and the copper is converted into the sulphate, chalcanthite, which forms a blue coating on the walls in several places, particularly at the north side of the main pit. Covellite has been found in the ore[b] and bismite and native bismuth have been reported.[c] Cassiterite has been found at this mine,[d] sometimes, as reported, in close association with the gold.[e] It seems probable that the cassiterite is an associate of the fluorine mineral of the original rock and that the ore, brought in later, was deposited about this difficultly soluble mineral.

The siliceous cement which binds the silicified fragments into a dense rock has been much attacked by surface water. Along certain planes or lines the cement has been removed by solution, allowing the rock to crumble to a very fine white powder which is almost pure silica. All the sulphur, iron, and copper of the sulphides have been leached out, but the gold remains, doubtless as free gold. Within these soft sandy portions residual masses are often found. They are hard and many of them when broken open are found to have a blue, unaltered core containing pyrite. In numerous instances they assume fantastic nodular forms resembling those of certain concretions. This sandy ore is especially sought for by the miners. In the first place, it is perfectly free milling. Moreover, it is of better value than the average blue unoxidized ore. This difference in value may be partly explained by the fact that the proportion of gold in the sand has been increased by the removal of such material as has been dissolved away. But this seems hardly adequate to account for the marked difference in value which is said to exist. The residual lumps of unoxidized rock found in the midst of the sand are said to be decidedly richer—they certainly hold more pyrite—than rock of similar appearance from the large unoxidized

[a] Nitze and Wilkens, Bull. North Carolina Geol. Survey No. 10, 1897, p. 144.
[b] Becker, G. F., Gold fields of the Southern Appalachians: Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 279.
[c] Tuomey, M., Geology of South Carolina, 1848, p. 97.
[d] Clarke and Chatard, Am. Jour. Sci., 3d ser., vol. 28, 1884, p. 25.
[e] Becker, G. F., op. cit., p. 308.

masses. Apparently this is another instance where descending, decomposing waters have found easiest passage along the same channel which gave to the original ore-bearing solutions their easiest ascent.

In certain places solution has gone on to the extent of forming cavities or vugs in the rock. One of these, encountered in the underground workings at the west side of the main pit, is 3 feet wide, 15 feet long, and 20 feet high. The two greater of these dimensions lie in the plane of a zone of the white sand above described.

The values of the ore mined in the early days can only be inferred from those known more recently; if what seems to be the general rule in this region applies to this particular mine, the first ore was considerably richer than that mined at greater depths. In their report in 1897 Nitze and Wilkens [a] state that the better grade of ore assays $5 to $7 per ton, while the average run of the mine is about $3. As a matter of fact the best ore has all been the decomposed, sandy material, or the residual nodules inside of it, with the one exception of a streak, near the southeast corner of the pit, of very siliceous rock which probably originally corresponded to the portions now decomposed, but which was so thoroughly sealed up by the siliceous cement that surface waters have not been able to penetrate it. At present only the sandy material is being sought for and the mining operations consist in gouging out and following the bodies of this character wherever they may lead. The resulting workings suggest and are indeed closely related in form to the honeycombed structure of much weathered limestone. It is said that under present conditions 60-cent ore can be put through the mill without loss, and $2 is about as good an average as can be obtained. In spite of the selection of the best ore, the grade of the ore is thus evidently decreasing, which probably indicates that the limits of the body from the standpoint of economy are being reached. Nitze's sketch plan of the mine,[b] which shows the unsilicified rock (mapped as granite) closing in on all sides, seems likewise to indicate that the limits of the ore are not far beyond the walls of the present cuts and stopes. It is not improbable, however, that other ore bodies, perhaps connected with the main deposit by comparatively narrow strips of profitable ground, might be discovered by more careful prospecting than has apparently been done. It seems, in fact, that the smaller pit is on such an ore body rather than on the same one as the main pit exposes.

BLACKMON MINE.[c]

The Blackmon mine, situated in Lancaster County, S. C., a little northwest of White Bluff post-office and about 14 miles north of Kershaw, has also been known since the early days of gold mining in this region. It is the property of the Piedmont Mining and Development Company, of Charlotte, N. C., and Mr. O. J. Thies is manager.

Until recently the mine has been idle for many years, although at one time considerable ore was taken out from an open cut.[d] Since the resumption of work all operations have been conducted underground. A shaft started in the hanging wall goes down vertically for 113 feet, where it reaches the foot wall and continues as an incline at about 40° to a point 180 feet from the surface, measured vertically. Drifts and crosscuts, probably amounting in all to 600 feet, have been run at the 80-, 113-, 153-, and 180-foot levels. The surface improvements consist of a 20-stamp simple amalgamation mill and a shaft house, with steam hoist and compressor.

The geology in this vicinity is much obscured by decomposition and by vegetable growth. While the rock relations are fairly plain in the mine, their significance is not so readily grasped. A body of extremely foliated sericite schist which strikes northeasterly and dips 30° to 70° NW. is cut by a porphyritic rock, also somewhat foliated, which lies to the southeast and has followed the planes of foliation of the schist. Both of these are crossed by a dike of diabase which has a northwesterly strike and dips steeply.

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[a] Bull. North Carolina Geol. Survey No. 10, 1897, p. 144.
[b] Nitze and Wilkens, op. cit., p. 146.
[c] Formerly known as Blackman's mine; cf. Tuomey, M., Rept. Geol. and Agr. Survey, South Carolina, 1844, p. 23.
[d] Tuomey, M., Geology of South Carolina, 1848, p. 95.

The schist has always been described as a talc schist, and its appearance certainly warrants such a description; but chemical examination shows that only a slight amount of magnesia is present, and the material is therefore sericite. The rock is more or less soft, decidedly fissile, and varies in color from dull gray to pinkish, bluish, and green. It is made up largely of shreds of sericite or fibrous mica, with a little quartz, numerous tiny red and black garnets, a little magnetite, and a few small fragments with high polarization colors whose identity is unknown. Where cut by the diabase dike the folia are much crumpled. It is probable that this rock is of sedimentary origin. The porphyritic rock, while fairly massive on the whole, is somewhat foliated near the contact with the schist, indicating probably that the intrusion took place just before the cessation of the shearing or folding movements which produced foliation. The contact is not sharp and simple; the schist was probably injected near the main porphyry mass by narrow dikelets of the porphyry, and the subsequent foliation has produced a mingling of the two rocks. In its present somewhat decomposed condition the rock consists of a fine-grained mosaic of quartz, sericite, epidote, and some zoisite, in which are imbedded large phenocrystic grains of quartz and of turbid feldspar, both orthoclase and oligoclase. A little biotite was probably present, but is now decomposed. This rock may be designated a quartz-monzonite porphyry, and is probably closely related to the tuffs which occur at the Haile and Colossus mines. The diabase is doubtless much later than either of the other rocks. Granite is known on the surface about one-fourth mile to the north.

The ore of the Blackmon mine is a zone of sericite schist occurring at the contact with the quartz-monzonite porphyry. Small siliceous lenses between the folia of the schist, averaging one-eighth inch wide and one-half inch long, have been formed, partly by filling and partly by replacement. Where this silicification is most marked the grade of ore is best. A small amount of pyrite accompanies the quartz and may carry gold, but the principal value is as free gold usually in tiny grains or flakes. In this ore zone the schist has a bright, vivid appearance—the colors are striking, ranging from delicate grays and pinks, resembling mother-of-pearl, to beautiful brilliant greens—and the rock is lustrous. Passing into the hanging wall to the more normal rock, the bright colors fade to dull grays and the hardness decreases. Narrow bands of quartz, true veins of filling, occur here and there in the ore body. They carry a little pyrite, but practically no gold. As in the case of all the mines thus far described, these barren quartz veins appear to be of a little later formation than the silicification which produced the ore. Between the ore body and the fairly massive porphyry there is a zone perhaps 5 to 20 feet thick, which forms the foot wall. In appearance it resembles the dull or "dead" schist of the hanging wall, but it is found to pass gradually into the unfoliated porphyry, and the microscope shows that it is of the same composition. It is pretty thoroughly impregnated with small cubes of pyrite, but carries only slight gold values. The density of the schist and the stability of its composition have resulted in excluding surface waters from the greater part of the ore body and the sulphides are in general unoxidized. But along certain fracture planes decomposition has converted the sericite into kaolin, the so-called "talc" of the miners. As a consequence great masses of ore, bounded by and resting on these sheets of soft and exceedingly slippery material, are continually tending to slide in and wreck the workings, and it is only by the strongest timbering that some portions of the workings are maintained. Another serious obstacle to economical mining which arises from the character of the ore is the difficulty of obtaining good results from blasting. The rock is so schistose that drilling can be done practically only at a large angle to the plane of foliation. A water Leyner drill has been put in and in this rock works far better than hand drills or ordinary machine drills. But even when the holes are obtained, it is almost impossible to get the powder to do more than shatter and loosen great slabs of the schist, which are still left wedged in place almost as firmly as before. Time and experience may disclose some more efficient manner of placing or loading the holes than has yet been discovered.

The ore body is a zone of altered schist parallel to the dip and strike of the schist of the region and to the contact with the quartz-monzonite porphyry. Measured horizontally, the mass that can be considered ore has an average width of 35 feet; it has been opened along the strike for 300 feet and may extend farther to the northeast. To the southwest it reaches practically to the diabase dike, but not beyond it, so far as present explorations have shown. As mined across this width the ore will average about $2 per ton. A richer streak occurs not far from the foot wall; it is usually green in color and is more siliceous than most of the ore, a fracture face across the foliation showing small siliceous lenses enmeshed in the sericite matrix. In this rich streak, about 25 feet northeast of the dike on the 113-foot level, a bunch of $35 ore was found. The values gradually decrease toward both foot and hanging walls. While the change from pay ore to unprofitable rock is not sharp and distinct, it is fairly abrupt, and there is little difficulty in recognizing the approximate line where pay values cease. The size and richness of the ore body appear to be holding out well with depth, and if the difficulties experienced in breaking and holding the ground can be overcome and the values can be successfully recovered by amalgamation, as seems thus far to have been the case, there is reason to expect that the future of this little mine should be bright. But developments are not yet sufficiently extensive to warrant any very far-reaching prognostications.

Apparently the ore-bearing solutions which produced this deposit were intimately related to the quartz-monzonite porphyry and closely followed the intrusion of that rock. Another peculiarity of this deposit which distinguishes it from those already described is that the gold occurs principally native, the pyrite carrying very little value. While this deposit can be regarded only as a replacement of the schist, in a way it approaches rather closely to the group which have been formed by the filling of fissures, and with the Ferguson mine, described on pages 96–99, constitutes a close bond between the replacement deposits and the vein deposits.

KINGS MOUNTAIN MINE.

This celebrated mine, first known as the Briggs [a] mine, and more recently as the Catawba [b] mine, is situated in Gaston County, N. C., near the western foot of Kings Mountain and about 2 miles south of Kings Mountain station. It has not been in operation for a number of years and was filled with water and inaccessible when visited by the writer. The following description is based mainly on the observations of others.

The mine was discovered in 1834 [c] and was successfully worked for several years by the discoverer, Mr. Briggs.[d] Later Commodore Stockton, who seems to have been a moving spirit in the gold-mining industry of this region, operated the mine for a number of years. Work was necessarily stopped during the war, but two or three years after its close a 20-stamp mill of the California type was built.[e] It is worthy of note that this was practically the first adaptation of western practice to the ores of the East.[f] Work continued at intervals up to 1895, since which time nothing has been done. It is said that the property is now involved in litigation among persons in Richmond, Va.

As is the case with nearly all the southern mines, no actual records of production have been kept. Kerr in 1875[g] stated that the production had been over a million, while Professor Hanna, who has been for many years in charge of the United States assay office at Charlotte, N. C., and who is probably best able to judge of the output of the Carolina mines, estimates the production of the Kings Mountain mine at $750,000 to $900,000.[h]

The amount of development can only be inferred from the incomplete descriptions of former writers. There are at least six shafts on the property. The two principal ones are the Holliday shaft, 330 feet deep, and the Rock or pump shaft, about 120 feet to the southwest, also 330 feet deep. All the shafts are vertical and are sunk in the hanging wall of the deposit. The main workings center about the Rock shaft. Crosscuts to the vein and

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[a] Lieber, op. cit., vol. 1, p. 92.
[b] Kerr and Hanna, Rept. North Carolina Geol. Survey, vol. 2, 1888, p. 304.
[c] Nitze and Hanna, Bull. North Carolina Geol. Survey No. 3, 1896, p. 147.
[d] Lieber, op. cit., vol. 1, p. 92.
[e] Kerr, W. C., Rept. Geol. Survey North Carolina, vol. 1, 1875, p. 280.
[f] Cf. Nitze and Wilkens, Bull. North Carolina Geol. Survey No. 10, 1897, p. 35.
[g] Loc. cit.
[h] Nitze and Hanna, Bull. North Carolina Geol. Survey No. 3, 1896, p. 147. Becker, G. F., Gold fields of the Southern Appalachians: Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 309.

levels on the vein have been run from the Rock shaft at a depth of 140 feet, mostly to the southwest, and from the 270-foot and 330-foot levels to the northeast to connect with the Holliday shaft. There are two shallower shafts farther northeast and two southwest of these workings. A large amount of stoping has been done on each side of the Rock shaft. Considerable decomposed rock from the outcrop of this deposit southwest of the Rock shaft has been removed and washed in rockers. Besides a shaft house, hoist, steam pump, and Cornish pump at the Rock shaft, there is a substantial 30-stamp mill with concentrating tables.

The geology is not well shown by surface exposures. As this mine is situated on the slope of the Kings Mountain Range, the rocks all strike to the northeast, and at this place the dip is northwest. A somewhat micaceous schist incloses an interstratified bed of limestone. The limestone is impure and schistose and is often closely interbanded with the biotite schist. The limestone is shot through with interlaminated stringers of quartz and is somewhat silicified and pyritized, especially along the planes of most intense foliation. A zone of impure graphite, in many places heavily impregnated with coarse-grained pyrite, underlies the limestone. Southwest of the Rock shaft the ground is strewn with lumps of iron oxide, probably derived from the decomposition of pyrite. Some of this iron is naturally magnetic. There are indications of a small lateral fault south of the Rock shaft, by which the northeast side of the vein is thrown 10 to 12 feet to the southeast. It has been said that a granitic dike was encountered in the workings.[a] This might be a dike of pegmatite, which occurs abundantly a mile or so to the northwest.

The richest ore of the Kings Mountain mine is contained in the narrow veins or stringers of quartz bearing gold and auriferous pyrite. These seem to have been rather more abundant in the upper portion of the mine than at the depth where the last work was done. The inclosing schistose limestone, however, has been sufficiently penetrated by the solutions which circulated in the veins to have deposited in it as impregnations enough gold and pyrite to make it an ore. In the upper decomposed portion, which is stained by the oxidation of the iron sulphides and called "brown ore," the gold occurred free, and so long as amalgamation was the only recovery process employed, this ore was eagerly sought for. There is no doubt, however, that this oxidized ore was really richer than the corresponding unchanged ore below. The quartz stringers were so charged with pyrite that when that mineral oxidized they were honeycombed and crumbled almost as easily as the softer decomposed schists, and thus the whole outcrop could be easily worked in rockers. It was only when development penetrated fresher rock that the presence of limestone was discovered. Whether the appearance of limestone at some depth is to be attributed to the fact that it is a lens-like body, not reaching to the surface, or that it was sufficiently impure to furnish, on oxidation and solution, the residual material occurring near the surface, it is impossible to decide, but the latter seems the more reasonable conclusion. Alternating bands of limestone and schist, when carrying workable values, were known as "calico ore." Both in the quartz and the impregnated limestone other minerals were present in addition to pyrite. Pyrrhotite, chalcopyrite, galena, and zinc blende were not uncommon, and among the rarer ore minerals were mispickel, tetrahedrite, nagyagite, altaite, and bismite; and besides the calcite and graphite of the limestone were the gangue minerals—quartz, sericite, and fluorite. The mineralogical character is thus seen to have been pretty complex. Whether the ore-bearing solutions differed correspondingly from that type of solution which seems to have formed most of the other gold deposits of the region, or whether the difference lies in the greater chemical instability of the limestone, it is impossible to determine. The fact that arsenic, antimony, and tellurium have not been found in the other mines described would lead to the conclusion that the solutions were of different character, while the presence of bismuth compounds at the Brewer mine and of fluorite at the Schlegelmilch and the general character of the Kings Mountain deposit, make it easy to believe that the two classes of deposits are intimately related in origin. Chalcanthite, which is present as a coating on the stope walls, has doubtless been derived from oxidation of the

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[a] Becker, G. F., op. cit., p. 309.

chalcopyrite, and needles of epidote, found in some of the decomposed porous ore are perhaps likewise of secondary origin.

This ore has a rather wide range of values, assays showing from a trace up to over $75 per ton.[a] It is said that the ore as mined averaged perhaps $4 to $6 per ton.[a] Of this, not over $3 was saved,[b] largely, it is said, because the graphitic material of portions of the ore prevented the amalgamation of much of the fine gold. The concentrates ran $35 to $40 per ton. The amount of silver in the ore was very small, but was approximately proportional to the amount of gold.

The ore body consisted at the surface of the siliceous iron gossan, and in depth of the impregnated schistose limestone and the quartz stringers in it. It was parallel to the foliation of the rocks, striking about N. 40° E. and dipping 45° to 55° NW. This body reached in places a width of 60 feet. It consisted in reality of five known shoots of richer ore, especially penetrated by gold-bearing quartz stringers, and generally near the graphite foot wall, together with the poorer material which occurred between and along the walls of these shoots. It is said that a stope begins near the surface at one of the old rocker pits, 200 feet southwest of the Holliday shaft, extends beyond that shaft, probably 400 feet in all, and gradually deepens to the northwest till at the Holliday shaft it is 330 feet from the surface. The writer was told by Mr. R. Hufstickler, one of the former miners, that some of the best ore in the mine was left in the bottom of a 30-foot winze below the bottom level when work was last stopped. Beyond this meager statement nothing can be said as to the possible extent of this ore body or the future of the mine.

FERGUSON MINE.

The Ferguson mine is situated in the northwest corner of York County, S. C., about 7 miles by road northeast of Kings Creek station, on the Three C's branch of the Southern Railway, and about 11 miles southeast of Grover, N. C., on the main line of the Southern. It is owned by Messrs. Frank & Dover, who are operating it at the present time.[c]

This mine has been known for some time and was worked some years ago by Maj. John F. Jones, of Blacksburg, who is said to have hauled 1,500 tons of the ore to that place for treatment. Recently it has been taken up by the present owners. In addition to four old incline shafts sunk on the vein, that to the southwest being the deepest (80 feet), a new vertical shaft 100 feet deep has been sunk in the hanging wall and a crosscut run 60 feet to the vein, on which stoping is being done in a small way, really as exploration or development work. The surface improvements include a stamp mill (five stamps in place and foundation ready for five additional) with Wilfley table, and a cyanide plant, besides head frame and hoisting engine at the shaft.

The geologic relations were only partially grasped in the short time spent at the mine, and it required microscopic study of the specimens collected to reach the opinions now held. The Ferguson vein lies approximately at the contact between amphibolite and a porphyritic tuff, both of which have been subjected to much foliation. The amphibolite, which lies on the southeast, is a rather massive dark rock, which at close view is seen flecked all through with small light-colored particles. Toward the contact, which strikes about N. 40° E. and dips 65° to 75° SE., the foliation is more marked and the rock becomes slaty. The lack of sharpness at the contact with the porphyritic tuff may be an indication that the amphibolite has been derived from a rock which was also tuffaceous or brecciated, but certain remains of igneous-rock structure make it probable that the original rock was a diorite or gabbro. The tuff, which occurs on the northwest side of the contact and outcrops in the stream some distance west of the mine, is of gray color with a silvery luster, and has a decided fissility or schistosity which may correspond to original bedding of the tuff. The fresh and glistening rock from underground is called, as at other mines, "fish-scale slate." The mineral fragments which make up this rock show that the massive equivalent would be a quartz-monzonite porphyry. It is practically identical with the tuff at the Colossus mine and probably the same as that at the Haile. There seems to have been a zone of especially

[a] Nitze and Hanna, Bull. North Carolina Geol. Survey No. 3, 1896, p. 147.
[b] Nitze and Wilkens, Bull. North Carolina Geol. Survey No. 10, 1897, p. 67.
[c] According to report, this mine was closed down in 1905.

marked foliation at the contact of the two rocks or just within the amphibolite. The result is a band of exceedingly schistose rock of light-green color and lustrous surface, composed very largely of sericite but containing also quartz and epidote. It seems probable that this product is the outcome not only of the shearing but of the action of the vein solutions. This zone outcrops noticeably on the surface southwest of the shaft and is reached underground at the bottom of the shaft.

The Ferguson ore deposit lies principally in the porphyritic tuff. It would at first be taken as a representative of the fissure-vein type, and so it is; but it is more than that. By the deposition of quartz as a filling of space it represents the fissure veins and by the impregna-

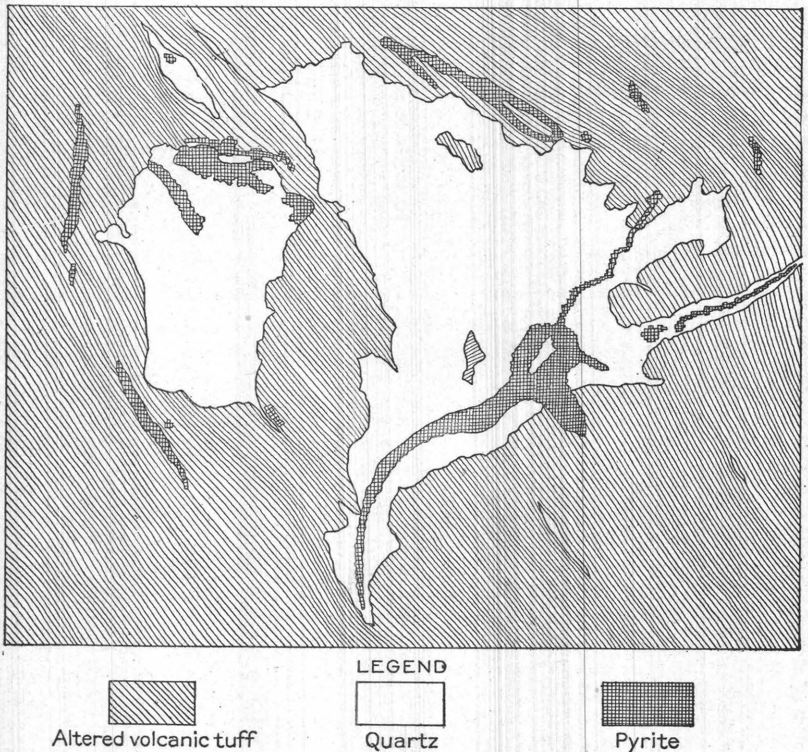

FIG. 11.—Sketch of vein, vertical section, Ferguson mine, winze, looking northeast.

ion of the fissure walls by the ore-bearing solutions it stands as a close link to the replacenent deposits. In fact, if the quartz lenses could be completely removed, there would emain a small and low-grade replacement deposit, similar in character to those of the Haile nd Colossus mines. The ore is thus of two kinds—vein quartz carrying good values and djoining wall rock (cf. pp. 59–61) carrying just about enough gold to pay for milling what s broken rather than sorting it out. The quartz ore from the vein carries only a slight mount of free gold where it is unoxidized;[a] but the proportion of pyrite is rather large, veraging about 10 per cent. The pyrite occurs plentifully within the quartz, but shows a narked tendency to segregate near the vein walls and in many cases it occurs in the wall ock just outside the quartz. Fig. 11 is a sketch of one side of the winze which is being sunk

[a] Mr. Frank informed the writer that he had never seen a particle of native gold in the undecomosed ore from this mine. Amalgamation tests have yielded $1 per ton.

from the 100-foot level. The quartz body represented continues upward toward the observer and downward away from the observer; like nearly all the quartz lenses, it has a pitch to the northeast in the vein. The irregularities shown in the figure indicate that replacement has gone on. Besides the pyrite which can be shown in the sketch, minute crystals are scattered through the wall rock and doubtless contribute to it a small amount of gold. The tuff is silicified, too, as in the other replacement deposits. Filling is indicated, on the other hand, by the fact that some of the solid bodies of quartz include fragments of the wall rock with foliation not corresponding to that of the walls in place. Moreover, in the roof of the crosscut from the shaft, just where it reaches the vein, the quartz adjoins amphibolite instead of tuff. Here the pyrite is mainly contained in the quartz; the contact between quartz and amphibolite is sharp and is defined by a narrow band of black biotite scales which separate the two and which have doubtless been formed from the amphibolite by the action of the vein solutions. Under the microscope this biotite possesses the clear chestnut-brown color characteristic of contact-metamorphic biotite. Here and there the vein quartz contains little flakes or tufts of sericite, which have the appearance of being contemporaneous with the quartz, but the evidence is not certain. A few tiny flat crystals of black ilmenite occur in the quartz. This strengthens the relation between the gold-quartz veins and those ilmenite-bearing quartz veins which are not known to be auriferous. (See pp. 64–65.) Numerous crystalline grains of apatite in the replacement portion of the deposits emphasize the similarity to the Haile mine and suggest relation to the Dahlonega deposits where apatite occurs in the veins (p. 124). Where the vein cuts amphibolite, the origina magnetite (or ilmenite?) of the rock is in many instances partly or completely replaced b pyrite, and in a few cases magnetite has been deposited on the pyrite. In the amphibolit near the vein are scattered small bunches of crystalline calcite, surrounded by dark-gree specular or micaceous chlorite, heavily impregnated by pyrite; this is undoubtedly product of the vein solutions.

The pyrite-bearing quartz ore from the vein averages $10 to $15 per ton. The replace wall rock, impregnated by silica and pyrite, averages about $3. The amphibolite wall roc is said to average $1.50 per ton and the sheared sericite zone in the amphibolite $2. Th concentrates average $100 and perfectly clean pyrite $150 to $175 per ton.

So little of the gold is free that amalgamation is not practiced. The pulp, stamped t 15-mesh, is run direct to the Wilfley table. The headings are stored, in the prospect being either shipped or roasted and cyanided on the ground. The tailings are run to pneumatic-cone separator, where the slimes, averaging 15 per cent of the tailings and ru ning $20 per ton, are taken out and cyanided during mechanical agitation, while the sand carrying $6 to $7 in gold, are treated with strong cyanide solution without agitation. It understood that the process is not yet wholly satisfactory. Possibly more careful crushi to avoid sliming, more efficient concentration and classification, and then roasting of all t headings and subsequent lixiviation might give a better extraction at perhaps no great cost.

The ore bodies of the Ferguson mine, like the other fissure-vein deposits, are influenced their form by the structure of the surrounding rocks. In this case their form has been fu ther modified by the effects of replacement. The result is rudely lenticular masses of quar surrounded by low-grade zones of replaced wall rock. Four of these lenses are known a have been worked to some extent by separate shafts. Only one, the northeasternmost, now being explored. Present work is being carried on as the downward continuation of former stope. On the 100-foot level this stope is 4 to 8 feet wide and 25 to 35 feet long. reaches upward to the surface and has been explored 30 feet below the level by an inclin winze sunk on the pitch of the shoot, which is steep to the northeast. This work is bei carried on solely with the idea of exploration, but in the hope that by following the ore it w pay for itself. The winze will be carried down to the 200-foot point if the ore continues, which event the shaft will be sunk another 100 feet and connected with the vein. If t present dip of the vein continues, the shaft should cut the vein at approximately 300 fe

If the pitch of the other ore shoots likewise persists, they should all be within easy striking distance of the shaft at that depth. The plan therefore is to explore this northeastern ore shoot to the 300-foot level and, if it proves satisfactory, to tap the other shoots, in the hope that they are similar to the first. The policy here adopted of exploring by *following the ore*, rather than by sinking and crosscutting in the hope of striking it, is to be heartily recommended in this region of irregular and nonpersistent deposits. The foresight with which the shaft has been located and future work planned is a gratifying exception to the way in which most of the gold-mining enterprises of the South have been started.

The structural and other outward features of this deposit strongly resemble those at many of the mines in the greenstone schists of central Ontario, where quartz veins carry auriferous pyrite.

Some specimens of vein quartz from a deposit about one-half mile to the southeast of the Ferguson shaft—probably what is known as the Ophir mine—contained free gold not derived from the decomposition of pyrite, although some pyrite was present. Some of this ore is said to be very rich. Two hundred tons have been hauled to the Ferguson mill. About 300 tons shipped to the smelter at Norfolk, Va., are said to have given returns of $25 per ton.

BROWN MINE.

This mine, situated in York County, S. C., about 4 miles south of Hickory Grove station on the Southern Railway, is owned by Mr. W. E. C. Eustis, of Boston. It was once worked by Mr. Fred Frank, now part owner of the Ferguson mine, who took out some good ore and made some money out of it. The production is not known—probably a few thousand. Three shafts and their workings and a crosscut tunnel, aggregating something like 1,500 feet of exploration work, comprised the development before the present owner took control. Since then an 80-foot inclined shaft has been sunk. Work was abandoned in 1905, after a small amount of ore had been taken out.

The country rock was probably an amphibolite, but the only obtainable specimens which had not been affected by weathering were so near the vein that they had suffered marked alteration by the vein solutions. The rock thus produced is dark gray, somewhat foliated, and resembles many granitic gneisses. It is composed of abundant feldspar, mostly microcline and albite; plentiful small flakes of biotite of the contact-metamorphic variety; numerous grains of epidote and almost as much zoisite, in short, stout crystals; and occasional grains of titanite. Lenticular aggregates of quartz, numerous grains of pyrite, and sparing pyrrhotite have probably been deposited by the vein solutions.

The vein, which strikes approximately N. 45° E. and dips about 70° NW., is parallel to the foliation of the amphibolite country rock. Its dip is not constant, flattening somewhat at about 30 feet, then steepening again at a depth of 70 to 75 feet.

With the exception of disintegration, resulting from decomposition of the vein and the surrounding rock, the vein is well defined near the surface, being a solid mass of pyritiferous quartz about 3 feet wide. In one place, however, near the old Frank incline, a lateral offset or jog of about 12 feet occurs, both at the outcrop and underground. The description of this occurrence underground is interesting as throwing light on the structure of these interfoliated veins in schist. On the surface the vein is continuous but crooked (see *A*, fig. 12), while underground at the 80-foot level the vein breaks up, probably somewhat as shown in *B*, fig. 12. These sketches are based on description of the behavior of the vein, supplemented by what was visible on the surface at the time the mine was visited and on assumptions drawn from occurrences at other portions of the vein. The influence of jointing has certainly been marked. *A* and *B*, fig. 13, represent what might possibly be the case at depths of 200 and 300 feet, respectively. This series, hypothetical with the exception of *A*, fig. 12, is intended to represent the variations in structure which may take place in a vein in a comparatively short distance. It also shows how such apparently disconnected lenses as occur in the Schlegelmilch mine (fig. 14) are in reality all connected, and it emphasizes the advisability of following stringers or offshoots if the main vein gives signs of pinching out.

There is evidence in other parts of the workings of the vein having pinched and offset, as in *A*, fig. 12. A crosscut tunnel from the northwest passes, at a depth of 60 feet, the point where the vein ought to be, without cutting anything but stringers, although the vein occurs with normal width on each side of this place on the surface. It is probable that this gap is

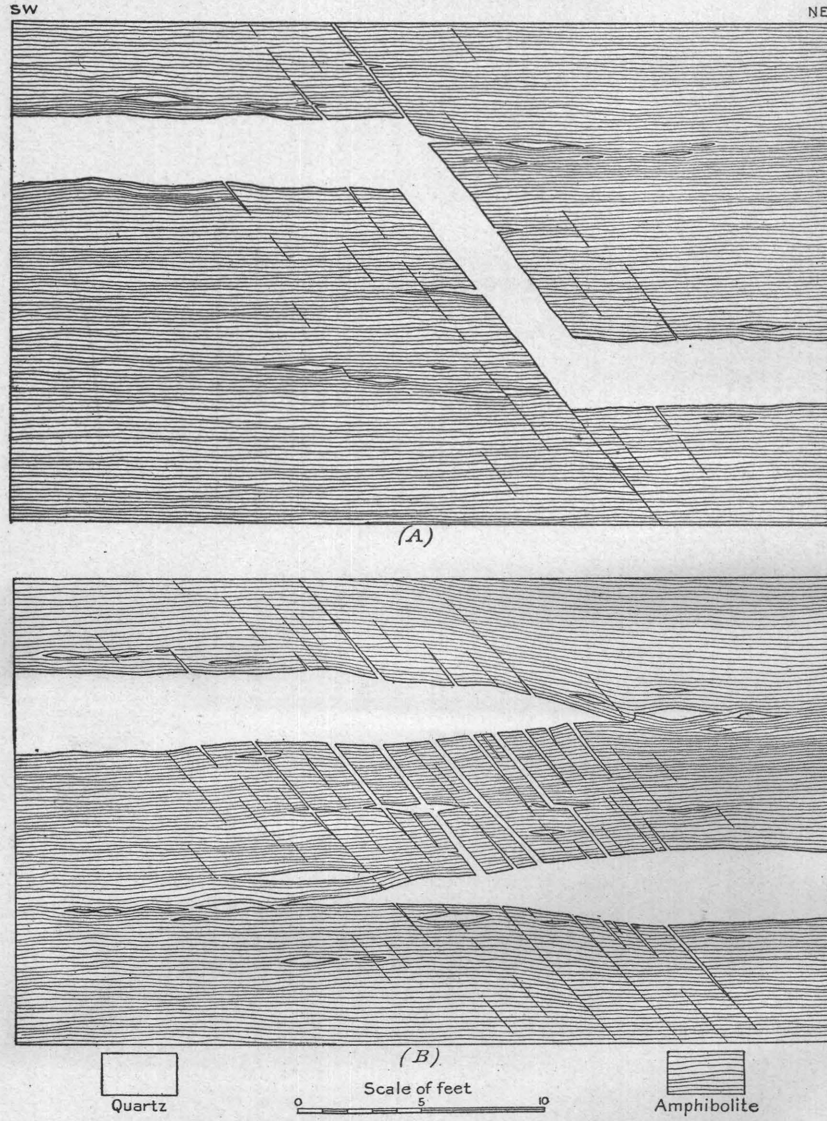

FIG. 12.—Diagrammatic sketch plan of vein at Brown mine. *A*, Vein at surface, showing offset due to presence of one predominant joint plane; practically no faulting. *B*, Vein at depth of 80 feet, showing pinching along one plane of foliation and continuation along another; also influence of numerous coordinate joints in leading the solutions from one main fracture to the other.

horizontal rather than vertical, for it corresponds in position to a gap encountered in the new incline a short distance to the southwest. In sinking this new shaft the vein was followed downward at 55° to a depth of about 55 feet, where it pinched out. It had been noticed that little joint planes or crevices branched off into the foot wall, so the shaft was steepened;

soon a narrow stringer dipping about 70° was picked up and followed. This stringer widened, and in a few feet had attained the proportions of the main vein. At 80 feet another irregularity occurred, and work was stopped at that point without determining the nature of the difficulty. A few feet southwest of the new incline the vein gives out. The miners believe that faulting has taken place, and such may be the case, but it may be that pinching alone is the cause, in which case a small amount of surface trenching ought to expose the continuation of the vein.

The ore at this mine is confined wholly to the fissure filling. The massive quartz contains pyrite—in some places a large proportion—of various degrees of perfection of crystal form. The sulphide carries the great portion of the gold. One peculiarity of the decomposition of the pyrite at this mine is the formation of crystalline sulphur (see p. 64). The ore as broken runs $4 to $7 per ton, although some heavy sulphide portions have been much richer. Sorting raises the average value to about $12, the quartz without pyrite always being rejected. Considerable stoping was done by Mr. Frank. He took out most of the vein from the 50-foot level and in places from the 80-foot level to the surface for a distance of probably 300 feet along the strike. A few hundred tons have been taken out along the new incline by the Eustis management.

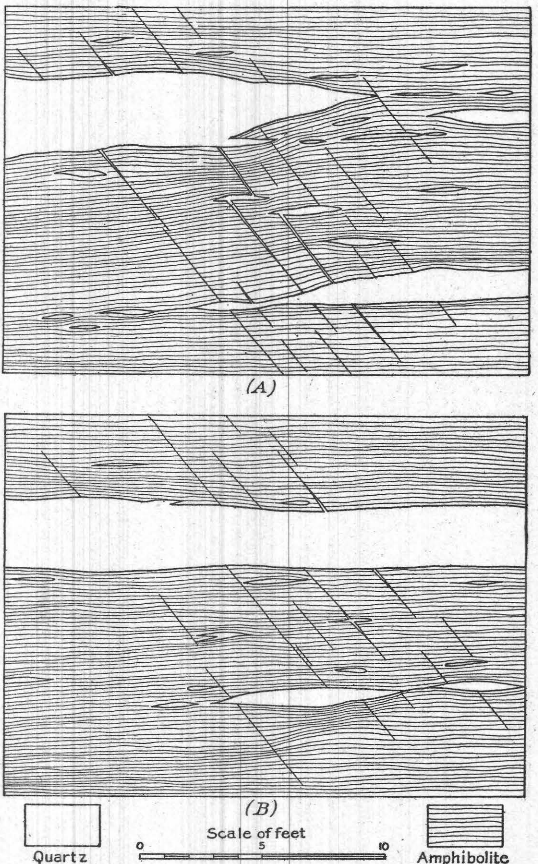

FIG. 13.—Hypothetical plan of vein at Brown mine as it might appear at greater depths. *A*, Vein as it might appear at some distance below the 80-foot level, showing pinching and the slight influence of joints. *B*, Vein as it might appear at some still greater depth, showing the vein again continuous by the uniting of so-called lenses.

The comparatively low grade of the ore, irregularity of the vein, and the combat with water will always make the working of this mine expensive.

SCHLEGELMILCH MINE.

In western York County about 3 miles southwest of Hickory Grove and about 1½ miles northwest of the Brown mine, is the Schlegelmilch mine, which is also the property of Mr. W. E. C. Eustis. This mine was worked over fifty years ago by the first owner, from whom it is named. No idea of the production can be given. It is known simply that some oxidized ore of good grade was taken out in the early days. The amount must have been small. Besides several old shafts extending down to water level, or down to the limit of general oxidation—perhaps 40 to 50 feet—which are in most cases caved in, a shaft about 100 feet deep has more recently been sunk and probably 250 feet of drifting done. A small steam hoist was in use. The Schlegelmilch mine was closed down at the same time as the Brown and is not now in operation.

The country rock for miles around, so far as known, is amphibolite, of varying degree of foliation but all sufficiently squeezed to be classed as schist. Several quartz veins occur in the amphibolite parallel to its foliation, which here strikes about N. 35° E. and dips about 65° SE. Although some work was formerly done on at least three of these veins, only the southeastern one is now being worked. On and near the surface the vein is fairly regular, averaging about 2 feet wide. At about 70 feet the vein pinches and soon splits up as represented in fig. 14, which is a sketch of the cross section of the vein as shown at the northeast end of the shaft at the 85-foot level. These lenses have been somewhat modified in form and outline by subsequent crushing, so that the exposure at the side of the shaft suggests magnified augen gneiss.

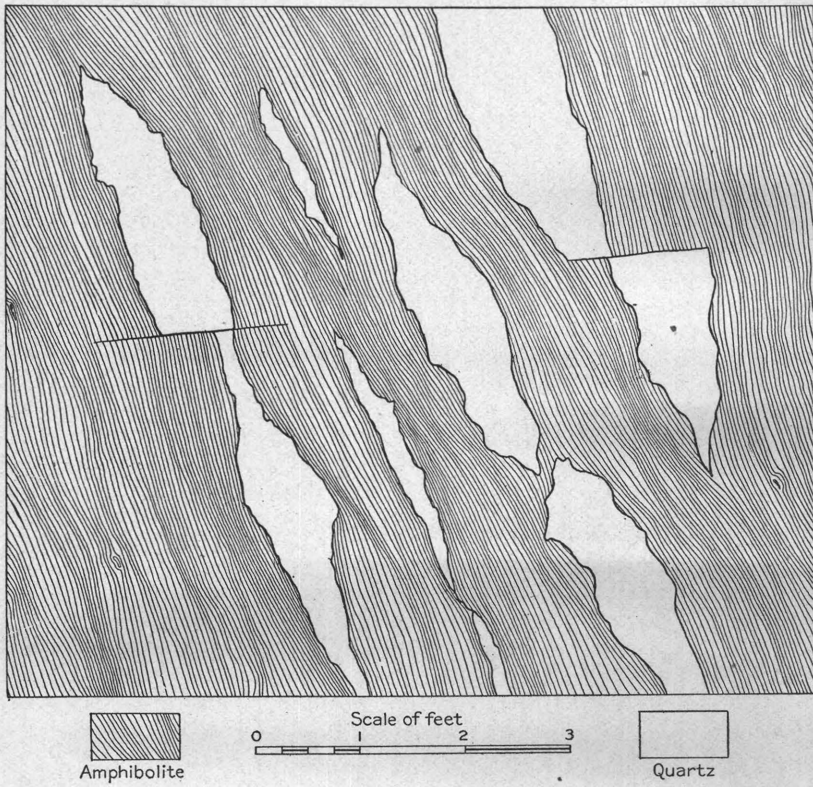

FIG. 14.—Sketch of vein, vertical section, Schlegelmilch mine, near bottom of shaft, looking northeast.

The vein stuff is quartz carrying a variable proportion of auriferous pyrite, which, in some cases at least, is slightly cupriferous. So far as known native gold does not occur in the unoxidized portions of the vein. Pyrite, sericite, calcite, biotite, chlorite, and perhaps serpentine are developed in the near-by amphibolite by the metasomatic action of the vein solutions. Pyrite is not abundant in the wall rock and occurs usually as small cubes. The calcite, because of its easy solubility, is frequently found in crevices in the quartz vein, having probably been carried in from the walls. Much of it is slightly greenish, perhaps because of a slight intermixture of chlorite. A narrow veinlet of fluorite cutting the quartz is obviously of later formation, but is doubtless referable to the same source as the siliceous solutions. Assays of specimens from neighboring portions of the vein show decided fluctuations from almost nothing to $50 or over per ton. The average value was not learned

No stoping nor drifting has been done below the 45-foot level, but from that level upward the ore has been about all extracted for 50 feet northeast and perhaps 150 feet southwest of the shaft. At least half of that stope, however, was made years ago. Since the writer's visit the shaft has been carried to a depth of 100 feet, where the vein is said to have pinched out entirely. Crosscuts were run in both directions, and while it is not known how carefully this exploration was carried on and to what extent the influence of the wall-rock structure was studied and considered in directing this work, the continuation of the vein was not discovered.

THOMPSON MINE.

The Thompson mine lies in the western part of Union County, S. C., about a mile northeast of West Springs post-office and about 3 miles east of Glen Springs, Spartanburg County, the terminus of a branch of the Charleston and Western Carolina Railway. The mine is the property of the Ophir Gold Mining Company, of Indianapolis, Ind., and is being worked under lease by Mr. M. C. Mayes. At the time of visit the mine was partially filled with water and thus inaccessible. Only meager information could be gleaned from an examination of the dumps and old cuts and from a study of specimens found there. What is here recorded has been obtained largely from the writings of others.

As early as 1847 this was one of the well-known mines of the State.[a] It is doubtless the same as that described by Tuomey[b] in 1844 as the Fair Forest mine. Work was continued in the fifties and perhaps until the beginning of the war. Little information can be obtained of more recent work, except that in the nineties Mr. O. J. Thies, now manager of the Blackmon mine, directed operations for a short time. Some hydraulicking, with attendant milling of the coarse material according to the so-called Dahlonega method, was done in 1895.[c] The production may have been considerable—perhaps $100,000 or more. The only statement in print is that $6,000 was taken from one shoot in 1847.[d]

The workings consist of a vertical shaft 165 feet deep and an incline reaching to about the same depth, connected by drifts and crosscuts. An open cut over 100 feet long represents the work done in early days and the recent hydraulicking. A 20-stamp mill with two Wilfley concentrators is connected with the workings by a tramway.

Two varieties of rock occur here. The one which is more widely exposed is a biotite schist of brown color and marked fissility. Feldspar is present as small grains with an albite core and labradorite interior. A little magnetite is present. The origin of this rock is unknown. The other rock is an amphibolite which is said to occur as a dike-like band in the biotite schist. Only one contact was seen and at this place the foliation of the two rocks is parallel, and in a tunnel which starts near the mill this mass of amphibolite seems to be fairly wide. The foliation of both rocks strikes about N. 10° E. and dips to the west something like 70°. The mica schist is the ore-bearing rock. No very good idea of the veins could be had, but it is certain that very quartzose zones parallel to the foliation of the rock have been the richest portions. Small quartz stringers seen in the decomposed upper portions of the deposit indicate that filling of fissures has gone on.[e] On the other hand, specimens of quartz-pyrite ore, carrying gold, from greater depth indicate that extreme silicification of the mica schist has taken place along certain narrow zones. This ore is composed principally of white quartz grains, with scattered interstitial flakes of biotite, muscovite, or chlorite. Pyrite is abundant in places. The actual contact of this mass with the schist, which would probably have decided whether replacement had or had not gone on, was not seen, but schist from near the "vein" or ore-bearing zone shows the effects of vein metamorphism; sharply defined plates of muscovite have been developed at the expense of the biotite, pyrite has been introduced, and well-crystallized prisms of a mineral of unknown

[a] Lieber, op. cit., vol. 2, 1857, p. 70.
[b] Rept. Geol. and Agr. Survey South Carolina, 1844, p. 24; also Geology of South Carolina, 1848, p. 91.
[c] Nitze and Wilkens, Bull. N. C. Geol. Survey No. 10, 1897, p. 77.
[d] Lieber, op. cit., vol. 2, 1857, p. 70.
[e] Becker, G. F., Gold fields of the Southern Appalachians: Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, p. 309.

identity but similar in some respects to epidote pierce both the schist and quartz lenses which have developed in it. The most probable conclusion is that intense replacement or metasomatism has gone on in the mica schist along narrow but easy fracture channels for siliceous sulphide solutions. On this ground, therefore, this deposit would also in a way stand between the replacement bodies of the Haile, Colossus, and other mines and the fissure veins like those at the Brown and Schlegelmilch mines, but it holds a different kind of intermediate position from that of the Ferguson deposit.

The ore consists of the granular white quartz with disseminated auriferous pyrite and free gold. Some very rich specimens were seen, in which the gold was scattered all through the quartz much as particles of magnetite might occur in quartz sand. This sort of ore has been found mostly near the surface, and the fact that at greater depth grains of pyrite play the same rôle as the gold above makes it probable that the gold has been liberated by oxidation of the sulphide. It is worthy of mention, however, that the quartz-bearing free gold is, in many cases, at least, wholly unstained by iron as would be expected where oxidation of pyrite had taken place. The concentrates are of good grade, having a shipping value of over $100 per ton, and this is another argument in favor of oxidation of the portion where the gold is now free. Moreover it is said that in general the heavier the pyritization, the higher the value of the ore. Of the unoxidized ore it is not known how much gold is recovered by amalgamation.

As nearly as could be learned, an ore shoot about 90 feet long has been followed from the surface down to the 165-foot level, where work is now being done whenever the water can be kept down. Another bunch of ore 200 feet to the north was worked in former days to a depth of probably something like 100 feet, but the shaft and workings are now caved in. The ore varies in width from a foot to 8 feet or more.

No information was obtained which throws light on the question of persistency of the ore body. The average value of the ore is not known to the writer, but is probably rather good.

OTHER MINES.

Mining for gold has been carried on in many other portions of the area included in this report. At most of these operations were abandoned so long ago—in many cases before the war—that their names were barely more than a memory in the minds of those interested in this subject; in fact, the existence of several mines has been learned only from old literature on the geology of this region. Many such were of course not visited at all. Brief mention is made of some of these, based on hearsay or on earlier writings. Some other mines or prospects were visited, but these were mostly inaccessible and but little could be learned, while a number of the places visited never deserved more consideration than the small amount of prospecting which was given them before they were abandoned.

West mine.—The West mine is in Union County, S. C., only a few hundred yards southeast of the Thompson mine. The two were probably discovered at about the same time and have always been treated together in descriptions. At the time of the writer's visit the workings were filled with water and the old stamp mill was in a sad state of dilapidation. One man was washing in a small stream near the mine gravels which had been subjected to the same operation many times before. As his labor was resulting in small profit and as he was unacquainted with the history of the underground workings of the mine, little information was elicited from him.

In 1844 a shaft had been sunk to a depth of 115 feet and was said to be the deepest shaft in the State.[a] In 1857 this shaft had been deepened to 150 feet,[b] and is now said to have a depth of 175 feet. An old, open cut, mostly filled with water, shows that the trend of the country rock is parallel to that at the Thompson mine (N. 10° E.) and that the ore is similar in character. It is said that some of the ore was of high grade, but that a large proportion of the value was lost because the sulphides were not saved.

[a] Lieber, op. cit., vol. 2, p. 70.
[b] Tuomey, M., Rept. Geol. and Agr. Survey South Carolina, 1844, p. 24.

Nott mine.—This mine is located in Union County, S. C., about 2 miles north of the Thompson mine. It must have been worked during about the earliest days of gold mining in the South and was one of the prominent mines of the time.[a] Portions of the deposit were very rich, $3,000 having been taken from something like half a ton found in one pocket.[b] The country rock is amphibolite, some of it evenly fine grained, some coarser and banded. The vein, which is said to have had a strike of about N. 75° E., was about 8 feet wide on the surface and 5 feet at the bottom of the workings (110 feet), but reached a maximum width of 14 feet at 30 feet from the surface.[c] It is said that the vein split toward the east, that portion which continued along the strike being barren, while the branch which bore off more to the northeast carried the values.[d] Since this statement was not based on the personal observation of Doctor Lieber, its authenticity may be questioned, inasmuch as such splitting is not known elsewhere in the region.

The quartz vein carries considerable pyrite, which doubtless contains most of the gold. It was a bunch of decomposed pyrite that gave the $3,000 mentioned above. The pyrite is also cupriferous, as shown by iridescent films on the slightly weathered sulphides and greenish stains where more oxidation has gone on. It is said that thin scales of metallic copper were found near the water level, probably indicating that some secondary enrichment has taken place.

Magnolia mine.[e]—This mine, located in western York County, S. C., about 3 miles southwest of Hickory Grove, is the property of the Magnolia Mines Company, of Memphis, Tenn. It was worked before the war, under the name of the Louise mine, to a depth of 30 to 40 feet, or as deep as complete oxidation extended, and is said to have been profitable, but no idea of the total production could be had. The oxidized ore was treated in a stamp mill in which the mortar and stems were of wood, and the iron shoes struck upon cast-iron bottom plates instead of dies. The present mill, erected a few years ago, is the fourth mill which has been built on the property. It has three stamps of 1,250 pounds each, and discharges on all four sides. Screens of 80 mesh were first used, but were exchanged for 20 mesh. One Wilfley and one Standard table are installed. No work is being done at present in mine or mill.

The country rock is amphibolite, much decomposed at the surface. Numerous quartz veins, parallel to the foliation of this rock, strike N. 35° to 40° E. and dip about 75° NW. There are two groups of these veins; one situated near the mill, close to Guionmoore Creek, may be called the Magnolia group, and consists of the Magnolia, Gertie, Spring, Sea Crest, and at least two other veins; of the other group, about a mile northwest of the mill, only the Dorothy vein has been worked, although other veins are present. This Dorothy group is the northeastern continuation of the veins of the adjoining Schlegelmilch property. The Dorothy vein is probably the same as one which was worked in the early days just to the northwest of the present Schlegelmilch shaft. Of the Magnolia group, the Magnolia and Gertie veins are most important, although some good ore was taken from shallow workings on a vein a little to the southeast of these. A shaft 110 feet on the Gertie vein and an adit striking the shaft at 75 feet are now caved. This adit, called the Rock drift, is said to be about 1,100 feet long, but left the vein soon after passing northeast of the shaft and became in reality a crosscut tunnel. Several veins are said to have been encountered, but were not worked. The Magnolia vein, a short distance to the southeast, is opened by a 150-foot adit tunnel, which gains only 30 or 40 feet of depth in that distance. This tunnel is partly caved, but allows a view of the vein, which is 2 to 2½ feet wide, contains considerable partially oxidized pyrite, and has the appearance of good ore. Stoping has been carried to the surface for nearly the full length of the tunnel. A shaft about 40 feet deep close to the Magnolia vein is said to cut both it and the Gertie vein by a northwest crosscut from the bottom. The partially oxidized ore which is here encountered in the Magnolia vein is said to assay

[a] Lieber, op. cit., vol. 2, p. 64.
[b] Tuomey, M., Geology of South Carolina, 1848, p. 92.
[c] Lieber, op. cit., vol. 2, p. 66.
[d] Idem, p. 65.
[e] Perhaps the Smith mines of Lieber, op. cit., vol. 1, p. 46.

about $45. It is said that the average of a shipment of ore from these veins gave smelter returns of $56. The mill was then erected, but at best saved only 60 per cent of the assay value, and a sample from the tailings pile showed a content of $34 per ton. The writer was told that the mill and the one table used were crowded, causing incomplete amalgamation and concentration, and that much fine pyrite was lost. The tailings certainly are very fine, and it is probable that a large proportion of slimes was formed. It would seem that the use of lighter stamps with low discharge and plentiful water feed and of both concentrators might raise the efficiency of extraction. More development might well be carried on, however, before further outlay is made on experiments in extraction.

The Dorothy vein strikes about N. 32° E. and dips about 80° SE. It ranges in width from 18 inches to 3 feet, with an average of about 30 inches. The outcrop is plainly visible for several hundred feet. A shaft has been sunk 106 feet on it and short levels run in each direction from the bottom. This shaft, being located high above a small creek which flows across the rock structure between it and the Schlegelmilch shaft, is dry. The air in the bottom is bad and necessitates the running of a blower when work is going on. But little ore has been taken from this place. It is said that the values fell from about $35 near the surface to less than $20 near the bottom of the shaft.

Darwin mine.—At this old mine, about 2 miles northeast of Smiths Ford of Broad River, little is now to be seen except the prominent outcrop of a northeastward-trending quartz vein, probably 5 or 6 feet wide. One or two pits and a shallow shaft on the vein are now so filled in that they expose nothing of interest. Little indication of sulphides is to be seen, although it is said that pyrite and chalcopyrite were fairly abundant.[a] The vein is reported to have been irregular, inclosing numerous horses of the wall rock and thus adding to the cost of mining. According to Lieber [a] some success attended the early operations. No work has been done for many years.

Ross & Carroll mine.—About three-fourths of a mile north of the Darwin mine is a quartz vein on which mining has been done intermittently for a long time and which was last worked some years ago by Messrs. Ross & Carroll, of Gaffney, S. C. It is often spoken of as the Wolf Creek mine. The vein, 2 to 2½ feet wide, outcrops on a prominent ridge and has been opened by several pits for about a quarter of a mile. At Wolf Creek the ridge is cut down fully 150 feet. The vein continues on the northeast side of the creek, and most of the workings, a tunnel and shallow shaft, are on that side. About fifteen years ago a stamp mill was erected at the creek and considerable ore put through. It is understood that the large proportion of pyrite, in which the gold was mainly contained, made the percentage of recovery low. The writer was told that a few tons of rich ore were hauled to Blacksburg for treatment, but that the returns, $52 per ton, were disappointing.

McGill mine.—This mine, a fraction of a mile northeast of the Ross & Carroll mine, is said to be on the continuation of that vein. Work was done many years ago, and again somewhat more recently by Maj. J. F. Jones, of Blacksburg. The vein is said to split up toward the northeast into a number of small veins too narrow and low in grade to be of profit. On the main vein two shafts, 90 and 80 feet deep respectively, were sunk and some good ore was taken from certain pockets or shoots rich in sulphides. It is learned that this ore averaged about $25 per ton.

McCaw mine.—About 2 miles southwest of Smyrna and 1 mile southeast of the McGill mine is a property worked in 1904 by Mr. W. B. McCaw, of Yorkville, S. C. A quartz vein striking N. 50° E. and dipping very steeply to the northwest occurs in a much decomposed schistose rock, probably amphibolite. The vein, which is something over 2 feet wide, has been proved for about 200 feet by several pits. A shaft 35 feet deep was sunk on the vein and drifts 30 to 40 feet long run in each direction. A little stoping was done above these drifts and a few tons of ore have been shipped, the value assigned being about $25 per ton. Pay ore was found only in bunches in the vein and values are said to have pinched out in the bottom, although the vein itself continues downward. The shaft is situated in low ground, and in consequence fills with water nearly to the collar when pumping

[a] Lieber, op. cit., vol. 2, pp. 56–57.

is not done. The ore from the bottom, nevertheless, is considerably oxidized. Work at this place was stopped in the autumn of 1904.

Love mine.—About 1 mile southeast of Kings Creek station and just east of the railway some work has been done on a quartz vein in schist. The vein is probably 3 feet wide on the average, strikes about N. 35° E. and dips about 70° NW. Several inclined shafts ranging from 30 to 50 feet deep prove the horizontal extent of the vein for a distance of 1,000 feet or more. Toward the northeast especially the vein is rather heavily impregnated with partially decomposed pyrite, which in some cases occurred as cubical crystals as much as an inch across. Several tons of the ore are now on the surface and it is said that a number of carloads have been shipped. The ore has a promising appearance, but it is of course impossible to judge of the value of such ore without assay. Reports as to value are not wholly concordant, some being to the effect that a part of the ore shipped gave returns of $80 per ton, while others declare that the ore is of low grade. If the value is good the extent and regularity of the deposit would seem to warrant further exploration. No work is being done at present.

Wilson mines.—About 6 miles northeast of Yorkville, in York County, S. C., near the road leading to Nannies Mountain, are situated the Big Wilson and Little Wilson mines. They are under the control of Mr. W. C. Latimer, of Yorkville, who furnished the greater part of the information which follows. In the forties oxidized ore from the Big Wilson is said to have been worked in an old mill of the arrastre type, in which oxen supplied the power. Later, when sulphide ore was struck, the ore was "burned" or roasted in kilns [a] and then treated after the same fashion as the oxidized ore. The water level was only a few feet below the surface, and although a Cornish pump was used water put an end to work at a depth of 65 feet. In the early part of 1885 work was resumed and a 10-stamp mill erected. It is stated that $18,000 had been recovered by the end of the year simply from sinking the shaft to the 92-foot point, and in the first six months of 1886 $6,000 was taken out. Work was again suspended till 1896, when a Mr. Clark is said to have extracted $12,700 from a six months' run and saved 40 tons of concentrates. No work of consequence has been done since that time. There are three shafts, each about 90 feet deep, of which two are now out of commission, while the most recent one, though nearly full of water, appears very well timbered and is said to be in good condition. These shafts are all connected at the bottom by a drift 120 feet long. There are a few other short drifts and crosscuts. A number of veins are said to be present on the property, but only one has been developed. This vein, inclosed in amphibolite, strikes N. 40° E. and dips approximately 75° SE. The writer was told that this vein has been opened at five different places in a distance of seven-eighths of a mile. It is about 4 feet wide at the surface, but is said to widen decidedly with depth. Pyrite is plentiful and is said to assay $30 to $40 per ton, while the average ore runs about $12. Along the foot wall of the vein chalcopyrite is said to be present in sufficient amount to make the ore important as a source of copper. Some specimens of free copper were seen, said to have been taken from narrow kaolin seams at the side of the chalcopyrite vein.

About a mile southwest of the Big Wilson is the Little Wilson property. It adjoins on the southwest the Mary mine, which was once exploited for the copper contained in quartz veins carrying chalcopyrite, as mentioned on page 112.

The Little Wilson vein is a big quartz body striking about northeast and dipping about 70° SE. Two inclines about 35 feet deep appear to be on the foot wall and hanging wall, respectively, and thus indicate a width of 20 feet in one place, but it may be that they are on separate veins of less width. A shaft 90 feet deep gets into quartz carrying finely granular pyrite arranged in rude bands parallel to the walls, but possessing few others of the features significant of crustification. It is said that some chalcopyrite was found near the bottom of this shaft. High assays are said to have been obtained from picked specimens, but the average run of the vein was not learned.

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[a] Cf. Lieber, op. cit., vol. 1, p. 47.

The above statements regarding size and value of the ore bodies of the Wilson mines were not capable of verification by the writer and are given for what they may be worth.

Prospects.—A number of small workings of either old or recent making were visited in the course of the reconnaissance. These are briefly mentioned or described in the following paragraphs:

Some work was done in the early days on a quartz vein occurring on the property of George R. Wallis,[a] about 4 miles northeast of Yorkville, and desultory exploration has been carried on up to a few years ago. It is said that John W. Mackay worked here as a common laborer before going to California. One shaft is said to have been over 100 feet deep. A vein ranging from 1 to 4 feet wide, striking N. 75° E. and dipping about 70° NW., has been opened up at various places for about three-fourths of a mile. The country rock appears to be a sheared granite. Granite appears close by. A 100-foot northwesterly diabase dike appears to fault the northeast part of the vein 200 or 300 feet to the northwest. The quartz carries rather abundant pyrite, some of which, as concentrates, is said to run $100 per ton. It is reported that the ore averages $10 to $20.

Messrs. Small & Johnson are prospecting in a small way on two properties about one-half mile northwest of Smyrna, York County, S. C. On what is called the Allison (formerly Bolin) place some rather promising-looking quartz with decomposed pyrite has been encountered in a vertical vein about 15 inches wide, which strikes about N. 70° E. A 20-foot pit and a short tunnel comprised the development work at the time of visit. Not far from this, at the Bradley place, a 20-foot shaft has been sunk on what is said to be a vertical ore shoot 10 feet long in a 15-inch quartz vein. The values in the shoot are said to be good, while outside the shoot the vein is of very low grade. A little ore has been shipped to Perth Amboy, N. J.

The Horn property, in the town of Smyrna, is said to have within a few feet of each other, three parallel quartz veins striking about N. 38° E and dipping steeply to the southeast, which in places are rather heavily impregnated with pyrite. These it is said are cut by a pyrite vein striking N. 30° W. and dipping about 45° NE. As the shallow pits, which were sunk years ago, were either caved or completely filled with water, the writer was able to judge of this occurrence only from material on a small dump. This was quartz heavily impregnated with partially decomposed pyrite. It was stated by the owner, Mr. Horn, that a ton of ore shipped to Jersey City gave returns of $43 gold and 26 ounces of silver, while 2 tons shipped to a Norfolk smelter gave very low returns. If gold is present in the partially oxidized pyrite it does not appear on panning.

On the place of James Love, about a quarter of a mile west of Broad River, at Smiths Ford, a little tunnel and shaft work was done years ago on a good-sized vein of massive white quartz, in which no indication of sulphides could be seen. It is not known whether or not gold was found here.

About a mile north of Smiths Ford, on the east side of the river and about 12 miles southeast of Gaffney, is situated what is known as the Flint Hill mine. Several pits and two 50-foot shafts have been sunk on what appear to be two northeastward-trending quartz veins which carry pyrite, and are said to assay $11 to $16 per ton. The work was done many years ago and no information could be gained concerning the extent of the deposit.

At the Rosa Arrowwood mine, about 1 mile east of Smiths Ford, some good ore was taken from pockets in a northeasterly-trending quartz vein. The work was done years ago, and only a few old pits, partially filled and overgrown, remain to indicate that gold was ever present here.

The Mitchell place is about a mile south of the Rosa Arrowwood. A few years ago a vein was opened here which was heavily impregnated with pyrite, and the prospectors were much encouraged by the general appearance of the ore, but when assays were made

[a] Probably same as Wallace mine. See Nitze and Wilkens, Bull. North Carolina Geol. Survey No. 10, 1897, p. 77.

80 cents was the best that could be obtained. A little placer work was done in the small creek just to the west, but is said not to have been profitable.

Farther to the southwest, about a mile from the Mitchell place, a vein striking N. 30° E. with steep dip to the northwest has been opened on the Parker property. Three short tunnels which appear to cut this vein show that it is very irregular in width, ranging from 4 feet down to 2 inches. The northeasternmost opening exposes a lens-like mass of quartz, 10 to 12 feet long, inclosed in decomposed schist, probably amphibolite. Farther southwest a 35-foot shaft and drift explore more of the vein. The quartz contains oxidized sulphides, which are said to carry fair gold values, although smelter returns from a small shipment were low.

A small, mound-like elevation known as Mose Mountain, just to the northeast of the Brown mine, is cut by many veins of "hungry" or barren-looking quartz, which, however, have received considerable attention from prospectors because of the story, presumably as ill founded as such tales usually are, that some very rich ore was once found there by an old miner, who died without disclosing the exact location of his find.

The Bolin mine, so called, is about 1 mile south of the old Darwin prospect. Several pits were sunk years ago on a quartz vein of northeasterly strike. Nothing further is known concerning this property.

On the Terry place, which adjoins the McCaw property on the northeast, a 30-foot pit on a vein of quartz afforded opportunity to take out a small amount of ore, which was shipped. The value of the ore was not learned. This work was done only a few years ago.

A little prospecting has been done on the Love property, about 2½ miles northeast of Yorkville, not far from the Wallis place. A 2-foot quartz vein striking to the northeast is irregular in form and includes horses of the schist wall rock. A streak about 4 inches wide in the middle of the vein, carrying decomposed pyrite, is said to assay as high as $50, while the remainder of the vein is lean. It is stated that some copper is present, but no indications of that metal were seen by the writer.

About 3½ miles southwest of Gaffney, on the Nott property, not far from the old Cameron lead mine, a couple of men were at work at the time of the writer's visit sinking a prospect shaft near the site of an old placer, which corresponds in description to the Austin placer of Lieber,[a] and which is said to have yielded $50,000 to $75,000. This shaft, which had attained a depth of about 20 feet, exposed only a 3-inch seam of quartz, with some decomposed pyrite. Work was stopped here in the early autumn of 1904.

Old abandoned mines.—For the sake of completeness the names of a number of old mines once more or less important, many of which have long since been forgotten, are given here. These names are taken from the early literature on the geology of this region and are arranged according to geographic position. In most cases more or less complete descriptions of these mines will be found in the references cited.

In Chesterfield County, S. C., the Leach[b] mine is near the Brewer mine, and was said to resemble that mine in the character of its ore deposit. The Kirkley[c] and McInnis[c] mines are also near the Brewer. Other old mines in the western portions of Chesterfield County are the Miller,[d] Huff,[d] and Hendrix.[e]

In Lancaster County, S. C., the Funderburk[f] and the Gay[g] or Little Brewer are near the Haile mine and are said to resemble it in character. The Ingram,[h] Clyburn,[i] Williams,[i] Belk,[j] Massey,[k] Stevens and Belk,[k] Phiffer,[k] and Knight[k] mines are also in the vicinity of

[a] Op. cit., vol. 2, p. 71.
[b] Lieber, op. cit., vol. 1, pp. 56, 68–69; vol. 2, p. 53. Nitze and Wilkens, Bull. North Carolina Geol. Survey No. 10, 1897, p. 77.
[c] Lieber, op. cit., vol. 2, p. 53. Nitze and Wilkens, loc. cit.
[d] Tuomey, M., Geology of South Carolina, 1848, p. 98.
[e] Lieber, op. cit., vol. 1, p. 69.
[f] Lieber, op. cit., vol. 1, pp. 59–60. Nitze and Wilkens, op. cit., p. 77.
[g] Lieber, op. cit., vol. 1, pp. 57, 62. Nitze and Wilkens, loc. cit.
[h] Lieber, op. cit., vol. 1, pp. 57, 63.
[i] Nitze and Wilkens, loc. cit.
[j] Lieber, op. cit., vol. 1, p. 55. Tuomey, M., Geology of South Carolina, 1848, p. 98.
[k] Lieber, op. cit., vol. 1, p. 55.

the Haile mine. The Potts,[a] Izell,[a] Johnson,[b] and Hagin[c] mines are situated elsewhere in Lancaster County.

In York County, S. C., the Wylie,[d] Kennedy,[e] Sutton,[f] and Palmetto[g] have been noted or described by previous writers.

The mines in Union County, S. C., which have not been described in the foregoing pages are the Bogan[h] and the Harman[i] or Mud[j] mines, both of which are situated in the northwestern part of the county not far from the Thompson and West mines.

The Lockhart[k] mine, near Limestone Springs (just south of Gaffney), in what is now Cherokee County, was worked in the early days of the Southern Appalachian mining industry.

In that part of Gaston County, N. C., with which this report deals the following mines have at some time been worked: Crowders Mountain[l] or Caledonia, Patterson,[l] Rhodes,[m] McLean[m] or Rumfeldt, and Oliver.[n] The Long Creek[o] or Asbury mine, 7 miles northeast of Kings Mountain station, is said to contain similar ore to that in the old Kings Mountain mine, being characterized by more or less uncommon minerals,[p] such as tetradymite, arsenopyrite, leucopyrite, bismutite, and bismite.

In the southwestern part of Union County, N. C., the Howie (now Colossus), Wyatt, Washington or Bonny Belle,[q] and Penman mines collectively made up what was known as the Grand Union gold mine.[r] Numerous other mines to the north and northeast in Union County and to the northwest in Mecklenburg County have been worked, but fall outside the area here described.

SUMMARY.

The locations of the mines of this area, outlined above, indicate two broad belts along which gold has principally been found. These two belts have been generally recognized by most writers heretofore. They trend northeastward in a general way parallel to the strike of the rocks and the general structure of the region. One belt extends from the western part of Union County, S. C., through eastern Cherokee and western York counties, S. C., and on through the eastern half of Gaston County and western Mecklenburg County, N. C. The other belt is broader and in a measure less defined. It includes Lancaster County, eastern York and western Chesterfield counties, S. C., and Union County and the eastern edge of Mecklenburg County, N. C. Scattered mines or occurrences of gold are known between these two belts.

To the south of the area which forms the subject of this report these belts become indistinct, but their continuation is probably represented by a number of gold deposits in Laurens, Abbeville, and Edgefield counties, S. C., and in McDuffie, Warren, Wilkes, Lincoln, and Columbia counties, Ga.[s]

To the north these two belts merge into one rather indefinite zone, including Lincoln, Catawba, Cabarrus, Stanley, Montgomery, Moore, Randolph, Rowan, Davidson, and Guilford counties, N. C. Taken collectively, this Carolina belt, as it is called, has been one of the most important gold regions of the eastern United States.

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[a] Lieber, op. cit., vol. 1, p. 50.
[b] Lieber, op. cit., vol. 1, p. 69.
[c] Lieber, op. cit., vol. 2, pp. 49–50.
[d] Lieber, op. cit., vol. 1, p. 45.
[e] Lieber, op. cit., vol. 2, p. 63.
[f] Lieber, op. cit., vol. 2, p. 48.
[g] Nitze and Wilkens, loc. cit.,
[h] Tuomey, M., Geology of South Carolina, 1848, p. 92. Lieber, op. cit., vol. 2, pp. 66–67.
[i] Tuomey, M., op. cit., p. 91.
[j] Lieber, op. cit., vol. 2, pp. 57–58.
[k] Tuomey, M., op. cit., p. 88.
[l] Kerr and Hanna, Ores of North Carolina (chap. 2 of Geology of North Carolina, vol. 2), 1893, p. 306. Nitze and Hanna, Bull. North Carolina Geol. Survey No. 3, 1896, pp. 147–148.
[m] Nitze and Hanna, op. cit., p. 148.
[n] Nitze and Hanna, op. cit., p. 149.
[o] Kerr and Hanna, op. cit., p. 304. Nitze and Hanna, op. cit., p. 149.
[p] Becker, G. F., Gold fields of the Southern Appalachians: Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, pp. 274–278. See also pp. 62–63 of this report.
[q] Nitze and Hanna, op. cit., p. 104. Becker, G. F., op. cit., p. 310.
[r] Kerr and Hanna, op. cit., p. 261.
[s] Cf. Nitze and Wilkens, Bull. North Carolina Geol. Survey No. 10, 1897, p. 84.

At the time of the writer's visit (autumn, 1904) the Haile mine was in active operation, the Blackmon was working a force temporarily reduced on account of scarcity of labor, the Brewer and Thompson were working in a small way under lease, the Ferguson, Brown, and Schlegelmilch were carrying on development work, Messrs. Small & Johnson were exploring their properties near Smyrna, and extensive work was going on at the Colossus mine preparatory to beginning active mining and milling. In addition to these operations a few individuals were washing stream gravels for placer gold. So far as known, no other mining for gold was being done in this region. Since that time work at the Brown and Schlegelmilch mines has been stopped.

CONCLUSIONS.

The condition of the gold-mining industry in this region to-day is fairly well outlined in the preceding paragraph. In 1859 there were in the South Carolina portion alone 40 working mines,[a] and it is probable that the decrease in the North Carolina portion has been of about the same order of magnitude. Furthermore, most of the mines now working were then known and were mining richer ores than at present. If these former conditions are compared with the present status, it is at once apparent that the gold-mining industry of this region has suffered a decided decline. The fact that a very few mines (of which the Haile is really the only one of importance in this respect, as will be shown presently) have been able to maintain and even increase the total production of earlier years is not surprising in view of the advances which mining as an industry has made, and in reality has little to do with the consideration of this district as a whole. For the last fifteen years or thereabouts only a small addition to the production of this region has been made by any but the Haile mine, which has maintained its average yearly production at something like $100,000 during that time. This mine has been compelled to reduce more and more the cost of operating per unit of product, because of decreasing grade of ore, and has been forced to gradually encroach on and deplete its known reserves of workable ore, so that the time is not far distant when a falling off in production must be expected unless some of the development work now being carried on can bring to light new supplies of ore.

So far as the other mines are concerned, it may be said that in spite of the unsystematic and unscientific management which has been the rule rather than the exception in this region, most of them which seem to have possessed any sign of promise have been given a pretty fair chance to show what they are worth. In the case of the Colossus, it seems safe to say that if the ore bodies are as persistent as those at the Haile have been—a statement which there may be no reason to doubt, but which ought to be demonstrated—if the ore averages as well as the reported assays indicate, and if the cyanide process now being applied proves a successful means of extraction, then a good production may be expected for some years. The Blackmon mine likewise may make a respectable addition to the output of the region if the size and value of the deposit persists and certain obstacles to mining, already enumerated, can be overcome. There appears little reason to hope that the Brewer mine will ever again become an important producer. While much gold undoubtedly exisits in that immense deposit, it is doubtful if it can be extracted with profit. Little can be said of the Kings Mountain mine, because of lack of authentic information, but it is unreasonable to suppose that it would now be lying idle if much ore of the grade which it has already furnished were known to exist. Certain of the smaller mines may, and probably will, prove profitable for a period, but in the case of the vein mines the irregularities of the deposits will make mining an uncertain enterprise and the relatively small size of the ore bodies will demand that the value of the ore must remain fairly high as compared with that of the large replacement deposits.

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[a] South Carolina, Resources, etc., State Board of Agriculture, Charleston, 1883, p. 134. There were, in 1859, 21 working mines in Lancaster and Chesterfield counties and 19 in Spartanburg, Union, and York counties. These three last-named counties were a few years ago divided, portions of each constituting a fourth county, Cherokee. It is certain that of these 19 mines, nearly all of which were situated in the old Spartanburg County, are now included in Cherokee County, and are thus within the area studied.

It must be remembered also that in both classes of deposits increasing depth will in general mean increasing cost of production, especially in this region where there is no apparent solution of the water problem except by pumping. A further serious handicap to success is the fact that in nearly all the mines the decomposed ores, which allowed comparatively easy extraction of the gold, are now almost or quite exhausted, and that the sulphide ores to which operators now must look for future production can be treated only if rich enough to warrant being shipped to a smelter, or, if of lower grade, only by the outlay of considerable capital in the erection of a plant for concentration, if not for roasting and lixiviation also.

Finally, there arises the question of discovery of new mines or ore bodies. There is little doubt that there exist in this region many deposits of gold which are now unknown. When it is remembered, however, that prospecting has been going on more or less actively right here for nearly a century, with only unimportant results in recent years, and that for a decade or two before the war this was distinctly a mining region where practically the whole population was incited to activity by the possibility of discovering gold, and when it is considered what great amounts of money must have been spent in the early stages of exploratory development, one can but admit that the ground has been pretty carefully searched. Add to this the fact that probably a great proportion of the placer gold, which in the early days aided materially in the location and discovery of the deposits in place, has been removed, and it becomes plain that the prospect for any important addition to the localities of gold now known is not bright.

In conclusion, then, it seems probable that if the production of the region is to be maintained or increased, this will be due to a few large mines, and that more likely the future will bring to this region a gradual decline in importance, both relative and actual.

OTHER MINERAL PRODUCTS OF THE REGION.

SILVER.

Silver has never been found in commercial quantities in this area, and so far as known no distinct silver mineral has been reported. The metal is not wholly absent, however. It probably constitutes a large part of the material which brings down the fineness of the gold bullion to an average of about 0.900. It also probably occurs in the galena and tetrahedrite of the Kings Mountain mine and was said to be present to the extent of about 50 ounces per ton[a] in some of the ore from the old Cameron lead mine in Cherokee County, S. C. Silver occurs in some quantity at the Silver Hill mine in Davidson County, N. C., but on the whole is not very plentiful in the Southern Appalachians.

COPPER.

Copper occurs in many parts of the area, as may be seen from an examination of the list of minerals given under gold (pp. 62–63), but in nearly all cases the amount is so small as to be negligible. Chalcopyrite is the most common copper-bearing mineral, and has been found at the Kings Mountain, Ferguson, Big Wilson, and Colossus gold mines; at the Mary copper mine; at the Cameron lead mine; at the Jones tin mine, and at other places. At the Brewer mine enargite, the copper-arsenic sulphide, occurs in small crystalline grains in the blue siliceous gold ore. By decomposition it furnishes covellite (cupric sulphide), and on complete oxidation chalcanthite, the hydrous cupric sulphate, is produced. The chalcanthite forms blue coatings on the walls of the open pit wherever recent work has not been done. It is also noted by Becker in the Kings Mountain mine, forming a blue slime on the walls. Chrysocolla is said to occur in an old shaft of the same mine. Metallic copper is said to have been found at the Nott mine in Union County, S. C. From the description of the occurrence there it seems probable that this copper is a product of secondary enrichment from original sulphide ores above. Pyrrhotite, probably copper bearing, is found at

[a] Cf. Lieber, op. cit., vol. 2, p. 78.

the Kings Mountain, Colossus, and Haile gold mines; at the Cameron lead mine, and at the Jones tin mine. It is likely that much of the pyrite of the gold mines contains a small percentage of copper. Tetrahed te is said to have been found at the Cameron lead mine.

The only place at which copper is known to have been sought is at the Mary mine, about 5 miles northeast of Yorkville, S. C. This mine was considered by Lieber [a] to offer very favorable indications. The country rock is a dioritic species originally containing fairly calcic plagioclase, hornblende or augite, ilmenite, and sphene. Regional metamorphism converted the original bisilicate into secondary hornblende and the plagioclase into oligoclase or andesine, abundant epidote, and a little zoisite. Metasomatic alteration along the sulphide-bearing quartz veins has almost completely converted the uralite into brown biotite and has changed much of the feldspar into sericite; pyrite has also been introduced. The quartz itself carries both pyrite and chalcopyrite in large and small crystalline masses and grains. From the statements of Lieber regarding the occurrence of secondary minerals arranged in vertical zones, it seems probable that leaching of the upper, oxidized portions of the vein has resulted in secondary enrichment below. It is interesting to note, in this connection, in what clear terms Lieber described certain features of the process now known as secondary enrichment.[b] It is probable that the "black oxide" which he describes as occurring just above the primary pyritic ore was in reality the sulphide, chalcocite. A large quartz vein, apparently barren, occurs a short distance from the copper-bearing vein. Several pits have been sunk, and it is rumored that some ore was shipped to Charleston during war time and was manufactured into shells, but this seems to be without foundation.

LEAD.

Lead is known to occur at the Kings Mountain gold mine as galena and as nagyagite. A more important deposit was known as the Cameron mine and earlier as the Morgan or Leitner mine.[c] This mine is situated just east of the limestone belt of the Kings Mountain Range and is about 4 miles southwest of Gaffney, S. C. It was opened before the war as a copper mine, but lead was soon found to be the most important metal present. During the war the demand for lead for bullets caused active work to be carried on at this place.

The country rock is amphibolite, cut by a granitic gneiss containing a small amount of albite, showing crushing, particularly along certain bands, and undoubtedly closely related to the granite of the tin belt.

The vein, which was said to be 2 to 2½ feet wide, is parallel to the foliation of the country rock and consists principally of quartz, coarsely crystalline siderite, and chlorite. The ore minerals are galena, decomposing to cerussite and leadhillite, and wulfenite (lead molybdate). The small needles of pyromorphite, the phosphate, found with quartz in vugs are also probably secondary. Pyrite, chalcopyrite changing to covellite and malachite, pyrrhotite, and arsenopyrite are sparingly present in the quartz. "Gray copper" (tetrahedrite?) is said to have been found here. Thin botryoidal coatings of brown iron oxide, showing beautiful radiating structure, line many cavities in the vein. The galena is said to contain considerable silver, the amount per ton of ore in one lot of metal being reported as 49 ounces.[d] Gold is also said to have been present.[e] The development consisted of two shallow tunnels and an inclined shaft nearly 150 feet deep. The writer is informed by Capt. A. Thies, who worked the mine for the Confederate government; that not much lead was present and that the total output of the mine amounted to a few hundred tons. It was at one time contemplated to work the siderite for iron.

Rich galena ore occurs at the Black mine, near Indian Trail, Union County, N. C., just outside the area contained in this report, but the quantity was not ascertained.

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[a] Op. cit., vol. 1, pp. 82-83; vol. 3, p. 199.
[b] Op. cit., vol. 1, p. 84; vol. 2, pp. 11-12.
[c] Lieber, op. cit., vol. 1, p. 86; vol. 2, pp. 74-78. Shepard, C. U., Report on the Morgan Silver-Lead and Copper Mine in Spartanburg District, S. C. London, 1855.
[d] Lieber, op. cit., vol. 2, p. 78.
[e] Lieber, op. cit., vol. 3, p. 198.

ZINC.

With the exception of a small amount of sphalerite found at the Kings Mountain mine, no zinc is known in this area.

IRON.

Considerable activity was once manifested in this region in the mining of this most essential of the metals. Of the several iron-producing regions in the Carolinas, that along the Kings Mountain Range was in the early days one of the foremost. The Hills Iron Mining Company is said to have worked before the Revolutionary war a deposit occurring on Nannies Mountain, about 12 miles northeast of Yorkville. The Swedish Iron Mining Company in the vicinity of Cherokee Falls and the Kings Mountain Iron Mining Company in the vicinity of Kings Mountain carried on rather extensive operations before and during the civil war. More recent work has been done at the Ormond mine, northeast of the town of Kings Mountain, N. C., and at several places south, southwest, and southeast of Blacksburg, S. C. Nothing is being done at present.

Owing to the fact that nearly all the workings are inaccessible or because they are either caved in or filled with water, a satisfactory idea of the character of these deposits was not obtained. The only place where geologic relations are adequately exposed is at what is known as the No. 2 magnetite pit, about 2½ miles south-southwest of Blacksburg and only a short distance southeast of the limestone belt. This is a cut 50 to 60 feet long, 30 feet wide, and about 30 feet deep. There is at present about 12 feet of water in the pit. The rock, which is a dark slate, strikes about N. 60° E. and dips very steeply to the southeast, although there appears to have been considerable folding and contortion. Masses of dense blue-gray rock occurring in several places may be basic eruptive material. Magnetite is irregularly distributed through the slate in disseminated grains, large and small lenses, and shapeless masses. Associated with it, in bunches and veinlets, is a white fibrous material, locally called serpentine, which proves to be mostly actinolite, although some serpentine and a little carbonate are present. The slate consists of extremely fine shreds of serpentine with a small amount of carbonate and a few fragmental grains of a pale-greenish amphibole probably actinolite.

The origin of this ore is uncertain. The association with serpentine may indicate that the magnetite is a segregation from a basic igneous rock, the whole having then been subjected to folding and consequent metamorphism.

This magnetite is said to be of very good quality. Considerable was mined and used before and during the civil war in the furnaces along Broad River. Remains of some of these furnaces are still to be seen. Several tons of ore are at present piled up near the pit. From its appearance the writer would judge that its content of iron is rather too low to be profitable, and it is questionable if high-grade ore can be mined from this deposit.

About one-fourth of a mile farther northeast a pit which is probably on the same deposit exhibits similar conditions. The slaty rock shows better foliations, dipping very steeply to the southeast. Iron appears less abundant.

At several points along the eastern side of the Blacksburg fold and near the quartzite ridges occur deposits of iron oxide. Some of these are limonite, some hematite, some magnetite, and some mixtures of any or all. This belt is known to extend from a mile or two south of Broad River through Cleveland, Gaston, and Lincoln counties and into Catawba County. Following closely along this iron belt through nearly its whole extent is a band of manganese oxide.

Considerable work was once done on the south side of Broad River. Before the Michigan and Alabama fields were worked these deposits furnished a great part of the iron locally consumed, and it is said that some was shipped away. Other workings were located in Gaston and Lincoln counties. Deposits of this kind are known on the ridge north of Cherokee Factory, in Cherokee County, and in the vicinity of Wolf Creek, near the York County line. At the latter place, on property of Mr. W. B. McCaw, a deposit of solid crystalline hematite occurs. The iron ore is also disseminated through the wall rock for some distance away from the main body. The surrounding rock is much decomposed, but is probably a quartz-sericite schist. It is said that the iron is of good grade and contains only small amounts of sulphur and phosphorus. If the pits which have been dug give any idea of the extent of the deposit, little can be expected of it from the commercial standpoint. The same statement may be applied to all the other deposits of this type which have been visited.

It seems not unlikely that these bodies represent deposits of bog iron ore buried by later sediments and then subjected to metamorphism which converted much of the limonite into hematite and in part even to magnetite. Such an origin would explain the small extent and the discontinuity of the deposits. A small deposit of limonite ore in decomposed schist has been opened in shallow pits on the property of William Martin, about 3½ miles northwest of Blacksburg and just over the line in Cleveland County, N. C. The interbedding of the deposit with the surrounding slates suggests that it likewise originated from bog iron ore.

South of Kings Mountain the Kings Mountain Range breaks up into smaller mounds and separated ridges. East of Blacksburg on one of these ridges some pits have been sunk on iron-rich places in the schist, and a comparatively small amount of ore has been taken out. It consists of both limonite and hematite, but at a depth of 20 to 25 feet becomes pyritic and soon passes into solid pyrite.

Ore of a similar nature has been found on the knob just south of Broad River not far from Cherokee Falls. Open cuts of considerable size furnished ore for several blast furnaces and bloomeries situated along the river in war times. These old openings are now nearly filled with débris and material from the caving of the walls. The ore here is not so certainly derived from pyrite as that on the north side of the river just above, but the similarity in appearance and occurrence of the oxide ores is great.

Iron of good grade occurring in streaks or vein-like masses was once mined to a small extent from the Ross property, near Wolf Creek.[a] Here, too, the percentage of sulphur increased with depth, and finally, it is said, the ore became such massive pyrite that it was used for the manufacture of sulphuric acid.

During Revolutionary times iron was mined at the Hills iron works on Nannies Mountain, York County. The rock, an impure foliated quartzite, is cut by a "vein" which strikes N. 15° E. and dips 80° to 85° E. Where best exposed it is 6 feet wide, but must have been much wider in places, to judge from the width of some of the pits on it. This band is composed of mixed limonite and hematite, much of it porous. Near a small stream which crosses the belt a shallow pit reaches granular quartz heavily impregnated by pyrite. It is evident, therefore, that the iron mined was simply the oxidized cap of a pyrite vein. It is said that prospecting by means of a diamond drill showed a heavy body of sulphides, partly pyrrhotite, at a depth of 400 feet. It seems probable that oxidation of this deposit has been pretty complete down to water level, while below that the sulphides are little altered.

It is probable that these sulphide bodies represent veins and fahlbands and are distinct in origin from those deposits which are believed to have accumulated in bogs.

The Ormond mine, about 5 miles northeast of the town of Kings Mountain, has been more developed than any of the iron deposits in the district described. At the time of visit the workings were inaccessible, and little but waste was to be seen on the dump. A rather full description of the mine is given by Nitze.[b] The main shaft, 173 feet deep, encountered some good ore bodies at the bottom, considerably below present water level. On the other hand, masses of pyrite and pyrrhotite [c] have been found in various portions of the workings. Manganese, nickel, and cobalt oxides have been found with the ore.[d]

[a] See Lieber, op. cit., vol. 1, p. 89.
[b] Bull. North Carolina Geol. Survey No. 1, 1893, pp. 93–102.
[c] Wurtz, H., Proc. Am. Assoc. Adv. Sci., vol. 12, 1859, p. 223; Am. Jour. Sci., 2d ser., vol. 27, 1859, p. 26. Cf. also Tuomey, M., Geology of South Carolina, 1848, pp. 81–83.
[d] Wurtz, H., loc. cit.

Whether this ore was once a sulphide that is now oxidized below the water level or whether original oxide ores are present along with pyrite the writer is unable to say.

The presence of gold in an old iron deposit known as the Bird bank, mentioned by Tuomey,[a] may be an indication that the deposit was the gossan of a sulphide vein.

In conclusion it may be said that so long as the great sources of present supply of iron maintain their productiveness there seems little hope of the deposits of this portion of the Carolinas assuming much commercial importance.

MANGANESE.

So far as known no manganese has ever been produced in this region, although it has long been known to occur. Mention has already been made (pp. 26, 114) of the black belt carrying manganese, which occurs on the east side of the Blacksburg fold. In places the percentage of manganese is high and ought to warrant more exploitation than the few shallow pits which have been sunk east of Blacksburg. Analyses of specimens from this place by Nitze [b] run up to 57 per cent of metallic manganese. A qualitative examination of this manganese ore by Dr. E. C. Sullivan, of the United States Geological Survey, shows that it contains traces of both nickel and cobalt.

It seems probable that these deposits are metamorphosed bog ores. On the property of Dr. F. H. Morton, near Draytonville Mountain, about on the strike of this manganese belt, a depression of several acres in extent is covered with a layer of concretionary manganese oxide, with some iron, mixed with a small amount of clay—a typical bog ore. It has probably been derived by decomposition of the manganiferous belt. It is possible that a sufficient amount of ore of suitable grade is present to make the deposit valuable.

PYRITE.

Some years ago pyrite was mined a few miles north of Kings Mountain and was used by the Virginia-Carolina Chemical Company for the manufacture of sulphuric acid. For reasons which were not learned operations were suspended, and in 1904 the machinery was being hauled away.

A plant near Blacksburg, erected some years ago for the purpose of manufacturing sulphuric acid and iron paint from pyrite, and at the same time recovering any gold which the sulphide might contain, obtained most of its ores from mines in the northwestern part of York County, the Ferguson, McGill, and Ross & Carroll mines being among the number. The general report is that the process was not successful.

GRAPHITE

Bands of graphite occurring as members of the rock series which makes up the Kings Mountain Range attain in places a thickness of 20 feet, but the mineral is said in general to be too impure to have commercial value.

BARITE.

Barite is said to occur in considerable amount on the eastern side of Kings Mountain. Specimens indicate that some of it is rather pure. Mining was carried on for some time up to about three years ago, and the output, which was shipped, reached at times 20 wagon loads per day. Recently no work has been done.

MONAZITE.

Beginning about 3 miles west of Gaffney, the rare-earth phosphate, monazite, occurs along a northeasterly belt which, with a short gap near Broad River, continues into Cleveland County, N. C. To the south the monazite belt is known to reach nearly to Greer, Greenville County, S. C. The most extensive deposits occur in the northern portion of this belt,

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[a] Op. cit., p. 88.
[b] Bull. North Carolina Geol. Survey No. 1, 1893, p. 112.

outside of the territory embraced in this report, but considerable of this mineral has been obtained by placer-mining methods in the western part of Cherokee County, which is within the area here described.

On Cole Creek, about 3 miles west of Gaffney, are situated the Littlejohn and Huskey workings. The Littlejohn deposit, near the head of the creek, has been worked over several times 20 or 30 feet wide along the creek. The soil at farther distances shows considerable monazite on panning, but the distance to water is too great to make recovery profitable. At the time of visit Cole Creek was so low that but little washing could be done.

The Huskey placer adjoins to the south, or downstream. The workings here have been wider, owing to richer ground and more water. This deposit likewise has been worked over several times, giving each time a profitable amount of monazite. Two small branches of Cole Creek come in from the west on the Huskey property, and the southern one of these has been very rich.

The Lemon mine, about three-fourths of a mile north-northeast of the Littlejohn, has been the most productive deposit in the region. Situated on the forks of a small stream at its junction with Cherokee Creek, the workable area is comparatively extensive. Rich bars have been found to contain as much as 30 per cent of monazite.

About a mile still farther northeast, on a small stream running southeast, are the Magness, Swafford, Jones, and Sarratt placers, the latter said to be controlled by the Welsbach Company. These are said to have produced well. They are not being worked at present.

All these placers are situated practically at the source of the monazite. So-called ledges exposed in the stream cuts carry monazite as a constituent of the rock. These ledges, which have every appearance of dikes, cut a country rock of greenish-gray garnetiferous schist. They consist of quartz, feldspar, and brown biotite, and according to the proportion of the mica are either light or dark in color. The dark ledges are more common. In all cases observed these ledges are intercalated with the surrounding schist. Although somewhat crushed, showing a faint augen structure which might class the rock as a gneiss, these ledges exhibit plainly the intergrowth of quartz and feldspar characteristic of pegmatite dikes, and microscopic evidence is confirmatory. These dikes have already been described (pp. 20–22). The monazite occurs as an original constituent of the dikes in crystals which usually have well-developed faces and which range in size from microscopic to half a centimeter in diameter.

It is possible that monazite also occurs as an impregnation in the schist near the pegmatite dikes, but the writer found no proof of this. An interesting feature in connection with these dikes is the presence in them, apparently as an original constituent, of numerous scales of graphite. So far as known, no apatite has been found associated with the monazite in this region. Cerite, a rare-earth silicate, in specific gravity and appearance similar to monazite, is said to occur in considerable quantity at some of the mines, and being incapable of separation from the monazite by any method yet devised seriously affects the value of the product. In a few cases, where the richness and the degree of decomposition of the dikes permit, they are worked in the same way as the gravel, being washed through a screen and caught in a sluice box; but in general the sticky kaolin resulting from the decomposition of the feldspars makes thorough washing and complete recovery difficult.

While the gravel or soil at some distance from the streams not uncommonly contains as high a percentage of monazite as is found in the stream bed on the second and subsequent washings, it is in few cases profitable to work such deposits. The mineral from this source, however, serves to replenish the supply in the streams, being carried in by the heavy rains. That the stream gravels can be worked with profit several times is probably owing as much to this fact as to the low recovery of the early washings.

The region seems to have been pretty thoroughly prospected, and there can be little doubt that the richest ground has already been found and exhausted. Mr. M. E. Gettys, of Gaffney, is principally interested in these deposits.

A little monazite has been found on the Perry place, near Gaffney, and at several localities in the northern part of York County.

LITHIUM.

The occurrences of spodumene, mentioned on page 48, may be worthy of investigation as a source of lithium or even as a possible locality for the spodumene gems—kunzite, hiddenite, triphane, etc.

MICA.

Although some prospecting has been done on pegmatite dikes northeast of Kings Mountain station and northwest of Blacksburg, mica has never been found in commercial quantities in this immediate region, although not far to the northwest the mica industry is one of importance.

CORUNDUM.

Corundum is known to occur in the vicinity of Nannies Mountain in York County, and has been reported from the Perry place, just west of Gaffney. At two places near Nannies Mountain it has been mined. On the Barron property, southeast of the summit, a few shallow shafts have been sunk and some of the mineral obtained. The workings are now in such condition that they show nothing of the occurrence, and no rock is exposed near by. At the Clinton place, 1½ miles northwest of Nannies Mountain, some pits and trenches and a 30-foot shaft constitute the development work. These also are caved in and grown over with grass, so that no good idea of geologic relations can be obtained. A few rods away a decomposed granitic rock cut by diabase is exposed. Some corundum is piled up near the pits and shows decomposition into muscovite. Some of the mineral occurs in masses a foot in diameter, with imperfect radial structure. It is said that several tons have been shipped from this place by Rickard & Hewitt, of Brooklyn, N. Y., who control both this and the Barron property. Float is rather plentiful for some distance northeast of the Clinton place.

LIMESTONE.

Besides a fairly wide use as building stone in this region, the limestone of the Kings Mountain belt has been rather extensively quarried and burned to form lime. Quarries, now abandoned, have been made at Kings Mountain and at Blacksburg, and two quarries of good size (see Pl. II, p. 18) are now being worked at Gaffney, where a number of continuous kilns with iron shells produce about 200 barrels of lime daily. The crystalline rock, almost white, is said to produce so low a grade of lime that but little of it is used, while the blue compact rock furnishes a lime of good quality. The crystalline variety is probably rather dolomitic. (See analyses, p. 19.)

CLAY.

Near Grover, N. C., clay from some beds of comparatively small extent is shipped to Richmond, Va., and is said to be used for pottery and as fire clay. A deposit occurring 6 miles southeast of Gaffney furnishes material for a small oven which produces rough pottery.

THE GOLD DEPOSITS OF DAHLONEGA, GA.

By Waldemar Lindgren

INTRODUCTION.

The gold mines of the Southern States, especially of the Carolinas, Georgia, and Alabama, have during the last decades declined in importance, and they have also been eclipsed by the larger production due to successive discoveries in the Western States. In consequence of this they have not in recent years obtained their share of attention from geologists. But it must not be forgotten that they were the first gold deposits which were studied by American geologists, and that about forty to sixty years ago they received much attention by such men as Silliman, Rogers, Whitney, E. Emmons, Lieber, and Kerr. The results of their studies were naturally applied to such western discoveries as the California gold-quartz veins, and thus the conceptions of "lenticular masses" and "segregated veins" were improperly transferred to western occurrences. No doubt the southern gold veins and those of California present some striking features of similarity, but the profound differences were overlooked, and the correct view of the latter as sharply defined fissure veins has only lately found acceptance in the general literature of ore deposits.

The first modern geological investigation of the southern gold deposits was made by Dr. G. F. Becker in 1895,[a] and his results throw much light on their mode of formation and aid in their proper classification. Since then detailed descriptions of many mines have been published by the State geologists of North Carolina and Georgia. When Mr. L. C. Graton was detailed to the investigation which forms the subject of this report, namely, the examination of the gold and tin deposits of the central portion of the Carolinas, it was my hope that, besides the practical results, some data on which to base conclusions as to origin might be gained, and a perusal of the bulletin will show that this hope was justified. After visiting some of the principal occurrences in the region under investigation, Mr. Graton and myself made a brief trip to Dahlonega for the purpose of comparing these veins with those farther north. The notes obtained, as well as some general conclusions, will be found in the following paragraphs, and, though very incomplete, may serve to fix a little more sharply than has been done before the group in which these deposits belong and some of their more striking distinctions compared with the gold deposits of the Cordilleran region.

GENERAL GEOLOGY.

The mines of the Dahlonega district of Lumpkin County, Ga., have been described in more or less detail in several publications. Among them should be mentioned the "Reconnaissance of the gold fields of the Southern Appalachians," by Dr. G. F. Becker,[b] and "The present condition of gold mining in the Southern Appalachian States,"[c] by Messrs. Nitze and Wilkens. Besides these, Dr. W. S. Yeates published, in 1896, as State geologist of the Georgia Geological Survey, "A preliminary report on a part of the gold deposits of

[a] Gold fields of the Southern Appalachians: Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1895, pp. 251-331.
[b] Sixteenth Ann. Rept U. S. Geol. Survey, pt. 3, 1895, pp. 251-331.
[c] Trans. Am. Inst. Min. Eng., vol. 25, 1896, pp. 661-796, 1021, 1025.

Georgia."[a] Finally, Mr. Edwin C. Eckel has recently described the "Gold and pyrite deposits of the Dahlonega district,"[b] in "Contributions to economic geology for 1902."

It will be seen from this list that the district has received a considerable amount of attention, and that the main features of the occurrence of the mineral deposits are fairly well known. It is not the purpose of the present contribution to present a detailed description, nor a complete one, of the Dahlonega mines. Indeed, for such a purpose the time allotted was by far too short. It is intended, however, to bring out in a little more detail than has been done before a few of the petrographic and mineralogical features, by which, perhaps, a somewhat clearer light may be thrown on the true character and origin of that peculiar class of deposits to which these gold-quartz veins belong.

The general geology of the district has been outlined by several of the writers mentioned above, especially by Eckel, and to the description of the main relations of the rocks there is but little to add.

The two most common rocks of the district are a mica schist and an amphibolite. The mica schist, which is the prevailing rock, is exposed, for instance, at the Preacher Cut, at the Benning mine, along Yahoola Creek, and in many other places. The rocks strike in general about N. 60° E. and dip at a high angle to the east, but both strike and dip are subject to abrupt variations. The mica schists are, in general, dark gray to dark brown and medium to fine grained. In places they approach perfect fissility, but ordinarily show curved and irregular surfaces of schistosity which are covered with glistening scales of biotite and muscovite. One of the most typical rocks is that exposed at the Preacher Cut, about one-half mile south of the town of Dahlonega. (See fig. 15.) This is a fine-grained brownish-gray schist. The small flakes of biotite have accumulated on the cleavage faces, which show fairly good fissility. Under the microscope the rock shows quartz mosaic with very few feldspar grains. Embedded in this mosaic lie abundant idioblasts of magnetite; brownish-green biotite in parallel orientation; straight, small muscovite foils, also mainly extended along one plane; and finally, rather abundant, well-developed, small bluish-gray prisms of tourmaline. The structure is typically crystalloblastic, to use the term recently introduced by Prof. F. Becke, of Vienna.[c]

The origin of a rock so thoroughly recrystallized as this is always open to some doubt, but I consider it reasonably certain that the quartz-mica schist of the Preacher Cut is of sedimentary origin. The consensus of opinion thus far regarding the mica schists appears to be that they are not indisputably sedimentary rocks. The normal schist of the country, wherever good exposures are available, proves to be similar to this specimen just described, although the grain is usually somewhat coarser and the sedimentary origin, though probable, is less distinctly indicated. A specimen of dark brownish-gray mica schist, from the Jumbo mine, shows again a mosaic of quartz, with a few grains of albite. This mosaic contains abundant dirty-brown, sharply outlined foils of biotite and smaller ones of muscovite. Pyrrhotite is present in small anhedrons, but no muscovite was observed. The structure here also is typically crystalloblastic.

No further clew has been found as to the age of the schists. They have, in common with all the other rocks of the district, been regarded as pre-Cambrian by Becker and other observers, but Eckel is inclined to question this conclusion and thinks that they may possibly be of Cambrian or Lower Silurian age. So far as known, however, no Cambrian rocks in the South are intruded by granite, but, as is shown on page 122, these mica schists contain considerable bodies of such intrusives.

As emphasized by previous writers, several large and irregular bodies of amphibolite occur in the district, as well as in adjoining regions. The contacts beween amphibolite and mica schist are usually sharply defined. In some places, as at the Preacher Cut, the relation of the two rocks decidedly indicates that the amphibolite is intrusive into the

[a] Bull. Georgia Geol. Survey, No. 4-A.
[b] Bull. U. S. Geol. Survey, No. 213, 1903, pp. 57-63.
[c] Ueber Mineralbestand und Struktur der kristallinischen Schiefer: Sitz.-Ber. d. Wiener Akademie, May 7, 1903.

mica schist and that it was originally a diorite or a diabase which has been deeply altered by dynamometamorphic processes. The strike and dip of the schistosity is, in general, conformable to that of the mica schists, but this again is subject to some marked exceptions. The strike and dip of the schistosity vary considerably from place to place.

The amphibolite is well exposed in the town of Dahlonega, near the Preacher Cut, and on the road from Dahlonega to the Lockhart. The amphibolite from the dump of the Crown Mountain mine, at the mill below the Preacher Cut, is a typical, dark-green, roughly schistose rock of medium grain, in which, by the naked eye, may be distinguished small prisms of amphibole with specks of pyrrhotite. In places narrow streaks appear in which

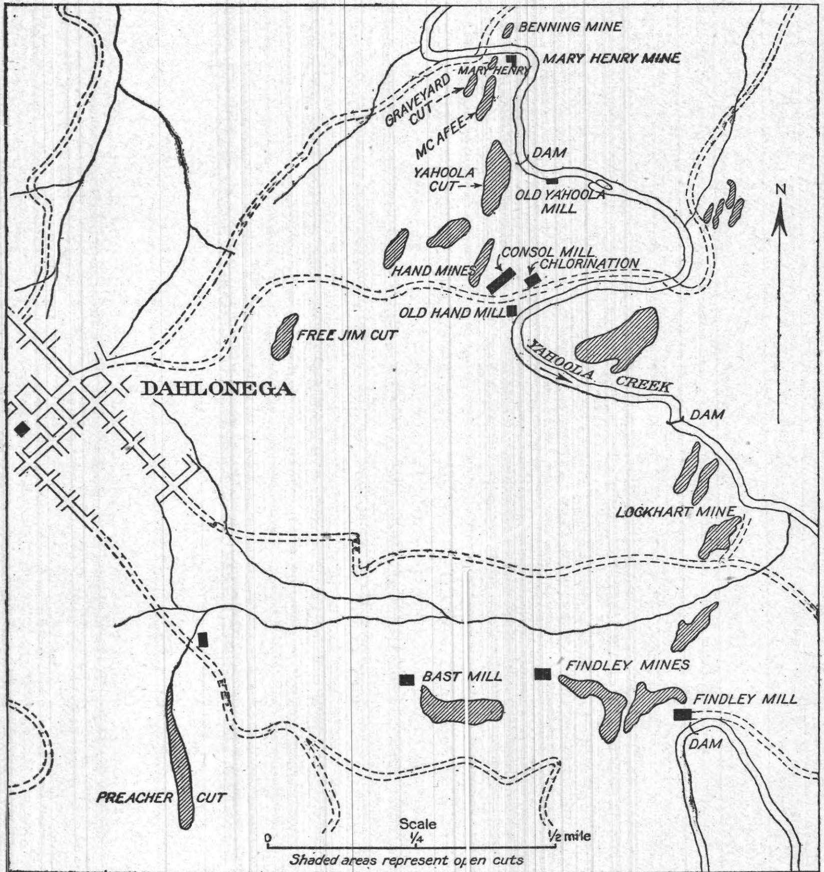


FIG. 15.—Sketch map of the vicinity of Dahlonega, Ga., showing location of mines.

the feldspar prevails over the amphibole, thus giving a lighter, greenish-white aspect to the rock. The constituents, as seen under the microscope, comprise green amphibole, chlorite, calcite, quartz, albite (?), magnetite or ilmenite, pyrrhotite, and chalcopyrite. The structure of the rock is characteristically crystalloblastic. Thorough recrystallization has taken place, and the principal mass now consists of a quartz-feldspar mosaic in which lie embedded ragged and elongated grains of hornblende, some of them inclosing small parts of the mosaic. The mosaic contains very few striated feldspar grains, but much feldspar is present, and most of it, as indicated by its optical properties, is an oligoclase, although some of it may also be albite. The chlorite has the normal characteristics of that mineral, and its occurrence renders it probable that it is wholly derived from the hornblende by hydrochemical metamorphism. Calcite is present in compact or elongated aggregates, many of which include small parts of the quartz mosaic; it penetrates and is being penetrated by hornblende. The only mica present consists of small foils of chestnut-brown biotite embedded in the mosaic.

Of the metallic minerals, magnetite is present in elongated masses, in places intergrown with pyrrhotite and chalcopyrite. There is no pyrite, but a considerable amount of pyrrhotite, usually intergrown with smaller grains of chalcopyrite. In many places these sulphides are inclosed in calcite or in hornblende.

The most recent rock of the bed-rock series is a light-colored, coarse-grained granite, exposed at the Benning mine and at several points west of Yahoola Creek, in a westerly direction from Dahlonega.

The relations of granite to the mica schists are very clearly exposed at the Benning mine, and the contact is illustrated in Pl. VIII. The main contact, shown near the right of the plate, is somewhat indistinct for a distance of several feet, and this is due to the thorough injection of the schists near the contact plane by granitic magna, so that the rock here has the appearance of granite containing a great number of thin and dimly outlined streaks of schist. About 10 feet to the north of the contact the schist contains dikes of granite. These dikes, which are injected between the planes of schistosity, are bent and in some places contorted and have acquired a slight schistosity, as has also the main mass of the granite wherever exposed.

The Benning granite is a white, coarse, granular, imperfectly schistose rock. The schistosity is apparent chiefly by the development of sericite on incipient planes. In sections perpendicular to the schistosity the lenticular form of many of the grains indicates the pressure to which the rock has been subjected. Besides quartz and feldspar, the rock contains large flakes of biotite, 5 to 8 mm. in diameter, which, however, have mostly been converted into aggregates of muscovite. The microscope shows a granular but distinctly compressed rock. The large quartz grains are converted into aggregates of the same mineral. The feldspars, which consist of orthoclase and oligoclase in large grains, contain an abundance of straight muscovite foils, which have developed on the cleavage planes. They also contain zoisite and epidote in small crystals and grains. In places a great amount of recrystallized aggregates of quartz and feldspar mingled with muscovite have formed.

A white, coarsely granular rock, collected from the Benning mine, proved to be almost wholly composed of albite in large anhedral or roughly square grains with thin twin lamellæ. There is no other mineral present in this rock except a little muscovite in small foils and a little microperthite. This albite rock probably occurs as a dike near the granite contact.

Although the grain of the schist is somewhat coarser than usual at the Benning contact, there is little evidence of contact metamorphism, except by the development of garnets and tourmaline in the schist, as described in more detail under the heading of the Benning mine (pp. 127–128). Whether the garnet is really of contact-metamorphic origin is not certain. The same doubt applies to the tourmaline, which is present in some schists at a considerable distance from granite contacts.

PRODUCTION.

The gold deposits of the Southern States have been known for one hundred years and were probably the earliest discovered and worked within the present area of the United States. Possibly some little placer mining had been carried on by the Indians in New Mexico prior to that time, but the important placer mines of that Territory were not discovered until 1828. Between 1799 and 1830 a small amount of gold was washed in the Carolinas. In 1828 gold was discovered near Dahlonega, and in 1830 the first deposit of gold from Georgia, amounting to $212,000, was made in the United States Mint. Shortly afterwards, in 1838, a branch mint was established, which, from 1838 to 1861, coined $6,115,569. The total production of gold and silver in Georgia, from the discovery to 1900, is between sixteen and seventeen million dollars, and of this amount the largest portion has been produced by the mines of Lumpkin County, in which Dahlonega is situated. The

CONTACT OF GRANITE AND MICA-SCHIST AT BENNING MINE.

Main contact 2 feet to right of hammer. Injected zone about hammer. Granite dikes to left.

total production of the Appalachian States from 1800 to 1900 is considered to be $47,000,000. For the last few years the total annual production has been about $300,000, while the production of Georgia has varied from $130,000 to $60,000, the latter figure being recorded in 1903.

GENERAL CHARACTER OF THE VEINS.

As already pointed out by Eckel, many of the gold deposits lie on the contact either of mica schist and amphibolite or of mica schist and granite. This does not apply to all of them, however, for some, like the Jumbo and Garnet, are entirely inclosed in mica schist.

Of the three rocks, the mica schist is the oldest and the granite the youngest. The quartz veins are later than the granite and appear to exhibit a certain relationship to that rock in their occurrence. At no place are the veins located far from the granitic intrusions; even at the Jumbo mine, which is wholly in mica schist, granite outcrops only a few hundred feet away. The veins follow the schistosity in strike and dip, although at each deposit there are many stringers of quartz which cut across the division planes of the rock.

The deposits are in part "stringer leads," to use Becker's expression, and in part distinct veins, composed of a series of flat lenticular bodies of quartz, usually strictly conformable to the schistosity and following even its minor curves. The familiar, sharply cut fissures of the western veins are absent. In some cases the veins are corrugated or curved. As Becker has pointed out, all this shows that there was a certain degree of correspondence between the forces which produced the schistosity and those which opened the fissures. The quartz is, as a rule, compact, milk-white or even glassy, and shows normal coarse, hypidiomorphic vein structure without evidence of much crushing and shearing even in the veins which appear bent and curved; drusy places with projecting crystals are not uncommon; comb quartz is rare, although occurring in some narrow seams which cut across the prevalent fissures, as, for instance, in Preacher Cut. Much of the bright-yellow gold is coarse, and forms, without doubt, a primary constituent of the ore. The sulphides are relatively poor, but in the oxidized zone they have naturally contributed their quota of gold to enrich the ore. The sulphides associated with the quartz are pyrite, chalcopyrite, and zinc blende; pyrrhotite occurs sparingly. In the Benning vein magnetite occurs anhedral or in octahedral crystals and intergrown with pyrrhotite, chalcopyrite, calcite, and chlorite; pyrite is also contained in the quartz. Of gangue minerals there is some calcite or dolomitic carbonate; in many places in the Benning veins this lies along the wall, as it commonly does in California veins. Garnet, apatite, ilmenite, muscovite, dark-green mica, and green hornblende occur in the altered wall rocks of some veins, but also in places directly in the quartz. Dark-green zinc spinel or gahnite in octahedral crystals is embedded in quartz with free gold and small foils of sericite from the Rosamund vein of the Standard group.

Gahnite is a rare mineral and, like spinel, usually occurs in gneisses or as a result of contact metamorphism. It is not altogether unknown in mineral deposits, for Genth[a] describes it from the Cotopaxi mine, Chaffee County, Colo., associated with pyrite, galena, and chalcopyrite, and containing inclusions of chalcopyrite. A. G. Dana[b] mentions an occurrence of gahnite from the Rowe pyrite deposit in Massachusetts. This is a lenticular vein in gneiss, and the gahnite occurs partly in the pyrite and partly lining cavities subsequently filled with quartz. It is here associated with apatite, ilmenite, rutile, epidote, garnet, calcite, triclinic feldspar, pyrite, and sphalerite.

In the lenticular veins pay shoots occur similar to those elsewhere found in gold veins, and Mr. Joe Clement informs me that the rule in Dahlonega is that they pitch to the left of an observer standing on the croppings and looking down along the dip.

The wall rock adjoining the quartz at many places contains enough gold to be classified as an ore, though, as a rule, the principal values are considered to be contained in the quartz. In the same veins garnets, hornblende, apatite, and a green mica may develop along the quartz vein, as shown, for instance, at the Lockhart mine and several other places. The

[a] Am. Jour. Sci., 3d ser., vol. 29, 1885, p. 455.

[b] Proc. Am. Phil. Soc., vol. 20, 1882, p. 397.

garnet, as already indicated by Becker, contains native gold. At other mines the alteration of the mica schist is not extensive, though the rocks next to the vein may acquire a more silvery luster, due to some additional development of muscovite in the schist. The biotite in the schist remains unaltered, as does the chlorite and feldspar. Crystals of garnet may develop in the schists near the vein. Chalcopyrite, pyrite, and pyrrhotite, probably due to vein-forming action, appear in small quantities in the wall rock, but with these magnetite or ilmenite may be associated.

As observed in the Benning vein, the alteration of the granite adjoining the veins is very slight, being limited to a slight development of chlorite along the contact. In the Jumbo mine, on the other hand, the mica schist has been altered next to the quartz seams; sericite has evidently developed at the expense of biotite, which is practically eliminated. Nor is there any magnetite or ilmenite in the altered rock, though much pyrite and rutile have developed.

All this seems to show that the veins of Dahlonega were not all formed under the same conditions. There are, on one hand, the prevailing veins like the Standard, Lockhart, and many others in which, during the vein-forming processes, biotite, hornblende, garnet, epidote, spinel, magnetite, and ilmenite were stable compounds. These again may be divided into those carrying garnets, like the Lockhart, Findley, and McAfee veins, and others in which garnet is absent, like the Benning or the Standard. On the other hand, in the Jumbo mine biotite and magnetite appear to be unstable under the influence of vein-forming solutions.

The association of minerals and the metasomatic alteration in the first of these two classes is very different from that prevailing in the California gold-quartz veins and in fact in all the principal classes of gold and silver veins of the West.

In these California veins magnetite, garnet, ilmenite, spinel, hornblende, and apatite are practically unknown as vein minerals. In the alteration by the vein solutions magnetite, feldspars, biotite, hornblende, and epidote are unstable and are converted to a fine-grained aggregate of sericite with quartz or carbonates, as has taken place in the Jumbo mine. In the prevailing class of Dahlonega mines, on the other hand, the products of alteration are such minerals as occur in areas of regional metamorphism or in contact zones, and yet the association of quartz and some calcite with native gold and pyrite, chalcopyrite, and zinc blende is unmistakably similar to that of the California veins. It may be permissible to conclude from this that the solutions in both cases were similar, but that they acted under different physical conditions. The temperatures prevailing during the deposition of the southern veins were probably much higher than those in the Cordilleran region at the levels now accessible to us in mineral deposits there exploited. Becker justly remarks that the southern veins have been subjected to long-continued erosion and that the present croppings are far below the original ones, possibly as much as 15,000 or 20,000 feet. On the other hand, in the western mines, the amount of rock removed undoubtedly falls far short of this amount.

If this conclusion is correct, it is evident that the precipitation of gold from vein-forming solutions extends over a very large vertical range. In California this range is known to be at least 3,000 feet.[a] At Bendigo, Victoria, mining has reached a depth of 4,000 feet, and at least 2,000 feet of rock have been removed by erosion. The veins still bear the general character of the California gold-quartz deposits.

It is scarcely to be expected that a brief investigation like the present one should yield any definite clews as to origin of the gold. The clustering of the veins about intrusive masses of granitic rocks is, however, a very suggestive fact which previous investigations of Dahlonega mines have not sufficiently emphasized and which is repeated in practically all known occurrences of typical gold-quartz veins. The probable great depth of deposition would also suggest that circulation of surface waters was a negligible factor, although it is conceded that the plasticity of the rocks was not so great as to preclude the existence of

[a] Lindgren, W., Gold-quartz veins of Nevada City and Grass Valley districts, California: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1896, p. 183.

open spaces of moderate size. Briefly, I am convinced that the mode of origin of the Dahlonega deposits was entirely similar to that of other auriferous quartz veins of Californian and Australian type, although, owing to physical causes, some features of their development differed. In all three cases it seems a probable hypothesis that the gold was contained in the granitic magma and that it was separated from it during the cooling process and carried to the veins in the form of solutions in magmatic water.

The study of the mode of alteration of wall rocks in different mines affords some basis for the suggestion that there may have been two epochs of vein formation in which the physical condition during deposition differed in a decided manner.

The abundance of intergrown pyrrhotite and chalcopyrite in some of the amphibolites of Dahlonega brings to mind the occurrence of deposits of such minerals at other places in the South—Ducktown, for example. In the present case these sulphides have every appearance of having been formed by the same metamorphic processes which made an amphibolite out of a diabase or diorite, and, if this is true, the chalcopyrite merely represents the concentration by aqueous agencies of the copper distributed through the rock.

DESCRIPTIONS OF MINES.

PREACHER CUT.

The pit known as the Preacher Cut, made by hydraulic work, is situated half a mile south of Dahlonega. Amphibolites, striking northeastward, prevail between this mine and the town, but near the cut mica schist is the country rock and strikes northwesterly, dipping to the northeast or southwest at angles of from 35° to 65°. This cut is about 800 feet long, extending in a southwesterly direction, 200 feet wide, and about 60 feet deep. The central part is occupied by a well-defined dike of amphibolite about 60 feet wide and gradually tapering toward the southwest. At the lower end of the cut, nearest to the town, the contacts of the amphibolite and mica schist are sharply defined and about perpendicular. The amphibolite is fairly fresh in the bottom of the cut, but elsewhere red and softened. The schistosity of the mica schists continues in imperfect development across the dike. Along both sides of the dike the schists contain numerous thin stringers of solid quartz dipping with the schistosity; there are also a few veinlets along the contact. The gold occurs to some extent in the veinlets with schist, but chiefly in the schist surrounding these stringers along both sides of the amphibolite dike. There is very little gold in the amphibolite. The schists and the quartz stringers near the contact are in places contorted and corrugated. Garnet occurs at this locality, probably associated with the quartz, but the specimens were too decomposed to ascertain this definitely. A northwestward-trending dislocation crosses the upper part of the cut. In this break or fault are several narrow quartz veinlets with fine comb structure; native gold is said to occur in these.

The peculiar feature in this mine is that the gold-bearing zone extends along both sides of the amphibolite dike in a direction perpendicular to that of the schistosity and of the auriferous veinlets. In the bottom of the cut the rocks are hard and the hydraulic process scarcely feasible, while the average values are said to be low.

CONSOLIDATED MINES.

Half a mile east-northeast of Dahlonega on the road to Yahoola River are the extensive hydraulic cuts of the old Hand properties, now owned by the Dahlonega Consolidated Gold Mining Company. Some years ago a large shaft was sunk here, near the bottom of these cuts, and a 120-stamp mill built, with a 30-ton chlorination plant and 48 Frue vanners, with the idea of mining the stringer zone on a large scale. Probably the grade proved rather low. At the present time 30 stamps are dropping.

The country rock in the Hand cuts and in the tunnels of the Dahlonega Consolidated Gold Mining Company below them is a garnetiferous mica schist, contorted in places and containing many dikes of a white, somewhat aplitic granite up to 1 or 2 feet wide, which likewise have suffered corrugation and bending. This is probably the southerly continuation of the Benning contact zone. The schist contains stringer zones of quartz veinlets trending northeastward, and some of these zones are now mined in the tunnels just back of the mill.

STANDARD MINES.

On the east side of Yahoola River and about a quarter of a mile northeast of the Consolidated mines are the Standard mines. They consist of a series of quartz lenses known as the Weaver, Campbell, Thaloneka, and Rosamund veins. The developments are confined to tunnels and small underhand stopes. From the Rosamund vein good ore was extracted at the time of visit and milled in the Standard mill with 20 stamps. Very rich pockets are occasionally found.

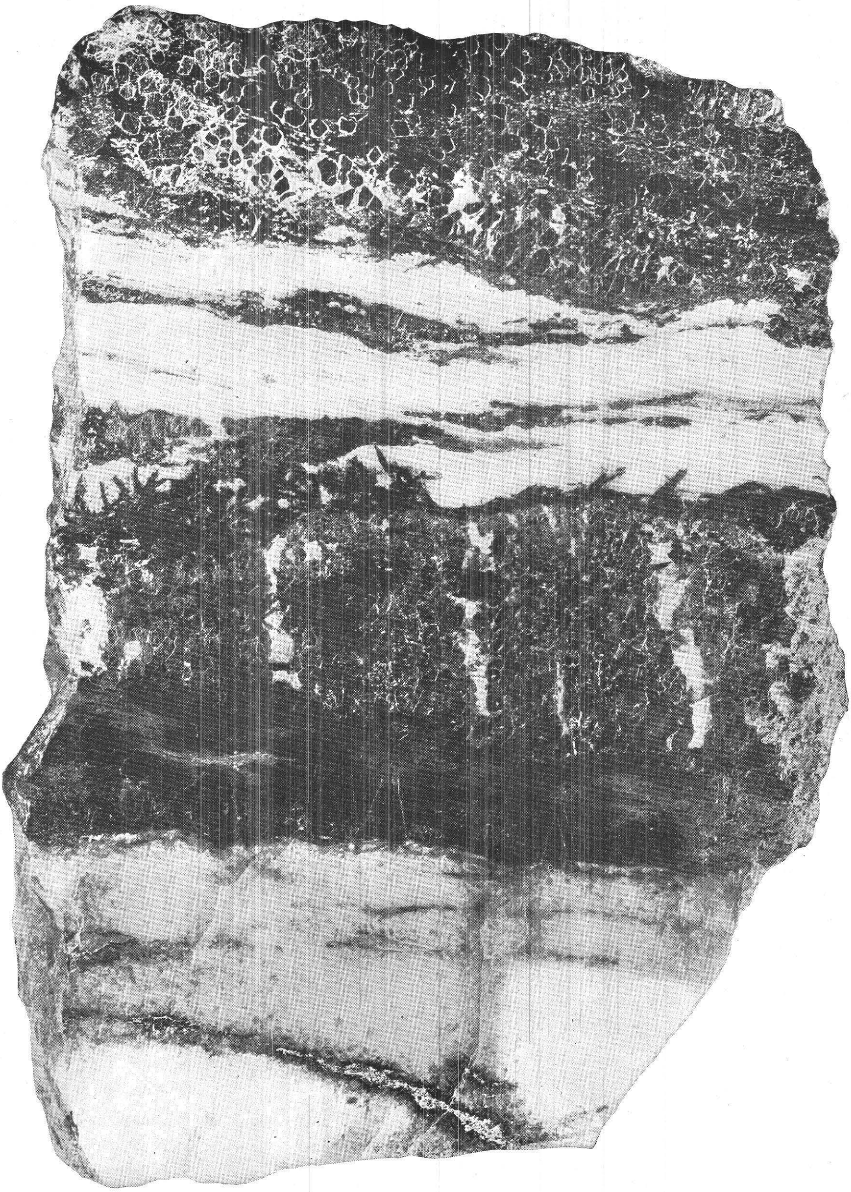
The country rock is a rather coarse mica schist which close to the veins appears to contain a little more muscovite than elsewhere. It is a normal biotite-quartz schist with a small amount of magnetite, albite, and muscovite, but contains no garnet or tourmaline. A little pyrite, pyrrhotite, and chalcopyrite are present in intergrown aggregates and probably are derived from the vein solutions. The schistosity strikes N. 12° to 25° E., the dip being 35° ESE. The quartz of the veins is compact, almost glassy, and contains irregularly distributed pyrite, chalcopyrite, zinc blende, and in some cases galena, besides free gold, partly intergrown with quartz, partly with sulphides. At the time of visit a stope 25 feet long was carried down below the tunnel level on the Rosamund and extracted 7 feet wide. No values are here contained in the schist adjoining the quartz. The manager, Mr. George Bryman, states that the ore contains $20 per ton in gold; the sulphides contain $25 per ton and are thus comparatively poor.

LOCKHART MINE.

Along Yahoola River from the Standard to the Lockhart mine, amphibolites prevail with north-northeast or east-northeast strike and variable dip. Near the Lockhart mine mica schist begins, and at a fresh exposure on the river bank was noted a small lenticular vein of quartz containing a few garnets. The same mineral was also contained in the immediately adjoining schist. This stringer probably belongs to the Lockhart zone.

The Lockhart mine has been worked successfully for many years, but on a small scale. A large surface cut is situated on the west side of the river, and recently a shaft 60 feet deep has been sunk near the stream and tunnels run in a westerly direction to intersect the veins. The veins lie in a belt of normal mica schists like those described on page 120, dipping about 40° E. or NE. and very near to a mass of amphibolite which conformably underlies these schists. The ore occurs in shoots, locally called "arms," which consist of a series of lenticular quartz masses in dark-gray or black mica schist, but very close to the contact of the underlying amphibolite. The veins, like the schists, dip 30° to 40° NE. In the large cut the rocks are much decomposed and the shaft was inaccessible on account of water, but excellent exposures were seen in a small tunnel or cut about 200 feet southwest of the shaft.

As shown in fig. 16, the vein is here 7 feet wide, dips 34° NE., and consists of a number of quartz stringers more or less lenticular in shape and separated and adjoined by streaks of a very coarse-grained rock, which consists chiefly of garnet, dark-green mica, and hornblende, and which evidently represents the country rock deeply altered by the same solutions as deposited the quartz. Beyond the walls indicated in fig. 16 the rock is the normal mica schist, though the amphibolite lies a short distance in the foot. Pl. IX represents in natural size a cut and polished specimen from the vein, which well illustrates the characteristic structure. The garnets are indicated in the dark central and upper portions by the light rims of remaining polishing powder. Most of the remaining dark portion is a dark-green, almost black mica, which also in places projects its foils into the white quartz. Little specks of pyrite are contained in the dark part, while none show in the quartz. Sulphides, however, occur in the quartz and consist of pyrite, pyrrhotite, chalcopyrite,



POLISHED SPECIMEN OF ORE FROM LOCKHART MINE, DAHLONEGA.

Showing quartz with streaks of garnet, dark-green mica, and hornblende.

and galena. Much of the ore is of good grade, the samples assayed by Dr. Yeates in his report on the gold deposits of Georgia containing from $12 to $15 per ton. The average is, however, probably less than this. Most of the gold in this vein is said to appear as native metal in the reddish-brown garnets and a specimen obtained substantiates this statement.

It is very clear that the coarse-grained mixture of garnet and mica is the result of the alteration of the schist and its study presents several interesting features. Sections of the quartz show normal, hypidiomorphic, coarse-grained structure, the grains exhibiting no optical disturbance. Fluid inclusions with gas bubble and in some instances solid transparent particles also are very abundant. Embedded in the quartz lie streaks of aggregates of common green hornblende, usually in irregularly lath-like grains molded by the outlines of the quartz grains; in places radial bunches of hornblende prisms also project into the quartz. Associated with the hornblende are granular aggregates of a mineral which corresponds well to apatite; locally these are also wholly embedded in quartz. There are also small foils of muscovite and isolated similar forms of biotite. Anhedrons of pale-red garnet are inclosed in the quartz or conform to the outlines of the quartz grains. In the hornblende lie embedded scattered grains of pyrite and more abundant ilmenite. A few imperfect crystals of ilmenite are contained in the quartz grains, between which a little calcite also appears.

Other sections made from the polished specimen show large rounded crystals of garnet, with a few inclusions of green mica. The garnets are contained in a coarse aggregate of straight mica foils, with a pleochroism varying from pale green to deep leek green. The exact mineralogical position of this mica has not been ascertained. Veins similar to the Lockhart are mined at the Findley and the McAfee mines. In the McAfee the garnets are said to be smaller than in the Lockhart, but they also contain native gold.

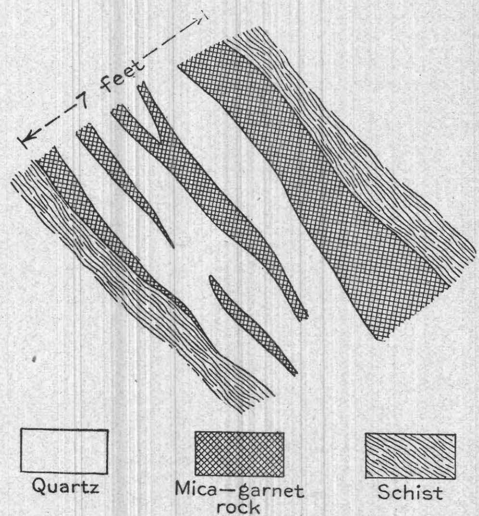


FIG. 16.—Diagram showing structure of Lockhart vein.

BENNING MINE.

The Benning mine is situated 1 mile northeast of Dahlonega, on Yahoola River. The developments are limited and consist chiefly of a large incline driven on a wide quartz lens in the mica schist within 25 feet of the granite contact, but parts of the vein are also contained in granitic dikes. The country rock is here a dark-gray glistening mica schist consisting of a quartz mosaic without much feldspar; in this are embedded dirty-brown sharply outlined foils of biotite, many of them small and straight; a smaller amount of muscovite is present in similar foils. There are also a few grains of calcite, inclosing some mosaic, and a few foils of chlorite, probably not derived from the biotite. Magnetite is distributed throughout rather abundantly and there are a few grains of pyrite and pyrrhotite. The schist also contains a few large crystals of garnet inclosing smaller masses of mosaic; a few prisms of tourmaline were noted. The whole structure is typically crystalloblastic.

Along some small stringers of quartz to the left of the granitic dike garnets have developed abundantly, but whether this quartz is of the same origin as the gold-quartz veins or represents a local quartz facies of the granite could not be definitely ascertained.

The quartz lenses which range up to several feet in width consist of coarse normal vein quartz, with a little calcite or dolomitic carbonates, pyrite, pyrrhotite, chalcopyrite, and magnetite. The sulphides in places give a banded appearance to the quartz.

Neither schist nor granite is noticeably altered along the vein. Biotite, albite, and orthoclase from the wall rock adjoin the quartz without change.

JUMBO MINE.

The Jumbo property is situated 6 miles northeast of Dahlonega, near the Garnet mine and on Cavender Creek, which has proved auriferous up to these mines. The developments consist of several tunnels and a 60-foot shaft. The country rock is a dark brownish-gray mica schist, with curved surfaces of schistosity; it is similar to the schists already described, but contains very little black iron ore; instead, small anhedrons of pyrrhotite are present.

The surface rocks are very soft and decomposed to a depth of about 50 feet. Granite is said to outcrop a short distance away from the mine. Over a width of several hundred feet the schists, which strike N. 20° E. and dip steeply to the northwest, contain a great number of chiefly conformable quartz stringers and several good-sized quartz veins with some pyrite. Within this zone are several narrower belts from a few feet up to 50 feet in width, in which the gold values are especially concentrated. The gold has a crystalline appearance and is very fine grained.

Specimens of the ore from the shaft show that it consists of a bleached schist with more or less lenticular quartz veins having an allotriomorphic structure and containing sharply defined cubes of pyrite. The schist adjoining the veins is bleached by abundant development of sericite; it contains no garnets nor biotite, but some chlorite and many microscopic crystals of rutile. It is proposed to mine the decomposed surface rock at this mine by hydraulic methods.

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