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UNIVERSITY OF VIRGINIA
THOMAS LEONARD WATSON, PH. D.
DIRECTOR

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The Geology and Ore Deposits of the Virgilina District of Virginia and North Carolina

BY

FRANCIS BAKER LANEY

PREPARED JOINTLY BY THE
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LETTER OF TRANSMITTAL

VIRGINIA GEOLOGICAL SURVEY,
UNIVERSITY OF VIRGINIA,
CHARLOTTESVILLE, December 15, 1917.

Governor Henry C. Stuart, Chairman, and Members of the State Geological Commission:

GENTLEMEN:—I have the honor to transmit to you herewith, and to recommend for publication as Bulletin No. XIV of the Virginia Geological Survey Series of Reports, a manuscript and illustrations of a report on "The Geology and Ore Deposits of the Virgilina District of Virginia and North Carolina," by Francis Baker Laney.

The Virgilina District, which lies partly in Virginia and partly in North Carolina, is one of the more important copper districts in the eastern United States that has produced considerable tonnages of ore. This report, prepared jointly by the Virginia Geological Survey and the North Carolina Geological and Economic Survey, embodies a detailed study of the ore deposits in parts of Halifax, Charlotte, and Mecklenburg counties, Virginia, and in Granville and Person counties, North Carolina, and should prove of considerable value in directing further attention to an economically important area of copper deposits. Since it supplies the needed detailed and accurate information on the ore deposits, it is confidently believed that it will stimulate further development and production of copper ores in the district.

Respectfully submitted,

THOMAS L. WATSON,
Director.

PREFACE

The publication of this report, entitled "The Geology and Ore Deposits of the Virgilina District of Virginia and North Carolina," is a new departure in State Geological Survey reports, since it represents a joint investigation of an important copper district lying partly in each state, carried on coöperatively by the Virginia Geological Survey and the North Carolina Geological and Economic Survey.

In order to insure uniformity for the district as a whole, the same geologist, Doctor Francis B. Laney, was employed by the Virginia and North Carolina Geological Surveys to make the survey in the two states under the general supervision of the State Geologists of Virginia and North Carolina. Doctor Laney was assisted in the field work in North Carolina for a part of the time by Doctor Joseph E. Pogue, of the North Carolina Geological and Economic Survey; and, in Virginia, by Mr. Joel H. Watkins, of the Virginia Geological Survey.

The investigation covers an area of approximately 550 square miles, including parts of Charlotte, Halifax, and Mecklenburg counties, Virginia, and parts of Granville and Person counties, North Carolina. Chapter I gives a short but concise geographic sketch of the district, including location, topography, drainage, soil, and climate, closing with a complete account of previous geologic work in the district in the form chiefly of an annotated bibliography. Chapters II and III discuss the general geology of the district and give a detailed description and classification of the rocks, their structure and metamorphism. Chapter IV comprises a detailed description of the veins and ores, in which the mineralogy of the ore and gangue minerals is fully described, and the relations of the copper-bearing sulphides to each other and the origin and deposition of the ores are discussed. Chapter V, entitled, "The Mines and Ores of the Virgilina District," gives a full description of the individual mines and prospects, closing with a discussion of the methods best adapted to the utilization of the ores.

The traverse map which has been used as the base of the geologic map accompanying this report was prepared in coöperation with the United States Geological Survey.

The author and the State Geologists wish to make grateful acknowledgment to all persons who have assisted in various ways in facilitating the work of this investigation.

THOMAS LEONARD WATSON,
State Geologist of Virginia.

JOSEPH HYDE PRATT,
State Geologist of North Carolina.

AUTHOR'S PREFACE

During the field work upon which this report on the Geology and Ore Deposits of the Virgilina District is based, the writer had the advantage of the supervision and advice of Messrs. Thomas L. Watson and Joseph Hyde Pratt, state geologists, respectively, of Virginia and North Carolina, and he wishes to gratefully acknowledge his indebtedness to each of these men who spared neither time nor expense in furtherance of the work.

To the U. S. Geological Survey and to the U. S. Bureau of Mines the writer is indebted for the privilege of carrying on in their laboratories the microscopical and mineralogical investigations necessary in the preparation of this report. Many of the facts regarding the texture and structure of the different minerals as well as the photomicrographs showing these structures would have been impossible without the use of the excellently equipped microscopical laboratory of the U. S. Bureau of Mines at Salt Lake City, Utah.

During part of the field work the writer had the assistance in North Carolina of Dr. J. E. Pogue, now Associate Professor of Geology in Northwestern University, and in Virginia of Mr. J. H. Watkins, now Geologist for the Southern Railway Company. Mr. Watkins also did the drafting necessary in preparing the geologic map and the plans and drawings illustrating the development work at the different mines and prospects. To these men the writer gratefully acknowledges his indebtedness.

To many of the operators and residents of the Virgilina district the writer is under many obligations. Among these are Mr. A. W. Tucker, former manager of the Seaboard mine; Mr. Robt. G. Lassiter, former manager of the Blue Wing mine; Dr. Franz Koempel, of the Littlejohn Copper Co.; the late Mr. Wm. M. Pannebaker, owner of much property in the district; Miss Florence Pannebaker; Mr. J. D. Battershill, formerly superintendent of the Holloway mine; Mr. H. C. Crowell, of the Virgilina Gold Mining Co.; Mr. F. Durgy, of the Durgy mine; and Mr. John Taylor. These persons spared neither time, pains, nor convenience in assisting the writer in his work in every way possible for them to do so. Without their interest and coöperation it would hardly have been possible to collect the data so necessary in the preparation of this report.

To Miss Florence Pannebaker the writer is greatly indebted for a collection of ores from the Cornfield Prospect No. 1, which enabled him to

determine the relationship between chalcopyrite, bornite, and chalcocite. This obligation is gratefully acknowledged in the body of the report, p. 87.

The people of the district without exception were greatly interested in the work and were always willing and glad to render any assistance within their power.

FRANCIS BAKER LANEY.

THE GEOLOGY AND ORE DEPOSITS OF THE VIRGILINA DISTRICT, VIRGINIA AND NORTH CAROLINA

By Francis B. Laney.

GEOGRAPHY AND HISTORY.

GEOGRAPHICAL SKETCH.

Location.—The Virgilina mining district is crossed by the North Carolina-Virginia boundary line about 140 miles west of Norfolk, Va., and 40 miles east of Danville, Va. About one-half of the area, which up to the present has been the most productive, lies within each state. The North Carolina portion, as included in the accompanying map, comprises an area about 22 miles long and 18 miles wide, and lies in the northwest portion of Granville and the adjoining northeastern corner of Person counties. The Virginia area is longer but narrower, is about 50 miles long and 15 miles wide, and, excepting a narrow strip along the western side of Mecklenburg County, lies within Halifax and Charlotte counties. The town of Virgilina, from which it takes its name, and which is the principal railroad point, is a village of about 600 inhabitants, and is located on the State line near the center of the most productive portion of the district. The Norfolk and Danville division of the Southern Railway, on which the town is located, crosses the district, approximately following the state line, and renders the center of activity easily accessible. The northern end of the district, which contains a number of somewhat promising prospects, but no developed mines, is crossed by the Richmond and Danville division of the Southern Railway, which, after crossing the district between Keysville and Drakes Branch, two railroad and supply points in the north end of the area, turns southwestward and runs within the area near its western border to Dan River. The Durham division of the Norfolk and Western Railway crosses the Southern Railway at Denniston Junction, about 12 miles west of Virgilina, closely paralleling the western side of the district. Thus it is that no part of the district, except the extreme southern end, is without ample railroad outlet. The wagon roads for the most part are fair, and some of them are good.

Topography.—The Virgilina district lies wholly within the Piedmont Plateau, and presents the topographic features common to that physiographic province. The topography is mature, the hills are all well rounded, and relief is much subdued. In fact, there is little relief noticeable to the casual observer, except where streams have cut through the Virgilina ridge,

a low-lying, nearly flat-topped ridge with very gentle slopes, which forms the most prominent surface feature of the district. The most marked relief is along Dan River, which crosses the district near its center. This stream crosses the rocks approximately at right angles to the strike of the schistosity, and, where it cuts through the Virgilina ridge, the slopes are steep and the topography is rather rugged. The remainder of the district is without prominent relief, but is decidedly hilly.

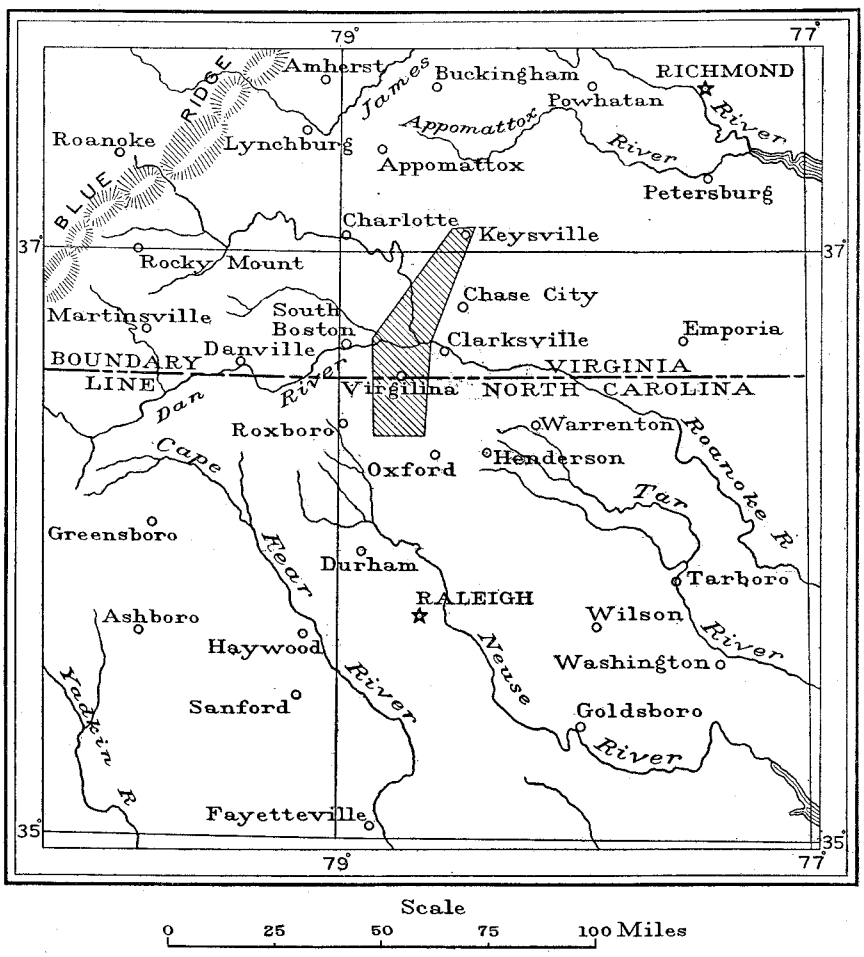

Fig. 1.—Map of a portion of North Carolina and Virginia, showing the location of the Virgilina district.

(Taken from a map of the United States by the General Land Office, 1915.)

Drainage.—The principal stream is Dan River, which flows in a southeast direction across the center of the district. Within the area the Dan is joined from the north by Bannister and Roanoke rivers, and from the south by Hyco River and Aaron's Creek. The Roanoke receives Horsepen Creek from the east, and Difficult Creek from the west, while Hyco receives Blue Wing and Mayo creeks from the east. These make up the principal streams, but rainfall during certain portions of the year is very heavy and smaller streams are numerous. The larger streams, especially Dan and Roanoke rivers, hold their course regardless of the character of the underlying rocks, but the creeks and smaller streams are greatly influenced, if not controlled, by it. Rainfall, especially during the winter and spring months, is heavy, and for the most part the district is well watered.

Soil.—The character of the soil depends upon the nature of the underlying rock. The tuffs and other volcanics produce a lean, shallow soil; the granite produces a strong, rather sandy soil; and the other igneous rocks break down into a rather sticky but fairly strong soil. Of all the truly igneous rocks, the diabase produces the leanest and least desirable soil. The volcano-sedimentary rocks—the greenstone and sericite schists—as a rule form a lean and shallow soil. Rock outcroppings are not numerous except along stream courses, but almost invariably the partially decayed rock is very near the surface. Such soil is generally lean and does not produce good crops except when heavily fertilized. The granite is invariably deeply decayed, and produces the most fertile soils in the district. When properly cared for and well cultivated, the granite soils yield bountiful crops, and the most prosperous farms in the district are either in the rich, alluvial lands along the rivers or in the granite areas.

Much of the district is still in forest, but the greater part of the good timber has been cut off, so that what remains is either culled forest or "old field" pine. The original timber consisted largely of oak and other hardwoods with a moderate amount of yellow pine. The present timber, while for the most part second class and small, is ample for the needs in mining and for fuel.

Climate.—The climate of the Virgilina district is agreeable and pleasant throughout the year. As a rule it is neither excessively hot during the summer nor extremely cold during the winter. The mean annual temperature is between 55 and 60 degrees Fahrenheit. The winter temperature rarely reaches zero, and in summer does not often go above 90 degrees. Average yearly precipitation is between 50 and 55 inches and is fairly well

distributed throughout the year. There is only a moderate amount of snow, which comes during the months of January and February, and a single fall rarely lies on the ground more than a few days. It is therefore feasible to carry on out-of-door work throughout the whole year with little or no loss of time because of inclement weather. The heaviest rainfall comes during the early spring months and in the late fall. July and August are the driest and hottest months. Early autumn and late spring are delightful.

Culture.—All types and conditions of rural and village life common to the Piedmont Plateau are represented in the Virgilina district as included in the accompanying map, Plate I. The type of civilization and culture of the people of any portion of the district depends largely upon the fertility of the soil upon which they live. The rocks in which the ores are deposited produce a very lean shallow soil, and, as a consequence, the Virgilina ridge is thinly settled, and as a rule the farms are apparently not very prosperous. On the other hand, the alluvial bottoms and the granite soils are rich and fertile, and the farms located on these soils are well ordered and prosperous. Considerable intelligent effort is constantly being put forth to extend and improve the country roads, and its results are showing in graded, well-kept roads between all the principal towns and villages. More and more attention is being given to schools and to general social and economic development. The people are industrious, hospitable, and favorable toward outside interests that are calculated to in any way develop the district. In fact, many places in the district are as attractive and desirable for homes as any other places in this beautiful section of the United States.

The importance of the mining industry varies according to the market price of copper. As the mines are located, equipped, and operated it costs from 10c to 12c per pound to produce copper, and, as a consequence, when the price is low the mines are usually not operated. It is believed that by consolidating interests, or by working coöperatively, that the industry could be developed until it would at all times be a profitable business.

PREVIOUS GEOLOGIC WORK.

The first account of the region in which the Virgilina ore deposits occur is found in the writing of Col. William Byrd,[a] who, as a member of a com-

[a] History of the dividing line between Virginia and North Carolina, as run in 1728-1729 (published from the original manuscript), Richmond, 1866.

The Westover manuscripts. Containing the history of the dividing line betwixt Virginia and North Carolina. Petersburg, 1841, pp. 1-102.

The writings of Colonel William Byrd of Westover in Virginia, Esq. (Edited by J. E. Bassett), New York, 1901, pp. 1-277.

mission appointed by the states of North Carolina and Virginia to settle a boundary line dispute, in 1728-1729, surveyed the boundary line between the two states from the coast to the Blue Ridge. A few names of streams commemorate the passage of the party through the Virgilina district. These are: Aaron's Creek, Blue Wing[a] (spelled Blewing in Col. Byrd's manuscript, and so named by the party because of the presence of great numbers of a kind of water fowl called Blewings on the stream); Mayo Creek,[b] named for William Mayo, a surveyor in the party; and Hyco River, to which Col. Byrd gave the name which had been applied to the stream by the Indians resident in the region, Hicootomony River,[c] meaning Turkey Buzzard.

The account is one of the most readable of its kind ever written, and contains many valuable notes on the soil, the climate, the natural resources, and the general conditions of the country through which the party passed.

The earliest record of geological work in the territory, included within the accompanying map of the Virgilina district, is by Wm. B. Rogers[d] in his report as State Geologist of Virginia for the year 1840. A part of Professor Rogers' work consisted of geological cross-sections at short intervals through the state from east to west. One of these sections (No. 95 in the plate of cross-sections accompanying the "Geology of the Virginias") was made on a line extending through Clarksville and Halifax Courthouse and passes through the central part of the district as mapped, while another similar cross-section made on a line from Belfield to Charlotte Courthouse passes through the northern part of the district. The chloritic and schistose character of the rocks were noted and remarked upon by him, and, as shown by notes in MacFarlane's Railway Guide, the geological data for which were supplied by Professor Rogers, it is clear that he regarded the rocks of the Virgilina district as of pre-Cambrian (Laurentian) age.

Of the section passing through Lunenburg, and Charlotte Courthouse, he remarks:[e]

> "The chief peculiarities presented in this line are the increasing abundance of the Hornblende slates and the Hornblende Gneiss, the occurrence of Chlorite, associated with numerous bands of quartz towards its western termination . . ."

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[a] Loc. cit., Vol. 1, p. 93.
[b] Loc. cit., Vol. 1, p. 127.
[c] Loc. cit., Vol. 1, p. 95.
[d] Rogers, Wm. B.: Report of the progress of the Geological Survey of the State of Virginia for the year 1840.
Rogers, Wm. B.: A reprint of the annual reports and other papers on the geology of the Virginias. New York, 1884.
[e] Geology of the Virginias, p. 481.

Further in the same connection, in regard to the section passing through Clarksville and Halifax Courthouse, he says that "the greenish chloritic and talcose rocks are largely expanded . . . "

Nothing was known at this time of the copper deposits in the district, unless the traditions in regard to the Barnes mine (see p. 144) are correct. It is reasonably certain, since Rogers does not mention the copper ores, that no mining or prospecting were in progress at the time of his field work in 1839.

The first published description of the ores of the Virgilina district is a short account of the then recently opened Gillis mine, by Ebenezer Emmons, State Geologist of North Carolina, in his report on the Midland Counties,[a] published in 1856. Emmons visited the district in the early spring of 1854, and studied the mine in considerable detail. He classified the country rock as "an altered slate belonging to the Taconic system." A brief description of the vein is given together with a list of both gangue and ore minerals. He remarks that the "vitreous copper" (chalcocite) did not change with depth to the "yellow sulphuret" (chalcopyrite) as was expected. The account closed with a statement that:

> "The indications which the rocks furnish, taken in connection with the fact that there are other veins than the one described in this neighborhood, are that this part of Person and Granville (counties) will prove a mineral district of considerable importance."

In 1857 Dr. C. T. Jackson made a private report on the Gillis mine and the then known copper-bearing district from which Kerr and Hanna[b] make the following quotation:

> "The strata are occasionally disrupted by dikes; about half a mile, from the Gillis mine, and dipping westward to it, is a dike bearing N. 20 degrees E., containing abundant sprigs and grains of disseminated native copper. Epidote occurs both in the trap rock and in the quartz, and in the slate strata near the dike, which seems to indicate that the trappean rock is of the same geological age as the quartz veins."

The present writer visited this so-called dike and examined the intervening territory between it and the Gillis mine in close detail, and was unable to find even an indication of a dike. The rocks referred to as carrying native copper are portions of the massive andesite, and are usually, if not always, porphyritic and occasionally amygdaloidal. So far as our observations have extended, the only dikes at all closely associated with the

[a] Emmons, Ebenezer: Geological report of the Midland Counties. North Carolina Geological Survey. Raleigh, 1856, pp. 344-346.

[b] Kerr, W. C., and Hanna, Geo. B.: The ores of North Carolina: being Chapter II of the second volume of the geology of North Carolina, Raleigh, 1893, p. 219.

ore bodies are the diabase dikes described on pages 107 and 133, which bear no genetic relation whatsoever to the ores and veins. Such errors as the one just quoted were made before the nature of the rocks had been determined, and on such grounds are certainly pardonable.

In 1857 Emmons[a] published his text-book of American geology in which he discussed in some detail his "Taconic" rocks of North Carolina, and the veins and economic minerals contained in them. He adds little or nothing to what was included in his report on the Midland Counties.

During the Civil War little or no mining was done in the Virgilina district, and, so far as the material available to the writer goes, little or nothing of importance was published on the geology between the appearance of Emmons' report on the Midland Counties, and the publication of Kerr's Geology of North Carolina[b] in 1875. Accompanying this report is a geologic map of the state which places the Taconic rocks of Emmons in what Kerr called the Huronian, or the uppermost division of the Archean as defined by him, but nothing is said of the Virgilina district.

In 1893 there appeared Kerr and Hanna's[c] description of the ores of North Carolina, in which is given a short description of the district as a whole, and detailed notes on the mines in operation when the report was written. These authors say that the formation immediately enclosing the veins is "chloritic slate," thus correcting the statement of Emmons[d] that the rocks are argillaceous slates. This report gives a geologic map of the state on which the Virgilina district is located.

One of the most important papers bearing on the geology of a region similar in some respects to the Virgilina district, the Catoctin belt, was published in 1893 by Arthur Keith,[e] who states that in 1890 he recognized the volcanic nature of the schists of Catoctin Mountain and the Blue Ridge. This was four years before Williams[f] published his paper on the distribution of ancient volcanic rocks along the eastern border of North America, and two years before he published his article on the volcanic rocks in the

[a] Emmons, Ebenezer: American Geology, containing a statement of the principles of the science, with full illustrations of the characteristic American fossils; 2 Pts. in 1 Vol., 1857.

[b] Kerr, W. C.: Report on the Geological Survey of North Carolina, Vol. 1, Raleigh, 1875.

[c] Kerr, W. C., and Hanna, Geo. B.: The ores of North Carolina: being Chapter II of the second volume of the geology of North Carolina, Raleigh 1893, pp. 214-221.

[d] Loc. cit., p. 345.

[e] Keith, Arthur: Geology of the Catoctin belt, U. S. Geol. Survey, 14th Ann. Rept., Pt. I., 1893, p. 298.

[f] Williams, George H.: The distribution of ancient volcanic rocks along the eastern border of North America, Jour. of Geol., Vol. 2, 1894, pp. 1-31.

Catoctin region of Maryland and Virginia.[a] It, therefore, appears to be clear that to Arthur Keith must be given the credit for first recognizing the true nature of the great group of volcanic rocks along the eastern coast of the United States.

Keith is also the first geologist who recognized in the Catoctin region of Virginia,[b] and described in great detail, volcanic rocks similar in some respects to the volcanics of the Virgilina district. The sequence of the rocks in the Catoctin belt as determined by Keith[c] is the same as in the Virgilina district. Other significant close resemblances between the rocks of the two localities are that they have approximately the same mineralogical and chemical composition (see pp. 33 and 34 for chemical analyses of the two), and the andesitic volcanics of both districts contain somewhat similar granite intrusives. These facts suggest that both are of the same age, and that both were deposited under somewhat the same conditions.

In 1894 Williams[d] published his paper on the ancient volcanic rocks of the eastern border of North America, which served to call attention to the fact that such rocks exist in great quantity along the Atlantic seaboard from Nova Scotia to Alabama. He does not mention the volcanics of the Virgilina district, but discusses in considerable detail different types of volcanic rocks a short distance southwest of the district. This paper is one of the most important contributions to the geology of the general region in which the Virgilina mining district lies.

In 1896 there appeared a bulletin of the North Carolina Geological Survey by Nitze and Hanna[e] on the gold ores of the state. They retain Kerr's classification of the metamorphic slates, as Huronian, but add considerable descriptive matter in regard to the rocks. Since the publication of Kerr's report some of the rocks making up his Huronian had been recognized as of volcanic origin. No detailed geologic work had been done in the Virgilina district and it is given about a page and a half, for the most part a brief summary of the data given in Kerr and Hanna's ores of North Carolina.

In 1899 Phillips[f] published a popular account of the mining operations then in progress in the Virgilina district, adding very little to the knowl-

[a] Am. Geologist, Vol. 8, 1892, p. 366.
[b] Loc. cit., pp. 302-318.
[c] Loc. cit., opposite p. 312 and p. 318.
[d] Williams, George H.: The distribution of ancient volcanic rocks along the eastern border of North America, Jour. of Geol., Vol. 2, 1894, pp. 1-31.
[e] Nitze, Henry B. C., and Hanna, George B.: Gold Deposits of North Carolina, N. C. Geol. Survey, Bulletin No. 3, Winston-Salem, 1896.
[f] Phillips, William B.: Copper deposits of North Carolina, American Manufacturer, March 17, 1899; Abstract, Eng. and Min. Jour., Vol. 67, 1899, p. 382.

edge of the geology, beyond the conditions of mining and a partial list of the minerals making up the ores. He stated that the "country rock is slate, quartzite, etc., and porphyry belonging to the oldest formations, probably Laurentian, and in places impregnated with copper-bearing material apart from the seams (veins) themselves." He also published a similar account in Mineral Industry,[a] describing in some detail the Holloway and Blue Wing mines.

In 1900 Weed[b] published his "Types of copper deposits of the Southern United States," and in it gave the first detailed account of the geology of the district. Weed, so far as the writer is aware, was the first to recognize the true character of the rocks in which the deposits occur. He says, in this connection:[c]

> "The rocks are all of igneous origin—even the softest and most shaly show this character in thin sections under the microscope. But in a few instances only, is the igneous nature of the schists recognizable to the eye. This was observed at the Thomas mine, where a purplish rock is clearly a porphyritic meta-andesite. These schists are cut by dikes of later igneous rock (diabase). . . Apart from the dikes, however, I would say, on the strength of field observations alone, that the rocks are of igneous origin, and belong to the various porphyries which have been discovered in the Appalachian belt. This conclusion is confirmed by microscopic examination of thin sections, which has shown the rocks to be altered andesites, that is, meta-andesites and andesite tuffs."

In addition to this interpretation of the rocks of the district Weed[d] describes four types of copper deposits in the Southern United States as follows:

> "1. The first type of deposit is that of a true fissure-vein, the quartz vein—formed by the filling of open cavities, with only minor and accessory replacement of country rock. The Virgilina deposits are representative of this type. The ore is glance and bornite, without chalcopyrite or pyrite. The veins cross the schists or conform with them.
>
> "2. The second type is that of auriferous quartz veins common in the Appalachians. Although true fissure-veins, they are formed by the replacement of country rock along sheeting-planes or true fissures, and accompanied by the filling of open cavities as a minor and accessory feature. It is named from the Gold Hill mines, where such veins have yielded several millions in gold.
>
> "3. The third type is a pyrrhotite-vein—a true fissure-vein the filling of which is essentially pyrrhotite or pyrite, almost barren of quartz, and represents the replacement of a zone of sheeted rock which was composed largely of metamorphic minerals.

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[a] Mineral Industry, Vol. 7, 1899, p. 211.

[b] Weed, Walter H.: Types of copper deposits in the Southern United States, Trans. Am. Inst. Min. Eng., Vol. 30, 1900, pp. 449-504.

[c] Loc. cit., p. 454.

[d] Loc. cit., p. 452.

"4. The fourth type comprises local segregations of native copper, copper oxides and carbonates along shear zones in altered igneous rocks. Such deposits, so far as known, do not extend below the groundwater level in depth."

The deposits of native copper in quartz and epidote, and in the greenstone schists without vein matter, are classified by Weed as belonging in his fourth or Catoctin[a] type. This paper also gives detailed descriptions of the veins and vein structure, and detailed accounts of the different mines then in operation (1900), together with methods and costs of operation.

In 1901 L. N. White,[b] who at that time was superintendent of the Durgy mine, published a short paper setting forth his ideas of the geology of the district together with description of the veins and ores, with a short account of the development work.

In 1902 Watson[c] published an important contribution to the geology of the Virgilina district. This paper deals in considerable detail with the general geology and in great detail with the petrography of the district, and is the first published description of these features. Watson clearly recognized the rock types most closely associated with the ore deposits as altered andesites and andesitic tuffs. The microscopic and chemical characters of the rocks are clearly set forth, but little attention is given to the ore deposits, so that the paper in a way supplements Weed's[d] paper published two years before. The two papers taken together give a good and accurate account of the geology and ore deposits of the district.

Watson states his conclusions[e] as follows:

"1. The rocks of the area here described have been greatly altered through pressure and chemical metamorphism, as indicated in the prevailing secondary schistose structure and the abundant development of the secondary minerals—chlorite, epidote, and hornblende—and small amounts of others. The alteration has advanced sufficiently far in the schistose phases to destroy in most cases the original structure and minerals of the rock.

"2. From structural, petrographic, and chemical evidences the rocks are shown to have been derived from an original andesite, but in their present much altered state they are, according to present usage, more properly designated meta-andesites; that these are intimately associated with the corresponding volcanic clastics. Furthermore, the popular name greenstone

[a] Keith, Arthur: Geology of the Catoctin belt, 14th Ann. Rept. U. S. Geol. Survey, Pt. 2, p. 309.

[b] White, L. N.: The Virgilina copper district, Mining and Metallurgy, Vol. 24, 1901, pp. 635-639.

[c] Watson, Thomas L.: Copper-bearing rocks of the Virgilina copper district, Virginia and North Carolina, Bull. Geol. Soc. Am., Vol. 13, 1902, pp. 353-376.

[d] Weed, W. H.: Types of copper deposits in the Southern United States, Trans. Am. Inst. Min. Eng., Vol. 30, 1900, p. 453.

[e] Loc. cit., p. 376.

applied to many areas of greatly altered massive and schistose rocks along the Atlantic Coast and Lake Superior regions, shown to have been derived from an original basic eruptive rock type, has equal application to the existing rocks of the Virgilina district.

"3. The rocks are pre-Cambrian in age and represent an area of ancient volcanics similar to others described as occurring along the Atlantic Coast region from Eastern Canada to Georgia and Alabama and in the Lake Superior region.

"4. The rocks are cut by numerous approximately parallel quartz veins which contain workable copper deposits. The veins have been described as true fissure veins, and the ore is glance and bornite without chalcopyrite and pyrite."

Early in 1906 Weed and Watson[a] published a paper on the copper deposits of Virginia, several pages of which are devoted to the geology and ore deposits of the Virgilina district. It consists largely of restatements of data published by the authors in previous papers[b] with notes concerning development work in the district up to the date of publication. They describe in some detail the rocks, veins, and ores, the greatest stress being laid upon the rocks of the area, which are correctly identified as andesites and andesitic tuffs. The following conclusions in regard to the rocks of the district are stated:

"1. The rocks have been greatly altered from pressure and chemical metamorphism, as indicated by the prevailing schistose structure, and the large development of secondary minerals, chlorite, epidote, and hornblende; and smaller amounts of others. The alteration has advanced sufficiently far in the more schistose phase to destroy, in most cases, the original structure and minerals of the rock.

"2. From structural, petrographic, and chemical evidence, it is shown that the rocks are derived from an original andesite. The altered andesite is intimately associated with the corresponding volcanic clastic. The name greenstone is applicable to the altered andesite of the district because of the abundant development of chlorite in it which imparts a somewhat distinctive green color.

"3. The rocks are pre-Cambrian in age and represent an area of ancient volcanics similar to others described from numerous localities along the Atlantic Coast region from eastern Canada to Georgia and Alabama."

Late in 1906, Watson[c] published on the general geologic character and mode of occurrence of the copper ores in the Virginia areas, with notes on past production. The principal point of interest in this publication

[a] Weed, W. H., and Watson, T. L.: The Virginia copper deposits, Economic Geology, Vol. 1, 1906, pp. 309-330.

[b] Weed, W. H.: Types of copper deposits in the Southern United States, Trans. Am. Inst. Min. Eng., Vol. 30, 1900, pp. 449-504.

Watson, T. L.: Copper-bearing rocks of Virgilina copper district, Virginia and North Carolina, Bull., Geol. Soc. Am., Vol. 13, 1902, pp. 353-376.

[c] Watson, Thomas L.: The Copper Deposits of Virginia, Eng. and Min. Journ., Nov. 3, 1906, pp. 824-826. Map and figure.

is that the geology of the ores and associated rocks of the Keysville area in Charlotte County, which represents the northern extension of the Virgilina district, were described for the first time, and their identity with those of the Virgilina district farther south was pointed out.

In 1906 Judd[a] published a short illustrated article on the Virgilina district, dealing in a popular way with the development of the district, and included short descriptions of the principal mines, and a few general notes on the geology of the district. Beyond bringing the account of the development of the district up to the date of publication, the article adds little to the geology that was not already known.

In 1907 Watson[b] again published an account of the Virgilina district, summarizing what he had previously published in the different articles herein listed, together with additional notes on the development work.

In 1907, Weed[c] included a brief summary of the geology of the copper deposits of the Virgilina district in his book entitled "The Copper Mines of the World".

In the early fall of 1908 the North Carolina Geological Survey published a preliminary outcrop and tentative geologic map of the North Carolina portion of the Virgilina district by Laney and Pogue.[d] This is a traverse map on which the geology and veins and mines were shown. The work has since been revised and corrected, and the map and all the data shown on it are incorporated in the present report.

In 1910 the writer[e] published a report on the geology and ore deposits of the Gold Hill district, a district lying about 150 miles southwest of the Virgilina district, which in part includes ore deposits and rocks similar in all respects to those of the Virgilina district. The two districts resemble each other in that their most important rocks are of volcano-sedimentary origin, which were first highly metamorphosed and rendered largely schistose, and then, later, intruded by large bodies of igneous rock, granite, diorite, and gabbro. Most of the volcano-sedimentary rocks of the Gold

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[a] Judd, Edward K.: The Virgilina copper belt, Eng. and Min. Jour., Vol. 82, 1906. pp. 1005-1008.

[b] Watson, Thomas L.: Mineral resources of Virginia, Lynchburg, 1907, pp. 494-500.

[c] Weed, Walter Harvey: The Copper Mines of the World, Hill Publishing Co., N. Y., 1907, 375 pp. Illustrated. (For Virgilina district in Virginia and North Carolina, see pp. 270-272.)

[d] Laney, F. B., and Pogue, J. E., Jr.: An outcrop map of the Virgilina copper district, N. C., N. C. Geol. and Economic Survey, 1908.

[e] Laney, F. B.: The Gold Hill Mining district of North Carolina, N. C. Geol. Survey, Bull. No. 21. Raleigh, 1910.

Hill district are rhyolitic or dacitic in character. There is, however, a fair-sized area of greenstone, massive and schistose, porphyritic and tuffaceous, and of basaltic or andesitic character which is very similar to the greenstone schists of the Virgilina district. It carries small deposits of copper ores similar in all respects to the Virgilina ore deposits.

Following the Gold Hill report there appeared in the same year (1910) a report of the Cid mining district of Davidson County, North Carolina, by Pogue.[a] This district adjoins the Gold Hill district on the northeast, and contains similar volcano-sedimentary rocks, except the greenstone. The geology of the district is summarized as follows:

> "Wide bands of a sedimentary, slate-like rock, composed of varying admixtures of volcanic ash and land waste, have the greatest areal extent. Intercalated with these occur strips and lenses of acid and basic volcanic rocks, represented by fine- and coarse-grained volcanic ejecta and old lava flows. The acid rocks include fine tuffs, coarse tuffs, and breccias, chiefly of a rhyolitic and dacitic character; together with flows of rhyolite and dacite. The basic series embraces fine tuffs, coarse tuffs, breccias, and flows of an andesitic and trachy-andesitic stamp. Gabbro and diabase dikes cut the other formations.
>
> "The region has suffered a period of severe dynamic matamorphism or mashing, consequent upon a great compressive force which squeezed the beds into enormous folds; followed by a time of chemical alteration and mineralization; which in turn was succeeded by a long period of erosion and weathering. The rocks have suffered to a variable degree from all these factors. In general, each formation has a massive and a mashed or schistose phase, with every gradation between the two. . . Finally, erosion has planed off all the upper portion of the folded series; but weathering has proceeded in excess of erosion to such an extent that the region is now deeply decayed, so that only here and there the rocks project through a thick mantle of decomposed rock or soil."

In 1911 the writer[b] published an account of a detailed microscopic study of the ores of the Virgilina district with a few general statements in regard to the geology. In this paper it was shown by photomicrographs of polished sections of the ores that the chalcocite is of two periods of deposition, one later than the bornite and derived from it, and one intimately intergrown with and believed to have been deposited contemporaneously with the bornite, which was believed to be of only one period of deposition. The general conclusions as stated in the paper are as follows:

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[a] Pogue, Joseph E.: The Cid Mining district of Davidson County, North Carolina, N. C. Geol. Survey, Bull. No. 22. Raleigh, 1910.

[b] Laney, F. B.: The relation of bornite and chalcocite in the copper ores of the Virgilina district of North Carolina and Virginia, Proc. U. S. Nat'l Museum, Vol. 40, 1911, pp. 413-424.

Laney, F. B.: The relation of bornite and chalcocite in the copper ores of the Virgilina district of North Carolina and Virginia, Economic Geology, Vol. 6, 1911, pp. 399-411.

"The rocks of the Virgilina district are greenstone and sericitic schists, which in places have been intruded by granite and gabbro. The intrusive rocks show none of the schistosity of the other rocks. The schists have been derived from a series of volcano-sedimentary rocks of two types—andesite and quartz porphyry, with a preponderating amount of tuffs corresponding to these rock types. Their age is probably early Paleozoic.

"The veins are true fissure veins which have a more northerly trend than the schistosity of the country rock, and the filling of which is quartz—about 70 per cent silica—with local and varying amounts of epidote and calcite. The ore-bearing veins are confined to the more basic portions of the greenstone schists, and the values lie in well-defined ore shoots.

"The ore minerals are bornite and chalcocite. They apparently prefer the quartz, but are not confined to any one of the gangue minerals. Bornite is present in slight excess over chalcocite, and is apparently of only one period of deposition. Chalcocite is clearly of two periods: One confined to the upper portions of the veins, more recent than, and filling a network of minute fractures in, the bornite; the other contemporaneous and intergrown often crystallographically with it. There is no evidence that any of the bornite is of secondary origin. It is, therefore, believed that in the Virgilina district the greater part of the chalcocite is a primary mineral contemporaneous with the bornite and in no way derived from it, or from any other copper-bearing mineral, by processes of secondary alteration."

In 1911, Weed[a] published a rather detailed description of the geologic character and mode of occurrence of the ores and associated rocks of the Virgilina district in Virginia and North Carolina. Individual description was given of the principal mines, accompanied by many drawings as text-figures illustrating special features of the veins and ores.

DESCRIPTION OF THE ROCKS.

INTRODUCTION.

The Virgilina district lies wholly within the Piedmont Plateau and like that physiographic province is made up almost wholly of igneous and highly metamorphosed rocks. They include ancient metamorphic gneisses and schists the origin of which is unknown; a series of volcanic rocks of both acid and basic types and volcanic clastics of each type, together with much volcano-sedimentary material; intrusive rocks of both basic and acid types, such as gabbro, diorite, granite, and syenite; a small area of red or brown sandstone of Triassic-Newark age; and different types of dike rocks, especially diabase. Except the intrusives, the sandstone and the dikes, the rocks are all highly schistose and gneissoid in texture, the metamorphism having been so extensive in most cases that little of the original

[a] Weed, Walter Harvey: Copper Deposits of the Appalachian States, Bull. 455, U. S. Geol. Survey, 1911, 166 pp., 5 plates and 22 text-figures. (For the Virgilina district, see pp. 67-89.)

structure and texture and few of the original minerals of the rocks remain. The acid volcanics originally were rhyolite or quartz porphyry and rhyolitic tuffs, but in their present condition are largely sericitic schists which may or may not show more than remnants of their original minerals and texture. In this report these rocks are described under the name Hyco quartz porphyry. The basic volcanics, for which the name Virgilina greenstone is proposed, were originally andesite and andesitic tuffs, but have become through intense metamorphism chlorite-epidote schists or simply greenstone schists. These for the most part retain something of their original minerals. The greenstone schists are more closely associated with the ore deposits than any other rocks in the district. In fact, so far as exploration has extended, the productive veins in the district are confined to these rocks. The rocks referred to as of volcano-sedimentary origin consisted originally of andesitic ash and tuff with which varying amounts of land waste were intermixed at the time of deposition, which probably took place under water. It appears that conditions were extremely variable at the time of their deposition, and that during some periods volcanic material predominated, and at others terrigenous material was most abundant. Thus some beds or bands of the rock consist almost wholly of volcanic material, while others are made up largely of land waste, while in much of it the two are about evenly mixed. Thus, on the one hand, these rocks may be fairly pure greenstone, and, on the other, fairly pure sandstone and conglomerate together with many beds made up of the two types of material in varying proportion. Like the other volcanics these rocks, which were called "sandy tuffs" during the field work, have been highly metamorphosed and are now gray, and greenish-gray, sandy schists with more or less of their original texture and minerals remaining. Some narrow bands are fairly pure conglomerate, some are largely argillaceous sandstone, others are fairly pure greenstone, but the greater part of the formation is made up of different amounts of each. The name Aaron slate has been proposed for these rocks.

The intrusive rocks, while they are deeply weathered and broken by joints, and have suffered more or less chemical metamorphism, are massive; that is, they show little or no schistosity. Of the intrusives, the gabbro, while it shows little or no schistosity, has suffered the greatest amount of alteration, which has been chemical rather than dynamic, and has to a great extent destroyed the original minerals of the rock.

The red and brown Triassic sandstones and conglomerates are much jointed and weathered. These rocks contain much shaly material, and

consequently are easily affected by the agencies of weathering. Aside from these alterations they are fresh and show no effects of metamorphism. This sandstone occupies only a small portion of the area—merely a patch along the west central portion of the district near the town of Scottsburg, and is of little importance so far as the general geology of the district is concerned.

The dikes, almost wholly of diabase, and of Triassic age, are widely distributed throughout the district, are always small, and are of little importance in the geology of the district. They are all deeply weathered, and, as a rule, have no surface outcrops except small rounded boulders scattered here and there on the surface along the trend of the dike. In the Blue Wing and also in the Durgy mine a dike was encountered in the development work. In the Blue Wing mine the dike intersects the vein. In neither case has the dike had any influence upon the ore, and their occurrence together in the two instances is wholly accidental.

The rocks will now be considered in greater detail, beginning with the oldest formations represented in the district, the biotite and the hornblende gneisses and schists. It might be well to state here that this report has to do primarily with the economic features of the district—the ore deposits—and that the writer believes it not best to burden it with too much detailed petrographic description. In this chapter, as in the report as a whole, he will endeavor to give only the most important features of the rocks and such details as appear to be necessary to a thorough understanding of the economic features of the district. While a detailed study of the rocks from a petrographic standpoint is, from the viewpoint of pure science, very desirable, the writer believes it would detract from rather than add to the usefulness and interest of a purely economic report. The practical mining engineer, the investor, and the mining public in general are much more interested in the facts closely related to the ore deposits and such considerations as their distribution, their relation to the rocks in which they occur, their continuation in depth, their mineralogy, and other practical factors, than in petrographic details. The rocks making up the ore-bearing horizon, the veins, the ores, and the structure so far as it may be of importance in studying, developing, and locating ore deposits, are therefore discussed in considerable detail, while many other factors of equal scientific interest are treated only in a general way.

GNEISSOID ROCKS.

Mica Gneiss.

The oldest geological formation in the Virgilina district is a mica gneiss or mica schist, a narrow strip of which is included along the western side of the district as shown on the accompanying geologic map, Plate I. This formation has a wide distribution west, southwest, and northwest of the district, and, in fact, is one of the most important geological formations of the Piedmont Plateau. In general characteristics it closely resembles the Carolina gneiss of Keith,[a] a formation of wide distribution in central and western North Carolina and South Carolina.

The rock consists of fine to coarse mica gneiss, mica schist, and fine granitoid layers. In places it contains veins and lenses of pegmatitic material varying in width from less than an inch to more than a foot. These usually lie parallel with the schistosity, but in some instances cross it. Quartz veins of similar distribution are not uncommon. It is indeed believed to be the same rock described by Keith and others as Carolina gneiss. In fact Keith's description of the Carolina gneiss of the Washington, D. C., folio is so characteristic of the mica gneiss of the Virgilina district that it might have been written with the Virgilina rock in mind. He says:[b]

> "The formation is composed of alternating layers of gneiss and schist of a prevailingly gray color, dark bluish gray where fresh and greenish or yellowish gray where weathered. Individual bands vary from a few inches up to several feet in thickness, with an average of perhaps less than a foot. Both kinds of layers are highly siliceous, and are composed mainly of quartz, orthoclase, and plagioclase fieldspar, muscovite and biotite. In places the rock contains numerous small crystals of garnet. Quartz and mica predominate in the mica-schist, and quartz and feldspar in the mica-gneiss, some of the latter having the aspect of a fine granite. Certain layers of the gneiss are to be seen in which the quartz and feldspar bodies have the appearance of sedimentary pebbles, a resemblance which is probably deceptive. These individuals are usually round; occasionally, however, they are flattened into "eyes." They seldom have a diameter greater than one-fourth of an inch. The original nature of the gneiss, whether igneous or sedimentary, is quite unknown. The thickness of the formation can not be determined in any way because there are no distinctive beds, but judging from the large area which the formation covers, its thickness is doubtless many thousands of feet."

The rock is deeply weathered; in fact, no natural outcrops were found except along stream courses. Typical exposures of this rock as well as of the hornblende gneiss may be seen along the Southern Railway near

[a] U. S. Geol. Survey, Geologic Atlas of the United States, No. 70 Washington folio, 1901.

[b] Loc. cit., p. 2.

Denniston Junction. The soils produced from this rock are usually light, somewhat clayey, and red or reddish-brown in color.

Hornblende Gneiss.

Occurring in intimate association with the mica gneiss are narrow and irregular areas and dike-like bands of hornblende gneiss. This rock tallies very closely in texture, composition, and in mode of occurrence with the Roan gneiss of Keith.[a] In fact his descriptions of the Roan gneiss, so far as texture and composition go, are equally applicable to the hornblende gneiss of the Virgilina district. The color is usually a greenish-black, but in some instances is considerably lightened by a greater amount of white material, for the most part plagioclase feldspar, but with varying quantities of quartz. It is a well-defined gneiss, consisting of alternating bands of hornblende and the light-colored minerals just mentioned. The texture of the rock varies considerably, but it is usually of medium grain. There is no way of determining its age or its original condition. It is believed, however, to be younger than the mica gneiss and intrusive into it. As compared with the mica gneiss it has a small distribution, and is not found in any other formation in the district. Like the mica gneiss it is deeply weathered, and natural outcrops are rare.

VOLCANO-SEDIMENTARY ROCKS.

INTRODUCTION.

The rocks designated as of volcano-sedimentary origin are by far the most important formations in the Virgilina district, and make up at least three-fourths of its areal extent. Under this group are placed both the acid and basic flows and tuffs, and the water-laid tuffs and slates. They occur as narrow belts or bands with fairly regular outline, and extend the whole length of the district. They, especially the basic (andesitic) flows and tuffs, are the most resistant rocks of the region, and form the most prominent elevations in the district, the Virgilina ridge, and also constitute the ore-bearing horizon. The geologic relation of these rocks to the underlying schists and gneisses is not definitely known. They are believed to rest unconformably upon the gneisses and schists, although it is possible that they were brought in by faulting. However, if such faulting exists, no

[a] U. S. Geol. Survey, Geologic Atlas of the United States, No. 90 Cranberry folio, 1903.

evidence of it was detected. For convenience of description the formations will be treated under the following formation names: the Hyco quartz porphyry, the Aaron slate, the Virgilina greenstone, and the Goshen schist.

The *Hyco quartz porphyry* consists largely of quartz-sericite schist, which represents a mashed and otherwise metamorphosed quartz porphyry or rhyolite, and which was tuffaceous in certain areas. The formation appears to be the oldest of the volcanic rocks, at least its areal distribution indicates that it underlies the other volcanics. It occurs as a narrow belt on each side of the district as shown on the accompanying map, Plate I. Its largest and most typical exposures occur along Hyco River, from which it is named.

The name *Aaron slate* has been applied to a slate-like rock formed by mixtures of varying amounts of andesitic volcanic ash and ordinary land waste, which through pressure and other agents of metamorphism have been changed or altered into a kind of hybrid slate—in some places into a schist. It varies from nearly pure greenstone to fairly pure argillaceous sandstone and slate, and in certain places is decidedly conglomeratic. It is realized that the rock is by no means a normal slate, and the term slate was applied to it only after much hesitation and many vain attempts to find a better name. It is the formation immediately overlying the Hyco quartz porphyry, and, like it, is exposed in long narrow bands on each side of the district. It is well exposed in many places along Aaron's Creek, from which the name is taken.

The name *Virgilina greenstone* has been given to the schistose greenstone in which all the developed ore deposits are located and which forms the Virgilina ridge. It is the altered equivalent of andesitic flows and tuffs and, while always more or less schistose, is, in some places, decidedly porphyritic and in others plainly tuffaceous. It occurs as long and narrow bands which make up the backbone, as it were, of the district. The rock occurs in typical development in and near the town of Virgilina, whence the name.

The term *Goshen schist* is applied to a highly schistose acid tuff, probably a tuffaceous phase of the Hyco quartz porphyry. In most places it is so highly altered that little or nothing of its original structure and texture is discernible. Its manner of occurrence and its relations to the adjacent formations strongly suggest that it is the same as the Hyco quartz porphyry, only much more tuffaceous. It is so named because of its typical occurrence in the southeastern part of the district in the vicinity of Goshen.

Hyco Quartz Porphyry.

Occurrence.—The Hyco quartz porphyry or rhyolite lies unconformably above the mica gneiss and the hornblende gneiss, and occurs as a narrow band on each side of the Virgilina district as shown on the accompanying geologic map, Plate I. In a few localities the rhyolite is apparently lacking. In two places, one in the extreme southwest corner of the district, and the other a short distance southwest of the confluence of Dan and Roanoke rivers, the formation is cut out for a short distance by the Redoak granite. It is also apparently missing for a short distance along the western side of the district near the town of Clover. In the extreme southeast portion of the area the place of the rhyolite is apparently taken by the Goshen schist, which probably represents the highly metamorphosed tuffaceous phase of the quartz porphyry.

The largest area of the formation is found on the west side of the district along Hyco River. At this place it attains its greatest width as well as its most typical development. In some places there occur quartz veins apparently similar to those in the Virgilina greenstone, but almost invariably without ore, or, if not wholly barren, carrying only a trace of valuable metal.

Macroscopic description.—It must be borne in mind that, while this rock is described as a quartz porphyry or rhyolite, the name applies more appropriately to its original than to its present condition. If one regarded only the present texture of the rock, he would call it a sericitic schist, which in fact the rock really is. Since much of the formation retains enough of its original texture and minerals to enable one to recognize it as a quartz porphyry, it was decided to describe it under that name.

While the Hyco quartz porphyry is, in all instances, decidedly schistose, there is usually, except in the decidedly tuffaceous phases, and in some cases even in these, enough of the original texture of the rock remaining to enable one to identify it with the unaided eye with a considerable degree of accuracy. It occurs in two phases, one of medium texture and decidedly porphyritic, with phenocrysts of both quartz and feldspar, and the other plainly tuffaceous or fragmental. While much of the rock is tuffaceous and so highly metamorphosed that its original texture has been more or less completely destroyed, the greater part is to a considerable degree massive and is clearly porphyritic. The strike of the schistosity as well as its dip is similar to that of the other schistose rocks of the district, and varies from N. 10 degrees to N. 40 degrees east. The dip so far as was observed is always toward the southeast from 70 to 80 degrees.

The color of the rock is usually light gray, that of the porphyritic phase always so, while the tuffaceous phase varies from light gray to purplish-gray, the color being due to iron oxides. About all that can be learned with the unaided eye in regard to the rock's texture and mineralogical composition is that it is usually highly schistose, has a dense light gray or nearly white matrix in which are numerous phenocrysts, mashed out into lens shapes, of feldspar and quartz. Sericite, recognizable because of its pearly luster, coats the surfaces of the fragments of the more highly schistose phases. In the tuffaceous phases the fragments are mashed and smeared out, but are easily recognized, especially when a cleavage surface of the rock is examined. On such a surface the fragments show as irregular blotches or spots of varying color.

Few, indeed almost no, natural outcrops of this formation were seen. The rock seldom outcrops at all except in and along streams, and in road and other artificial cuttings.

Microscopic description.—In thin section, under the microscope the following minerals are recognizable: Quartz, orthoclase, plagioclase varying from albite to oligoclase-andesine, hematite, and sericite in large amount. The phenocrysts are frequently fragmental, and the quartz usually shows resorption embayments. These are irregularly distributed throughout a dense, usually cryptocrystalline groundmass of quartz and feldspar in individuals so small that the microscope all but fails—in some instances does fail—to resolve it. The alteration products of the rock usually contain much sericite, which is readily distinguishable by its high polarization colors. The feldspar phenocrysts are all much altered, but they are usually fresh enough for identification. Quartz phenocrysts were not found in all specimens of even the most massive phases of the rock. When they occur at all, they are usually in anhedral forms, occasionally as well-defined crystals, and rarely as fragments, and show well-formed resorption embayments filled with groundmass material. The feldspars, both orthoclase and plagioclase, occur in short, stocky prisms. They often show twinning and in rare instances zonal development. They are often fragmental and in most instances so badly altered that identification is by no means an easy matter. Sericite is always present in large amount and at times is the most prominent mineral in the rock. All phenocrysts show the effects of mashing in that they are more or less in the form of lenses or "eyes," and they usually show typical undulatory extinction.

A few minor accessory minerals, such as zircon, apatite, hematite, etc., are present, but in such small amount that they are unimportant.

Chemical composition.—A specimen of the typical porphyritic quartz porphyry was selected for chemical analysis and gave the results in I in the following table. Numbers II to V, inclusive, are analyses of somewhat similar rocks from localities to the north of the Virgilina district in Pennsylvania and Maryland and to the southwest in Davidson County, North Carolina, and are included for comparison. It is clear from the analyses that the rocks are all closely related, the principal differences being in the lime and alkali content and minor variations in the amount of silica. Analysis V is of a sericite schist from South Mountain, Pennsylvania, and is almost a duplicate of the analysis of the Virgilina quartz porphyry. Both rocks have suffered a high degree of metamorphism. It is believed that, during the alteration from a rhyolite to a sericite schist, the greater part of the Na_2O might be removed while the K_2O uniting with other elements to form sericite would remain. It is perfectly clear from the analyses that the rocks are all similar, and that if one is a quartz porphyry all are quartz porphyries.

Analyses of quartz porphyry.

	I	II	III	IV	V
SiO_2	77.78	74.67	73.62	76.34	73.45
Al_2O_3	12.78	10.78	12.22	11.60	13.77
Fe_2O_3	2.09	1.25	2.08	2.41	2.76
FeO	0.31	2.11	4.03	0.30	
MgO	0.77	Trace	0.26	0.06	1.22
CaO	0.24	1.47	0.34	0.55	None
Na_2O	0.54	5.31	3.57	5.50	0.18
K_2O	3.63	2.68	2.57	2.75	4.47
H_2O-	0.06	0.59	0.40	0.10	3.08
H_2O+	1.60			0.39	
TiO_2	0.28	.....	.....	0.26	0.21
P_2O_5	0.66	.....	.....	Trace	0.03
MnO	Trace	1.30	.....	Trace	.....
CO_2	Trace	.....	.....	Trace	.....
	100.74	100.16	99.09	100.26	99.17

I. Typical quartz porphyry, Blue Wing Creek, 3 miles north of Christie, Va. Wm. M. Thornton, Jr., Analyst.

II. Rhyolite from Flat Swamp Mountain, Davidson County, North Carolina. J. E. Pogue, Analyst, Bull. No. 22 N. C. Geological Survey, 1910, p. 54.

III. Devitrified rhyolite from South Mountain, Pa. C. H. Henderson, Analyst, Williams, G. H., The volcanic rocks of South Mountain in Pennsylvania and Maryland. Am. Jour. Sci., Vol. 44, 1892, p. 493.

IV. Aporhyolite, Monterey, Berks County, Pa. H. N. Stokes, Analyst, U. S. Geol. Survey, Bull. 150, p. 343, Florence Bascom.

V. Sericite schist, Pine Grove Furnace, South Mountain, Pa. W. T. Schaller, Analyst, U. S. Geol. Survey, Bull. 419, p. 30.

Weathering and soil.—Except in localities, such as along stream courses, where erosion is exceptionally active the quartz porphyry weathers somewhat, but very little faster than the débris is removed by erosion. Hence, aside from such localities, and in road and other artificial cuttings, the rock is almost invariably covered with shallow soil. Along streams it forms rather rugged bluffs of dirty gray color. The soil is usually thin, lean, sandy, and not very productive unless heavily fertilized.

Goshen Schist.

General description.—The term Goshen schist is used to designate a highly schistose, clastic, acid rock, probably of volcanic origin which is extensively developed in the southeastern portion of the Virgilina district in the vicinity of Goshen. Microscopic examination of thin sections of the rock renders it reasonably certain that it is the metamorphosed equivalent of an acid tuff. It is, therefore, not at all improbable that it represents a very highly metamorphosed area of the tuffaceous phase of the Hyco quartz porphyry, and that it should be included with this formation. If such is the case, the most careful search failed to find any conclusive proof of it, and, until proof is found, it is thought best to keep the two formations separate.

In the hand specimen this rock presents a very fine-grained texture, has a light gray color, and is decidedly schistose. No phenocrysts are discernible, and the lack of noteworthy features, excepting the smeared-out fragments, is probably its most important characteristic. The fragments are best seen on a cleavage surface, upon which they are mashed out almost to a paper-thin condition, and each fragment has a slightly different color from the mass of the rock and the adjacent fragments.

In its present condition the Goshen schist is a well-defined sericite schist, and does not show even a vestige of the original texture or minerals of the rock. In this respect it differs very much from the Hyco quartz porphyry, which always presents something of its original characteristics. The microscope, while failing to reveal the texture and minerals of the original rock, does very clearly show that it was a rhyolitic tuff. It is light gray or almost white in color, very dense, and fine-grained except where the schistosity and secondary minerals have changed the texture, and is highly schistose. It weathers into a light-colored or ashy soil of no great degree of fertility, very much like the soil of the Hyco quartz porphyry. So far as is known no ore deposits of any kind occur in the rock, hence a detailed microscopic

and chemical examination was not made. The distribution of the formation is shown on the accompanying geologic map, Plate I.

Aaron Slate.

Occurrence.—The Aaron slate has an areal extent almost if not quite three times as great as any other member of the Virgilina series, and as regards distribution it is the most important formation in the district. It occurs as the other formations of the district in long narrow bands, the largest of which extend the whole length of the district, except where they are cut out by the Redoak granite. The rock is found in typical development on each side of the Virgilina greenstone which forms the Virgilina ridge. Its greatest development is in the southern portion of the district along a line from Mill Creek on the west side of the district to Adcock's store on the east. Its least development is in the northern portion of the area near Keysville. Between the Pannebaker prospects southwest of Virgilina and the Pontiac mine, a narrow lens of Aaron slate occurs in the Virgilina greenstone, while to the south is a single point and to the north from this included area are two points or tongues of the slate extending into the greenstone. Also about one mile east of St. Matthew's Church a narrow lens of the slate is enclosed in the Goshen tuff. Its distribution is shown on the accompanying geologic map (Pl. I), to which the reader is referred for details.

Macroscopic description.—Much hesitancy was felt by the writer in calling this formation a slate, and indeed during all the field work it was designated as "sandy tuff," but it is believed that the name slate is more suitable than the term sandy tuff. According to strict usage the formation is neither a tuff nor a slate, but a kind of compromise between the two. While there is much variation in texture and composition, the formation in the main appears to be made up of varying proportions of volcanic débris—ash and small fragments of an andesitic nature—and land waste, which varied from mud through fairly pure quartz sand to small pebbles. That is, the formation was originally built up of such material.

Like the other members of the Virgilina series of volcanic rocks it has suffered intense dynamic and chemical metamorphism, and, in its present condition it is for the most part a more or less sandy chloritic slate, varying, however, from nearly pure sandstone and conglomerate to nearly pure greenstone similar in all respects to and not distinguishable from the Virgilina greenstone. The purest sandstone found in the formation is

(A) Outcrop of Aaron slate, showing alternating bands of nearly pure sandstone and slate. The dip is toward the southeast. Railroad cut three-fourths mile west of Virgilina.

(B) Typical outcrop of Virgilina greenstone (tuffaceous phase). A short distance west of wagon road, two miles southwest of Virgilina.

(A) Outcrop of Aaron slate, showing alternating bands of nearly pure sandstone and slate. The dip is toward the southeast. Railroad cut three-fourths mile west of Virgilina.

(B) Typical outcrop of Virgilina greenstone (tuffaceous phase). A short distance west of wagon road, two miles southwest of Virgilina.

exposed in a cut west of the town of Virgilina. At this place the beds of nearly pure sandstone are separated from each other by thin partings of slate. The dip and strike of the beds are shown better at this place than at any other known locality in the district. This exposure is shown in Plate II (A).

The conglomeratic beds are well shown at many places along Blue Wing and Aaron creeks. The most typical conglomerate, and also that containing the largest pebbles, occurs in a small cut on the Southern Railway about one-fourth of a mile west of the trestle over Blue Wing Creek. The conglomeratic beds, which are badly mashed and highly schistose at this place, can be easily traced for considerable distances both northeast and southwest of the railroad. In this bed pebbles 3 inches in diameter are common, and some 6 inches in diameter are occasionally found. The matrix is apparently fine sand with only a minimum amount of volcanic material. Farther northeast along Blue Wing Creek many narrow conglomeratic beds consisting of small rounded quartz pebbles in a sandy chloritic matrix are exposed. East of Virgilina about three-fourths of a mile the conglomeratic beds are again exposed in the public road just east of Wolfpen Branch. The quartz pebbles are small, rarely an inch in diameter in these beds, and the matrix is the usual sandy, chloritic material. This conglomeratic horizon, believed to be the same as that along Blue Wing Creek and to have been brought to the surface again by folding and erosion, can easily be traced for some distance along the strike of the beds in both directions from the exposure in the wagon road.

In the hand specimen, with the unaided eye, one may readily distinguish the true character of this rock. The metamorphism has not been intense enough to destroy the sand grains, and they can always be recognized in the argillaceous and chloritic matrix. The color of the rock depends upon its composition. When it is made up largely of quartz sand, the color is gray, and with increase of argillaceous and chloritic material becomes darker and greener. In natural outcrops the color is usually a dirty, greenish-gray, almost the same as that of the lichens which cover its surface.

Microscopic description.—The microscope reveals little of importance in regard to this rock that was not evident in a careful examination with the unaided eye. Quartz, chlorite, epidote, zoisite, black ores, especially hematite, sericite, calcite, occasionally a grain of feldspar, and much fine clay-like material make up about all the minerals revealed by the microscope. The minerals present in any section as well as the proportions in which

they occur always depend upon the nature of the rock. If it contains much volcanic débris it will approach the Virgilina greenstone in mineralogical composition, and will contain much chlorite and more or less green hornblende, much epidote and zoisite, with a small amount of quartz and varying amounts of calcite. If, on the other hand, it approaches a sandstone in composition, it will present a great deal of quartz, varying amounts of clayey material, and a minimum amount of chlorite, hornblende, and other minerals characteristic of the greenstone. If the specimen is taken from an area that has suffered intense metamorphism, the quartz grains will almost invariably show granulation around their borders, hornblende will be more prominent, and much of the original texture, and many of the original minerals will have been destroyed through recrystallization. Schistosity is well shown by the parallel arrangement of the minerals, as well as by the "Augen" structure of the larger quartz grains and pebbles.

Chemical analysis.—Very little of value is to be learned from a chemical analysis of a rock of such variable nature as the Aaron slate. The chemical composition will vary as widely as the physical. However, a specimen of what was considered typical material was selected for chemical analysis and gave the following results:

Analysis of typical Aaron slate.

(Wm. M. Thornton, Jr., Analyst.)

SiO_2	70.53
Al_2O_3	13.21
Fe_2O_3	3.46
FeO	1.93
MgO	1.06
CaO	2.38
Na_2O	4.56
K_2O	0.40
H_2O+	0.05
H_2O-	1.06
TiO_2	0.78
P_2O_5	0.38
MnO	Trace
CO_2	Trace
	99.80

The high percentage of silica is due to the quartz sand. The alumina and alkalies are probably for the most part from the clayey material, with smaller amount from the feldspar fragments which occur sparingly in the rock.

Weathering and soil.—Natural outcrops of the Aaron slate are inconspicuous and rare except along stream courses where it forms rather rugged bluffs. Throughout the greater part of its area the rock does not outcrop. The soil, however, is usually shallow and not very fertile. The character of rock decay and soil from the formation varies according to the nature of the rock in the particular area. The sandy beds produce a light, sandy, fairly fertile soil, while those which contain little sand and are made up largely of volcanic material, produce a thin, lean soil very much like that of the Virgilina greenstone. Between these two extremes there are all variations. The soil is, as a rule, not regarded as very desirable for agriculture, and much of it is not in cultivation.

Virgilina Greenstone.

Introductory statement.—The term Virgilina greenstone as used in this report includes the greenstone schists that form the country rock in which all the commercial ore deposits of the district thus far discovered are located. The formation in its present condition is a well-defined greenstone schist. Originally it consisted of andesitic flows, porphyritic in texture, and of andesitic tuffs which in amount greatly exceeded the porphyritic phase. In many places the rock has been so profoundly metamorphosed that it is very difficult, without the use of the microscope, to distinguish the tuffaceous from the flow rock. However, in most cases there is little or no difficulty in recognizing the two phases. The two types are in all places very intimately associated with each other, in fact, so intimately that it would be impossible to separate them in mapping. There has, therefore, been no attempt to separate them on the accompanying geologic map, Plate I. The ore deposits are apparently as closely associated with one type of the rock as with the other and there is on this account no very urgent call for their separation in mapping.

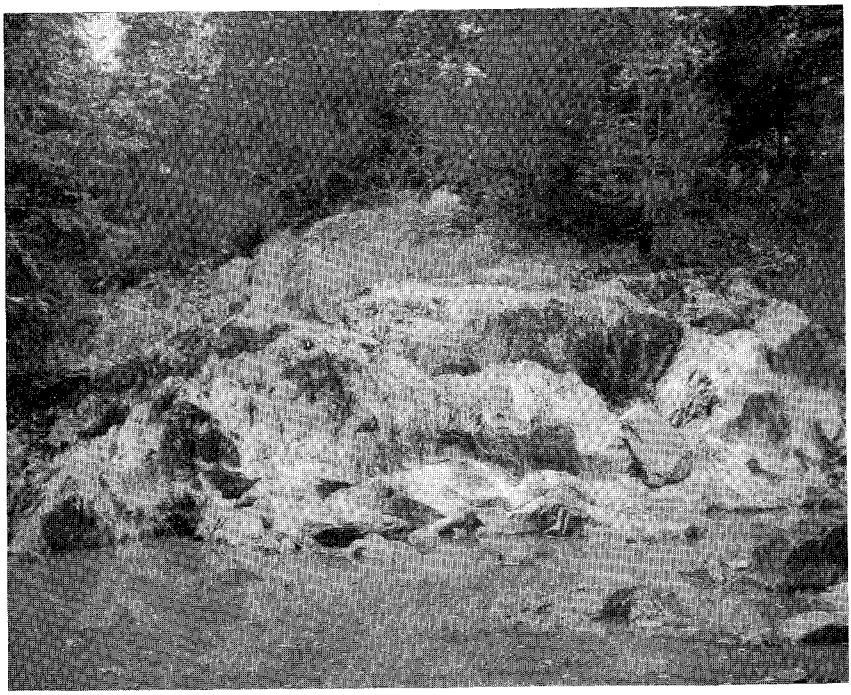
Distribution.—The Virgilina greenstone occupies the central portion of the district, making up, for the most part, the Virgilina ridge. Excepting a few miles in the vicinity of Redoak, Va., where the formation is cut out by the Redoak granite, the greenstone extends the whole length of the district, and, indeed, much farther both to the northeast and to the southwest of the limits of the accompanying geologic map, Plate I. In both the southern and the northern portion of the area mapped the formation consists of a single band, while in the central portion it includes one or more narrow bands of Aaron slate. In addition to this there are at least three

elongated, lens-shaped areas of the greenstone included in the slate. As shown on the map one of these is crossed by the wagon road about two miles west of Wilbourn's store. Another occurs at Ragland's mill, and the third extends as a narrow band from near Green Level schoolhouse to a short distance north of Smith's store on the wagon road about halfway between the town of Clover, Va., and Lack's ferry.

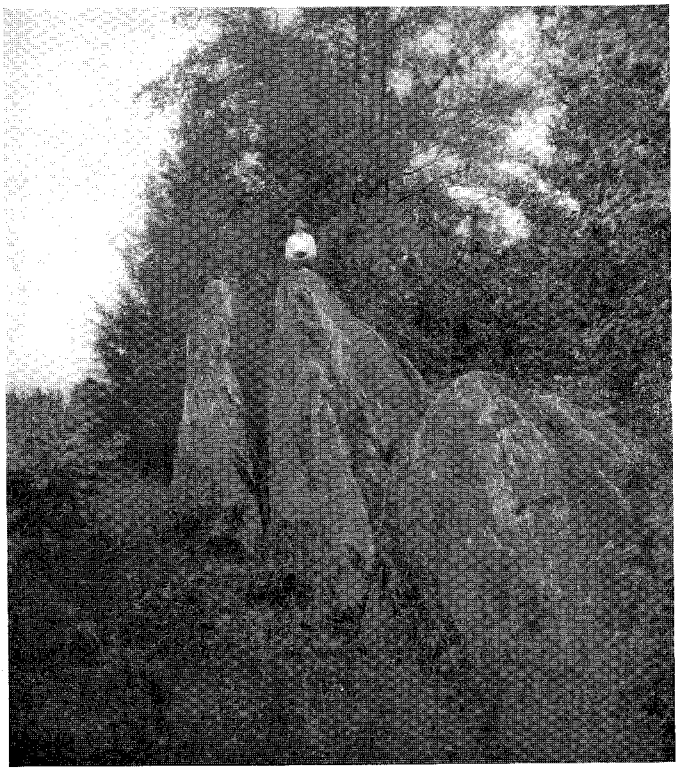
One or the other phases of the greenstone forms the country rock of all the known ore deposits of commercial value in the district, and it may be seen in typical development, either porphyritic, amygdaloidal, or tuffaceous in piles of waste rock at all the mines and prospects in the district. Because no workable ore deposits have been found in other formations, the Virgilina greenstone is regarded as preëminently the ore-bearing formation of the district. This matter is discussed in considerable detail in the chapter on the veins and ores, but it may not be out of place to state here that it is believed that the greenstone supplied only the conditions suitable for the deposition of the ores, and that it is in no way related to the original source of the ores.

The greenstone has its greatest development in the vicinity of Moffett, where it attains a width of about four miles. Another place in which it is prominently developed is about two miles south of the town of Virgilina, in the vicinity of the Pannebaker prospects, where the formation is over three miles in width. Its least development is immediately south of where it is cut out by the Redoak granite. At this place it is less than two miles in width.

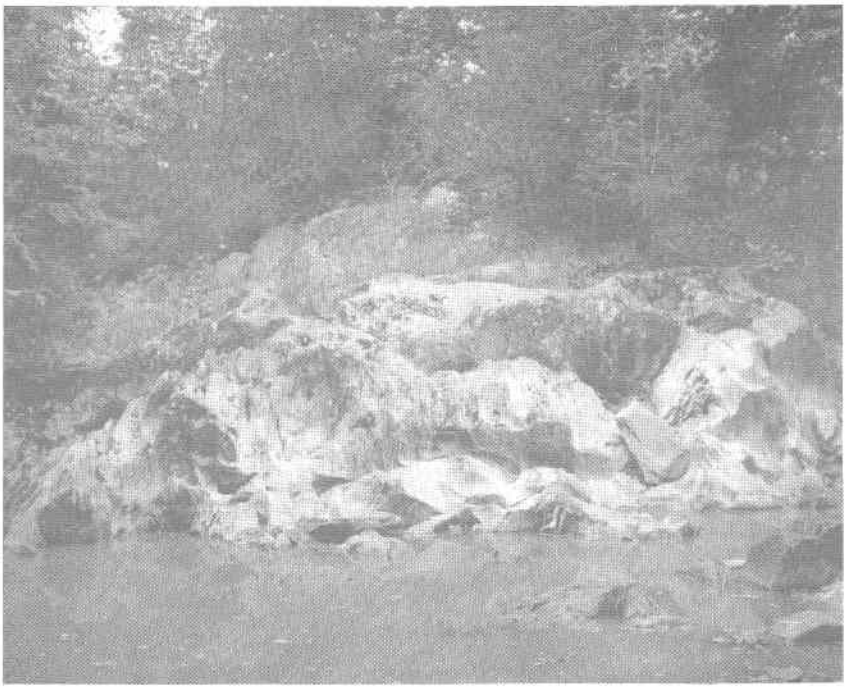
Macroscopic description.—The three types of the Virgilina greenstone are usually distinguishable in the hand specimen without great difficulty. Two of them, a porphyritic and an amygdaloidal type, are effusive rocks and the other is a tuff derived from the same magma. Of these the tuff is by far the most abundant. The porphyritic phase is common, but the amygdaloidal is only occasionally found. Except when highly schistose, in which condition the amygdules, which are generally composed of material differing in color from the mass of the rock, are mashed and drawn out so as to very closely resemble the fragments of the tuff, one can easily distinguish the amygdaloidal phase from the others. Certain phases of the porphyritic type, especially the finer-grained rock, are very difficult to distinguish from certain kinds of the finer-textured tuff. This is exceedingly difficult when both rocks are highly schistose, and in some instances it is possible only with the microscope.



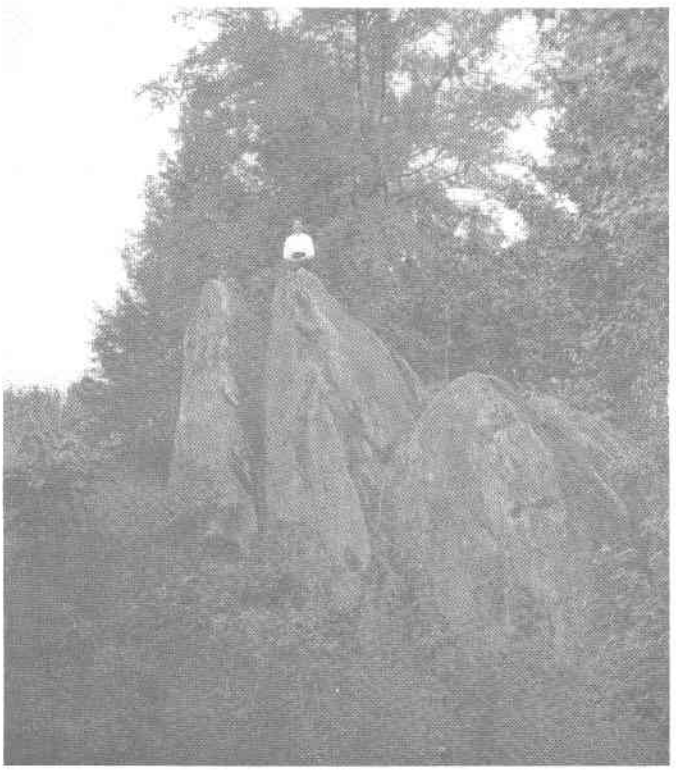
(A) Outcrop of Virgilina greenstone, North Fork of Aaron's Creek, five miles north of Virgilina.



(B) Typical outcrop of Virgilina greenstone three miles northwest of Virgilina.



(A) Outcrop of Virgilina greenstone, North Fork of Aaron's Creek, five miles north of Virgilina.



(B) Typical outcrop of Virgilina greenstone three miles northwest of Virgilina.

The color of the porphyritic and the amygdaloidal rocks varies greatly, but is usually a kind of grayish-green, the intensity of the color depending upon the relative amounts of chlorite, epidote, and hornblende in the rock. Some areas have a purplish-gray color, but this is not nearly so pronounced as with the tuffaceous rock, which is occasionally of a decidedly purple color. Many specimens of the rock, when viewed on a cleavage surface, present a kind of pearly lustre or sheen, which is probably due to the development of sericite or some other micaceous mineral in the planes of schistosity. It is also not usually possible from the examination of such a surface to distinguish the porphyritic rock from certain phases of the mashed tuff. The determinative characteristics of the porphyritic rock consist of phenocrysts of plagioclase feldspar which can be seen to good advantage only when the rock is broken at right angles to the planes of schistosity. They are also more readily seen on a slightly weathered than on a fresh surface. This is also true to a certain extent of the amygdaloidal rock. Further than these feldspar phenocrysts, massive epidote in varying amount and in irregular patches, a little secondary quartz, occasionally a small amount of secondary calcite, one can distinguish with the unaided eye little or nothing as to the texture of the rock. As regards the amygdaloidal rock, one is able in like manner to distinguish the same minerals, and in addition the fillings composing the amygdules. Typical outcrops of Virgilina greenstone are shown in Plates II (B) and III.

Microscopic description.—The microscope reveals the presence of the following minerals: Plagioclase, hornblende, chlorite, epidote, zoisite, calcite, clinozoisite, apatite, the black ores, and quartz.

The plagioclase is all more or less altered and much of it so badly decomposed that a positive identification is not possible. However, some of the freshest phenocrysts were measured according to the Michel-Levy method and found to conform to oligoclase, oligoclase-andesine, and andesine. The phenocrysts often present a short, stocky, prismatic development and are nearly always more or less shattered and drawn out into "eyes" indicative, of course, of the intense dynamic metamorphism which the rocks of the region have suffered. The feldspars of the groundmass occur for the most part in slender, prismatic crystals, and are very much altered.

The amphibole appears to be wholly secondary. It has a beautiful light green or light bluish-green color, is not at all strongly pleochroic, usually occurs in slender, prismatic crystals which are in many instances curved

or bent, and in all other characteristics seems to correspond to actinolite. In the material studied not even a vestige of the original ferromagnesian minerals remained. It is impossible, therefore, to state what the original nature of the rock was, whether an augite or a hornblende andesite.

Epidote occurs in varying amounts in all the thin sections studied. In some instances it makes up the greater part of the rock, while in others it is only sparingly present. Usually, however, it is very abundant. It generally occurs in irregular grains of varying size, and rarely shows well-defined crystallographic development. Aside from a variation in color from the usual pistachio green to a decidedly yellowish-green, the mineral possesses only its usual and normal optical properties. In some instances, especially in the rocks immediately associated with the native copper deposits, the rock is largely replaced by a mixture of quartz and epidote. In such cases the quartz and epidote are most intimately intergrown with each other. The mineral is also intimately associated, in some instances with chlorite and invariably, except in the quartz-epidote intergrowths just mentioned, with zoisite and clinozoisite when the last-mentioned mineral is present.

Zoisite and clinozoisite are alteration products and are derived largely from the feldspars. Consequently their abundance in any specimen of the rock is to a great extent determined by the degree of alteration which it has suffered. The two minerals are very closely related to each other genetically, and while not always occurring together they very often do. They are also very closely related to epidote, and in many instances the three are found together. In fact, epidote and clinozoisite frequently occur with gradations, the one into the other, and in some instances the three are found together. In fact, epidote and clinozoisite frequently occur with gradation, one into the other, and in some instances the same grain is part epidote and part clinozoisite. The usual mode of occurrence is in the form of irregular grains, although a prismatic form is met with occasionally. The two minerals have only their usual and normal characteristics.

Chlorite is one of the most abundant minerals of the Virgilina greenstone. It was present in large quantity in every thin section examined, and in many it was second in abundance only to the feldspars. It is an alteration product derived from the original bisilicate minerals of the rock—in fact, it is exceptional to find even a vestige of the original amphibole or pyroxene, the whole having been replaced by chlorite. The mineral in ordinary light has its usual light green or pea green color, and is seen to be slightly pleochroic. In addition to filling the areas originally

occupied by the bisilicate minerals, which it has replaced, it also fills irregular spaces in the rock, and fractures in the other minerals, especially the feldspars. Between crossed nicols it is seen to be made up of radiating bunches or tufts which have aggregate polarization, somewhat like that of chalcedony. Aside from this the mineral possesses only its usual and normal characteristics. The fact that chlorite is so very abundant in all phases of the rock, and at the same time all other ferromagnesian minerals are so rare, certainly justifies the name "chlorite-epidote schist," which has been given to this rock.

Calcite is present in considerable amount in all phases of the rock. It is in all cases a secondary mineral, probably derived for the most part from the decomposition of the original lime-bearing minerals of the rock. It occurs in irregular areas and patches, fills fractures and veinlets, and in many instances appears to be replacing the feldspars and other minerals of the rock. In some specimens from near the mineralized veins calcite as well as quartz is very abundant.

Quartz occurs in fine granular condition in the groundmass, in some instances closely associated with the feldspar microlites, fills minute fractures, and in some instances appears to be replacing other minerals in much the same manner as the calcite. Like the calcite it is much more abundant in the vicinity of the veins. It is regarded as a secondary mineral.

The black ores are present in varying amount in all phases of the rock, the most abundant one being hematite. Ilmenite and magnetite appear to be present in about equal amount. They have their usual and normal characteristics. In some places hematite is so abundant that it can easily be distinguished in the hand specimen by the unaided eye. In such cases it occurs as minute flakes in the planes of schistosity.

Other secondary minerals, such as kaolin and sericite, occur in considerable amount. They have their normal and usual characteristics. Sericite is present in varying amount in the ores as a gangue mineral. In such relations it has been described by Rogers,[a] who concludes from its association with bornite and chalcocite that the latter is a secondary mineral and not contemporaneous in deposition with the bornite. It is probable that much if not all of the sericite, especially that occurring with the ores, is of hydrothermal origin. Kaolinite, on the other hand, may originate either by hydrothermal or ordinary weathering processes. It is more abundant in the greenstone than sericite.

[a] Rogers, A. F.: Sericite, a low temperature hydrothermal mineral, Economic Geology, Vol. 11, 1916, pp. 118-151.

The amygdaloidal phase of the greenstone is similar to the porphyritic phase in all respects as regard minerals, alteration products, metamorphism, and texture in general. It differs in that the amygdules are composed to a certain extent of minerals foreign to the rock, such as quartz and zeolites, in addition to the usual epidote, chlorite, and calcite; and in the texture of the groundmass of the rock in the immediate vicinity of the amygdules. All the thin sections studied showed the microlites of plagioclase arranged with their longest direction tangent to the circumference of the amygdule, an arrangement common in amygdaloidal rocks.

Tuffaceous phase.—As regards mineralogical composition, alteration products, color, relation to the veins and ores, and general metamorphism, the tuffaceous greenstone is similar to the porphyritic rock. It differs in texture, the proportion in which the different minerals are present, and consequently in chemical composition. In texture the rock is clearly fragmental, the fragments differing considerably in composition and color, and greatly in size and shape. They are all sharply angular, and vary in size from less than a centimeter to more than two feet in longest direction. The fragments have been so much drawn out in the dynamic metamorphism which the rocks have suffered, that it is difficult to recognize them with the unaided eye except on a surface parallel with the schistosity. In thin section under the microscope they are easily recognized. In color the fragments vary from the usual green of the mass of the rock through reddish-brown to a kind of purple.

Chemical composition.—In the table (pp. 33-34) are given chemical analyses of carefully selected material as nearly typical of the average Virgilina greenstone as could be collected. It represents both the porphyritic and the amygdaloidal phases of the rock. Numbers I and II are from material collected by the writer; the others are from Watson's papers on the rocks of the Virgilina district.[a]

Certain features of the greenstone are brought out very clearly by the chemical analyses, and it may be best to call attention to them. Numbers I, III, and IV represent specimens of the porphyritic greenstone taken from widely separated localities, and yet they show a marked uniformity of composition throughout. These analyses, taken together with the equally uniform mineralogical composition of the greenstone as shown by the microscope, prove that the magma from which the rocks now forming the

[a] Watson, Thomas L.: The copper-bearing rocks of the Virgilina copper district, Virginia and North Carolina, Bull. Geol. Soc. Am., Vol. 13, 1902, p. 364.

Virgilina greenstone was derived probably as uniform in composition as such material usually is.

Numbers II, V, VI, VII, and VIII represent tuffaceous and highly altered material, and are not nearly so uniform. They are all low in silica, and three of them—V, VI, and VII—are high in alumina, indicating that instead of being pure andesitic tuffs they represent material with which considerable clay was mixed at the time of their deposition. High lime and carbon dioxide contents in I and VII indicate the presence of considerable calcite in the rock.

Classification.—The mineralogical composition of the greenstone, when taken into consideration with the chemical analyses of the rock, indicate very clearly its andesitic character, and also as clearly show that it has suffered profound alteration. It will be noted that the analyses of the porphyritic rock show a moderate silica content for andesite. This, however, only indicates that the rock is an andesite of intermediate composition. Nothing remains of the original ferromagnesian minerals of the rock, and it is therefore not possible to state whether the original rock was a hornblende or an augite andesite.

Analyses of Virgilina greenstone.

	I	II	III	IV
SiO_2	62.86	47.61	64.12	62.32
Al_2O_3	15.98	15.55	16.32	15.79
Fe_2O_3	2.44	7.33	6.72	3.57
FeO	2.61	1.76	1.38	4.61
MgO	3.36	4.91	0.33	2.53
CaO	4.54	8.60	3.49	3.65
Na_2O	4.52	4.00	6.22	4.51
K_2O	1.22	1.52	0.53	0.76
H_2O-	0.09	0.04	0.34	1.89
H_2O+	2.19	2.70		
TiO_2	0.89	0.78	Trace	0.06
P_2O_5	0.52	0.45	Not det.	Not det.
MnO	0.10	0.13	0.64	0.35
CO_2	Trace	4.97	None	None
	101.32	100.35	100.09	100.04

I. Virgilina greenstone, porphyritic phase, Thomas mine. Wm. M. Thornton, Jr., Analyst.

II. Virgilina greenstone, tuffaceous phase, Durgy mine. Wm. M. Thornton, Jr., Analyst.

III. Virgilina greenstone, dark purplish gray, porphyritic phase, Cornfield prospect. Thomas L. Watson, Analyst.

IV. Virgilina greenstone (porphyritic phase), Overby prospect. Thomas L. Watson, Analyst.

Analyses of Virgilina greenstone—Continued.

	V	VI	VII	VIII
SiO_2	51.34	48.20	46.45	49.51
Al_2O_3	20.07	22.10	13.79	22.42
Fe_2O_3	7.03	7.61	7.60	10.03
FeO	4.03	3.95	6.41	2.42
MgO	4.18	0.86	9.81	2.81
CaO	2.83	8.86	10.13	7.68
Na_2O	1.83	4.90	Not det.	Not det.
K_2O	5.53	1.16	Not det.	Not det.
H_2O- / H_2O+	2.90	2.31	2.66	3.41
TiO_2	0.38	0.24	Trace	0.57
P_2O_5	Not det.	Not det.	Not det.	Not det.
MnO	0.38	0.35	Trace	0.42
CO_2	None	None	2.27	0.90
	100.50	100.54	99.12	100.17

V. Virgilina greenstone, bright schistose tuffaceous phase, Blue Wing mine. Thomas L. Watson, Analyst.

VI. Virgilina greenstone, bright schistose, tuffaceous phase, Fourth of July prospect. Thomas L. Watson, Analyst.

VII. Virgilina greenstone, bright schistose, tuffaceous phase, Anaconda mine. Thomas L. Watson, Analyst.

VIII. Virgilina greenstone, partially decayed, tuffaceous phase, Anaconda mine. Thomas L. Watson, Analyst.

Weathering.—Natural outcrops of the Virgilina greenstone are not plentiful, and are rarely found except in places in which erosion is very active. The rock, however, does not decay very much faster than erosion can carry away the débris, and in no place is the rock covered with more than a few feet of soil.

Watson[a] in his paper on the rocks of the Virgilina district gives a detailed discussion of the process of weathering from which the following quotation is made:

> "The decayed rock is of a pronounced yellowish-brown color, readily crumbling under slight pressure. It effervesced very feebly in dilute acid, indicating hardly more than appreciable traces of carbonates. When further digested for some time in very dilute hydrochloric acid, the brown coloring matter was removed and the residue consisted of the usual green products composing the fresh rock. The percentage of residue composed of the green colored minerals was very large.
>
> "As indicated by the analyses of the fresh and decayed rock, the change has been one of hydration—the assumption of water, accompanied by the peroxidation of the iron and the partial removal of the more soluble constituents, lime, magnesia, and alkalies."

[a] Watson, Thomas L.: The copper-bearing rocks of the Virgilina copper district, Virginia and North Carolina, Bull. Geol. Soc. Am., Vol. 13, 1902, p. 374.

INTRUSIVE ROCKS.

Redoak Granite.

General description.—Four areas of granite occur within the Virgilina district as shown on the accompanying map (Pl. I): One in the vicinity of Buffalo Lithia Springs; one in the vicinity of Redoak post-office; one in the extreme southwest corner of the district; and one, only a small patch, about one mile west of Christie. Of these the area in the vicinity of Redoak is the largest and of the most importance. It has roughly the form of an ellipse the longest diameter of which is about 15 miles and the shortest approximately 7 miles. In this area the rock is so deeply weathered that no natural outcrops could be found, although they were searched for with the greatest care. On this account very little could be learned as to the character of the formation as a whole. So far as could be learned from the few specimens that could be obtained, the rock is a medium-grained, light gray, biotite granite, rather quartzose, and containing orthoclase and plagioclase feldspars in approximately the same amount. The area of the rock is well marked by the loamy sandy soil which it produces. This is the strongest and best soil in the district, and is the most prosperous portion of the region.

The area of granite in the vicinity of Buffalo Lithia Springs is similar to the Redoak area. It is a light gray, medium-grained, moderately quartzose, biotite granite in which the orthoclase and plagioclase feldspars are present in about equal proportion. Natural outcrops are very rare, and on this account little can be said in regard to the uniformity of the rock. Thin sections of the rock under the microscope show the following minerals named in the approximate order of their formation: Apatite, zircon, biotite, orthoclase, microcline, plagioclase, and quartz. The rock in places shows considerable alteration, and such secondary minerals as kaolin, muscovite, sericite, epidote, zoisite, and chlorite are occasionally met with. Small areas of a coarse porphyritic granite occur as intrusives in this area of the granite. These have been described under the term Buffalo granite. The weathering and decay of this area are similar in all respects to that of the Redoak area.

The granite area in the southwestern portion of the district is similar in all respects to the areas just described and on that account need not be discussed in this place in detail. The topography is somewhat more rugged

in this portion of the district than in the other granite areas, and because of this outcrops of the rock are more plentiful which make it possible to learn more as to the uniformity of the rock than in the other areas. So far as could be determined the granite in this area is fairly uniform in both texture and mineralogical composition.

The small area of granite northwest of Christie is not well exposed, and very little could be learned as to its texture and general characteristics. So far as could be determined from the material available, it is considerably finer in texture than the other areas of the rock which have just been described.

The size and location of the granite areas within the Virgilina district are shown on the accompanying geological map (Pl. I). It should be stated, however, in this connection that the boundaries of the different areas are only approximately correct. The rock in all the areas is so deeply weathered and so deeply buried beneath its own decay that outcrops are not plentiful enough to enable one to determine boundaries very accurately. The granite produces a soil very characteristic and very different from that of any other formation in the district, and by using the soil as a guide it was possible to locate the boundaries of the different areas with a considerable degree of accuracy.

So far as is at present known, there are no ore deposits in any of the granite areas, and, so far as observations have extended, there are no indications that any such deposits exist in the rock. Notwithstanding this it is believed that the solutions which deposited the ores were directly associated with the intrusion of the granite masses. This matter is discussed in detail in the chapter on the origin of the ores and need not be repeated here.

Buffalo Granite.

General description.—The term Buffalo granite is used to designate small masses or areas of a coarse porphyritic granite with very large feldspar phenocrysts which occur in the Redoak granite in the vicinity of Buffalo Lithia Springs.

The rock is a light gray, coarse-grained, porphyritic granite which differs from the main granite masses very little except in texture. The same minerals are present in both rocks, and bear in general the same relations to each other. The rock is present only in small amount, and, so far as could be determined, is of no commercial importance.

Abbyville Gabbro.

General statement.—A considerable area of much altered gabbro occurs in the vicinity of Abbyville. No prominent outcrops of the rock could be found, and because of this it has not been possible to learn much in regard to the texture and general characteristics of the rock as a whole. Such outcrops as could be found consist of irregular rounded boulders of a dirty greenish-gray color, which in some instances were altered more or less completely into an impure soapstone. The boundary of the formation as shown on the accompanying geologic map (Pl. I) was determined by the distribution of such boulders and by the color of the soil, and consequently is only approximately correct. The character of the particular outcrop depends upon the degree of alteration, and on this account a detailed petrographic description of the rock would involve more space and time than the importance of the rock from an economic standpoint warrants.

Macroscopic description.—In the hand specimen the gabbro usually has a kind of dirty greenish-gray color which varies greatly, depending upon the degree of alteration which the rock has suffered; the fresher the rock, the darker the color. Usually the rock is coarse-grained, and the individual minerals can be recognized by the unaided eye with considerable ease. The principal mineral thus recognizable is a light green hornblende. In many cases this is the only mineral that can be identified in this manner, but in a few instances other minerals, especially feldspars, are recognizable. The rock is generally very tough except the most highly altered phases, but even the freshest of it is moderately soft so that when an edge is struck with a hammer it usually mashes down to a whitish mass instead of flaking off.

Microscopic description.—In thin section under the microscope the following minerals are recognizable: Pale green uralitic hornblende, badly altered plagioclase feldspar, zoisite, clinozoisite, epidote, kaolin, sericite, chlorite, calcite, quartz, and black iron ores. The feldspars are so much altered that positive indentification is not possible. They show clear indications of broad twinning bands, and doubtless belong in the lower and middle portion of the plagioclase series. The fact that lime-rich secondary minerals, such as zoisite, clinozoisite, epidote, and calcite, have abundantly developed from and are replacing the feldspars, is strong evidence that they were originally rich in lime. This type of alteration, known as saussuritization, is characteristic only of the lime-rich plagioclases. The

other minerals have their usual and normal characteristics, and need not be described in detail at this place. The calcite and quartz are both secondary minerals.

It must be stated in connection with the description just given that while it is true for the sections studied, other thin sections made from portions of the rock in different stages of alteration will certainly show different mineralogical compositions and very different petrographic characteristics. In fact, one thin section examined by the writer contained traces of the original pyroxene of the unaltered rock. Thus it is certain that by diligent and prolonged search one could find specimens of the gabbro that will show practically every stage of alteration from the fairly fresh rock to the impure soapstone.

Unaltered gabbro.—As indicated on the accompanying geologic map (Pl. I) there are two areas of gabbro in the southern portion of the district. The rock in these areas differs materially from that in the Abbyville area, and, indeed, may be an entirely different type of rock. In fact, there is much evidence that indicates that such is the case, and that the rock is intermediate between gabbro and diabase. On this account much hesitancy was felt in using the same colors on the geologic map for the different areas. The question can not be settled without more extensive microscopic and chemical research than the importance of the rock would justify, certainly more than an economic report would call for.

This rock, as seen in the field, is fairly fresh and is of a black or very dark brown color—not decidedly unlike that of a diabase. It has from a fine to a medium granular texture. It is very tough and heavy, and in places appears to contain an excess of iron ores. When examined in thin section, the rock presents the following minerals: Hypersthene, augite, calcic plagioclase which varies from labradorite to anorthite, and large amounts of black ores. With these primary minerals there are such secondary ones as always develop from such combinations of primary minerals.

NORMAL SEDIMENTARY ROCKS.

Triassic (Newark) Sandstone.

General description.—One small area of reddish-brown sandstone of Triassic (Newark) age occurs within the district mapped. As shown on the accompanying geologic map (Pl. I), this formation occurs as an elliptical area about ten miles long and four miles wide, in the west-central portion of

the district, extending from a short distance southwest of Wolftrap to about two miles northeast of the town of Scottsburg. Natural exposures of the rock are very rare, in fact only two or three are known to occur, and the outlines of the formation as shown on the map are only approximately correct. The best-known exposure of the rock is in the railroad cut a short distance northeast of Scottsburg, in which place it is decidedly conglomeratic, the matrix being moderately fine reddish-brown sandstone in which are embedded pebbles and boulders up to over a foot in diameter. The color of the rock varies from chocolate-brown through reddish-brown to almost a brick-red. The exposures of the rock are so scarce that it was not possible to learn very much in regard to the characteristics of the formation as a whole.

This is one of the disconnected areas of the Triassic which are of common occurrence in the eastern portion of the Piedmont Plateau of North Carolina and Virginia. The formation, while of much interest from a purely geological standpoint, is in no way related to the ore deposits of the region, and, on this account, is of no great importance from the standpoint of the present report.

DIKE ROCKS.

General statement.—As in all other parts of the Piedmont Plateau, dikes are numerous in the Virgilina district, and while they are of little or no economic importance they form one of the district's interesting geological features. They are as a rule small, but widely distributed, no formation being free from them. In age they vary from early Paleozoic to late Triassic, the oldest being the syenite, granite, and gabbro, and the youngest the diabase of late Triassic age. Disregarding the probability that at least a part of the hornblende gneiss of pre-Cambrian age was intruded into the mica gneiss in the form of dikes, the dikes of the Virgilina district may be divided into the following groups or classes, named in the probable order of their respective ages: Granite, syenite, gabbro, and diabase. The largest, longest, and most persistent are the syenite dikes, the others coming in the following order: Granite, diabase, and gabbro. Of these the diabase dikes are the most numerous and granite the least so.

Granite.

General description.—Only one granite dike was found during the field work. It occurs a short distance east of the railroad at Randolph station, and extends northward a short distance east of the railroad to near Moss-

ingford. Its width, as well as it could be determined, varies from 100 to about 200 feet, and the rock is fairly uniform throughout the entire length. The rock appears to be a medium- to fine-grained, light gray to red granite. Its relation, if any exists, to the main granite area in the vicinity of Redoak could not be determined. In some places, especially near the State Farm at Saxe, it outcrops strongly, but in most places the outcrops are inconspicuous.

Syenite.

General description.—Two peculiar granitic dikes, which appear from examination in the hand specimen to be syenite, were found in the district. Both of them occur in the northern part of the district, and both have a linear length of several miles. The larger and longer of the two is well exposed in the town of Drakes Branch, where it has a width of about 150+ feet, and from which it may be traced northward some six or eight miles and southward for about twenty miles. So far as could be determined from meager outcrops, it maintains a fairly uniform width throughout its entire length. According to the observations of Mr. J. H. Watkins, who did the field work in that vicinity, this dike intersects the Redoak granite, and is therefore younger than that formation. Beyond a limited use for road metal the syenite is not known to have any commercial value. Thus far no ore deposits have been found associated with it in any way, and there appears to be no reason to expect that any such deposits will ever be found.

In the hand specimen the rock is seen to be rather coarsely crystalline and to be made up largely of feldspars, having only minor amounts of ferromagnesian minerals and quartz. In color, texture, and general appearance the syenite somewhat resembles a coarse-grained granite.

Gabbro.

General statement.—In the vicinity of the larger masses of gabbro a few small gabbro dikes were found. They are always small, and as far as is known do not extend long distances. In color, texture, and, in fact, in all particulars, the rock of the dikes is similar to that of the main Abbyville gabbro area already described. It is, therefore, unnecessary to repeat the description in this place.

Diabase.

General statement.—The most abundant and also the most widely distributed dike rock in the Virgilina district is diabase. It occurs in the

form of numerous narrow dikes, the width and trend of which are indicated by the presence of small boulders, locally called "nigger heads," scattered here and there on the surface. The rock has been weathered so deeply that, so far as observations have extended, the massive rock does not outcrop naturally in the district. The dikes are always narrow, and have never been known to extend over great linear distances. The diabase is the youngest rock in the district, and is found cutting all the other formations, even the Triassic sandstone. It also has the distinction of being the only dike rock that is in any way associated with the ores, but this association is wholly accidental, and there is no genetic relation between the diabase dikes and the ore deposits. The dikes are much younger than the ores, and, where the two are associated, as in the Blue Wing and the Durgy mines, the dikes cut the veins without producing any effects upon the ores or veins.

Macroscopic description.—The diabase is a massive, fine-grained rock of a black or bluish color when seen on a fresh fracture, but often a dark gray color on a weathered surface. The rock is usually so dense and the texture so fine that with the unaided eye one can distinguish little or nothing in regard to its mineralogical composition. It is very heavy and is exceedingly tough.

Microscopic description.—In thin section under the microscope the following minerals, named in the probable order of their formation, are revealed: Black ores, olivine, plagioclase feldspar in narrow, lath-shaped crystals, augite, and in some instances a small amount of green secondary hornblende. The texture is typically ophitic, and the feldspar laths have a decidedly random or haphazard arrangement. The rock is similar in all respects to the diabase of the Piedmont region. It has no genetic nor other important relation to the ore deposits, and, as it occurs in this district, is of no commercial value.

STRUCTURE AND METAMORPHISM.

GENERAL STATEMENT.

In other chapters the nature of the rocks and ores have been discussed, and their relationships to each other have been considered. The rocks although profoundly altered, both physically and chemically, since their original deposition, have been identified and classified, and their areal distribution has been determined and shown on the geological map (Pl. I) which accompanies this report. The ores have been studied in their relation

to the rocks and veins in which they occur, and the component minerals of the ores have been considered in their relation to each other. These studies have shown that certain profound changes have taken place in the rocks in the district since the original deposition, that many causes have been active in the production of the results, and that to a greater or less degree each cause has left its own particular imprint or effect upon the rocks or ores, each, of course, more or less obscured by the succeeding. The agents producing these changes have been physical (pressure) and chemical (solution) rearrangement, and redeposition of the respective constituents.

In the present chapter it is proposed to consider the effects of these various physical and chemical agencies as recorded in the rocks and ores, and to draw such conclusions as to the forces producing them as seem logical. Under the term structure will be considered largely the physical agencies, such as folding, mashing, shearing, jointing, faulting, and the intrusion of igneous rocks. Under metamorphism will be considered both the physical agent, pressure, and the various chemical changes that are shown by the rocks to have taken place. These are all scientific and theoretical considerations, but upon them rest the very practical considerations as to continuance of the ore with depth, the character and type of rocks in which the prospector may search for ore with the greatest possibility of finding it, the effect of fractures and faults upon the ore bodies, the causes for the segregation of the ores in certain places rather than in others, the origin of the ores, their parent rocks, and many other questions of prime importance to the mine owner and mine operator.

STRUCTURAL FEATURES.

FOLDING.

The mashed and highly schistose character of nearly all the rocks of the district is the most evident effect of the enormous compression to which the region has been subjected. The fact that the slaty cleavage of all the rocks dips almost invariably to the southeast is another almost, if not equal, evidence of the tremendous forces that have been in operation at various times in the long-past history of the district. This prominent schistosity is one of the last results effected by forces of compression, and is developed only after a region is thrown into a series of folds and these closely compressed. There are a number of possible interpretations of the structure, but the one which the writer deems to be most probable is that of a closely

compressed synclinorium, the folds of which have all been overturned so that the dip is almost entirely toward the southeast. The forces of deformation have been so intense that the bedding planes and other original features of the rocks have been almost entirely obliterated. It is therefore only in rare instances that one may observe in the field the actual crests and troughs of the folds, or even the bedding planes of the rocks. Thus it happens that the presence of folds must be determined by circumstantial or inferential evidence rather than upon direct observation. Two concurrent lines of evidence, such bedding planes as can be found, and the areal distribution of the different rock formations as shown on the geologic map (Pl. I), offer conclusive evidence of folding.

Bedding planes or lines of stratification are found in a few places in the district, and, while their dip is almost always uniform and toward the southeast, there are in a few places observable variations from this direction which indicate clearly the crests of pitching folds. These conditions may be seen in a cut on the branch railroad near the switch running from the road to the Holloway mine, and in another cut on the same road about one-half mile south of the Blue Wing mine; in an exposure in the wagon road a short distance south of Jones Ferry; and to a less extent in an exposure in the wagon road where it crosses Wolfpen Branch about one-half mile east of Virgilina. In many other places there are obscure indications of similar conditions. The structure has been so greatly obliterated by the development of secondary features, such as schistosity and by the heavy overburden of decayed rock and soil, that it was not possible to locate on the accompanying geologic map (Pl. I) the anticlines and synclines, and thus work out the structure. The bedding planes are for the most part parallel with the schistosity, and usually have the same degree of dip. These conditions may be seen in almost any prominent rock exposure in the Aaron slate. It is especially well shown in a cut on the Southern Railway about one mile west of Virgilina, where many thin beds of dense slaty material alternate with thicker beds of nearly pure sandstone. (See Pl. II (A).) It is also noted that where the bedding planes diverge from the general northeast-southwest strike of the district, the rocks are much more massive and show their original textures fairly well, and that where they are parallel with the schistosity the rocks are highly schistose and have suffered intense dynamic metamorphism. These facts indicate pretty clearly that there has been much close folding, and the variation in character of the rocks may be explained by the fact that dynamic metamorphism is always more intense on the limbs of folds than on their crests. The more

massive rocks therefore indicate the crests or troughs of folds, while those more highly schistose and altered indicate the limbs of the folds.

An equally strong, if not a stronger, indication of folding is the areal distribution of the different rock formations of the district. This is best seen on the geologic map (Pl. I) on which the different formations are shown in different colors. It will be noted that there are two general types or forms of rock distribution shown upon the map, one consisting of long narrow bands terminating for the most part in sharp points, and of blunt, more or less ellipsoidal, areas, the former indicating the volcano-sedimentary rocks and the latter those intruded into them.

Even a glance at the geologic map (Pl. I) will show that in a general way the narrow bands repeat themselves with great regularity. Any cross-section will show that if one assumes a northeast-southwest axis through the center of the district, there is a regular sequence of formations on each side of this axis. This is well shown in the section exposed across the district along the Southern Railway. The center or axis crosses the railroad about the middle of the band of Aaron slate a short distance west of Virgilina. Both east and west of this point the formations are repeated in regular sequence. It must be assumed that such rocks as these must have been deposited originally in approximately horizontal beds or strata, one above another. As they occur to-day these strata are turned almost on edge, and are repeated in more regular sequence such as one might expect would result from folding.

These lines of evidence seem to prove that the district has been thrown into closely compressed folds whose axes have an approximate trend of north 30° east. The exact nature and the details of this folding are very difficult, if not impossible, to determine. If one assumes one large regular syncline such as the distribution of the formations and their relation to each other would seem to warrant, it still remains to explain the conditions which could permit the building up of beds or strata of rock varying in thickness from one to more than three miles. While this conclusion at first glance appears to be justified, closer study reveals another which it is believed more logically follows from the observations, and also has the advantage of not requiring the assumption of strata of such enormous thickness. Therefore while fully realizing that other interpretations are possible and logical, the one outlined below is the most plausible to the writer.

The district represents a closely compressed synclinorium consisting of numerous anticlines and synclines only a few of which are at present

determinable, the major axis of which has a northeast-southwest trend and is located approximately in the center of the district. The folding has been close, and the compression so intense as to impose strong schistosity having a trend parallel with the main axis of the synclinorium and a steep southeast dip. What might be assumed from the distribution of the formations as their thickness is apparent and not real, there being a number of minor synclines and anticlines on each limb of the major syncline. The probability of this interpretation is strengthened by the occurrence of narrow, spindle-shaped areas of one formation in another, the explanation being that they are portions of overlying or underlying formations brought down or up in compressed pitching synclines or anticlines. Assuming this to be the case, there is no reason for assigning a thickness of more than one-half mile to any formation, which would not be excessive for tuffaceous rocks.

While the axes of the major folds have a northeast trend, the shape of the different clastic formations indicate very clearly a minor series or system of folds with axes almost at right angles to the major series. The effect of the second series was to form the first anticlines and synclines into a series of cross-folds or folds with axes at right angles to the major series, and thus throw the whole district into a series of pitching synclines and anticlines. Two such cross-folds and their resultant saddles are clearly indicated in the distribution of the formations as shown on the geologic map (Pl. I), one with an axis running about 20 degrees west of north, apexes somewhere near the High Hill schoolhouse, and the other occurs in the southern part of the area. Its axis would lie somewhere along a line drawn from St. Matthew's church to Bethel Hill. It was not possible during the field work to obtain any direct observations such as dip and strike of bedding planes to prove the presence of these cross-folds, but the distribution of the different formations at these points is so typically characteristic of pitching folds that it seems logical to assume that they exist. If this interpretation is correct, the crest of any of the major folds would be described by a wavy line with crests and troughs, and the two localities just described are cross-anticlines, while to either side of them are corresponding synclines.

Another feature of the folding is that, with very few exceptions, the bedding planes of the rocks dip steeply about 70 degrees toward the southeast, and have a strike parallel with the major axis of the folding. The exceptions to these conditions, as far as could be determined during the field work, are few and irregular, and are strongly indicative of pitching folds,

in which case they would mark the troughs and crests of the folds. It is believed that the only explanation of this almost universal southeast dip of the strata is to assume that during the time of folding there was considerable thrust from the southeast toward the northwest, and that the folds were all overturned toward the northwest.

SCHISTOSITY.

Probably the most evident structural phenomenon of the district is the very prominent slaty cleavage or schistosity of the rocks. This almost invariably has a north to northeast strike, and a dip of from 60 to 80 degrees toward the southeast. In many places it corresponds to the bedding planes of the rocks where such can be distinguished, but on the crests and in the troughs of folds the schistosity maintains its usual dip and strike regardless of the bedding planes. In studying the structure of the district one must, on this account, be very careful not to confuse the primary planes of stratification of the volcano-sedimentary rocks with the schistosity, which is in no way related to the bedding planes, but has been induced by compression. It is not intended to affirm that all the rocks of the district are uniformly and highly schistose, for such is not the case. The intrusive rocks, which are younger than the volcano-sediments, show little or no schistosity, and were therefore evidently intruded subsequent to the period of intense dynamic metamorphism. Furthermore, in many places, probably on the crests and in the troughs of folds, and also in certain areas in which the rocks are massive—probably normal andesites instead of andesitic tuffs—the schistosity is not so prominent as to obliterate the other features of the rock. In many places schistosity has destroyed all the original textures and features of the rocks, and is so prominent that they may be split into slabs almost thin enough for use as slates. This is especially well shown in a bold outcrop on the north bank of Ran Diver, a short distance below the mouth of Hyco River. At this place, known as the Harris slate quarry, an attempt has been made to quarry the material for use as roofing slate, but, so far as the work has extended, the rock has not been found to be suitable for such purposes.

Since it is known that the secondary phenomenon slaty cleavage or schistosity is developed by compression, and that it forms in a direction normal to the axis of application of the force producing it, one may safely conclude that the forces producing the schistosity in this district acted in a northwest-southeast direction.

The forces producing the folding and schistosity had ceased long before the formation of the veins and the deposition of the ores, and, of course, have had no effect upon either. The vein matter shows no schistosity.

JOINTING.

Joint planes are prominent in all formations, but are more prominent in the more massive rocks, and are very abundant where the volcano-sediments lie most nearly horizontal, and least abundant where schistosity is greatest. In strike the joints tend to group themselves in the northwest and northeast quadrants of the circle, with a smaller group having an approximate north-south strike, and very few approximating the east-west direction. In dip their planes cut the horizon at almost all angles, but it appears that by far the greatest number have a steep easterly or south-easterly dip. In the schistose formations the majority of the joints have a north to northwest strike, and an east to north dip. It is probable that the small number of joints in these formations with northeast strike may be accounted for on the basis that, because of the prominent schistosity with northeast strike, it was easier for the joint-producing forces to relieve themselves along the planes of cleavage already developed than to produce new fractures. Many of the joint-planes show slicken-sided surfaces, and it is not improbable that along many of them there has been more or less dislocation, but it is believed that in the great majority of cases they are merely fracture planes and not planes of dislocation or fault planes.

The joint planes have been of far greater importance in the geologic history of the district than one might at first thought suspect. They have formed the openings in which both dikes and veins occur, except where the latter follow the planes of schistosity, which is not usual, and are thus the controlling factor in the location, trend, and dip of dikes and veins. It is realized that some of the veins may have been developed in fault planes, but, so far as could be determined during the field work, there is little conclusive evidence that such is the case, and it, therefore, appears safest to assume that by far the greater portion of the veins has been developed in joint planes, opened in part by the linear force of the crystallization of the vein matter, and in part by replacement of the country rock.

A few words should be said in regard to the time of development of the joints. Little evidence on this question is available; but what there is indicates that the joints were formed in large part since the close folding of the district and the development of the schistosity. Joints are fractures in the rocks, and hence are formed in the zone of fracture, while folding

and the development of schistosity are flow phenomena, and are necessarily developed in the zone of flowage.

Furthermore, as shown in the mine workings, the trend of the most prominent system of joints in the district so nearly coincides with the strike of the schistosity that it is difficult to conceive of the two having been developed simultaneously and by the same force. It is not believed that all the jointing is necessarily contemporaneous. Indeed it is well known that the region has been subjected to more than one period of elevation and depression, and it thus seems logical to believe that a certain amount of fracturing would take place during each period of earth movement. As has been stated and discussed in detail in the chapter on the origin of the veins and ores, it is believed that they are connected genetically with the intrusion of the great masses of granite of the region, small areas of which occurring in the district are shown on the geologic map (Pl. I). It is well known that at one period in the geologic history of the Piedmont region enormous masses of granite were forced into the already existing rocks, and it is believed that while it is probable that not all the granite was intruded at one time, by far the greater part of it came in during a single more or less extended period of intrusion. Such great bodies of magma coming into the zone of fracture would necessarily produce more or less fracturing, some of which would be very deep. Hence it is believed that many of the deep fractures, which later were filled with vein water and became the ore deposits, were formed contemporaneously with the granite intrusions.

The system of fractures in which the veins occur appear to have been formed by a force applied so that the stress could be relieved in part by tearing the rock apart along the planes of schistosity, and in part by fracturing the rocks along planes forming very acute angles with the schistosity, thus giving the veins the appearance of fissures combined with "stringer lead" or rifted schist type of veins.

FAULTING.

There is but little direct or conclusive evidence of faulting in the district, and such as there is consists of minor displacements of a few feet in some of the ore bodies or veins. It seems hardly probable that so much dynamic metamorphism could have taken place in the district without producing a certain amount of faulting on a large scale. However, if such exists, it was not detected. It is not at all improbable that many of the prominent veins, both barren and ore-bearing, were developed in fault

planes; but, if they were, no direct evidence of it was detected, unless the thin laminæ of quartz and ore in the rifted schist which forms part of the vein in many places, or the slicken-sided walls which are found occasionally, are such evidence. The lenticular character of the veins, their pinches and swells, when explained on the theory of Becker that the fracture represented a wavy line and that any movement of either wall would tend to bring two crests and two troughs of the fracture opposite each other, and thus produce the pinches and swells, is also evidence of at least a small amount of displacement. While technically such movements along fracture planes is faulting, yet the results from a structural standpoint might be negligible, and, while it is possible that some of the veins were formed in planes of profound displacement, one certainly is not justified in assuming it from such evidence as that just stated. If such faults exist they were formed prior to the formation of the veins and the deposition of the ores, since these show no evidence of any such movements.

In three of the mines, the Seaboard, the Blue Wing, and the Durgy, there is minor faulting which affects the veins in a small way.

The dislocation in the Seaboard mine is at the south end of the 200-foot level, and the vein appears to be cut out completely by a cross-fault. There is little doubt as to the fault, but the development work has not been sufficient to furnish data as to the amount of displacement. Such evidence as could be obtained indicates that it is probably a minor fault, and that the displacement is slight.

The displacement or faulting, as exposed in the Blue Wing mine, occurs on the level immediately north of the diabase dike. The vein is shattered and displaced a few feet. The fault is probably contemporaneous with the intrusion of the dike.

The dislocations reported in the Durgy veins are all trivial, and appear to be similar to that in the other veins. They have no important influence upon the ore body and the dislocation is slight. Indeed it may not be faulting at all, and may be similar to a mud-filled fracture which Weed[a] states was encountered north of the shaft on the third level of the Holloway mine, which, while shattering the walls, did not displace the veins.

It is believed that these minor fractures and faults were probably developed during the earth movements attendant upon the outpouring of the basalt and diabase, and the intrusion of the trap dikes along the Atlantic Coast during Triassic times. So far as could be determined, they

[a] Weed, W. H.: Copper Deposits in the Southern United States, Trans. Am. Inst. Min. Eng., Vol. 30, 1900, p. 460.

have had no influence upon the vein development, nor upon the mineralization and enrichment of the ore deposits.

INTRUSION OF IGNEOUS ROCKS.

Intrusive rocks occur in considerable quantity in the district. They range in character from diabase and gabbro to syenite and granite. They all have been discussed in more or less detail in the chapter dealing with the rocks, and descriptions need not be repeated here. The syenite, diabase and much of the gabbro, and smaller amounts of the granite and diorite occur as dikes. The intrusion of these masses of magma has had little effect upon the structure of the district, in fact much less than might be expected. About the only effects so far as noted, aside from the probabiliy that the granitic intrusions are responsible for the solutions which formed the veins and ores, and the opening up of joint planes by the dikes and more or less bending of the planes of schistosity in the schists by the bodies of igneous rock.

METAMORPHISM.

General statement.—The term metamorphism is intended to be used broadly enough to include all changes which have taken place in the rocks of the district since their original deposition or intrusion. There are no means of learning even approximately all the changes that have taken place in the rocks of the district, nor of knowing the agencies which produced them, but enough of the previous, if not original, textures of the rocks remain to enable one to trace some of the changes that have taken place. Changes are produced by two kinds of agencies, each producing its own results, though modified, of course, by the other. These agencies are physical, represented by compression, and chemical, represented by metasomatism, solution, and deposition or precipitation.

TEXTURAL CHANGES.

The effects of dynamic metamorphism as shown by folding, jointing, faulting, and schistosity have all been discussed in considerable detail in another place in this chapter. All types of rocks of the district, except the Triassic sandstone and diabase dikes, which have been formed since the period of dynamic metamorphism, show more or less clearly a record of the changes that have taken place. Through pressure combined with a certain unknown amount of chemical activity, the open-textured tuffs of both

basic and acid types, as well as the massive types of the same rocks, have been changed into highly schistose rocks, the degree of schistosity varying according to the original rock and other factors. The rocks have been mashed and their various constituent minerals elongated and flattened and compressed until in many instances the original texture of the rock has been almost completely destroyed.

MINERALOGICAL CHANGES.

Concomitant with the textural changes there have been profound mineralogical changes; original minerals have been completely replaced by other entirely different minerals; certain minerals have altered wholly or in part to other minerals, and minerals entirely foreign to the rocks have been brought in from outside sources and deposited in them. These changes have taken place on a large scale, and are characteristic of the whole district. They have all been discussed more or less fully in the detailed description of the rocks, pages 14-41, and to a less extent in the chapter on the origin and deposition of the ores, but it may not be amiss to give a brief summary of the subject in this chapter.

Each class of rocks, is, to a large extent, characterized by a type of alteration peculiar to itself. In the acid rocks, such as the quartz porphyry and the acid tuffs, and to a less extent the granite, many of the original minerals, especially the feldspars, have been destroyed and their places taken by sericite or kaolin. There are all degrees of sericitization depending upon the intensity of the forces producing the change, the end product being a quartz-sericite schist which shows nothing of the original characteristics of the rock from which it was derived. In these rocks there have been developed also small amounts of biotite, chlorite, and epidote, but these minerals are characteristic of the basic rather than the acid rocks.

The secondary minerals peculiar to the basic rocks, andesite, andesitic tuff, and the basic dike rocks, gabbro, diorite, and diabase, are chlorite, actinolite, epidote, zoisite, clinozoisite, calcite, and to a less extent biotite. As with the acid rocks, there are all degrees of alteration, the end product being a chlorite-epidote schist.

MINERALIZATION.

The formation of the veins and the deposition of the ores are considered as a part of the metamorphic process. As has been stated in discussing the veins and ores, it is believed that the material for the veins was largely,

and the ores were wholly, derived from sources outside the rocks in which they occur. If these assumptions are true, and all the evidence available strongly supports them, the formation of the veins and the deposition of the ores form, from an economic standpoint, the most important metamorphic event in the geologic history of the region. It is believed that the materials for the highly siliceous veins and the ores were derived from the great masses of granitic rocks that were intruded into the region long after the period of intense dynamic metamorphism was past, and that they were carried in solution, probably highly heated, and deposited in fractures in the basic schists. The veins are believed to have been formed by opening fractures, in part by dynamic forces associated with the intrusion of the granite masses, and in part by the linear force of the crystallizing quartz; and that they were considerably widened and enlarged by replacement of the wall rocks by vein matter and ore where the ore occurs in veins, and by ore where the ores are more or less disseminated in the wall rocks near the veins.

It appears to be clear from the study of such ore deposits as the Holloway and the Copper King mines, ore bodies in which the replacement of the wall rock has probably played an important rôle, that the character of the rock has been a very important factor in the development of the ore body. From such accounts of the Holloway ore body as were accessible to the writer, it seems to be established that some of the pinches and swells in this mine were determined by the character of the wall rock, which in this mine is variable. Where the wall rock was tuffaceous and more or less open textured the ore body is said to have been wide, but where the rock was dense and hard as is much of the porphyritic phase of the Virgilina greenstone the ore body is said to have been much narrower.

WEATHERING.

The only metamorphic process active at the present time is the superficial alteration of the rocks and ores known as weathering. By the term weathering is meant all the changes involved in the transformation of the rocks into soil. Under surface conditions the rocks are not stable and gradually disintegrate and decay until in the final stage they pass into soil. The processes involved in this transformation are both physical and chemical. The physical forces, important among which are expansion and contraction, and the expansion of ice formed during the winter when the water in the surface rock is alternately frozen and melted—are in large measure responsible for rock disintegration. The chemical reactions

involved produce hydration, oxidation, carbonation, and solution. The complex minerals are broken up into simple combinations, the soluble portions are removed and in the end all that remains of the solid rock is soil. The tendency is always from the unstable to the stable, and in the end only those combinations of elements remain which are stable under the prevailing physical and chemical conditions.

When decomposition proceeds more rapidly than erosion, the rocks become covered with a thick mantle of material which at the surface is soil, but which gradually becomes with depth the fresh unaltered rock. In such a region it is only in places in which erosion is very active, such as stream beds and steep slopes, that rock outcrops are found. Much of the Piedmont area of the Southern States is in this condition, and indeed the same is true of the greater portion of the Virgilina district, as shown on the accompanying map, Plate I.

Weathering affects the veins and ores just as it does the rocks. The massive vein matter, quartz and calcite, is broken up, the calcite taken into solution, and the insoluble quartz fragments are left behind in the soil. The ore minerals are also unstable, are attacked and broken down, the soluble portions removed, and the remaining portion, usually iron oxide, remains in the form of gossan. The process is rarely carried to completion in the Virgilina district, and, so far as data were available, the outcrops of the veins even at or very near the surface are marked by green and blue copper carbonate stainings instead of by porous masses of iron oxide or gossan associated with quartz. As a general rule, the order of alteration in vein outcrops is as follows: From surface to level of permanent ground water, leached and highly oxidized vein matter with little or none of the original ores remaining; from the level of ground water to the depth of more or less active circulation, a zone of primary ores more or less enriched by high grade secondary ore minerals; and, finally, below this zone and extending to the depth of mineralization, the ores as originally deposited. In the Virgilina district, the original ores are the rich sulphides, chalcocite and bornite, the veins are tight and the circulation in them apparently not very strong. Consequently, there is no marked middle or enriched zone in the veins. The important secondary ore minerals are chalcocite, cuprite, malachite, azurite, chrysocolla, and possibly tenorite, which with the exception of tenorite, are fairly plentiful in the oxidized portions of the veins.

GEOLOGIC HISTORY.

GENERAL STATEMENT.

In the chapter dealing with detailed description of the rocks, and that in which the structure and metamorphism were discussed, many factors bearing on the geologic history of the Virgilina district were considered in their relation to the subjects under discussion, but anything in the order of a connected story of the geologic development of the district would have been out of place in those chapters. Since the geology of the surrounding region has not been studied in detail, and the relationships of the different formations of the district and their areal extent is unknown, no attempt will be made to correlate them with any known and described formations. Furthermore, so far as observations have extended, all formations exposed in the Virgilina district below the Triassic sandstone are nonfossiliferous. These conditions make it unwise to attempt to locate in the geological column any of the formations except the Triassic sandstone and the diabase dikes accompanying it. All, therefore, that will be attempted will be statements showing as far as possible the origin of the different formations, their relation to each other, and brief discussions of the important geologic events in the history of the district, together with surmises as to the age of the different formations.

MICA AND HORNBLENDE GNEISS.

The oldest rocks of the Virgilina district are found on the extreme western border of the area mapped (Pl. I), and it is assumed that its history begins with the deposition or formation of those rocks, which are of two types, a well-defined mica or biotite gneiss, and a smaller amount of characteristic hornblende gneiss, each intimately associated with the other. As has been stated in the chapter on the detailed description of the rocks, these formations resemble very closely the Carolina gneiss and the Roan gneiss, respectively, and it may be possible that future work will establish the similarity. As has been proved in regard to the Carolina and Roan formations, it is believed that the mica gneiss of the Virgilina district represents the metamorphosed equivalent of a sedimentary formation, older than the hornblende gneiss, which is believed to be of igneous origin, and to have been intruded into the sedimentary formation before its metamorphism. It is believed that these gneiss formations are of pre-Cambrian age, and that they formed the basement upon which the volcano-sedimentary series were deposited.

IGNEOUS ACTIVITY.

There is no means of knowing the interval of time that elapsed between the metamorphism of the gneisses and the beginning of the igneous activity which formed the greater portion of the rocks of the district. But it is certain that the basement rocks had suffered intense metamorphism before the deposition of the volcano-sedimentary rocks.

The beginning of igneous activity was marked by the outpouring of acid or rhyolitic lava, associated with which was explosive volcanic activity on an enormous scale. This is the period that produced the material which now forms the mashed quartz porphyry, and acid tuff, and the sericite schists which are regarded as the same as the quartz porphyry and acid tuff, only more highly metamorphosed. It is impossible to picture the details of this and the following volcanic activity, but it is believed, from the wide and regular distribution of the rocks, to have been both of the fissure types of eruption, in which the lava broke through the already-formed rocks at numerous places throughout the whole region. After a great thickness of this material was piled up, it appears that the vulcanism in a measure subsided, and that there was a change in the type of ejectamenta from acid to basic—from rhyolite to andesite—and that during the first part of the outpouring of andesitic lava and tuff the volcanic activity was either slight or intermittent. These assumptions are based upon the fact that the lower part of the basic portion of the volcano-sedimentary rocks is in part of terrigenous origin—that is, it consists of basic volcanic material intermixed with varying amounts of land waste. In fact, some of the beds are nearly pure sandstone, and others are nearly straight conglomerate.

After an unknown period in which a great thickness of this volcano-terrigenous material was laid down, the vulcanism again appears to have become very active, and it appears that the ejectamenta became clean andesite and andesitic tuff. There is no way of even surmising the duration of this type of activity, but it certainly continued long enough for an enormous thickness of the andesite and andesitic tuff to be built up. The activity seems to have subsided gradually and somewhat in the same manner as it developed, since immediately overlying the clean andesite and andesitic tuff there is an enormous thickness of volcano-terrigenous material that can not in any way be distinguished from similar material built up immediately preceding the outpouring of the andesitic material.

The evidence as to the conditions under which these volcano-sedimentary rocks were deposited is not clear and conclusive. So far as observations have extended, the acid flows and tuffs appear to have been deposited

upon dry land. At least no clearly water-laid materials such as conglomerate and sandstone were recognized. On the other hand there is nothing to prove they were air-laid or to determine that they were not laid down under water.

When the volcano-terrigenous beds which immediately overlie the acid flows and tuffs are examined in detail it is clear that a large part if not all of the material was laid down under water. There are irregularly intercalated beds of more or less pure sandstone and numerous narrow bands of well-defined conglomerate, the pebbles of which are of well-rounded quartz, and the matrix of more or less pure, fine andesitic material. In fact, the matrix is apparently as fresh and unaltered as similar material in the straight andesitic tuffs, a fact which makes it clear that the material while clearly water-laid was transported only a short distance, and that it was not exposed to weathering agencies for a great length of time. The distribution of the sandy and conglomerate beds indicates an offshore of or a flood-plain deposit. The fact that the conglomeratic and sandy beds occur in similar positions on each side of the area is regarded as evidence that the material was deposited in a shallow basin or an open arm of the sea. The latter hypothesis is regarded as the more probable of the two, since the series of volcano-sedimentary rocks increases greatly in areal extent toward the south.

The age of this volcanic activity is not known, and it has been considered by some, especially some of the early writers[a] on the subject, as pre-Cambrian, while more recent students, as well as the first writer on the subject, Ebenezer Emmons,[b] regard them as of early Paleozoic age. The most conclusive evidence on the subject is by Watson[c] and Powell, in a description of a somewhat similar volcano-sedimentary series of rocks and slates lying northeast of the Virgilina district. The slates are interbedded with the tuffaceous rocks, and contain early Paleozoic fossils. As the question stands at present there is not sufficient evidence to decide it, but it is believed that such as is available indicates that the vulcanism along the eastern border of the North American continent occurred in the early Paleozoic period.

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[a] Williams, George H.: The distribution of ancient volcanic rocks along the eastern border of the United States, Jour. of Geology, Vol. 2, 1894, pp. 1-31.

Nitze, H. B. C., and Hanna, Geo. B.: Gold deposits of North Carolina, N. C. Geol. Survey, Bull. 3, 1896, p. 37.

[b] Geological report of the Midland counties of North Carolina, 1856, p. 41, *et seq.*

[c] Watson, Thos. L., and Powell, S. L.: Fossil evidence of the age of the Virginia Piedmont slates, Amer. Jour. Sci. Ser. 4, Vol. 31, 1911, pp. 33-44.

CONSOLIDATION.

Regardless of the manner of deposition of the tuffaceous and sedimentary rocks, they must have been more or less consolidated before they could have been folded. It is believed that the process of consolidation was in progress during the deposition of the material, and that within a short time after the cessation of the volcanic activity the material had become fairly firm and solid rock. The fact that such a large portion of the series is water-laid makes it reasonably certain that the period of consolidation was short, since the cementation made possible by the presence of water would play an important part in the process and greatly hasten its completion.

FOLDING AND DEVELOPMENT OF SCHISTOSITY.

Following the consolidation of the rocks after an unknown interval, dynamic forces again became prominent, and the rocks of the district were thrown into closely compressed and for the most part overturned folds. The compressive force, as shown by the strike of the axes of the folds, acted in a northwest-southeast direction, and was so intense that not only were the rocks closely folded, but the process was continued until their original textures and structures were largely obliterated, and they were transformed into well-defined schists. It is probable that faulting may have accompanied the development of the folding, but, if so, the evidence of faults was either obliterated during the period of compression, or it was not recognized during the field studies in the district. It is also believed that much of the mineralogical alterations took place during the period of compression.

IGNEOUS INTRUSIONS.

It is believed that the interval between the folding and metamorphism of the volcano-sedimentary series and the intrusion of the granite and other rocks was a long one. One thing is certain, the rocks had been transformed into schists before the granite and other plutonic rocks now in the series came in. They are massive and show no indication of having suffered any dynamic metamorphism, facts which would be impossible if these rocks had been present in the series when it was compressed. There was no way of determining the relative age of the different intrusives except that the coarse-grained granite in the vicinity of Buffalo Lithia Springs is probably intrusive into the finer-textured granite at the same place. The intrusive rocks believed to belong to this period are granites of two types, a coarse-grained, in some instances decidedly porphyritic, and an even-granular,

fine-grained type; a coarse- to medium-textured gabbro, and small areas of diorite. From observations in areas of similar rocks outside the district, it is believed that the succession, beginning with the oldest, is diorite, granite, gabbro.[a] It is believed that the earth movements attendant upon these intrusions formed the greater part of the joints that cut the schistose rocks, in many of which mineralized or unmineralized veins of the district were developed.

DEVELOPMENT OF THE VEINS AND DEPOSITION OF THE ORES.

Closely associated with the intrusion of the granite, probably immediately following it, came the solutions forming the numerous quartz veins, and deposited the ores in the fractures previously formed in the schistose andesitic rocks. The reasons for associating the formation of the veins and the deposition of the ores with the intrusion of the granite have been given in detail in the chapter on the origin and deposition of the ores (pp. 88-93), but it may not be amiss to summarize them briefly at this place. They are: (1) The veins are highly siliceous, containing 65 to 75 per cent silica; (2) the rocks in which they occur are decidedly basic; (3) the ores and vein filling were derived from a source outside the rocks in which they occur and being siliceous they must be genetically associated with acid rocks; (4) the time of formation of veins and deposition of ores, so far as it could be determined, is approximately that of the intrusion of the granite; (5) the granite is the only acid igneous rock known in the district which could satisfy the conditions previously stated, and it is therefore believed to have been the source, or at least its intrusion opened up the source, from which the ores and vein fillings were derived. So far as observations have extended, there is no way of fixing the age of the vein formation and the ore deposition. The veins and ores show absolutely no indication of having suffered regional metamorphism, and on this account they must have been formed subsequent to any of the periods of important earth movements in the region. The last of these was the revolution at the close of Carboniferous time, and it seems to be clear that the ores were deposited some time since the close of this period, but further than this no surmises are possible with any degree of fact. What was going on in the district between the close of the ore deposition and the deposition of the Triassic sandstone is unknown. It is believed, however, that for a long period preceding Triassic time the district was under erosion.

[a] Laney, F. B.: The Gold Hill mining district of North Carolina, N. C. Geol. Survey, Bull. 21, 1910, pp. 73-74.

TRIASSIC SANDSTONE AND DIABASE DIKES.

The first geologic event of known age in the Virgilina district is the deposition of the red sandstone, a patch of which occurs in the western boundary of the portion included in the accompanying map (Pl. I), near Wolftrap station on the Richmond and Danville branch of the Southern Railway. This occurred during Triassic time, and shows that at least a portion of the district was under water, probably the bottom of a narrow arm of the sea at that time. It is not known how much of the district was covered by the Triassic sandstone, for all that remains of this formation at present is the little patch just referred to. Near the close of Triassic time occurred the intrusion of many diabase dikes into the rocks of the district. While these dikes are not numerous they are well distributed throughout the district and the surrounding region. At least two mines in the district, the Durgy and the Blue Wing, have disclosed such dikes, and in both instances it is perfectly clear that the dikes are younger than the veins and ores.

EROSION AND WEATHERING.

From the close of Triassic time all factors indicate that for the most part the Virgilina district has been under constant weathering and erosion. So active have been the agencies of erosion, that notwithstanding the fact that the region was reduced practically to base level during Cretaceous time, and then rejuvenated by uplift, it is again, from a physiographic point of view, in old age. The agencies of erosion are yet active, but the relief of the district is so subdued that weathering is more active than erosion, and, as a consequence, except in a few places, the rocks are deeply covered with soil derived from their own disintegration and decomposition.

PHYSIOGRAPHY.

The southeastern portion of the United States presents three distinct types of topography, each occupying a distinct area. These physiographic provinces, beginning at the coast and extending westward, have been named the Coastal Plain, the Piedmont Plateau, and the Appalachian Mountains.

The Coastal Plain occupies the area extending from the shoreline westward to an abrupt rise in elevation of the land known as the "Fall Line," which has a trend roughly parallel with the coast line. The belt as a whole is a rather monotonous plain without prominent elevations. Geologically it is made up of Cretaceous and younger sedimentary rocks, including much partially consolidated material.

Beginning at the "Fall Line" and extending westward to the foot of the Blue Ridge is a belt of moderate elevation—300 to 700 feet above mean sea-level. Relief is moderate and the general appearance is that of a moderately level region diversified with low-lying, well-rounded hills, and gently sloping valleys. The streams are fairly well graded and are not on the whole very swift-flowing. The rocks are for the most part of Paleozoic and pre-Cambrian age, and are of both igneous and sedimentary origin. They have suffered intense dynamic metamorphism, which has changed them for the most part more or less completely into schists and gneisses. The region has long been subjected to weathering and erosion, and for the most part the rocks are deeply covered with a thick mantle of soil and more or less completely disintegrated and decomposed rock. The region is regarded as the stumps of an ancient range of mountains which have been worn away by long periods of weathering and erosion. This belt or province is known as the Piedmont Plateau.

West of the Piedmont Plateau are the Appalachian Mountains, a region of rugged topography, long mountain ranges with many spurs, and steep, oftentimes precipitous, slopes, which comprise the highest mountain peaks east of the Rockies. The valleys are for the most part narrow. The streams have steep gradients and are consequently swift-flowing. The rocks are of Paleozoic and pre-Cambrian age, and are of igneous and sedimentary origin. For the most part they have suffered intense metamorphism which changed them into various types of slates, schists, and gneisses.

The Virgilina district lies wholly within the Piedmont Plateau, and its surface features conform to those of the province in general.

Relief.

It is not possible to discuss the surface features in detail or very accurately without a topographic map, which unfortunately is not available. The statements here made must, therefore, be regarded as only approximately accurate. However, the U. S. Geological Survey in coöperation with the State Survey has run the lines of primary levels for the district, which gives the elevation of a few places accurately. The levels were run along the railroad from Clarksville to Denniston Junction, thence to South Boston, to Keysville and to Buffalo Junction and along Dan River from South Boston to Clarksville. The elevation of the town of Virgilina is 516.1 feet.

The topography of the district is to a large extent determined by the character of the underlying rocks. This is especially true of the Virgilina

greenstone. These rocks make up the Virgilina ridge, which attains the highest elevation within the district, and which is its most striking surface feature. This ridge, while it is flat-topped, low-lying, and has very gentle slopes except where intersected by streams, forms the watershed of the district, and extends with considerable prominence through a good part of its length. It is said to extend with more or less prominence from Dan River to about 30 miles south of the state line. The most prominent portion reaches from Dan River to 5 or 6 miles south of the state line, and the part showing the greatest relief and most rugged topography is near the High Hill mine, where Hyco River crosses the ridge. The ridge is made up of the andesite and andesitic tuffs with their included terrigenous material, and its boundaries roughly delimit these formations.

Aside from the ridge, the district possesses nothing more important in the way of relief than low-lying, well-rounded hills. The large granite area in the vicinity of Redoak post-office has sufficient elevation above the surrounding country to form a low-lying, dome-like hill, deeply scored by streams, the highest portion of which is near the center of the area. Taking the district as a whole, the only prominent relief or rugged topography is along the more important stream courses, south of but including Dan River. Hyco River, Blue Wing and Aaron's creeks present fairly rugged topography along the lower portions of their courses.

Drainage.

The Dan and Roanoke rivers form the master streams of the district. Dan River crosses the district near its middle in a nearly east-west direction, while the Roanoke crosses it in a nearly southeast direction, and unites with the Dan to form the Roanoke a short distance east of the limits of the district as mapped. These streams and two others, Bannister and Hyco rivers, are antecedent streams and hold their courses irrespective of the rocks over which they flow. The courses of the other streams have been determined to a great extent if not wholly by the character of the underlying rocks, and are therefore consequent streams.

This indicates that the four rivers are perhaps older than the present topography and are, as it were, superimposed upon it, while all the other streams are flowing in courses determined largely by the nature of the rocks, and have therefore developed with and as a part of the present topography. These major streams have developed a surface configuration which in a great measure controls the direction of flow of the numerous

small streams. Many of the streams in the district have considerable fall in their courses and, as a consequence, flow fairly swiftly; in fact some of them in the more rugged portions of the district become roaring, rushing torrents after heavy summer rains. The larger streams also, during the rainy seasons of late spring and early summer, often overflow their banks and inundate considerable portions of the valleys through which they flow.

Erosion is rapid in the region, and little or no attempt is made on the part of the people to prevent excessive land wastage by control of forest fires and by grassing the land areas most susceptible to wash. As a result much of the soil is washed into the streams, which especially during the rainy seasons carry heavy burdens of sediment, and as as consequence, a great deal of the land is depleted and very lean.

Physiographic History.

A detailed examination of the present surface, in its relation to the underlying rocks and the relation of the present drainage systems to the geologic formations as well as to each other, offers certain indications of previous physiographic conditions of the Virgilina district.

A close consideration of these facts makes it possible with some degree of probability to make a few statements and surmises as to the physiographic history of the district. The surface features of a region have not come into their present form and conditions by mere accident, but have been governed by certain laws and conditions. The rate at which a stream deepens and modifies its channel depends upon many items, among which may be mentioned precipitation, gradient, character of formations over which it flows, and these in turn are dependent upon the ever-varying geologic conditions of the region. Each major type of surface has its own peculiar type of drainage, and as the surface features are changed by any geologic process, the drainage likewise changes and accommodates itself to the new conditions. One change does not always, nor usually, for that matter, completely obliterate the features of the previous cycle, remnants of which can almost always be recognized upon close examination. While it will be by no means possible to trace the physiographic history back to the beginning, it will be possible to enumerate a few of the most important items.

The nature of the rocks making up the greatest part of the Virgilina district—volcanic flows, volcanic tuffs with which in places are large amounts of terrigenous material, sands, and water-worn pebbles, is clear evidence that at the time of deposition the area was low-lying and in part

at least, under water—probably offshore or estuary conditions. After an enormous thickness of the volcano-sedimentary material had been built up, conditions changed and the region was uplifted high above the sea, probably into a mountain range. The closely folded, highly metamorphosed condition of the rocks is strong evidence for this assumption. Erosion then became active and a system of drainage was established, but what relation this drainage bore to the present system it is not possible to state. That the region was finally worn down to a comparatively level surface, and then submerged in part at least below the sea, is shown by the areas of red and brown sandstone of Triassic age which are found in the region and in one small area in the district. What the physiographic features were during Triassic times one can only surmise. That there was a well-established drainage system, and that at least a part of the district was submerged below the sea are certain, but there is no way of determining the location of the streams nor of knowing how much of the district was submerged.

It seems probable that the present drainage system has established itself since the close of Triassic time, but at what period following this time the master streams assumed their present courses is not known. It is certain, however, that Dan and Roanoke rivers and possibly the Hyco assumed approximately their present courses prior to the elevation of the district with which the present creeks and smaller streams are associated.

These conclusions are justified by the fact that the rivers follow courses contrary to or regardless of the present topography and geologic structure of the district. Their courses are largely, if not wholly, independent of the rock structure of the district, while the courses of the smaller streams have been determined in a large measure, if not wholly, by the geologic structure and the character of the formations over which they flow.

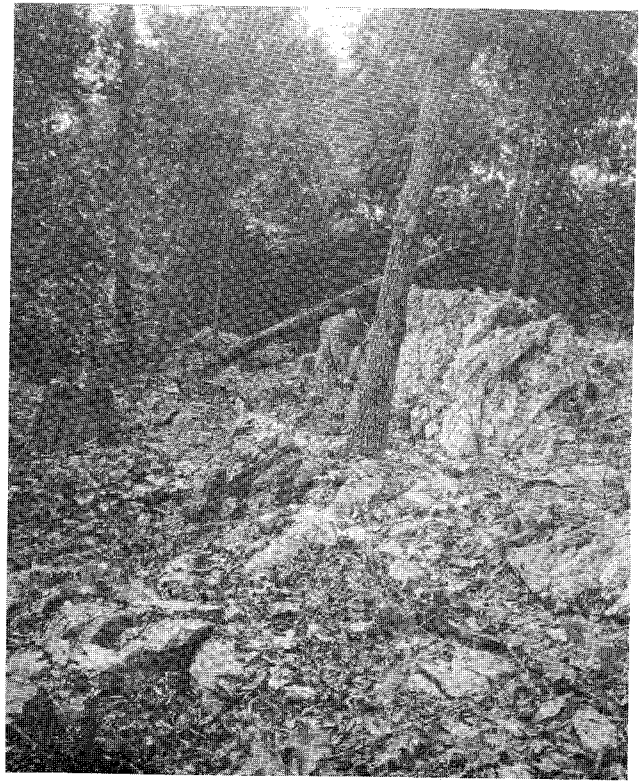
It appears, therefore, that the large streams had assumed their courses prior to the last uplift of the district and that they have been able to wear down their channels as rapidly as the country was uplifted, and thus that to-day these streams have courses that are genetically related to previous surface conditions rather than to the present, as are the smaller streams.

DETAILED DESCRIPTION OF THE VEINS AND ORES.

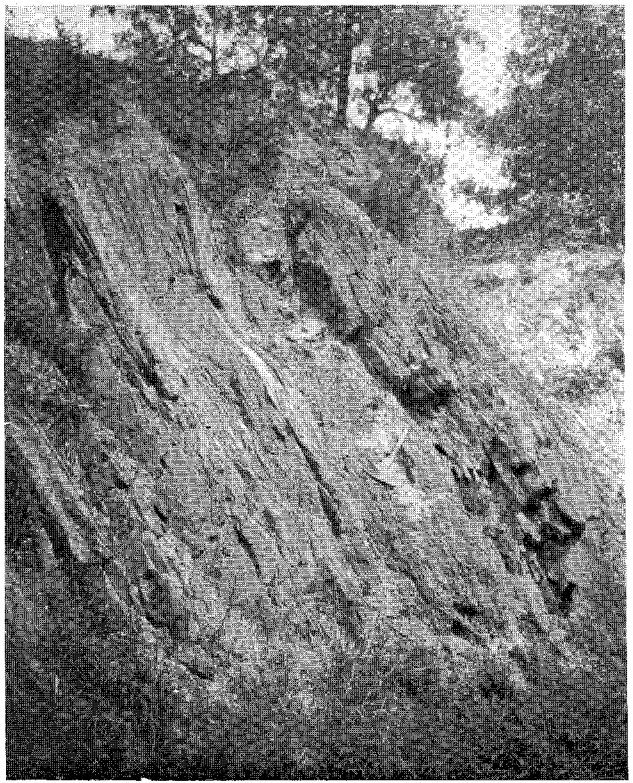
VEINS.

General statement.—The veins of the Virgilina district are typical fissure veins. With the exception of a few mineralized areas in more or less epidotized portions or zones of the true basic schist, the ore deposits

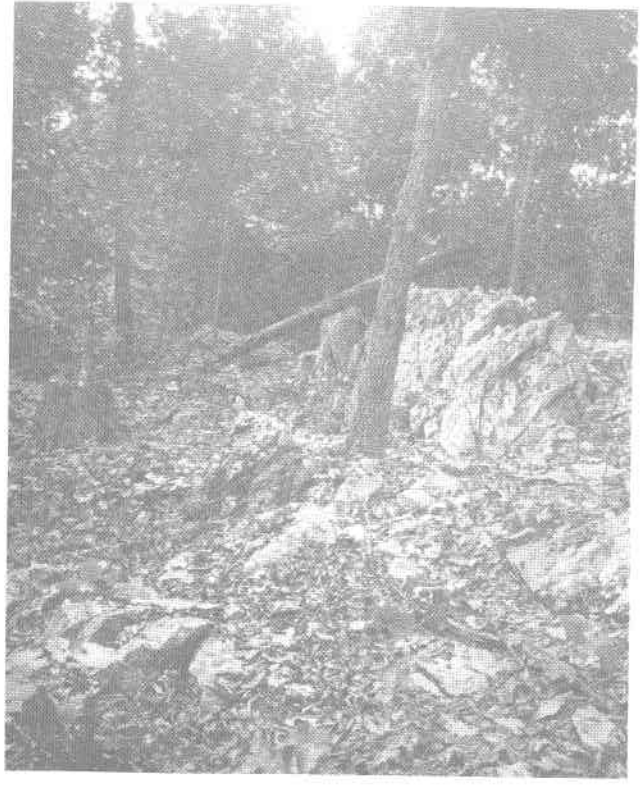
all occur in well-defined veins in which quartz is by far the predominant mineral. Calcite, epidote, chlorite, in a few instances small amounts of plagioclase, probably albite, and in some instances a little orthoclase, are present in varying amount. These veins occur in fractures—in some instances possibly fault planes—which, taken as a whole have a more northerly trend than the schistosity of the country rock, which averages about 30 degrees east of north. The majority of the veins have trends varying from 30 degrees east to 10 degrees west of north, while a few—the so-called cross-courses—vary from 10 to 45 degrees west of north. Almost every vein, except the "cross-courses," throughout some part of its length follows the schistosity of the country rock. After following the schistosity for varying distances, the vein is noted to assume at once a more northerly trend, usually only a few degrees, than the schistosity. This course will be held also for varying distances when it again assumes the trend of the schistosity, the same being repeated again and again. This feature of the veins offers strong evidence in favor of the hypothesis that the formation of the veins is a comparatively recent geologic event, and that prior to their formation the country rocks had been altered into schists and were in much the same condition that they are at present. If such were the case it would be quite normal for the shearing forces to relieve themselves in part along the parting planes of the schists, which are always lines of weakness. Thus any line of stress differing in direction from the trend of the schistosity only a few degrees would normally, in part at least, be relieved by shearing in the planes of greatest weakness in the country rock, that is, in the planes of schistosity. The veins are usually not continuous for long distances, but in a few instances a single vein may be traced either by the outcrop or continuous quartz débris for distances varying from one to two miles, and in one case the so-called Mother Lode vein was traced by outcrop or almost continuous quartz débris for nearly three and one-half miles. All veins of the district have characteristic peculiarities, such as "pinches" and "swells" both linearly and vertically, which tend to give them the appearance of numerous connected quartz lenses. In fact, in many instances the lenses are disconnected, and in others they are joined together only by a mere stringer of quartz. In other cases the fractures are apparently continuous for longer distances than the veins show them to be. In such cases vein matter has been developed only at irregular intervals in the fissures. These peculiarities have a practical application in doing development work, in that even though the vein pinches to very narrow limits, or is lost altogether, the fracture in which it



(A) Typical outcrop of a large but barren quartz vein near High Hill mine. Few veins outcrop as prominently as this one.



(B) Typical but barren vein exposed in railroad cut near Christie, Va. The irregularities shown by this vein, such as "pinches" and "swells" and lenticular form, are characteristic of all veins that have been opened in the district.



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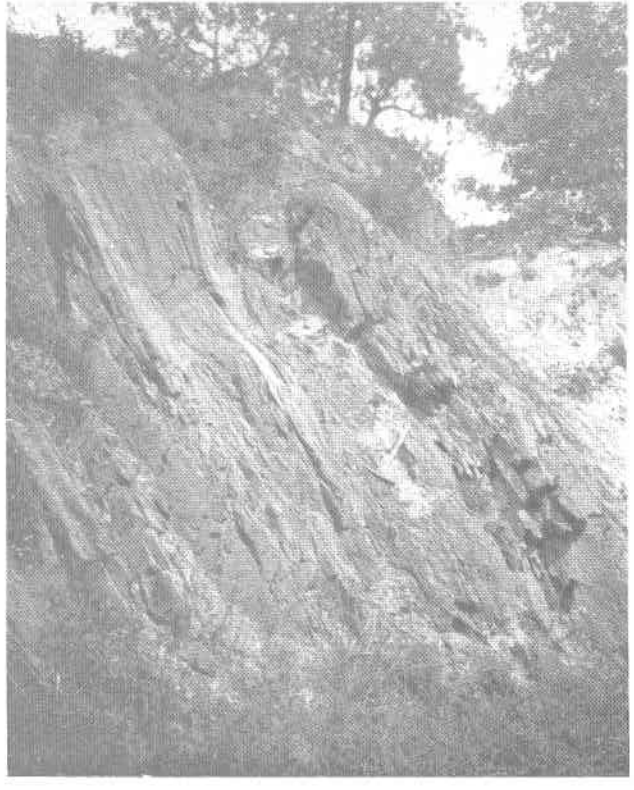


(B) Typical but barren vein exposed in railroad cut near Christie, Va. The irregularities shown by this vein, such as "pinches" and "swells" and lenticular form, are characteristic of all veins that have been opened in the district.

developed remains, thus giving the miner the walls of his vein which he can follow with some assurance that they may open again and more vein matter come in.

It is rare that an important vein fails to present some kind of an outcrop at some place along its course, but in a few instances small veins which had no surface outcrop have been exposed by cross-cutting and other development work. Also in many instances a well-defined vein will, at many places in its course, show no outcrop beyond a very small or insignificant amount of quartz débris on the surface. As a general rule, vein outcrops are rare and are found only where the vein happens to be exceptionally large or the topography very favorable for outcrops, such as steep-hill slopes or a stream or road cutting. The common and also unmistakable indication of a vein is the great number of quartz fragments marking on the surface of the ground the course of the vein. The usual outcrop consists of a ledge of irregular quartz boulders varying in size from a few inches up to several feet in diameter. A typical outcrop is illustrated in Plate IV (A).

Very few of the workable mineralized veins in the district are more than 10 feet wide, and the average width is about 3 feet. That they are numerous is shown by the large quantity of quartz débris which is found in greater or less abundance everywhere. As opened by mining the veins in general have well-defined walls which part readily from the vein in mining, although the mineralization is not confined exclusively to the vein, a small, but often important amount of ore occurring in the schist at the contact with the vein. In many instances numerous fragments and plates of country rock are included within the vein. This is so marked in some cases that it gives the vein a banded or brecciated appearance. The former especially is true at the High Hill and Blue Wing mines and to a less extent at the Durgy mine. At the last-mentioned mine in addition to the pseudo-banding, about 100 feet north of the shaft, on the 335-foot level the vein was split and included a "horse" of country rock in the form of a lens about 25 feet thick and 75 to 100 feet long. All the mines show numerous more or less altered angular fragments of the country rock, indicating that there must have been more or less brecciation when the fractures were formed. The dump at the Thomas mine shows more of such included fragments than any other mine in the district. In all such cases some of the fragments and plates of country rock included in the vein show evidence of metasomatic replacement in that they are in many instances more or less completely altered to quartz. This phenomenon is especially well shown in the Blue Wing vein. The

quartz thus formed generally has a decided blue or dirty gray color and contrasts strongly with the clean vitreous white quartz of the vein. In many instances near one of the walls a vein will consist of thin layers of quartz interleaved with similar layers or plates of schist, indicating that at the time the fracture was formed the schists were rifted or torn apart along the planes of schistosity, and that the vein matter had been subsequently deposited in the rifts.

In some mines, especially the Durgy and the Blue Wing, the walls at the contact with the vein in many places are very smooth and closely resemble slicken-sided surfaces. Such, indeed, may be the case, since it is not at all unlikely that there was considerable movement at the time the fissures were formed, or even since that time. Where there are no slickensides nor even any indication of them, the contact between vein and wall is generally clear-cut and sharp, and there are no very evident indications of replacement of wall rock by quartz and other vein matter. The only change at the contact is a kind of dark-colored chloritic material somewhat resembling altered schist, which in places wraps the vein. Weed speaks of this feature as being prominent at the Holloway vein, and describes it as a micaceous wrapping probably derived from the country rock.

Only a small percentage of the veins are mineralized, and they are almost exclusively confined to the Virgilina greenstone. With the exception of the Kay mine, every prospect opened to any important extent in the district is in a vein in the greenstone. About the only way in which the barren veins differ from those that contain the ores is in the fact that the ore minerals are lacking. Possibly calcite and epidote are also less plentiful in the barren veins, and feldspar and in places hematite are equally if not more abundant. So far as is known the quartz of the barren vein is similar in all respects to that in the veins which carry values. The veins at the different mines have been described in detail under the descriptions of the respective mines, and since this chapter is confined to descriptions of the veins as a class and to generalizations in regard to them, these descriptions will not be repeated here.

It may be noted that, if upon the accompanying geological map, Plate I, a line be drawn approximately 30 degrees east of north from the Duke mine, it will pass through or very near the following mines and prospects: The Cross Cut prospect, the Durgy mine, the Northeast prospect, the Copper World mine, the Gillis mine, the Thomas mine, the Holloway mine, and the Blue Wing mine. Thus this line forms, as it were, an axis along which practically all the developed mines of the North Carolina portion of

the district lie. It may also be noted that a second, but so far as developed at present, a secondary axis or zone of mineralization, is located about three-fourths of a mile northwest of the main axis and runs parallel with it. The ores of the main axis are those characteristic of the Virgilina district and consist of bornite and chalcocite in the usual quartz-epidote-calcite gangue, while that of the second includes the native copper deposits of the Catoctin type.

The writer freely confesses that thus far he has not been able to find a satisfactory cause for the relationships just described. Several factors suggest themselves as possibly having a bearing on the subject, among which may be mentioned the following: The mineralization may be associated genetically with certain phases of the Virgilina greenstone and consequently is found only where these phases of the rock occur. Or on the other hand, the mineralized bands or zones may represent lines or zones of deep fracturing and faulting which opened channels through which the mineralizing solutions came into the greenstone from an entirely outside source. The first hypothesis appears to fail because of the fact that, so far as could be determined, the greenstone of the mineralized zones does not in any way differ petrographically from that outside of these zones. Many factors seem to sustain the theory that the mineralized bands or zones represent lines of deep fracturing and it is, therefore, offered as a tentative explanation of the phenomena.

NATIVE COPPER DEPOSITS.

The deposits of native copper and cuprite in epidotized portions or zones of the country rock, while not occurring in veins, should be considered in this chapter. Thus far these deposits have amounted to very little from a commercial standpoint, but to the student of ore deposits they are very important, and of course, there is a possibility that such a deposit on a large enough scale to be worked on a commercial basis may be discovered. These native copper deposits are included by Weed[a] in his "Catoctin type."

The writer had little opportunity to study this type of deposit, there being only one small prospect in the native copper zone in operation at the time of the field examinations. Because of this, details were not obtainable and but little in the way of generalization can be given. Thus far only a few openings have been made in this type of deposit, and these have been for the most part confined to a narrow zone beginning at the southern

[a] Weed, Walter H.: Types of copper deposits in the Southern United States, Trans. Am. Inst. Min. Eng., Vol. 30, 1900, p. 452.

limits of the town of Virgilina and extending perhaps two miles southwestward. So far as noted there is no vein and no typical gangue minerals, unless the epidote and quartz be so regarded, and the copper occurs in the metallic state as small grains and small irregular areas in the highly silicified and epidotized areas or zones in the country rock. Unlike the vein deposits, in linear extension they appear invariably to follow the trend of the schistosity of the country rock. The native copper so far as noted is confined to areas of epidote, and in most instances in quartz stringers and areas in the epidotized schists, suggesting that the solutions which produced the alterations in the country rock also brought in the copper. It may also be further suggested that the fracturing was not extensive enough to permit the formation of the usual vein, the schists having been only sufficiently torn apart to permit copper-bearing solutions to circulate to a limited extent through them. This, however, does not throw any light on the question as to why the copper should have been deposited in the metallic state instead of as sulphides, as in the quartz veins. It might be suggested that ferrous iron in the minerals of the country rock may have caused it. It is known that minerals, even silicates, rich in ferrous iron may, under certain conditions, reduce copper in solutions to the metallic state.

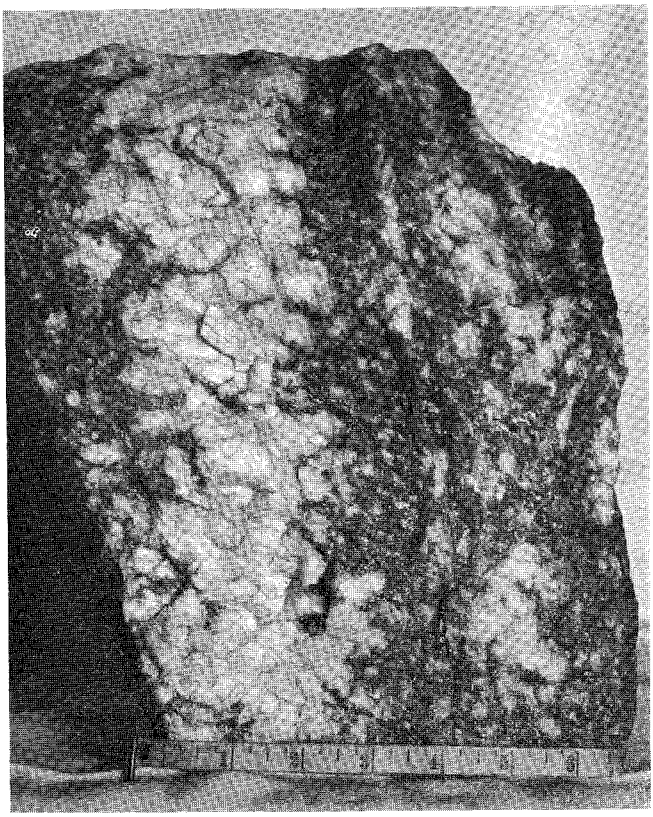
In a few instances native copper was noted in amygdules in epidotized schist derived from areas of amygdaloidal andesite intercalated in the tuffs.

The cuprite which occurs in this type of deposit is not confined to the epidote and quartz, but is found in the parting planes of the schists near the native copper in epidote. In some instances small areas were noted in the quartz and epidote, filling spaces that had once been filled with native copper. Other areas were seen in which a core of copper still remained. The cuprite is believed to be of supergene or secondary origin and to have been derived from the native copper.

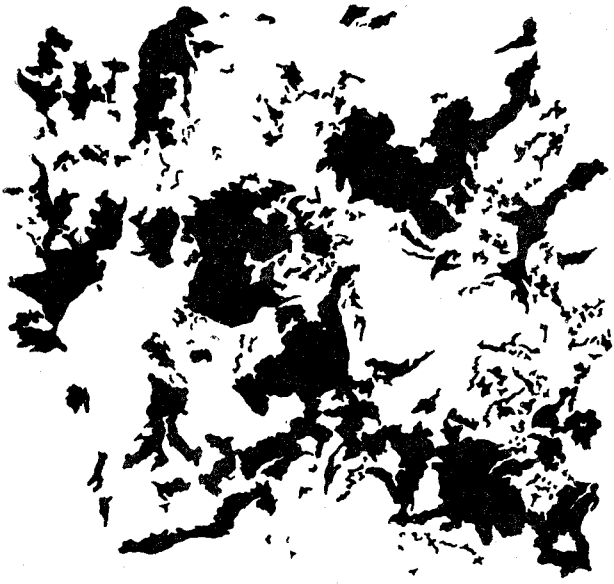
MINERALOGY OF THE VEINS.

General statement.—The gangue minerals of the veins, exclusive of included fragments of schist, named in the approximate order of their abundance are: Quartz, calcite, epidote, chlorite, hematite, sericite, albite, and possibly other plagioclase feldspars in small amount, and pink orthoclase.

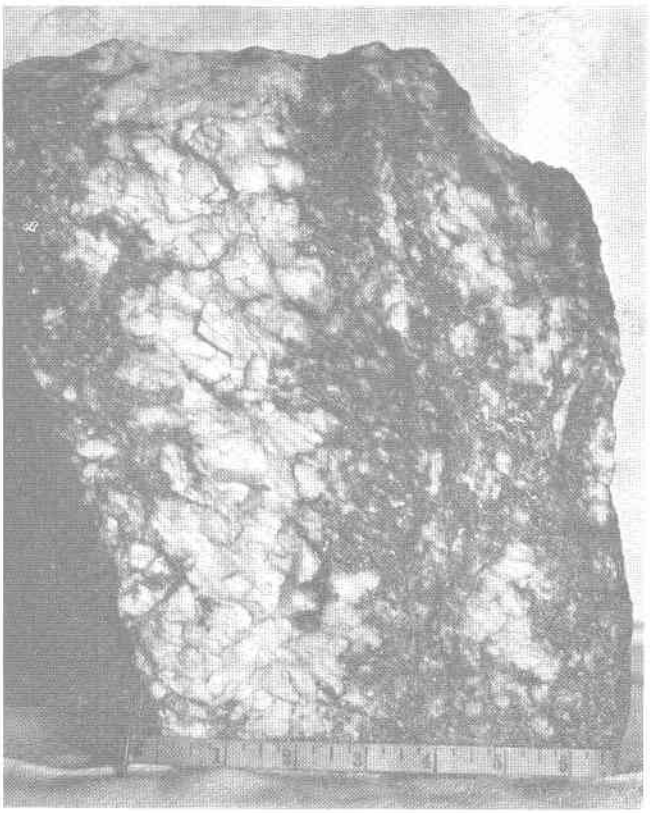
The ore minerals named in the approximate order of their abundance are: Bornite, chalcocite, native copper, malachite, azurite, cuprite, chalcopyrite, chrysocolla, klaprothite (?), pyrite, argentite, silver, and gold. Of these minerals, bornite (in part), chalcocite (in part), chalcopyrite (in



(A) Photograph of a specimen of ore from the Wall mine showing the relation of ore and gangue. The vein was divided at the point from which this specimen was taken, and the piece here figured represents the entire width of one portion of the vein.
Dark areas = ore, chalcocite and bornite. Light areas = vein matter, largely quartz.



(B) Tracing made from a polished surface of a specimen of ore from the Wall mine, natural size. Shows the relation of the ore to the quartz gangue. This relationship is typical of all the mines in the district. The ore and quartz appear to be of contemporaneous deposition.
Black = ore, chalcocite and bornite. White = gangue, largely quartz.



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part), pyrite, klaprothite, argentite, copper in the native copper deposits, and gold are regarded as hypogene or primary, while a part each of the chalcocite, bornite, and chalcopyrite, and all the native silver, cuprite, malachite, azurite, and chrysocolla are supergene or secondary.

From these statements it can be seen that the mineralogy of the veins of the Virgilina district is simple, there being few rare or complex minerals. The gangue minerals and the hypogene ore minerals are so intricately intermixed and intergrown that there is little doubt of all being contemporaneous in development. Typical relations between ore and gangue are shown in Plate V.

DETAILED DESCRIPTION OF GANGUE MINERALS.

Quartz.—The ores as they occur in the ore shoots that have been opened contain an average of 2½ to 3 per cent of copper, and carry an excess of from 70 to more than 75 per cent silica. The veins taken as a whole will carry a much higher percentage of silica. This shows at a glance that the veins must be made up largely of quartz.

The quartz of the veins is for the most part of the white vitreous variety, quite massive, and, while completely crystalline, rarely occurs in the form of crystals. As a rule it is very solid and dense and only in very rare instances does it show honeycomb structure. In a few places, notably in an abandoned field about 3 miles north of Virgilina, well-terminated crystals were found in the quartz débris on the surface. Only one end of the crystals showed perfect terminations, the other being broken or irregular, making it appear as if the crystals had formed with their points projecting into cavities. The forms on the crystals are simple, only common prism and pyramid faces having been noted. Crystals at this point were fairly numerous. They were peculiar in one respect, being made up of zones of clear transparent quartz alternating with others of white or milky appearance. At the Seaboard mine and to a less extent at the other mines quartz occasionally occurs as poorly terminated or rounded crystals which in some instances project into the larger masses of ore. As a rule the faces of such crystals are not well developed and they closely resemble rounded pebbles. Well-terminated quartz crystals occur in small openings or vugs associated with calcite crystals in the High Hill mine. Many fragments of the schists occur as inclusions in the veins, and in a few instances some of these were partially replaced by quartz. In many cases they have sharp and clear-cut boundaries and show little or no indications of metasomatism. The primary ores and all other minerals in the veins are inti-

mately and intricately intergrown with the quartz, which makes up from 50 to over 75 per cent of the veins.

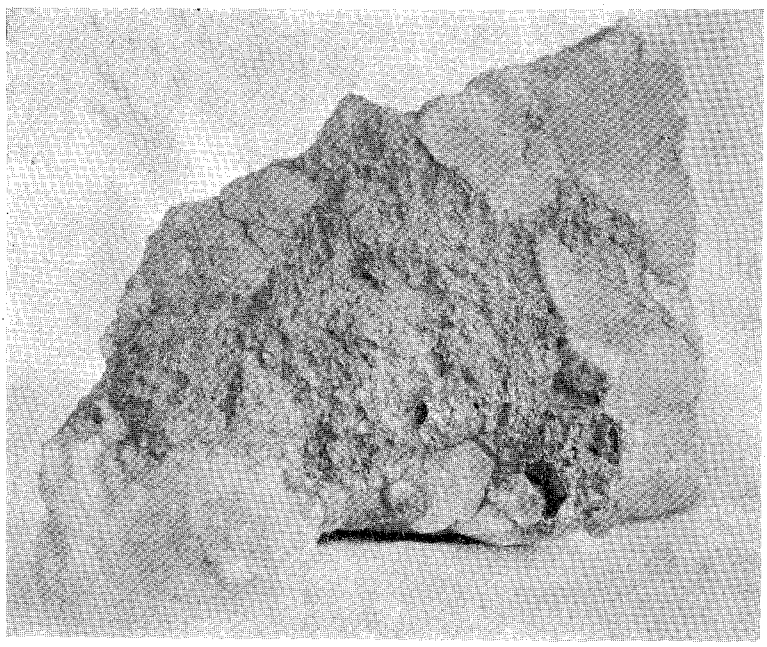
Calcite.—Calcite is next in importance to quartz. It occurs regularly in all the veins that have been opened, but is more abundant in some mines than in others. The Blue Wing vein contains much more of this mineral than any other mine in the district. It is massive, crystalline, and irregularly distributed through and intergrown with the quartz. This in fact is typical of the occurrence of calcite in all the veins. Very rarely is it found in crystals as in the High Hill mine, where small vugs are lined with well-terminated quartz and calcite crystals. Pogue[a] describes two types of calcite crystals from the High Hill mine, one type consisting of a combination of the positive rhombohedron $r(10\bar{1}1)$ and the rare scalenohedron $G:(72\bar{9}5)$, and the other of a symmetrical combination of the scalenohedron $Y(32\bar{5}1)$ and the negative rhombohedron $e(01\bar{1}2)$ modified by the positive rhombohedrons $r(10\bar{1}1)$ and $k(50\bar{5}2)$, and the rare scalenohedron $G:(7\bar{2}95)$.

In the Seaboard and Copper King mines calcite crystals occur with poorly developed faces. They are associated with quartz, epidote, albite in good crystals, and the ores. In ore from the Copper King mine copper crystals are occasionally found projecting into masses of bornite and chalcocite. (See p. 157.)

Calcite as it usually occurs is massive and intimately intergrown with the quartz in such manner as to make it clear that the two minerals are contemporaneous in development. The ore minerals occasionally occur in the massive white calcite in the same manner as they are found in the quartz. Very little calcite was noted in the veins in which the predominant values lie in gold; however, it is present to some extent in the Red Bank vein. (See p. 161 for description.)

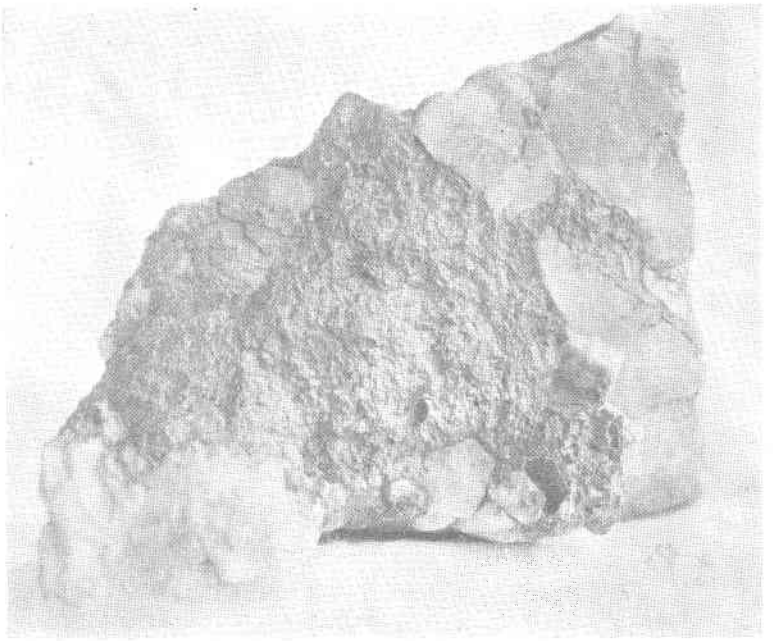
Epidote.—Epidote as it occurs in the veins possesses only its usual and normal characteristics, and is generally intimately intergrown with the quartz and rarely with the calcite. Where abundant it carries the sulphides as do the quartz and calcite. The color is the usual pistachio green, and its texture is generally granular, rarely in well-terminated crystals. In some places, especially in the native copper deposits, epidote and quartz occur in alternating bands. In such instances the epidote is always granular. It rarely or never occurs in crystal form.

[a] Pogue, J. E.: Crystallographic notes on calcite, Smithsonian Miscellaneous Collections, Vol. 52, 1909, Pt. 4, pp. 467-468.



(A) Photograph, natural size, of a specimen of ore from the Copper King mine showing association of ore (chalcocite and bornite) and calcite. Some of the calcite which is imbedded in the sulphides is in the form of well-terminated crystals.

(B) Photomicrograph of a polished section of ore from Blue Wing mine showing plates of hematite in quartz. Hematite occurs in both sulphides as well as in the rocks and gangue minerals of the district. An area of intergrown bornite and chalcocite is shown on one side of the figure, and a few small areas of chalcocite occur in the quartz.
White = hematite. Light gray = chalcocite. Darker gray = bornite.
Darkest gray = quartz.



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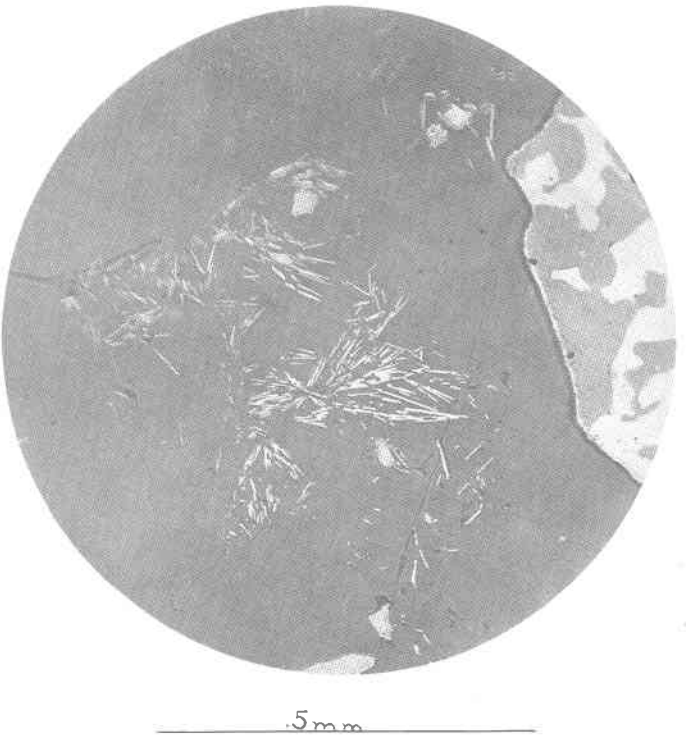


(B) Photomicrograph of a polished section of ore from Blue Wing mine showing plates of hematite in quartz. Hematite occurs in both sulphides as well as in the rocks and gangue minerals of the district. An area of intergrown bornite and chalcocite is shown on one side of the figure, and a few small areas of chalcocite occur in the quartz.
White = hematite. Light gray = chalcocite. Darker gray = bornite.
Darkest gray = quartz.

Chlorite.—Chlorite is an abundant gangue mineral in all the mines, but is more plentiful in some than in others. It possesses only its normal characteristics, is generally dark green in color, and is likely to be found in masses made up of tufts or bunches which show an aggregate polarization effect somewhat similar to that of chalcedony. In some instances the chlorite might be confused with sericite when the two occur in the same section. They may be distinguished from each other by noting the facts that chlorite is almost invariably a rather dark green in color, that it does not show the change in relief when rotated on the stage of the microscope which is characteristic of sericite, and that it always has its characteristic low birefringence. In a few places, especially in some of the ore from the Copper King mine, in which the mineral is very abundant, chlorite is intimately associated with the sulphides, and appears, in some instances, to have been replaced by them. However, in the specimens of this type that were studied, the evidence was not conclusive, and it is not certain that chlorite and sulphides were not of contemporaneous deposition.

Hematite.—Micaceous hematite, or specularite, as it is sometimes called, is present as a gangue mineral in all the mines of the district. For the most part it is present only in small amount, but in some places it is more abundant than the sulphides. This is especially true of a small prospect about half a mile southeast of the Blue Wing mine in which hematite makes up more than 60 per cent of the metallic minerals of the vein as shown in the material on the dump. In many instances the quartz of the gangue is literally filled with minute plates of hematite. A typical area of this kind is shown in Plate VI (B). In addition to its prominent place as a gangue mineral, hematite is also widely distributed throughout the country rock.

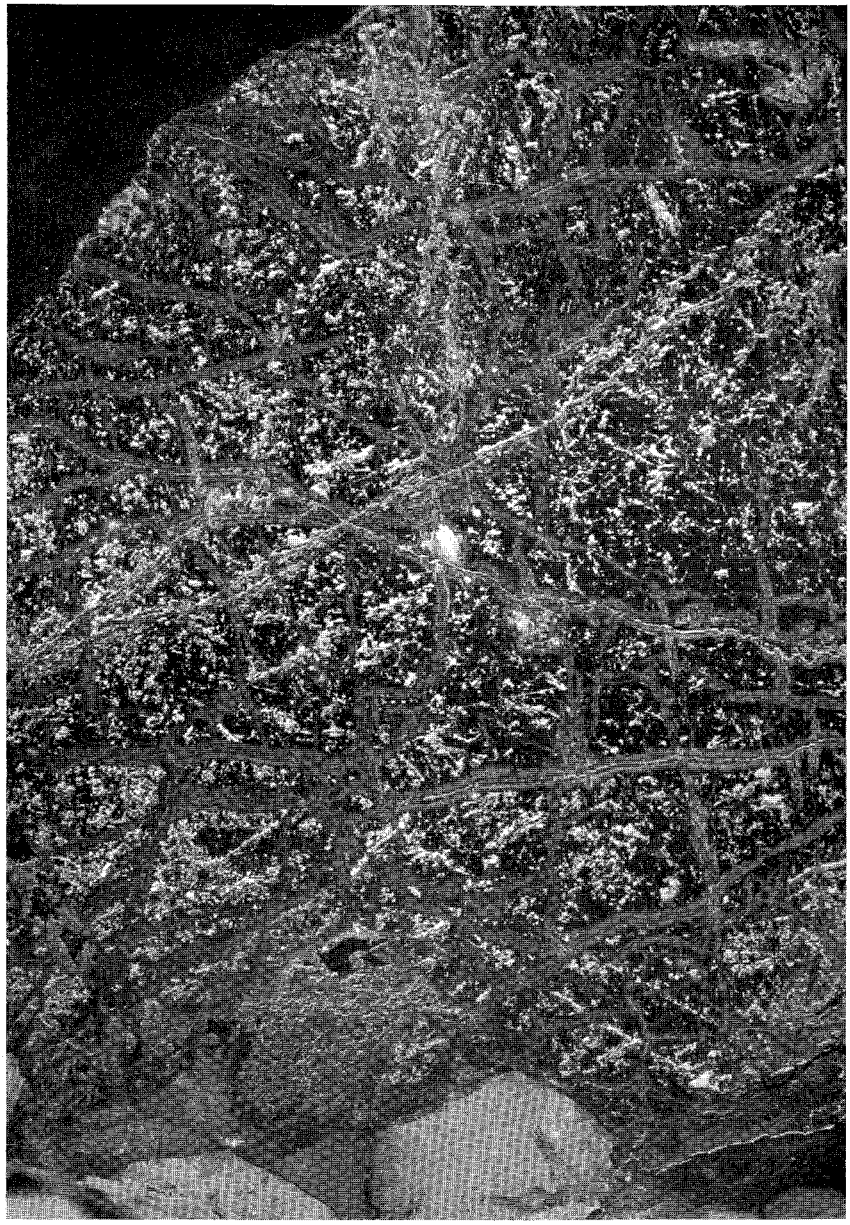
Sericite.—Another of the persistent gangue minerals, and one which is present in appreciable amount, is sericite. Almost any section of the ores and gangue from any mine in the district will show sericite very intimately associated with the sulphides. It occurs both as masses projecting from the other gangue minerals into the sulphides and as irregular bunches of crystals included within them. So far as the writer's observations have extended, the relation of the sericite to the sulphides does not warrant any positive statement as to the relative age of the two. He is inclined, however, to regard them as of contemporaneous deposition. The rôle of sericite as a gangue mineral has recently been studied in much detail by Rogers,[a] who,

[a] Rogers, Austin F.: Sericite, a low temperature hydrothermal mineral, Economic Geology, Vol. 11, 1916, pp. 118-150.

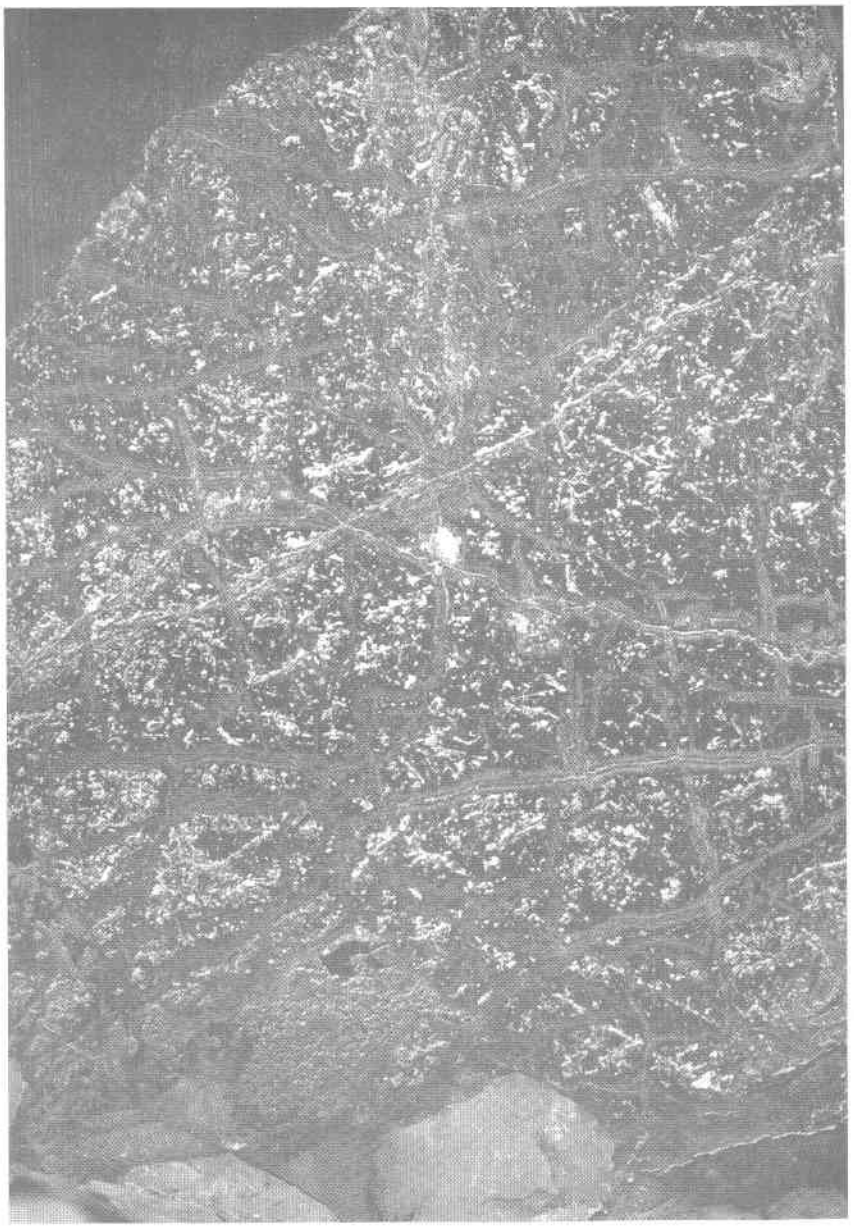
after an examination of a number of polished and thin sections of the Virgilina ores, comes to the conclusion that the sericite is later than the hypogene chalcocite and the bornite, but earlier than the supergene chalcocite. The article is illustrated with photomicrographs of polished sections of ore specimens from the Durgy and the Blue Wing mines, which Professor Rogers interprets as showing that the sericite is younger than the hypogene but older than the supergene sulphides. The writer, after a very careful study of many polished sections as well as many thin sections of the Virgilina ores and also a careful study of Professor Rogers' photographs, believes that the evidence presented by the ore sections is not conclusive, and that it points more strongly toward a conclusion that the sericite is contemporaneous with the hypogene sulphides.

Albite.—Albite, and possibly other plagioclase feldspars, is of frequent occurrence as a gangue mineral in the Virgilina ores. It usually occurs as well-developed crystals which vary in size from one-fourth of an inch to one inch in longest direction. It is intimately associated with quartz, chlorite, calcite, and the hypogene sulphides. In the Copper King mine albite occurs plentifully in well-formed crystals in massive sulphides which appear to have replaced chlorite, and the same hand specimen occasionally shows albite, quartz, and calcite in close association with the sulphides. It occurs in the Seaboard mine (shaft No. 3), with quartz, calcite, epidote, and the hypogene sulphides. It is also present in small amount in all the other mines of the district, but was not found in such intimate relations with the sulphides as in the mines just mentioned. In many of the prospect openings made in different barren veins in the district, albite is very abundant. This is especially true of an abandoned prospect in an old field about one-fourth of a mile southwest of the store at Red Bank. In the material on the dump at this place a cream-colored feldspar, probably albite, is second in abundance as a gangue mineral only to quartz. In the Red Bank gold mine albite and a delicate pink feldspar, probably orthoclase, occur frequently in stringers and veinlets in the ore and in the associated rock.

Orthoclase.—A delicate pink or flesh-colored feldspar, which, so far as methods of identification could determine, in the absence of chemical analyses, is orthoclase, which is found as a gangue mineral in the Holloway, Durgy, and Blue Wing mines, and in considerable amount in the two Cornfield prospects just south of Virgilina. In the first-mentioned places the mineral was not found in actual contact with the ores, but in the Cornfield prospects it serves as a host mineral for all the different hypogene sulphides.



Photograph of a polished surface of ore from the Seaboard mine, x10. This specimen shows a mass of bornite penetrated in all directions by a mesh or network of chalcocite which has formed in fractures in the bornite. This type of chalcocite is clearly of supergene origin and is typical of all such chalcocite examined, the only difference being the stage of development. This one is farther advanced than any of the others shown in this report. The line in the center of many of the chalcocite veinlets is quartz and marks the position of the fracture in which the chalcocite began to develop. Running diagonally across the specimen is a more recent fracture which cuts both bornite and chalcocite veins. A tiny veinlet of chalcocite has formed in this fracture.



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It frequently occurs in the form of small veins or stringers in the country rock in the vicinity of the veins. It is also fairly abundant in the Red Bank gold mine, occurring in a similar manner to that in the other mines. The occurrence of orthoclase as a gangue mineral in the ore deposits is of considerable importance in considering the question of the origin of the ores and the solutions which deposited them. So far as is known orthoclase does not occur as an original mineral in the Virgilina greenstone. The discovery of it in appreciable amounts in the ore deposits, therefore, is strong evidence in favor of the belief that the ores and the solutions depositing them were derived from a source or sources entirely outside of the greenstone, and in all probability from a granitic rock. No such rock except the Redoak and Buffalo granites is known in the district, and it is therefore believed that the ore deposits are genetically related to the granite and that they were formed contemporaneously with the intrusion of the granite masses, or immediately following the intrusion while the magma was cooling and giving off its emanations.

DETAILED DESCRIPTION OF THE ORE MINERALS.

General statement.—The ore minerals of the Virgilina district, named in the approximate order of their abundance, are: Bornite, chalcocite, malachite, native copper, azurite, cuprite, chalcopyrite, chrysocolla, klaprothite, pyrite, argentite, silver, and gold. It should be stated that this enumeration of the minerals is applicable to the copper and not to the gold deposits. In the gold deposits there is very little copper and the principal mineral is native gold, which occurs in the more or less silicified schist.

The following minerals are regarded as of hypogene or primary deposition: Bornite (in part), chalcocite (in part), native copper (in the deposits of the Catoctin type), chalcopyrite (in part), klaprothite, pyrite, argentite, and gold. The following minerals are regarded as of supergene or secondary deposition: chalcocite (in part), native copper (in all except the deposits of the Catoctin type), chalcopyrite (in part), bornite (in part), malachite, azurite, cuprite, chrysocolla, and native silver.

It might be well to add a word of explanation as to the use of the terms hypogene and supergene in describing the ores. These terms are not exact synonyms of the terms primary and secondary, respectively. Hypogene is used to designate the mineralization brought about through deep-seated agencies, solutions or otherwise. Supergene is used to designate the alterations and mineralization which have been brought about through superficial agencies, meteoric waters, oxygen, etc. It is, therefore, clear that they are

not used synonymously with the words primary and secondary as applied to the deposition of ores. A mineral may, therefore, be secondary in a mineralogical sense and still be of hypogene origin. In fact, some students of the Virgilina ores believe that the chalcocite which occurs in graphic intergrowth with the bornite is, in a mineralogical sense, secondary to the bornite, but still of hypogene origin. That is, they believe that this chalcocite was formed later than the bornite, but by deep-seated agencies. Such observers believe that the chalcocite which fills fractures in the bornite is also secondary in a mineralogical sense and at the same time of supergene origin. That is, they believe this chalcocite is younger than the bornite, that it was formed by descending meteoric water, and that it was probably derived from the bornite.

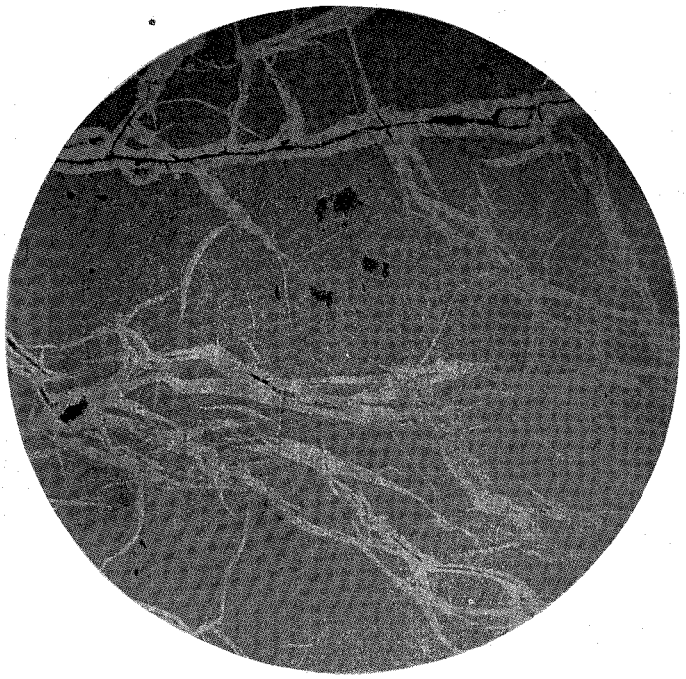
Bornite.—Bornite (peacock copper, Cu_5FeS_4, 63.33 per cent copper, 25.55 per cent sulphur, and 11.12 per cent iron) is the most abundant of the hypogene minerals of the district. It occurs in all the ore deposits and forms the most important of the so-called primary minerals. It is always massive, but often has a recognizable crystalline structure, and is almost invariably more or less intricately intergrown with chalcocite. On a fresh fracture the mineral has a beautiful bronze color, tarnishing readily and quickly to a kind of copper red, which in turn changes after a short time to an indigo blue. The purest bornite found in the district, that is, the bornite with the least chalcocite, occurs in the Seaboard mine. In most occurrences it is so intimately intergrown with chalcocite that it is all but impossible to free the two. When a polished section of bornite is etched and examined with the microscope it is seen to be made up of an interlocking mass of medium-sized, anhedral grains of different orientation. When the mineral is intergrown with chalcocite the intergrowths, when they involve the individual grains, are invariably along definite crystallographic directions of the two minerals.

In a recent article[a] Allen has shown that the chemical composition of natural bornite is Cu_5FeS_4 instead of Cu_3FeS_3 as given in most text-books of mineralogy. In this paper he quotes an analysis of bornite from the Virgilina district by Dr. Chase Palmer[b] of the U. S. Geological Survey as follows:

	Per cent
Cu	62.50
Fe	11.64
S	25.40

[a] Allen, E. T.: The composition of natural bornite, Am. Jour. Sci., 1916, Vol. 41, pp. 409-413.

[b] Jour. Washington Acad. Sci., 1915, Vol. 5, p. 351.



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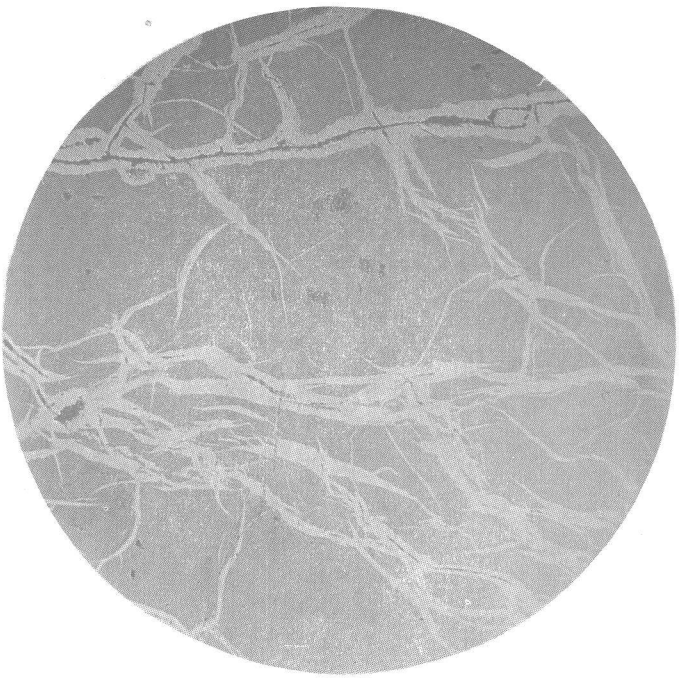
(A) Photomicrograph of a polished section of ore from the Seaboard mine. Shows typical development of supergene (secondary) chalcocite in fractures in bornite. The alteration begins in the minute fracture-openings, often so small that they are invisible except with the very highest powers of the microscope, and extends inward into the bornite until in the end only minute island-like patches of bornite remain in a mass of chalcocite. In many instances, as shown in the largest fracture in the photomicrograph, a line of quartz and iron oxide marks the original fracture in which the chalcocite began to develop.

This pattern is very different from the graphic intergrowth, and is strong evidence against the supergene origin of such intergrowths.

White lines = chalcocite. Dark areas = bornite.



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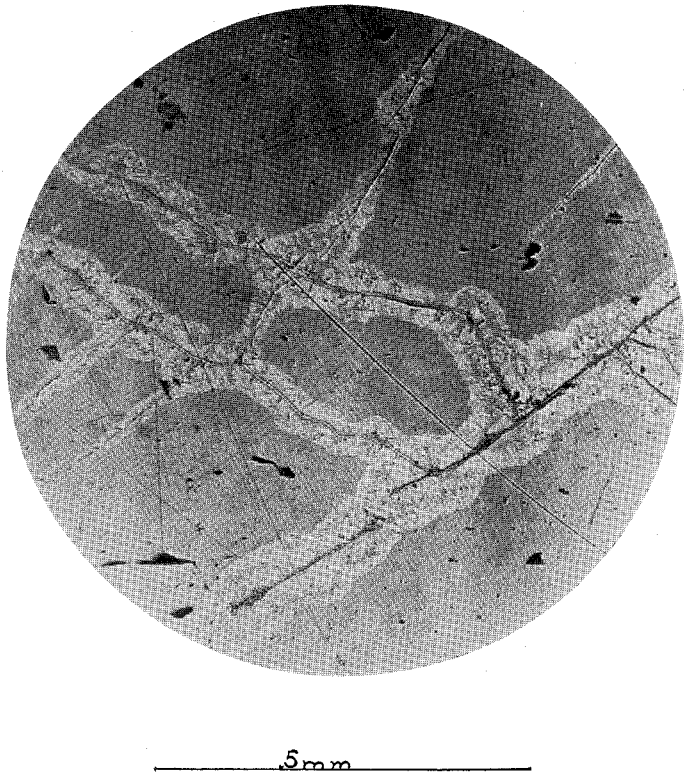
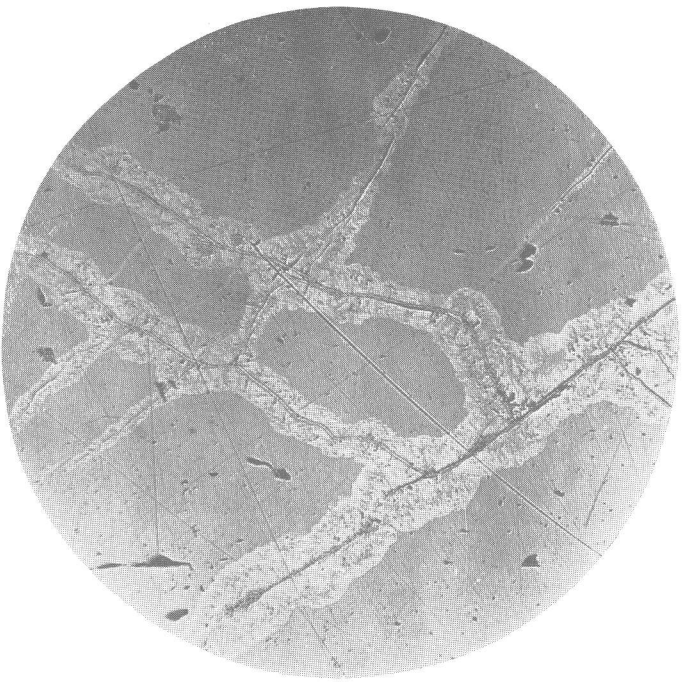


(B) Photomicrograph of a polished section of ore from the Seaboard mine. Shows typical development of supergene (secondary) chalcocite in bornite.

Similar in all respects to (A), except that the alteration in this section is farther advanced, and the statements made in regard to (A) are equally applicable to this section. It may be noted that there are at least two constituents in the chalcocite areas. These, so far as could be determined, consist of quartz and limonite. They are better shown in Plate XIII (A) and (B), which is a more highly magnified area from a polished section of ore from the Seaboard mine which shows the same phenomena in better development.

Light gray = chalcocite. Dark gray = bornite. Black = pits.



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This analysis which differs very slightly from the theoretical composition of the mineral shows the exceptional purity of some of the Virgilina bornite. The only impurity recognized by Dr. Palmer in the specimen analyzed was a minute amount of chalcopyrite.

Like chalcocite and chalcopyrite, the bornite of the Virgilina district is of two periods of deposition. One portion, by far the largest, is of hypogene origin and constitutes the most important original or primary ore mineral of the district. Another portion, much smaller than the first, is of supergene origin and occurs as a replacement mineral in veinlets in chalcopyrite. Except in the ore from the Glasscock shaft of the Pontiac mine and in that from the Cornfield No. 2 prospect, bornite is very rarely found in association with chalcopyrite. It was in specimens of ore from the Cornfield No. 2 prospect that the supergene replacements of chalcopyrite by bornite were found. This subject is treated in considerable detail on page 153, and the descriptions need not be repeated in this place. Plates IX and X are photomicrographs of ore showing bornite in its different relations to chalcopyrite.

Occasionally, as a result of supergene processes, bornite alters to chalcopyrite, as is shown in Plate IX (A). The alteration is discussed in detail on page 87. The usual and most frequent alteration of bornite in the Virgilina district is to chalcocite, and unless the chalcocite which occurs in graphic intergrowth with the bornite represents a hypogene alteration of the bornite, which the writer thinks is not the case, the chalcocitization of the bornite in this district is always a supergene alteration and is brought about only by superficial agencies. A typical intergrowth of bornite and chalcocite is shown in Plate XV (A and B). There is nothing in connection with such intergrowths, so far as the writer can see, that even suggests a replacement of the bornite by chalcocite. Such, however, is not the case as regards the chalcocite which occurs in fractures in the bornite as shown in Plate VIII (A and B). This type of ore is characteristic of the upper portion of the deposits, and so far as the observations of the writer have extended is not found below the depths reached by superficial alterations. It is clearly of supergene origin, represents secondary enrichment, and is brought about by descending meteoric waters. The relation of bornite and chalcocite to each other is discussed in detail in another place, page 83, and need not be repeated here.

Chalcocite.—Chalcocite (copper glance or vitreous copper, Cu_2S, 79.80 per cent copper and 20.20 per cent sulphur) as an ore mineral in the

Virgilina district is second in importance only to bornite, and the two together make up probably 90 per cent of all the copper-bearing minerals of the district. Indeed, it is doubtful that chalcocite is even subordinate to bornite. In the Holloway mine, so far as could be determined, chalcocite was by far the more abundant of the two minerals, but, as regards the other mines, it is probably subordinate to bornite. So far as observations have extended chalcocite occurs in the district only in the massive form. A careful lookout for chalcocite crystals was kept during the entire field work, but none was found. As is well shown under the microscope, the massive mineral as it occurs in this district is made up of irregular, interlocking, small- to medium-sized anhedral grains of different orientation. So far as could be determined from the cleavage in the different grains, as brought out by etching a polished surface, the mineral is in the orthorhombic form. Some students of the Virgilina ore deposits take this fact as proof that the chalcocite was deposited from low temperature solutions. It has been shown by Allen[a] that artificial chalcocite, when deposited at a temperature above 91 degrees C., crystallizes in the isometric system, and when at lower temperature it assumes the orthorhombic form. It is not known that the same is true of chalcocite deposited under the conditions of temperature and pressure that prevail during the deposition of minerals in the deep-vein zone. Under such conditions it is not known that chalcocite could not be deposited in the orthorhombic form at a much higher temperature than 91 degrees C., or, even if it were deposited in the isometric form, it is not known that it might not, in the course of time, or as a result of changes in the conditions, revert to the orthorhombic form. Until more is known about the subject the writer feels that it is not safe to base any far-reaching conclusions as to the origin of natural chalcocite or the temperature at which it was deposited, on so slender a premise as the relation of temperature to the crystal form of artificial chalcocite. He believes that the relation of chalcocite and bornite to each other, as well as the general conditions of the vein, indicate very strongly that the graphically intergrown bornite and chalcocite were deposited contemporaneously and that they are, therefore, both deep-seated hypogene minerals.

Chalcocite occurs in two very distinct ways in the bornite: as a supergene mineral secondary to and filling fractures in the bornite, and as a hypogene mineral intergrown, in many instances graphically, with it. The former type is shown in Plate XIV and in Plate XVI (A and B). The

[a] Posnjak, E., Allen, E. T., and Merwin, H. E.: Economic Geology, Vol. 10, 1915, p. 491.

latter type is well illustrated in Plates VIII and XII. The supergene or secondary chalcocite occurs for the most part in two forms, as replacement of the bornite along lines of fracture, and as rims of varying width representing replacement that has taken place around the periphery of areas of quartz embedded in the bornite and at the contact between bornite and larger areas of quartz. These types of replacement are also characteristic of chalcocite in chalcopyrite. They are illustrated in Plates IX and XI. In one instance, in ore from the Cornfield No. 2 prospect, a specimen was found which showed a rim of chalcopyrite between an area of quartz and bornite with a minute rim of chalcocite between the chalcopyrite and the quartz. This specimen is illustrated in Plate IX (A). These relations between the different minerals indicate that the bornite was first replaced by the chalcopyrite which in turn was replaced by chalcocite. In all the clearly supergene or secondary chalcocite examined, regardless of the mineral or minerals with which it was associated and from which it had been derived, it was invariably closely related with fractures in the original sulphide or to a contact between the original sulphide and a gangue mineral, usually quartz. Such, however, is certainly not the case with the chalcocite which is intergrown with the bornite. It is true that there are many fractures across the intergrown sulphides, in which chalcocite has developed, but they are clearly later than the intergrowths, and, so far as the writer was able to ascertain, had absolutely nothing to do with their development.

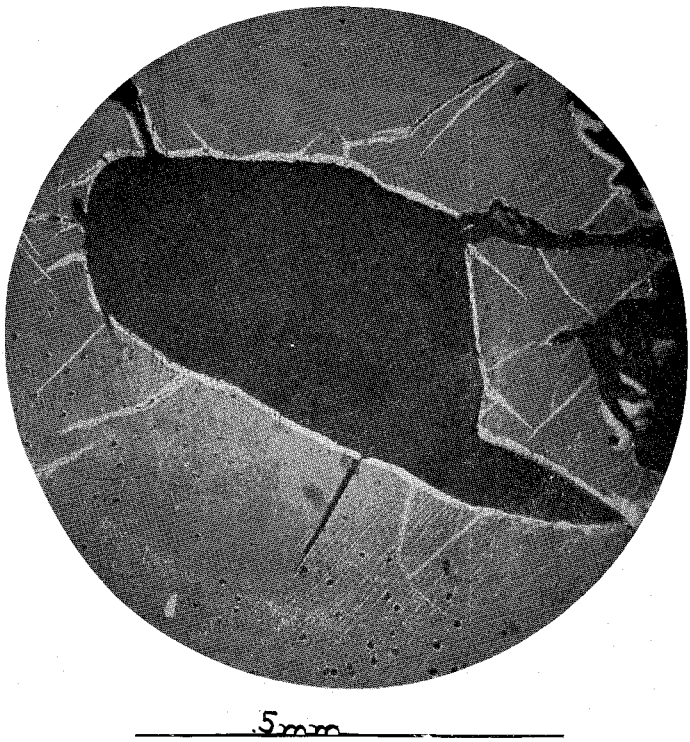
The color of the hypogene chalcocite is by no means uniform, but presents various tints of bluish-gray. Occasionally a specimen is found which in polished section shows areas of the mineral of different colors, each clearly outlined from the others and having its own distinct figure or pattern. This fact has been noted in chalcocite from other localities, especially from Butte, Mont., but the causes underlying its formation are not known. Chalcocite of two colors is shown in Plate XIX (A). In this instance the areas of the mineral having the deeper color are graphically intergrown with bornite while the others are not.

Chalcopyrite.—Chalcopyrite (yellow copper, $Cu_2S.Fe_2S_3$, copper 34.50 per cent, and sulphur, 35.00 per cent) is found in sufficient quantity to be of any importance as an ore in only two mines or prospects in the Virgilina district, the Pontiac and the Cornfield No. 2 prospects. In all other mines or prospects, so far as could be determined, the mineral, if present at all, occurs only in very small amount. In fact, except in the two places just mentioned, chalcopyrite is one of the scarcest minerals in the district. It

occurs in two ways in both of these prospects, as a hypogene mineral, contemporaneous with the bornite with which it is more or less intricately intergrown, and as a supergene mineral filling fractures in the bornite and as rims around quartz areas embedded within the bornite. Plate IX (A and B) shows the supergene, while Plate X (A) shows the hypogene chalcopyrite. In many instances the associations of hypogene chalcopyrite and bornite are apparently similar in all respects, as regards physical form and pattern, to those of hypogene bornite and hypogene chalcocite as illustrated in Plate XIV (A and B). An interesting relation between bornite and chalcopyrite is shown in Plate X (A). In this instance the bornite appears to be secondary to and to have replaced the chalcopyrite, but whether it is of hypogene or supergene origin is not clear. It appears to have developed in a fracture in the chalcopyrite, and extending outward from the fracture to have extended to varying distances into the host mineral. Following the change, after considerable secondary bornite had developed, the conditions evidently changed and some of the bornite was altered to chalcopyrite, which occurs as minute veinlets in the bornite. A still later change in the conditions is shown by the fact that some of the secondary bornite as well as some of the secondary chalcopyrite has been altered into chalcocite. These last two alterations are pretty clearly of supergene origin; the first alteration in the series, that of the chalcopyrite, is believed to be of supergene origin. However, if, as some students believe, the intergrown chalcocite represents a hypogene alteration of bornite, it appears to the writer that the alteration of chalcopyrite into bornite, as it occurs in the ores from Cornfield No. 2 prospect, may possibly be of hypogene origin.

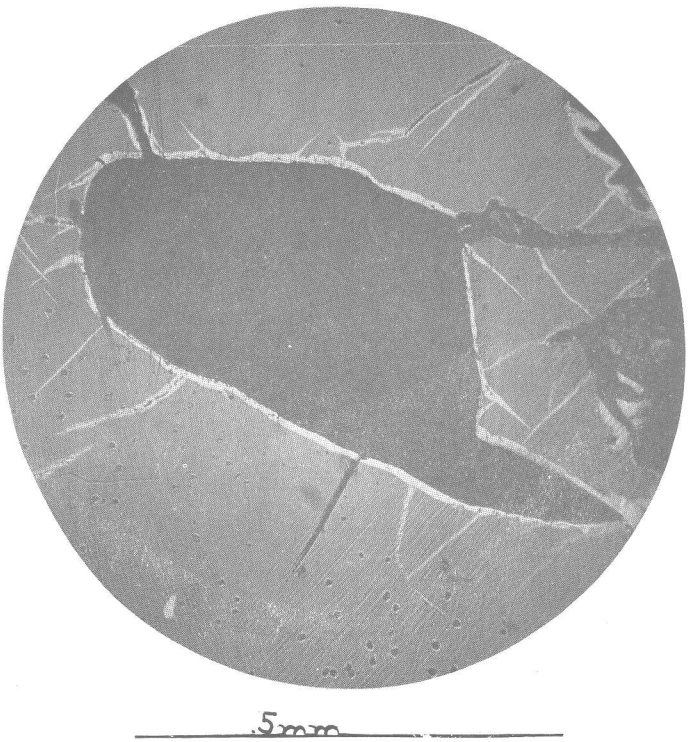
Native copper.—Native copper occurs in the Virgilina district in two ways: as a supergene mineral in the upper zones of the sulphide-bearing veins, and as a hypogene mineral closely associated with quartz and epidote in the so-called native copper deposits; that is, in deposits of the Catoctin type, such as the Native Shaft in the southern limits of the town of Virgilina, and in the Pannebaker and other prospects farther south in the same area.

Native copper of the first type, so far as observations have extended, occurs almost invariably as thin plates in fractures in the altered ores, and is confined to the upper and altered portions of the veins. It was found in the High Hill, the Holloway, and the Durgy mines, and it probably occurred in other openings. It is present only in minute quantities and consequently is of no importance commercially.



(A) Photomicrograph of a polished section of ore from Cornfield Prospect No. 1. Shows supergene chalcopyrite occurring as a rim at the contact of bornite and quartz and as gash veinlets in the bornite. Supergene chalcocite also occurs as a very narrow rim at the contact of the quartz and chalcopyrite, indicating that after the replacement of the bornite by chalcopyrite at the quartz contact, conditions changed and the chalcopyrite was replaced by chalcocite at the contact of the chalcopyrite. The photograph does not distinguish between the chalcopyrite and the chalcocite.

White lines and rim = chalcopyrite. Gray = bornite. Larger black area = quartz. Black dots = pits.



(A) Photomicrograph of a polished section of ore from Cornfield Prospect No. 1. Shows supergene chalcopyrite occurring as a rim at the contact of bornite and quartz and as gash veinlets in the bornite. Supergene chalcocite also occurs as a very narrow rim at the contact of the quartz and chalcopyrite, indicating that after the replacement of the bornite by chalcopyrite at the quartz contact, conditions changed and the chalcopyrite was replaced by chalcocite at the contact of the chalcopyrite. The photograph does not distinguish between the chalcopyrite and the chalcocite.

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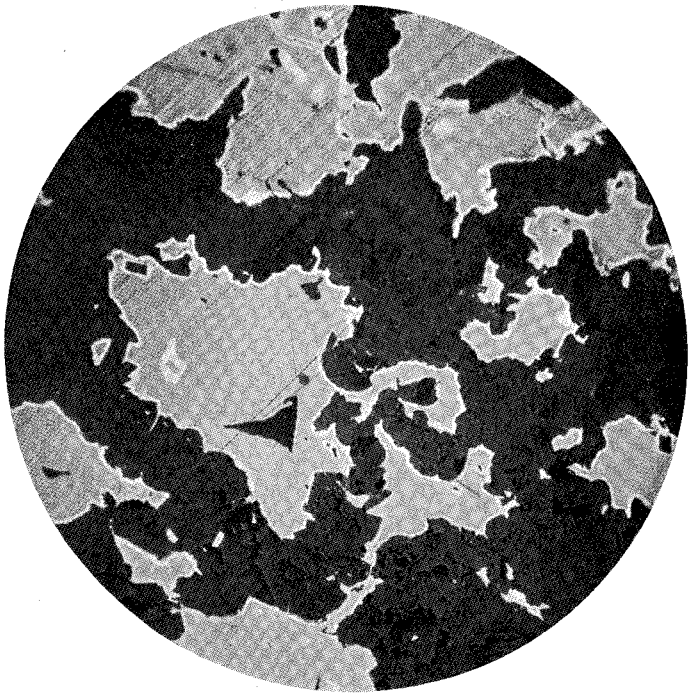

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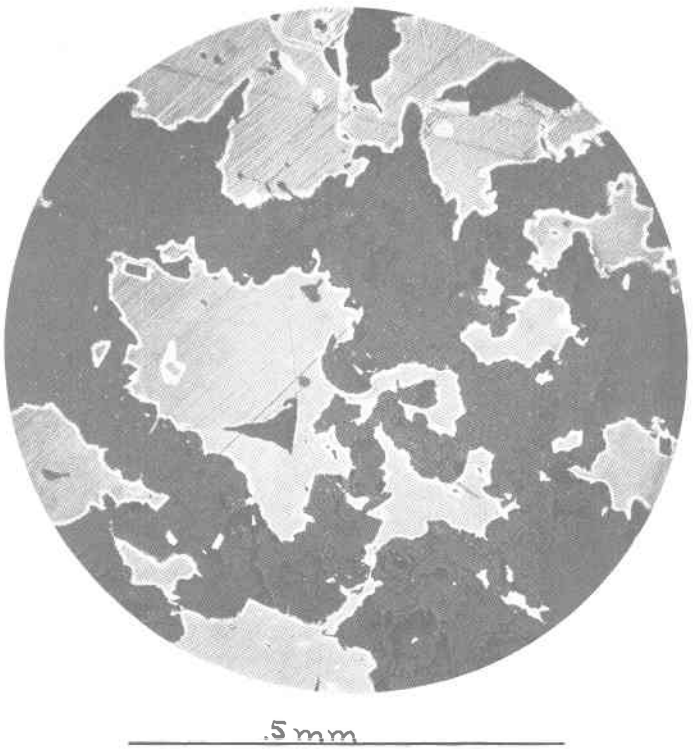
(B) Photomicrograph of a polished section of ore from Cornfield Prospect No. 1. Shows supergene chalcopyrite occurring as rims around irregular areas of bornite.

White = chalcocite. Gray = bornite. Black = quartz.



(B) Photomicrograph of a polished section of ore from Cornfield Prospect No. 1. Shows supergene chalcopyrite occurring as rims around irregular areas of bornite.

White = chalcocite. Gray = bornite. Black = quartz.

(A) Photomicrograph of a polished section of ore from Cornfield Prospect No. 1. Shows bornite and chalcopyrite in typical association in ore which is believed to be of hypogene origin. The pattern formed by the intergrowth very closely resembles the coarser intergrowths of bornite and chalcocite, but there are not so many hook-shaped forms. Occurring as rims at the contact of both chalcopyrite and bornite and quartz, and as narrow gash veinlets in both, is a small amount of supergene chalcocite.

White areas = chalcopyrite. Dark gray areas = bornite. Light gray rims and veinlets = chalcocite. Black = quartz.

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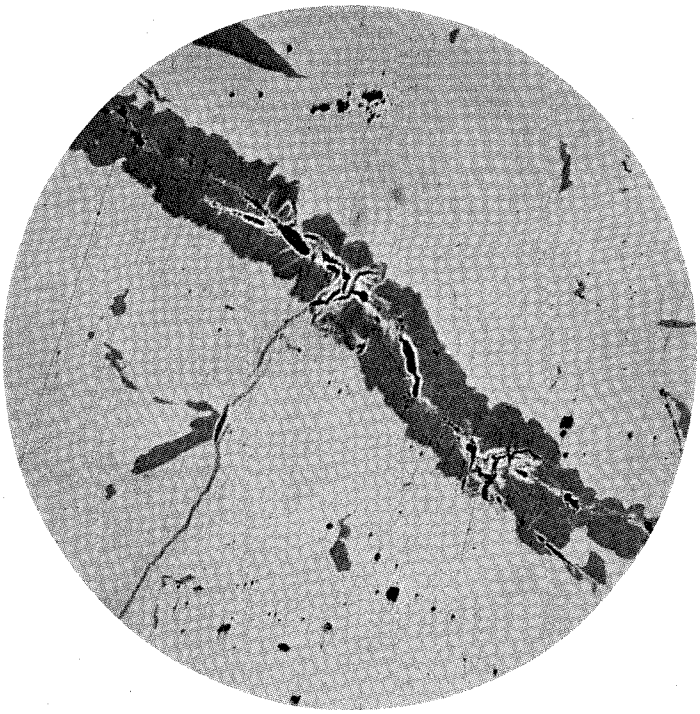

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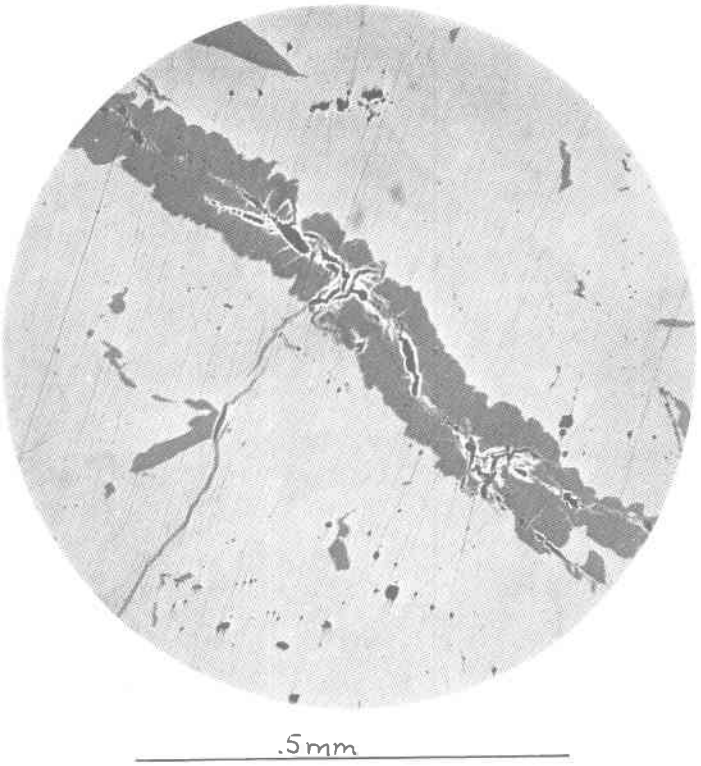
(B) Photomicrograph of a polished section of ore from Cornfield Prospect No. 1. Shows bornite in what are believed to be both supergene and hypogene relations with hypogene chalcopyrite, together with gash veinlets of supergene chalcopyrite in the supergene bornite. Supergene bornite that could be recognized as such is very rare in the Virgilina district; in fact, it was found only in this one prospect. In this section it occurs in what appears to have been a fracture in the hypogene chalcopyrite and to have developed from it in a manner similar to that of the formation of chalcocite in fractures in bornite. Minute veins of supergene chalcopyrite and chalcocite are seen in the large area of supergene bornite.

Light gray = chalcopyrite. Dark gray = bornite. Light gray veinlets = chalcopyrite. Darker gray veinlets = chalcocite. Black = quartz.



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Light gray = chalcopyrite. Dark gray = bornite. Light gray veinlets = chalcopyrite. Darker gray veinlets = chalcocite. Black = quartz.

The native copper in the deposits of the Catoctin type does not occur in veins, but in silicified and epidotized areas of the Virgilina greenstone. These deposits are always of irregular outline and the metal is distributed very irregularly through the quartz and epidote, evidently preferring the quartz, but occasionally in the epidote. Weed[a] believes that as a general rule copper deposits of the Catoctin type are formed by superficial alteration and that the values are always of shallow depth. So far as the writer's observations have extended, the native copper deposits of the Virgilina district are clearly of hypogene origin, and he believes there are no valid reasons for assuming that they are limited to shallow depth.

In these deposits the copper occurs in irregular and distorted crystals, as in irregular branching or tree-like form which generally show imperfect crystal faces, and as anhedral grains which seem to have accommodated themselves to the spaces available for their development. The copper as a rule is fairly pure, but in some instances it contains an appreciable amount of silver.

Klaprothite or Klaprotholite.—Klaprothite, $3Cu_2S.2Bi_2S_3$ (copper 25.30 per cent, bismuth 55.53 per cent, sulphur 19.17 per cent), a copper-bismuth sulphide, or at least a mineral having the physical properties of klaprothite, so far as they could be determined under the microscope, occurs very sparingly in the Virgilina ores. Thus far it has been found only in microscopic grains which could not be isolated for chemical examination. It was carefully compared under the microscope with known klaprothite from Butte, Mont., and so far as could be determined the two minerals are identical. The mineral was found only as small grains of fairly regular outline, embedded in the bornite.

Pyrite.—Pyrite (iron pyrites, "fool's gold," FeS_2) is one of the scarcest minerals in the Virgilina rocks and ores. In fact, it is so rare that one, unless he exercises the greatest care, will overlook it entirely. It was found most plentifully in the Cornfield No. 2 prospect, and in very small amount in ore from the Durgy and Blue Wing mines. It occurs as minute crystals and in veinlets in the greenstone associated with the ores.

The statements just made apply to the copper and not to the gold mines and prospects, in which pyrite while by no means an abundant mineral is present in appreciable amount.

Argentite.—Argentite (vitreous silver, silver glance, Ag_2S, silver 87.10 per cent, sulphur 12.90 per cent) is distributed throughout the bornite and

[a] Weed, Walter H.: Types of copper deposits in the Southern United States, Trans. Am. Inst. Min. Eng., Vol. 30, 1900, pp. 498-499.

chalcocite in minute amounts. Indeed it is so rare that the most careful microscopic examination of a great many polished sections of the richest ores at high magnification will be necessary in order to locate it. It was found in ore from the Blue Wing and the Durgy mines, respectively, in which it occurs as minute grains of fairly regular outline. So far as the writer could determine argentite does not replace the minerals in which it occurs, and it is believed to be of hypogene origin and contemporaneous with the sulphides in which it occurs. Such evidence as could be obtained indicates very strongly that all the silver in the original ores occurs in the form of argentite. The silver value, while it increases with the copper value of the ores and concentrates, varies widely in different samples from the same mine, and by no means bears a regular ratio to the copper as it necessarily should if silver were in chemical combination with either of the copper-bearing sulphides. In the reports of assays from the Durgy mine, available to the writer for study, the silver values varied from a trace to nearly one-half ounce per ton for each per cent of copper in the ore. This is a wider variation than might reasonably be expected if the silver were in chemical union with the copper-bearing sulphides, and exactly what would result if the silver were present as a definite silver mineral and irregularly distributed throughout the copper-bearing sulphides.

Gold.—Gold occurs in varying quantity in the ores from all the mines in the district, the amount varying from a trace to about 0.13 ounce to one per cent of copper. The gold values, however, are very irregular, and so far as can be estimated from such data as were available the average gold value is probably not much more than one-tenth of this amount.

Of the accessible records those from the Durgy mine showed the highest gold values. However, so far as could be learned, there is very little difference in the gold value of the ore from the different mines.

So far as is known the gold in the copper-bearing sulphides occurs only as the native metal. The assay records all show great variation in the gold value and that there is little or no ratio between it and the percentage of copper, facts which show that the gold is not a regular constituent of the copper-bearing minerals.

A careful lookout was kept during all the field work for specimens of copper ores carrying gold in visible quantity, but without success. The search was continued with the microscope in the laboratory with only doubtful results. The operators in the district state that occasionally a

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(A) Photomicrograph of a polished section of ore from Cornfield Prospect No. 1. Shows hypogene bornite and chalcopyrite and supergene chalcocite in quartz. The chalcopyrite is included in the bornite, while the chalcocite forms a narrow rim around the irregular areas of the bornite and chalcopyrite.

White in the gray = chalcopyrite. Gray = bornite. Light rims = chalcocite. Black = quartz.

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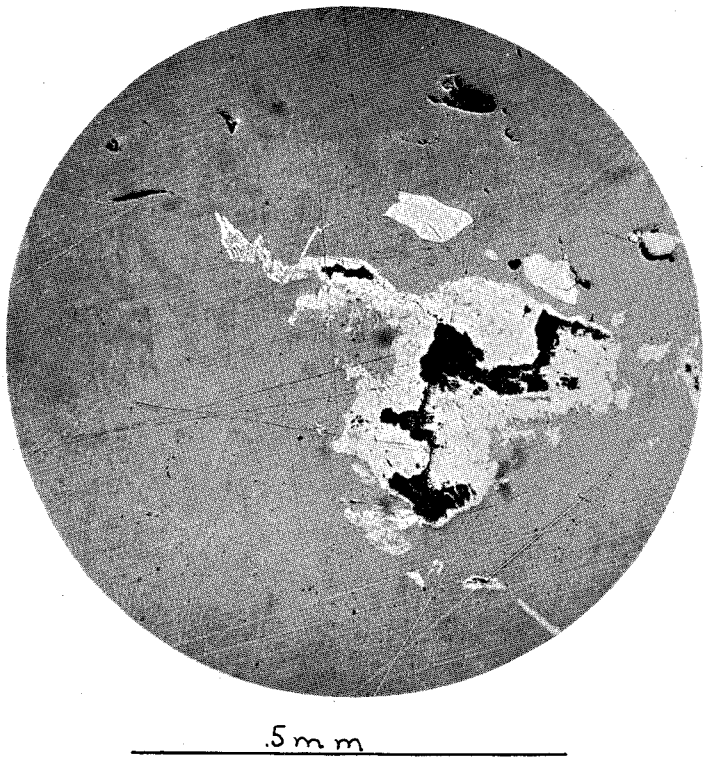
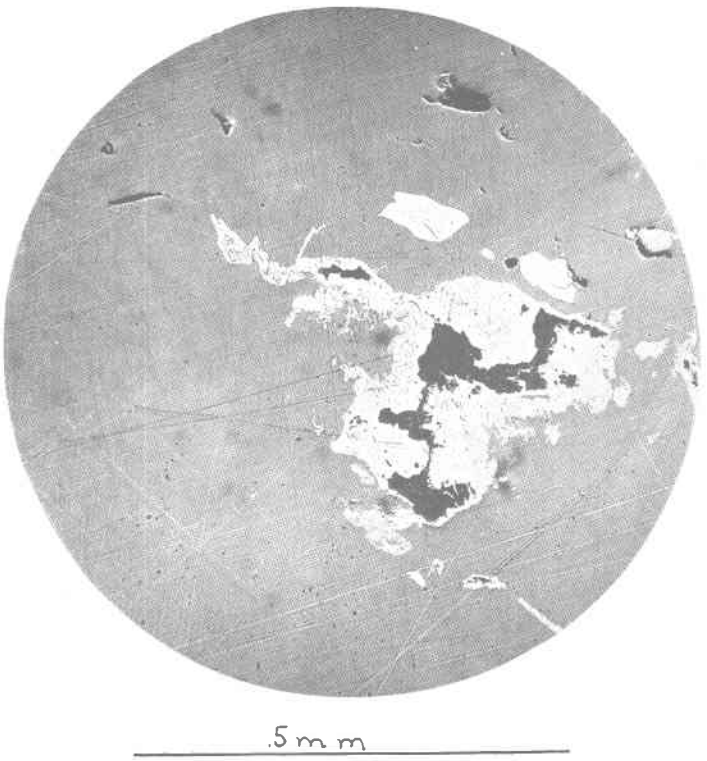


(B) Photomicrograph of a polished section of ore from Cornfield Prospect No. 1, showing supergene (secondary) chalcocite in bornite. The chalcocite in this section, while it is pretty clearly of supergene origin, shows almost typical graphic intergrowths between the two sulphides, thus affording strong evidence that such intergrowths may result from supergene agencies and that taken alone they are not of very great diagnostic value in deciding questions as to origin of chalcocite.

White = chalcocite. Gray = bornite. Black = pits.
Intersecting lines = scratches from polishing.



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specimen is found in which the gold can readily be seen. Pratt[a] in his professional report on the Durgy mine confirms these statements. He says:

"In cleaning up the Chilian mill, after crushing a considerable amount of ore, there are often found small nuggets of free gold, some of which have weighed from 8 to 10 dwt."

Malachite.—Malachite (the green carbonate of copper, $CuCO_3.Cu(OH)_2$, cupric oxide 71.90 per cent, carbon dioxide 19.90 per cent, water 8.20 per cent), the basic, green carbonate of copper, occurs prominently as a coating and stain in the oxidized portions of all the copper deposits in the district. In most instances it consists of only thin films and stains in the quartz, and other vein matter, and in the greenstone lying next to the copper minerals, and of itself is of little or no commercial value. In a few cases, as at the Glasscock shaft of the Pontiac mine and in the upper part of the Holloway mine, it occurred in larger amount, in radiating tufts and masses, and was probably valuable as an ore. It is clearly of supergene origin and is formed by the oxidation of the copper-bearing minerals and native copper. Malachite forms the principal criterion for guiding the prospector in his search for copper deposits in the district.

Azurite.—Azurite (the blue carbonate of copper, $2CuCO_3.Cu(OH)_2$, cupric oxide 62.20 per cent, carbon dioxide 25.60 per cent, water 5.20 per cent), the basic, blue carbonate of copper, is found with malachite in the oxidized ores from all mines and prospects in the district, but in much smaller amount than the green carbonate. In a few places, especially in the Glasscock shaft of the Pontiac mine and in a few places in the Holloway mine, it was more abundant. In the Glasscock ore it occasionally is found in well-formed monoclinic crystals. In this mine azurite was found in sufficient quantity to have some value as an ore. It must be stated, however, that in this district the copper carbonates are present in such small amount that they are of little or no importance commercially.

Cuprite.—Cuprite (red oxide of copper, Cu_2O, copper 88.80 per cent, oxygen 12.20 per cent), while present only in small amount, occurs in the oxidized portions of practically all the mines and prospects in the district. It is more abundant in the so-called "native deposits," that is, deposits of the Catoctin type, than in the vein deposits. In these deposits it usually is found as a red stain in the associated rock or coating and replacing the particles of native copper. It is usually massive, but occa-

[a] Pratt, Joseph Hyde: A Report on the Property of the Person Consolidated Copper and Gold Mines Company. 1904, p. 6.

sionally is found showing more or less well-developed crystal faces, and very rarely in the form of long, acicular, hair-like filaments, the so-called "plush copper ore," or chalcotrichite. In this last-mentioned form the mineral was found only in the Copper King mine in which, in very rare instances, it occurs in small vugs in the partially oxidized ore. Except in the "native deposits" cuprite is negligible as an ore of copper.

Melaconite.—Some of the black, earthy material closely associated with the partially altered material on the old dump at the Gillis mine closely resembles melaconite, the impure cupric oxide. Very little of the material was available, and the writer was not able to positively identify it. However, it is believed to be melaconite. It is clearly an alteration product from the usual copper ores and in this district is of no importance as an ore.

Chrysocolla.—The Gillis mine has also the distinction of having furnished the only chrysocolla, the hydrous silicate of copper, found in the district. The material was found in a small pile of ore which had lain upon the dump for years. The color varied from greenish-blue to dark brown and the mineral was evidently very impure. Physical and chemical tests, however, made the identification reasonably certain. The mineral is present in only small amount and is of no importance as an ore.

Native silver.—Native silver has been reported as occurring in minute amount in the upper portion of the sulphides in nearly all of the important mines of the district. The writer was able to find the mineral only in a single piece of ore from the dump of the High Hill mine. In this specimen the silver occurred as a thin film in a minute fracture in the ore, and was clearly of supergene origin.

RELATION OF THE COPPER-BEARING SULPHIDES TO EACH OTHER.

General statement.—The relations of the sulphides to each other have been discussed with some thoroughness in the pages devoted to the detailed description of the ores, pp. 63-82, but it has been thought best to repeat and to some extent enlarge, in this place, the descriptions of the interrelations of the ore minerals which have a bearing upon their origin, deposition, and the secondary alterations which they have suffered. Of greatest importance in these respects are the graphic intergrowths between bornite and chalcocite in the primary ores, or, in other words, the ores believed to be of hypogene origin. These relationships are so characteristically different from those of the secondary, or supergene sulphides,

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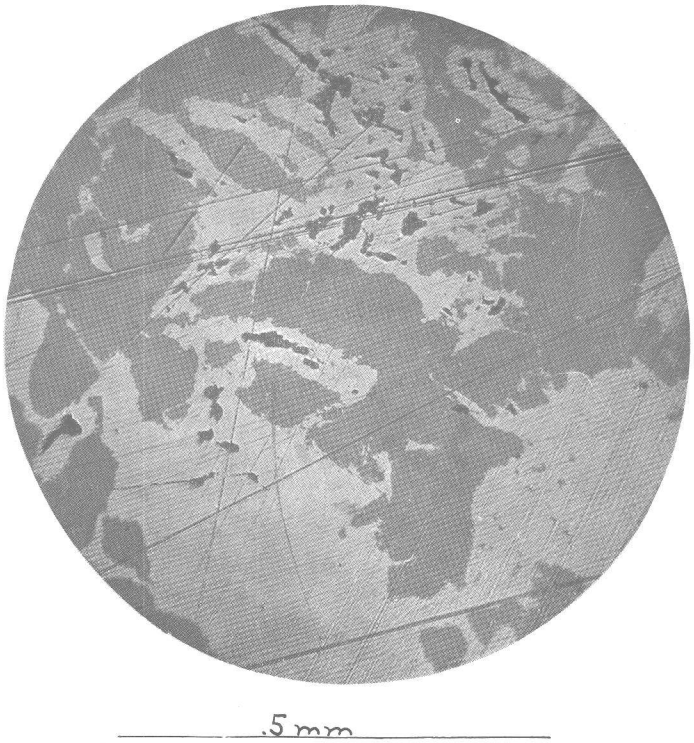
(A) Photomicrograph of a polished section of ore from Cornfield Prospect No. 2. Shows very clearly the typical pattern of supergene chalcocite in bornite. Note the irregularity of outline and the ragged edges of the chalcocite. It is a far cry from this sort of pattern to the regularity of pattern and even line boundaries between the two sulphides in the graphic intergrowths such as are shown in plates XVI and XVIII. It does not seem possible that similar agencies acting under similar conditions and upon exactly similar minerals could produce results so markedly different.

Light gray = chalcocite. Dark gray = bornite. Black = pits.



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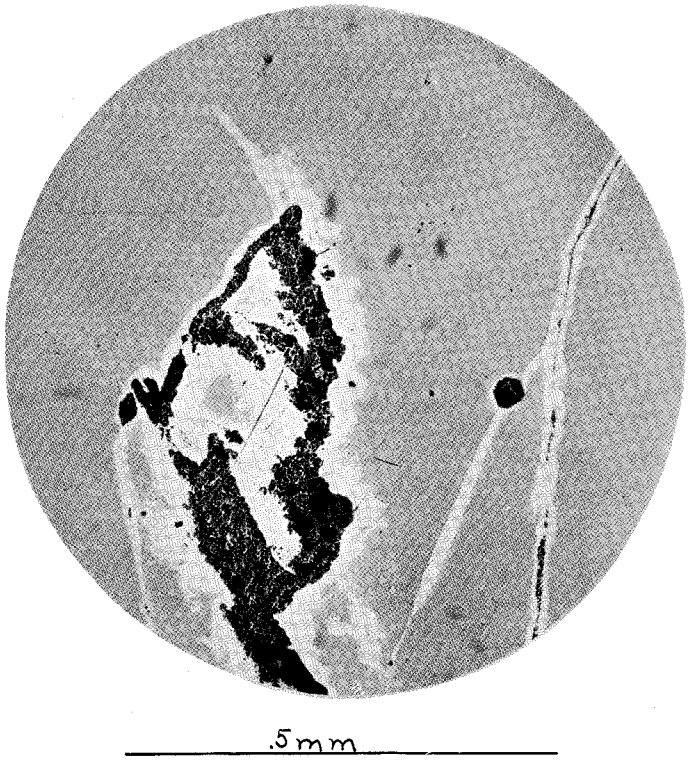
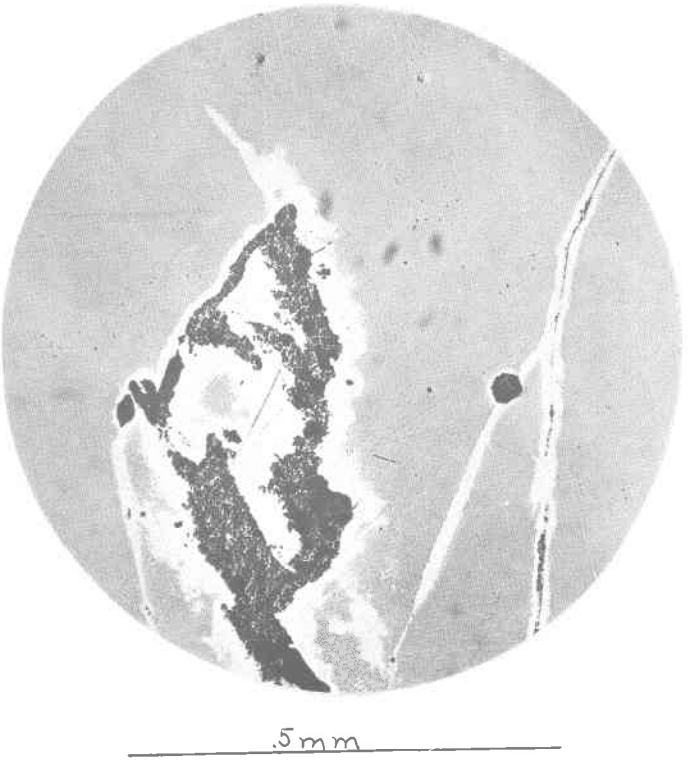


(B) Photomicrograph of a polished section of ore from the Pontiac mine (Glasscock shaft). Shows typical supergene chalcocite in bornite. Similar in all respects to the section shown in (A).

White = chalcocite. Gray = bornite. Black = pits.



(B) Photomicrograph of a polished section of ore from the Pontiac mine (Glasscock shaft). Shows typical supergene chalcocite in bornite. Similar in all respects to the section shown in (A).

White = chalcocite. Gray = bornite. Black = pits.

that when the two are contrasted it is very difficult to understand how the two types or textures could have been formed by similar processes. These features will be discussed and illustrated, and some surmises as to the origin of the different textures will be made, and their bearing upon the broader subject, the origin and deposition of the ores, will be considered.

Relations of bornite and chalcocite.—In the ores of the Virgilina district bornite and chalcocite occur in two very distinct relations to each other. In the first type the chalcocite occurs in the bornite in well-defined graphic intergrowths which so far as form is concerned are similar to the eutectic intergrowths in alloys, and there appears to be no conclusive evidence that the two sulphides are not of contemporaneous deposition. In the second type the chalcocite occurs in fractures, in irregular areas, and as rims around areas of bornite. The relations of the two sulphides in this case make it perfectly clear that the chalcocite is of supergene origin and that it has replaced the bornite.

The intergrowths between bornite and chalcocite occur in two forms, one in which the two minerals show a more or less irregular distribution, and one typically graphic.

The irregular intergrowth, as it is seen under the reflecting microscope, consists of myriads of the most irregular, angular, and hook-shaped areas of chalcocite embedded within the bornite. The appearance can best be imagined by thinking of a section through a honeycombed, cellular, or sponge-like mass of chalcocite so completely merged into a similar mass of bornite as to leave absolutely no spaces between the two components. So far as could be determined from careful microscopic study of more than 100 polished sections of such intergrowths, the chalcocite is in no way related to fractures in the bornite nor to any known process of supergene alteration. Many specimens examined contained fractures in which supergene chalcocite had formed, but these, so far as the writer could determine, cut across both minerals of the intergrowths alike without showing any indication that the intergrown chalcocite was genetically related to the fractures in any way. Many specimens of such intergrowths were to a greater or less extent porous, so that when polished sections were made the surfaces presented minute pits and openings. These, while apparently more numerous in the bornite, were by no means confined to it, and none of them were found which showed any alteration of the bornite around the openings, except where a fracture had broken through the opening. This type of intergrowth is found in great abundance in the ores from all the

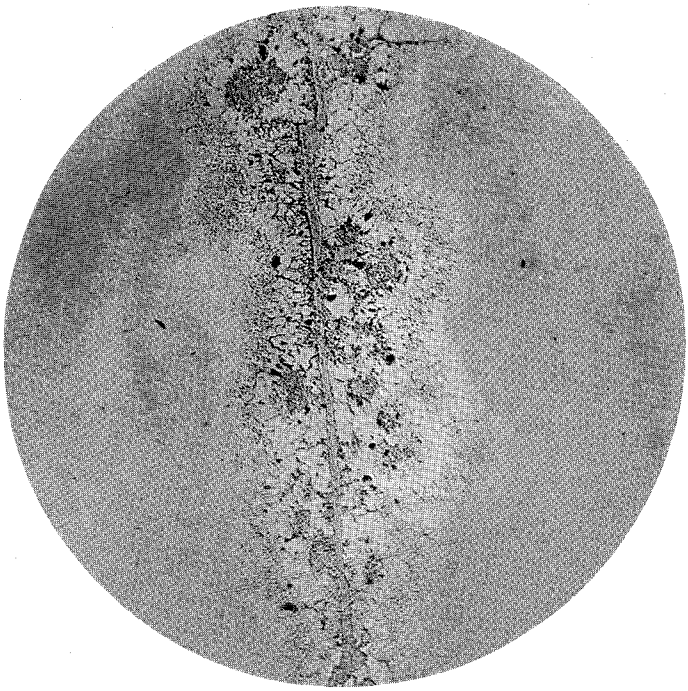
mines. In fact it is characteristic of the Virgilina ores, and, so far as observations have extended, it is not in any way related to the depth from which the ores are taken. Fine examples were found in ores from the deepest workings of the High Hill, the Seaboard, the Blue Wing, and the Durgy mines.

In many instances a single area under the microscope shows a field in which the irregular and the graphic intergrowths both occur, Plate XVII (A). In fact, it appears that the graphic is only a special case of the irregular intergrowth in which the form of the intergrowth was controlled by the crystallographic phenomena of the two minerals. Photomicrographs of typical irregular intergrowths are shown in Plate XIV (A and B).

In the polished section the typically graphic intergrowths occur in three fairly well-defined types, one in which the two minerals occur in more or less regular, alternating lamellæ, one which presents a reticulated pattern, and a third which is more or less irregular. It is not intended to state that these three types of graphic intergrowth are separate and distinct from each other, for there is every gradation from one into the other. In fact almost any graphic intergrowth will present an example or examples of all three types.

In the graphic lamellar intergrowth the bornite and chalcocite occur in minute alternating lamellæ, with still more minute lines of one mineral, usually chalcocite, breaking across a band of the other and joining another of its own kind. The pattern of this type of intergrowth when seen in polished section is an almost exact duplicate of the pearlite eutectoid in steel. Pearlite consists of a mechanical mixture of ferrite (free alpha iron) and cementite (an iron carbide, Fe_3C). Pearlite results from the contemporaneous solidification of ferrite and cementite as the alloy cools. Thus the lamellar graphic intergrowths still more closely resemble the eutectic or eutectoid structures of alloys. So far as observations have extended the lamellar intergrowths of these ores bear no relationship to fractures in the bornite and probably not to any known supergene processes. Such intergrowths are illustrated in Plate XVIII (A and B), and in Plate XVI (B). When these lamellar intergrowths are etched so as to reveal the internal structure of the component minerals, it is clearly seen that the intergrowths have developed along crystallographic directions in the minerals, and that, regardless of the method of their development, they are really crystallographic intergrowths.

The irregular graphic intergrowths differ from those of the lamellar pattern only in that the anastamosing filaments or branches of the com-



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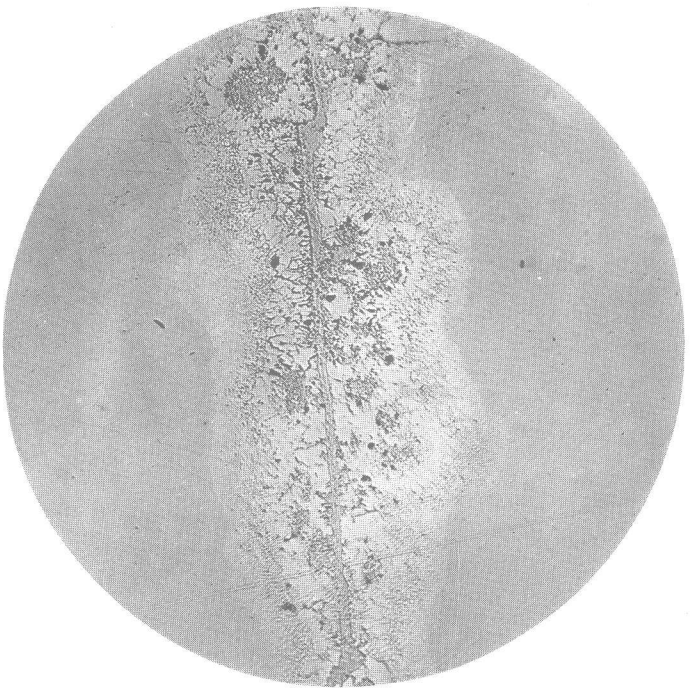
(A) Photomicrograph of a polished section of ore from the Seaboard mine. Shows the network of quartz and iron oxide that occasionally occurs in chalcocite veinlets which develop in fractures in bornite. In this structure the chalcocite at the borders of the developing veinlets is fairly pure. The anastamosing network of minute threads of quartz and limonite follow the replacement process very closely and extends its filaments, in many instances almost to the outer edge of the chalcocite.

These are strange phenomena and the writer can not offer an explanation as to their origin and development.

Light gray = chalcocite. Dark gray = bornite.
Network in light gray = limonite and quartz.



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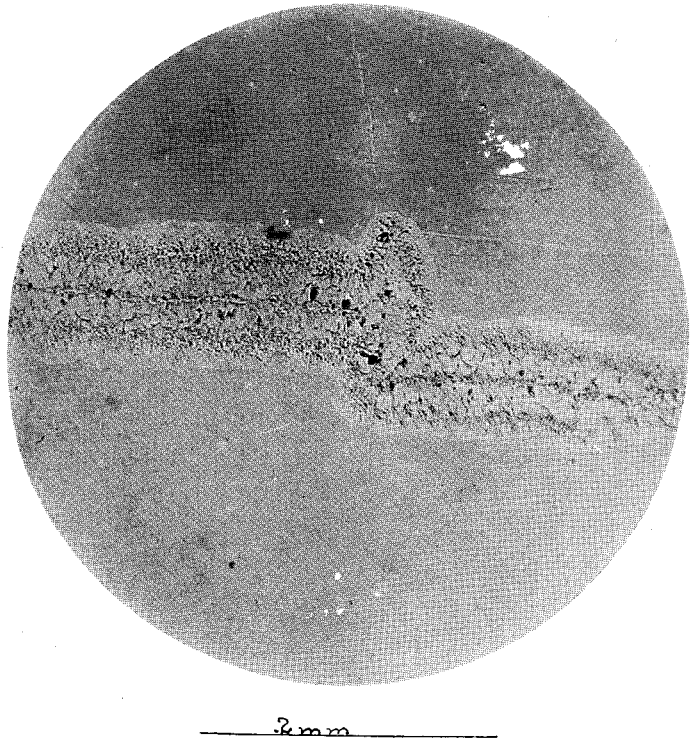
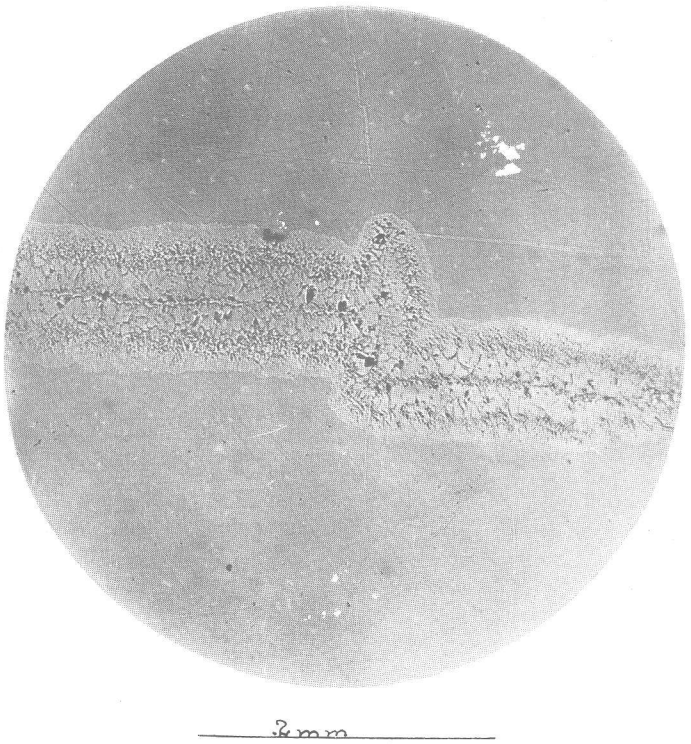


(B) Photomicrograph of a different area in the polished section illustrated in (A). Similar in all respects to (A), except that it shows a kind of banding of the limonite and quartz on each side of the center of the veinlet of chalcocite. The notes on (A) are equally applicable to this section.



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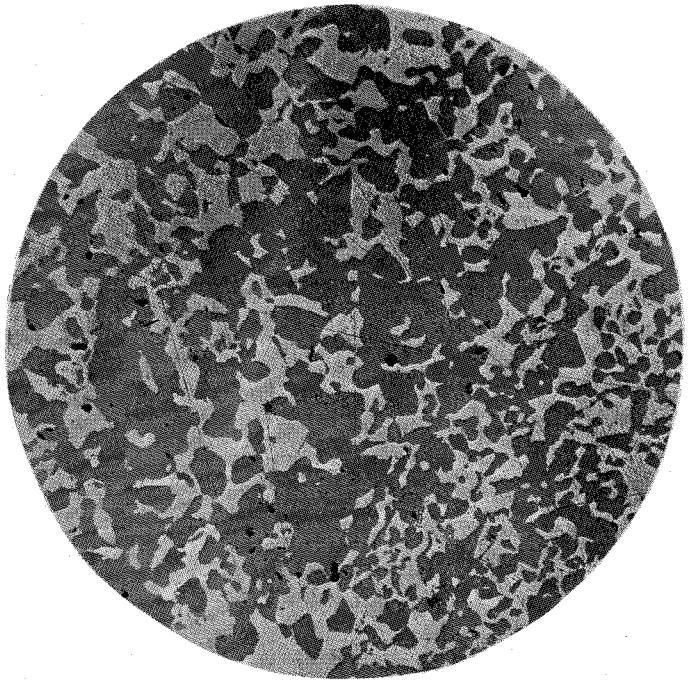
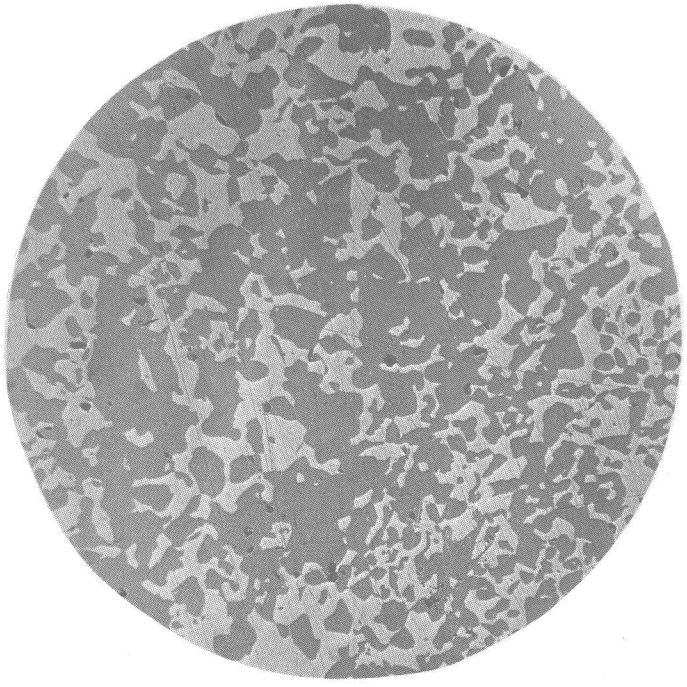


5 mm

(A) Photomicrograph of a polished section of ore from the Blue Wing mine. Shows normal intergrowth of hypogene chalcocite and bornite. So far as can be determined the areas of chalcocite are in no way related to fractures in the bornite nor to any visible channels of circulation along which solutions could flow. In fact the ore is perfectly massive and the texture here illustrated extends throughout all the ore of the deposit. If it represents secondary enrichment by supergene processes it remains to explain the means by which the solutions penetrated every portion of the massive bornite. Until proof to the contrary has been produced the writer will adhere to the belief that such intergrowths are the result of hypogene processes and that the two sulphides are of contemporaneous deposition.

White = chalcocite. Dark = bornite.



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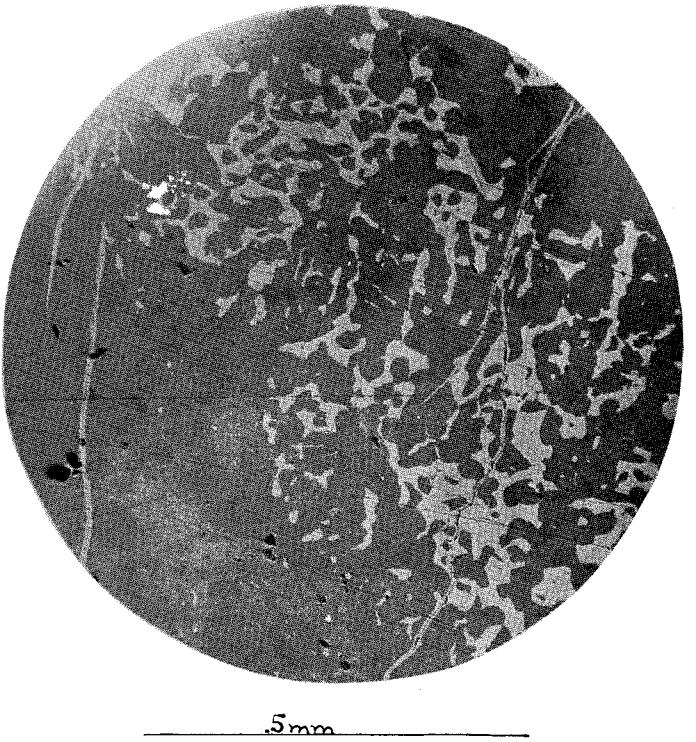
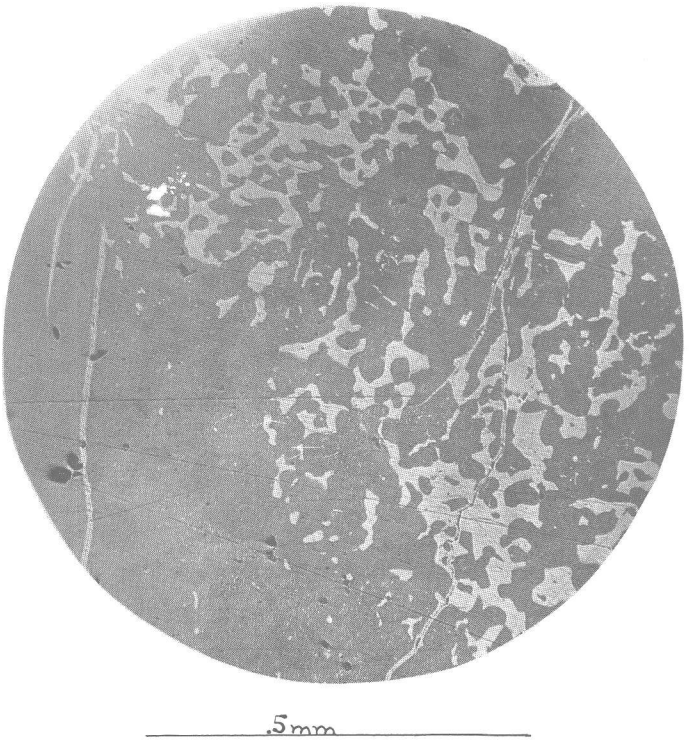


(B) Photomicrograph of a polished section of ore from the Durgy mine. Shows chalcocite of two periods of deposition, one of hypogene origin intergrown normally with the bornite, and one of supergene origin and filling fractures which cross both the hypogene chalcocite and the bornite. So far as could be determined the fracturing occurred long since the intergrown chalcocite was deposited and is in no way related to it.

White = chalcocite. Dark = bornite. Black = pits.



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White = chalcocite. Dark = bornite. Black = pits.

ponent minerals, instead of lying in roughly parallel lamellæ, bear a most intricate relation to each other. In most instances they appear to make up larger areas of the ore and the filaments are slightly larger than those of the lamellar intergrowths. They also are of more frequent occurrence. This type of intergrowth also, so far as physical form is concerned, very strikingly resembles certain copper-silver alloys, and many copper-rich mattes. The resemblance is so close that if unmarked photomicrographs of the three—the ore, the alloy, and the matte—are placed side by side, it is exceedingly difficult if not impossible to distinguish one type of structure from the other. Such graphic intergrowths are shown by etching to have formed along definite crystallographic directions, such as cleavage or parting planes in the minerals involved. They are therefore crystallographic as well as graphic. Photomicrographs of typical examples of this type of intergrowth are shown in Plates XVI and XVII.

The reticulated graphic intergrowths are similar to the irregular type except that in most instances the filaments of the intergrowth are joined so as to form triangles and irregular-shaped closed areas. Etching reveals the fact that those intergrowths in most cases have taken place along crystallographic directions, and that in their formation crystallographic phenomena determined the form of the intergrowth. In the material available for study, reticulated intergrowths were very rare. Unsatisfactory photomicrographs of this type of graphic intergrowth are shown in Plate XX.

As has been said, these intergrowths are in reality all special cases of the irregular intergrowths of bornite and chalcocite which have already been described. So far as the writer's observations have extended these intergrowths do not bear any genetic relation whatsoever to fractures or channels of circulation in the bornite, and so far as could be determined they are in no way connected with any known supergene processes. The pattern formed by the two minerals as seen in polished section bears a striking resemblance to the pattern formed in alloys of two components, one of which is present in excess. In some areas of such an alloy one component will be found in excess, in another area the other component will be in excess, while in still another the two will be present in graphic intergrowth in the form of a eutectic. Of course it is not intended to even suggest that these ores were deposited from so simple a system as one of only two components. It is altogether probable that a great many components entered into the system from which they were precipitated.

In the second great type of the relation of chalcocite to bornite in the Virgilina district the chalcocite occurs as veinlets of varying size in

fractures in the bornite, as rims around small areas of bornite, and as irregular areas surrounding openings in the bornite. This type of chalcocite invariably shows unmistakable signs of supergene origin and forms as a replacement of bornite. Very little beyond the photomicrographs of the different phases is necessary in the way of description of such ores. They show the relation of the two minerals to each other better than can be explained in written descriptions.

The veinlets of supergene chalcocite in bornite vary in width from sub-capillary cracks, scarcely visible even with the highest powers of the microscope, up to well-defined veins 10 or more centimeters in width. Certain specimens from the Cornfield Prospect No. 1 showed fractures in the bornite so small that they were not clearly visible at a magnification of over 2,100 diameters, which were rimmed with films of chalcocite, thus showing that such minute fractures could serve as channels for circulating supergene solutions. The alteration proceeds outward from the fractures until the whole mass of bornite has been changed into chalcocite. It was interesting to note that in every specimen examined the contact between the bornite and chalcocite is invariably perfectly sharp and clear-cut. It was noted, however, that in some instances the bornite nearest to the contact with the chalcocite tarnished more quickly and apparently more easily than that farther away from the contact. The rapidity of the alteration depends among other factors upon the amount of fracturing which the bornite has suffered. In many of the larger veinlets of such chalcocite there are dendritic "skeletons," as it were, of limonite which was probably derived from the iron in the bornite during the process of alteration. Plate VIII and Plate XII (A and B) are photographs showing veins of such supergene chalcocite in various stages of development. Plate XX (A and B) exhibits photographs showing typical dendritic "skeletons" of limonite in supergene chalcocite veins in bornite.

The rims of supergene chalcocite which form at the contact between bornite and the gangue minerals develop in a manner similar in all respects to that in the veinlets described in the last paragraph, and consequently do not call for further description in this place. Plate XI (A) is a photomicrograph showing such rims of chalcocite at the contact between bornite and quartz.

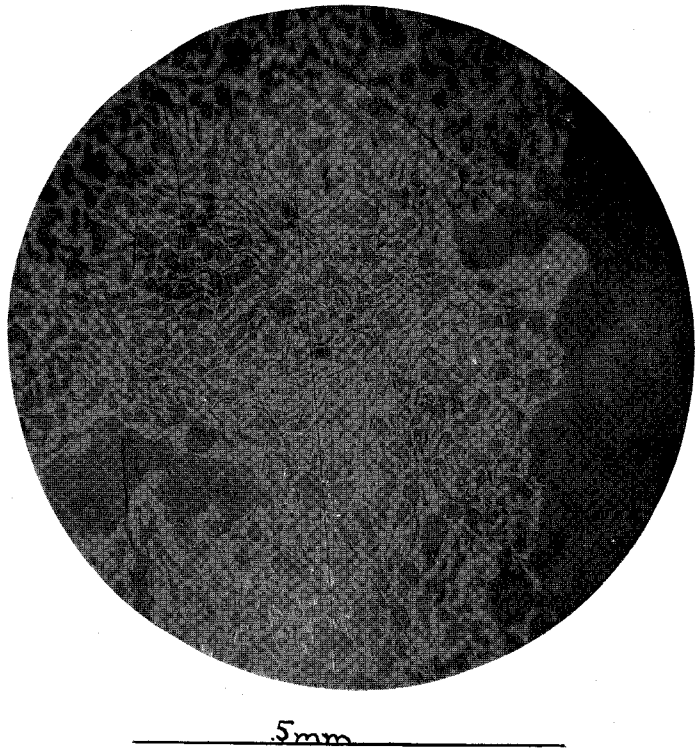
The irregular areas of supergene chalcocite surrounding openings in bornite are shown in Plate XI (B). They are formed in the same way that the other supergene secondary chalcocite is formed and do not require further description.

(A) Photomicrograph of a polished section of ore from the High Hill mine. Shows graphic and usual intergrowths of bornite and chalcocite. These intergrowths are not in any way connected with fractures in the bornite (at least none are visible at a magnification of 2,500 diameters), and the writer believes the two sulphides are of contemporaneous deposition.

Light = chalcocite. Dark = bornite. Black = pits.

(A) Photomicrograph of a polished section of ore from the High Hill mine. Shows graphic and usual intergrowths of bornite and chalcocite. These intergrowths are not in any way connected with fractures in the bornite (at least none are visible at a magnification of 2,500 diameters), and the writer believes the two sulphides are of contemporaneous deposition.

Light = chalcocite. Dark = bornite. Black = pits.

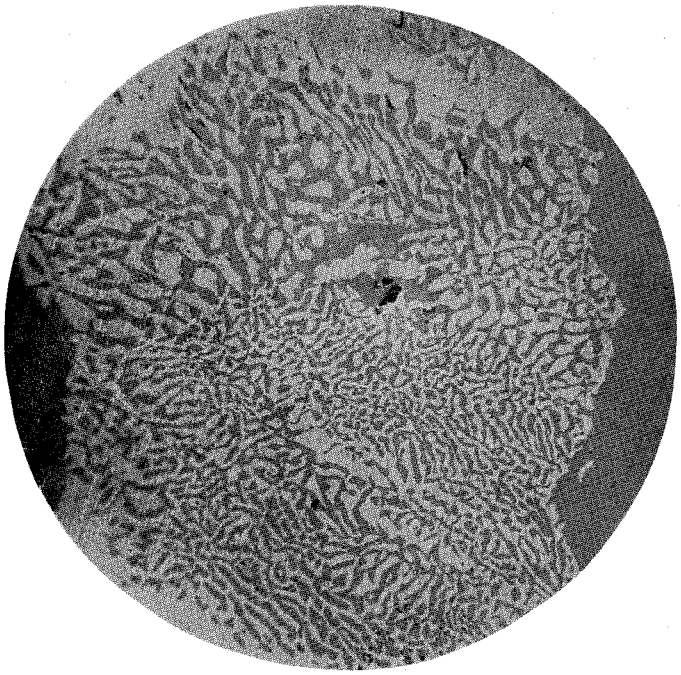


(B) Photomicrograph of a polished section of ore from the Durgy mine. Shows a typical graphic intergrowth of bornite and chalcocite. It will be noted that this section shows the irregular intergrowth, while that illustrated in (A) is largely of the lamellar type. They both show very marked similarity to the eutectic structures so characteristic of alloys, mattes, and slags, and the writer believes they represent contemporaneous deposition of the two sulphides.

Light = chalcocite. Dark = bornite.

(B) Photomicrograph of a polished section of ore from the Durgy mine. Shows a typical graphic intergrowth of bornite and chalcocite. It will be noted that this section shows the irregular intergrowth, while that illustrated in (A) is largely of the lamellar type. They both show very marked similarity to the eutectic structures so characteristic of alloys, mattes, and slags, and the writer believes they represent contemporaneous deposition of the two sulphides.

Light = chalcocite. Dark = bornite.



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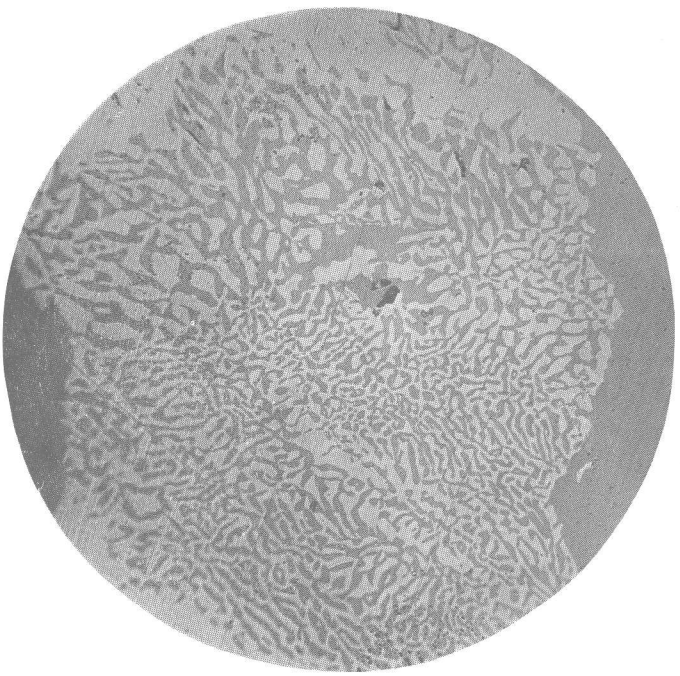
(A) Photomicrograph of a polished section of ore from the Wall mine. Shows a typical example of graphic intergrowth of bornite and chalcocite. This structure is so different from that of supergene chalcocite in bornite and so closely resembles the structures which are characteristic of alloys, mattes, and slags, that the writer, while admitting that it may possibly form as a secondary process, still believes that it is formed in a very different manner from the structures shown in plates VII and VIII. He believes that such structures form as a result of hypogene more often than from supergene processes and that in such cases as this the evidence is far more strongly in favor of a hypogene process and of contemporaneous deposition of the two sulphides.

White = chalcocite. Gray = bornite. Black = pits.



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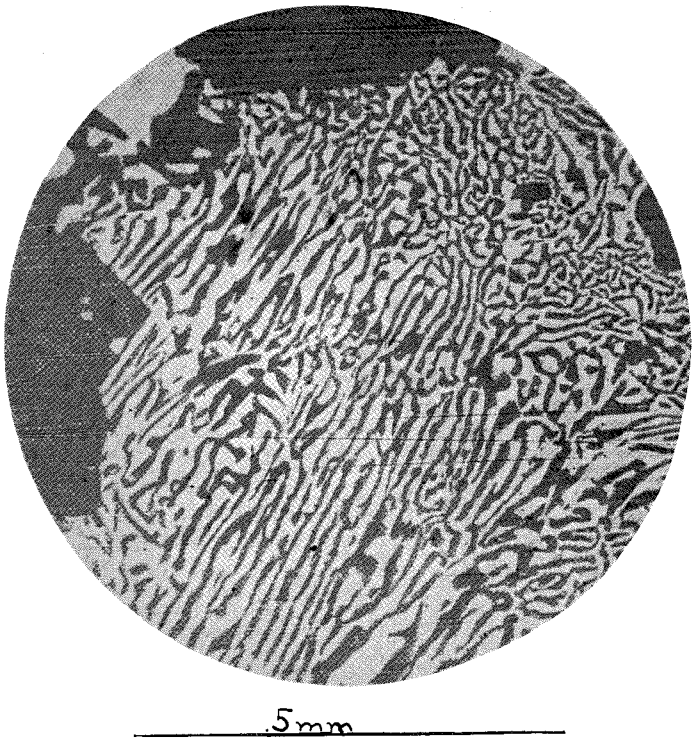
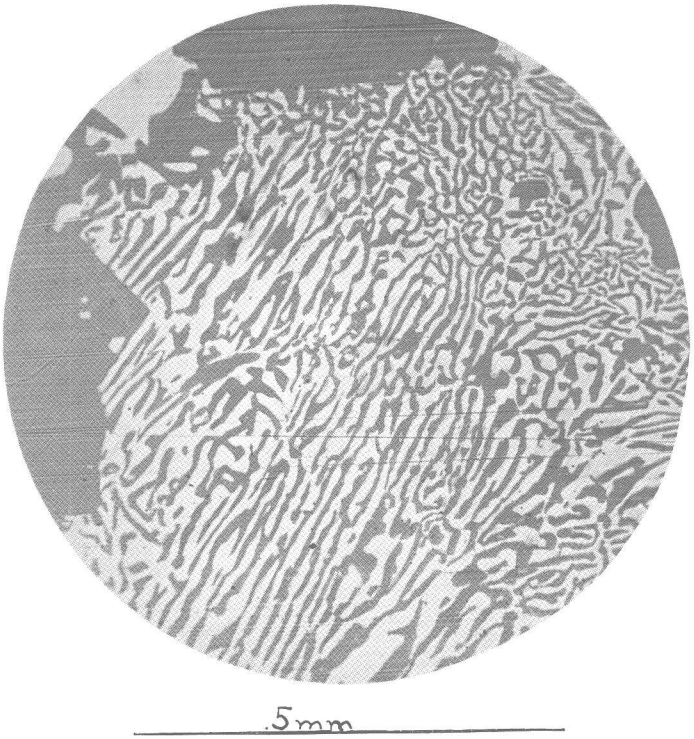


(B) Photomicrograph of a polished section of ore from Cornfield Prospect No. 2. Shows a typical lamellar intergrowth of chalcocite and bornite similar to the exceedingly fine lamellar intergrowth shown in Plate XVIII. When such intergrowths are etched it is clearly shown that in most instances the two minerals are intergrown along crystallographic directions.

White = chalcocite. Dark = bornite.



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White = chalcocite. Dark = bornite.

In studying the photomicrographs of the supergene secondary chalcocite and comparing them with those of the hypogene intergrowths of the two minerals especial attention should be given to the form or pattern of the two minerals in each type of ore. A glance is sufficient to demonstrate that they are decidedly different. Indeed they are so different that the writer can not understand how they could all have formed as a result of similar processes. It is known that the second type of chalcocite was formed as the result of supergene processes and that it is secondary to and replaces the bornite, and it is not understood how the same processes could possibly produce types of structure so materially different from the graphic intergrowths, which are consequently believed to be of hypogene origin, and contemporaneous with the bornite.

Relations of bornite and chalcopyrite.—Bornite occurs in two distinct relations to chalcopyrite, as a hypogene mineral intergrown with it, and as a supergene mineral replacing chalcopyrite. Chalcopyrite in turn bears exactly similar relations to bornite. It occurs as a hypogene mineral contemporaneous with bornite and intergrown with it, and as a supergene mineral secondary to and replacing bornite. Chalcopyrite is by no means an abundant mineral in the Virgilina district. In fact, it is very rarely found in any of the larger and extensively developed mines. Indeed it is so rare in all the developed mines in the district that from these alone nothing could have been learned as to its relation to the other sulphides. Fortunately, however, it was found in greater abundance in two partially developed mines, the Glasscock shaft of the Pontiac mine, and the Cornfield No. 2 prospect. From these material was obtained which showed the relations described and illustrated in this chapter. The best specimens were obtained from the Cornfield[a] Prospect No. 2. Those from the Glasscock shaft, however, are similar in most respects, and furnish supplementary evidence as to the relation of chalcopyrite to the other sulphides.

The intergrowths of chalcopyrite and bornite are in the main similar to the irregular intergrowths of bornite and chalcocite which were described on p. 83. The relations are not so intricate and no graphic intergrowths of the two sulphides were found. In the intergrowths examined there was

[a] This prospect was filled with water while the writer was engaged upon the field work for this report, and therefore not accessible. In the summer of 1915 the owner of the property, Miss Florence Pannebaker, had the shaft unwatered and instituted further development work. Noting the abundance of chalcopyrite, Miss Pannebaker collected and sent to the writer the specimens which are herein described. The writer wishes to acknowledge his obligations to Miss Pannebaker for supplying him with these important specimens and data concerning them.

found absolutely no conclusive evidence, and, indeed, no indications, for that matter, that the chalcopyrite and bornite are not of contemporaneous deposition. It is therefore believed that such is the case and that both sulphides in such instances are of hypogene origin. The photomicrograph, Plate X (A), shows the relationship of the two minerals so well that no further description is necessary.

The supergene bornite, secondary to and replacing chalcopyrite, occurs as veinlets in chalcopyrite probably in the same manner as supergene chalcocite develops in bornite. The photomicrograph, Plate X (B), shows the typical form of occurrence of supergene bornite. It appears to the writer that the evidence that the bornite is of supergene origin and that it has replaced the chalcopyrite along the fractures is perfectly clear.

It was interesting to note that in some areas of the specimen, which showed to best advantage supergene bornite in hypogene chalcopyrite, there was an appreciable amount of supergene chalcopyrite occurring as a replacement of both hypogene and supergene bornite. This supergene and secondary chalcopyrite is by no means abundant, but is found occasionally in ore from both the Cornfield Prospect No. 2 and the Glasscock shaft. It, so far as observations have extended, occurs only in two forms, as veinlets in minute fractures in the bornite, and as rims surrounding particles of bornite at their contact with the different gangue minerals. Plate X (B) shows supergene chalcopyrite occurring as minute veinlets replacing supergene bornite which in turn occurs in the same manner as a replacement of hypogene chalcopyrite. Plate IX (A) is a photomicrograph showing replacement rim of supergene chalcopyrite at the contact of hypogene bornite and a small area of quartz. It is not brought out in the photograph, but the specimen shows that a narrow replacement rim of chalcocite has formed at the contact of the rim of chalcopyrite.

These "flarebacks" or reversals in the normal processes of replacement are not uncommon and are found in many of the well-known copper deposits of the world. They are of common occurrence in the Butte ores. The alteration has also been produced in the laboratory. The method of producing it was discovered by Prof. S. W. Young, of Stanford University, and consists in immersing fragments of chalcocite or bornite in a fairly dilute solution of ferrous sulphate and slowly passing hydrogen sulphide through the solution. The reaction takes place rather quickly and in a short time the fragments will be coated with a film of chalcopyrite. The reactions take place at room temperature and under normal atmospheric pressure. These conditions are likely to occur occasionally in

upper portions of ore deposits, and the discovery of Professor Young appears to offer a satisfactory explanation of the phenomenon.

Chalcocite occurs as rims and veinlets in chalcopyrite just as in bornite, but, so far as observations have extended, never in intergrowths with it. Chalcopyrite has not been found in the Virgilina ores as a replacement mineral in chalcocite.

ORIGIN AND DEPOSITION OF THE ORES.

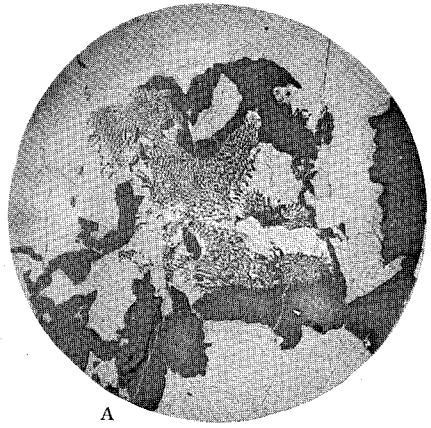
General statement.—The facts in regard to the veins, the gangue minerals, the ore minerals, the relations of the minerals to each other, and the relations of veins and ores to the rocks in which they occur afford premises upon which to base certain theories in regard to the origin of the veins and the origin and deposition of the ores. In the discussions and descriptions on the previous pages the writer has endeavored to confine himself primarily to statements of fact and to recording such observations in regard to the geology and ore deposits of the Virgilina district, drawing such conclusions and offering such explanations as appeared to be obvious and to be warranted by the observations. In this place he will attempt to offer such theoretical conclusions and submit such explanations in regard to the origin of the veins, and the origin and deposition of the ores as, in his judgment, the foregoing descriptions warrant. He is fully aware of the size of the questions as well as their complexity and offers his theories and explanations only as a possible solution, leaving to future students the final solution of the problems.

Origin of the veins.—The origin of the veins has been discussed in a general way in the first part of this chapter, in advance of the detailed discussion of their mineralogy. Since the minerals of the veins and their relation to each other have such an important bearing upon the subject, in fact, are the very premises upon which theories and conclusions in regard to the origin of the veins must be based, it was decided to postpone the detailed discussion of, and the proposal of theories relative to, the subject until those items had been considered in detail.

It has been shown in the chapter on the description of the rocks that the rock in which all the mineralized veins occur is basic in character, having the mineralogical and chemical composition of andesite. It has also been shown in the descriptions of the individual veins and in the discussion of their mineralogy in this chapter, p. 68 *et seq.*, that their predominant mineral is quartz, and that one of their minor, but persistent,

minerals is orthoclase. Both of these minerals are foreign to or occur very sparingly in rocks so basic as the andesitic material forming the Virgilina greenstone. It has also been shown that the veins are much younger than the Virgilina greenstone in which they occur and that they were not formed until the tuffs and flows which make up the greenstone had been consolidated, folded, mashed, and metamorphosed into schists. These facts all indicate that a very long period of time elapsed between the building up of the andesitic tuffs and flows, and the formation of the veins. Furthermore it has been shown that, so far as it was possible to determine, the normal Virgilina greenstone does not contain even a trace of copper. It has also been demonstrated that the veins were developed in fractures, possibly fault planes which intersect the schistosity of the greenstone at acute angles, and which, therefore, were not formed until after the rock had become a schist. All these facts indicate clearly that a source for the vein matter, both gangue and ore minerals, must be sought entirely outside of the rock in which they occur, the Virgilina greenstone. Such source must be a rock or magma which could normally supply the highly siliceous gangue minerals, quartz and orthoclase, as well as the ore minerals, and at the same time provide for the formation of the other gangue minerals, such as epidote, chlorite, calcite, and plagioclase feldspars. The only rock in the district, or in the region for that matter, which fulfills all these conditions is the granite. It is therefore believed that the veins were derived from the granitic magma and that they were formed as a concomitant phenomenon, probably contemporaneous with its intrusion or following immediately thereafter when the cooling magma would be giving off its emanations. It is also believed that the sulphides, the orthoclase, the greater part of the quartz, and possibly the plagioclase feldspars, were derived directly from the granitic source, and that the other minerals were derived largely from the country rock through alteration of its normal minerals. The causes for deposition are believed to have been such factors as decrease in temperature and pressure of the rising solutions, their commingling with other solutions, and the influence of the wall rock of the fissures through which they were moving.

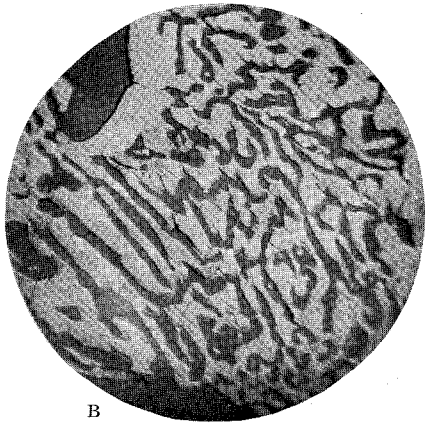
It is also believed that the vein-forming solutions did not find open cavities in which to deposit the vein matter. It is not understood how such cavities could possibly remain open under the conditions which seem to have prevailed during the formation of the veins. It is believed, however, that the solutions rising through the fractures widened them into the present veins through the forces of crystallization of the growing minerals



A

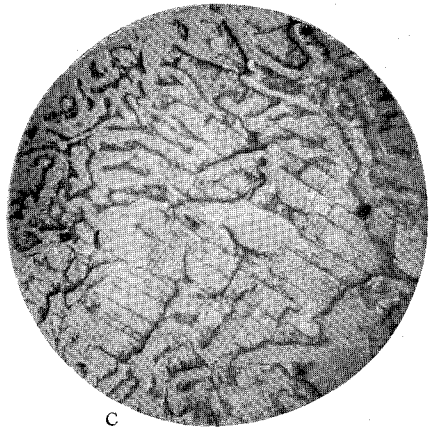
(A) Photomicrograph of a polished section of ore from the Wall mine, x 40. Shows graphic intergrowth of bornite and chalcocite, believed to be of hypogene origin. A few small fractures may be noted in which supergene, secondary chalcocite has formed. These fractures are clearly younger than the graphic intergrowths and so far as could be determined have had no influence upon their development.

Light areas = chalcocite.
Dark areas = bornite.



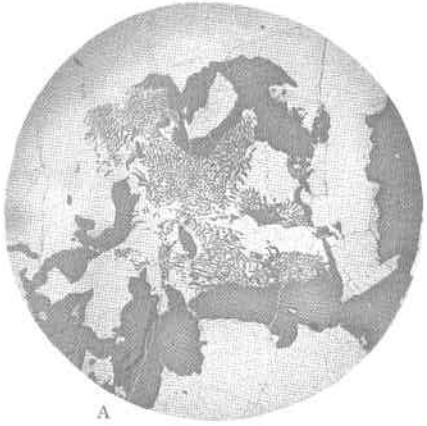
B

(B) Graphic intergrowth of bornite and chalcocite, x 220. This figure represents an area of the finely intergrown portion of the section shown in (A), but much more highly magnified.



C

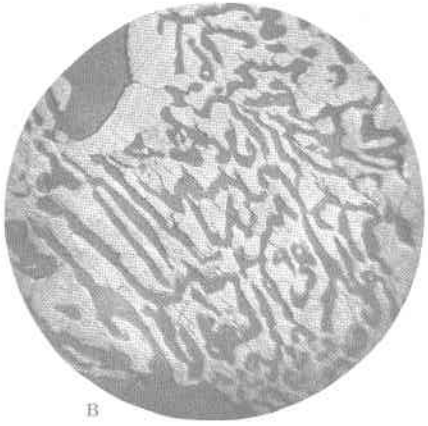
(C) Graphic intergrowth of bornite and chalcocite, x 220. This figure represents a portion of the intergrowth shown in (A), which has been deeply etched with nitric acid, and then highly magnified. It shows by the "etch figure" of the chalcocite—the straight lines which intersect each other at right angles—that the portion of this mineral here seen is a single grain or crystal, and offers strong evidence that the two minerals are of contemporaneous deposition.



A

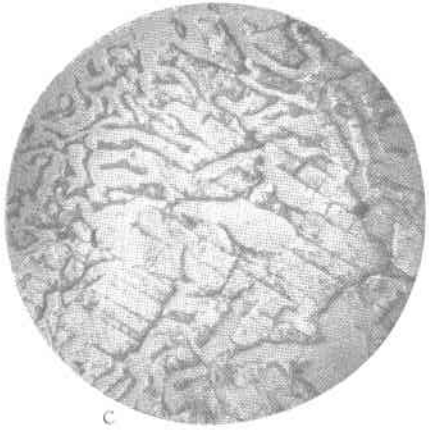
(A) Photomicrograph of a polished section of ore from the Wall mine, x 40. Shows graphic intergrowth of bornite and chalcocite, believed to be of hypogene origin. A few small fractures may be noted in which supergene, secondary chalcocite has formed. These fractures are clearly younger than the graphic intergrowths and so far as could be determined have had no influence upon their development.

Light areas = chalcocite.
Dark areas = bornite.



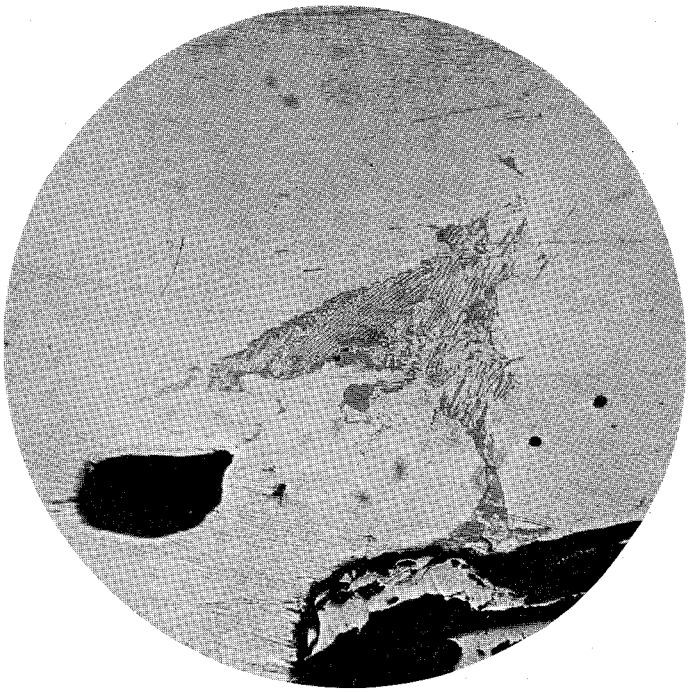
B

(B) Graphic intergrowth of bornite and chalcocite, x 220. This figure represents an area of the finely intergrown portion of the section shown in (A), but much more highly magnified.



C

(C) Graphic intergrowth of bornite and chalcocite, x 220. This figure represents a portion of the intergrowth shown in (A), which has been deeply etched with nitric acid, and then highly magnified. It shows by the "etch figure" of the chalcocite—the straight lines which intersect each other at right angles—that the portion of this mineral here seen is a single grain or crystal, and offers strong evidence that the two minerals are of contemporaneous deposition.



2mm

(A) Photomicrograph of a polished section of ore from Cornfield Prospect No. 1, showing graphic intergrowth of chalcocite and bornite. This intergrowth is believed from general relations to be of hypogene origin, but there is no way of proving that such is the case. If of supergene origin it offers strong evidence that in this case the alteration has been from chalcocite to bornite, it being noted that the bornite occurs in what appears to be a fracture in the chalcocite. This section is another good bit of testimony that the evidence afforded by graphic intergrowths as to the origin of the components is, to say the least, ambiguous.

White = chalcocite. Gray = bornite. Black = pits.
Intersecting lines = scratches made in polishing.

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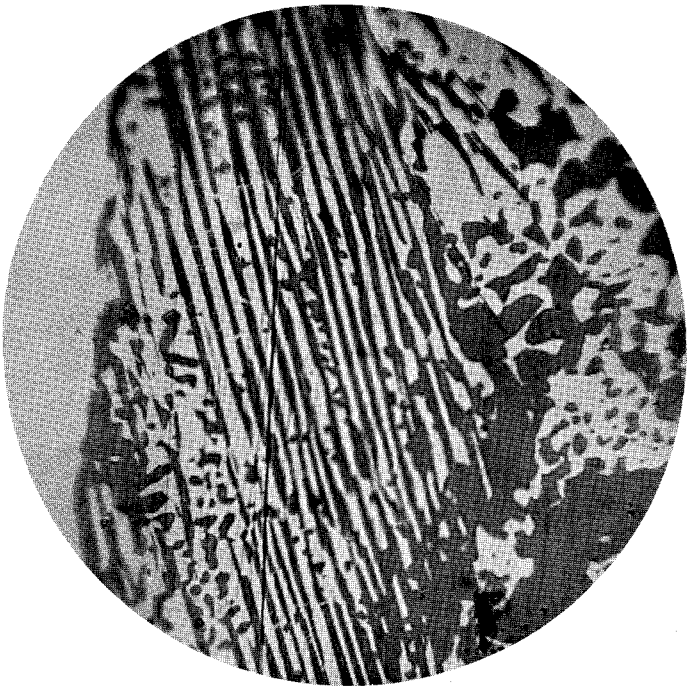
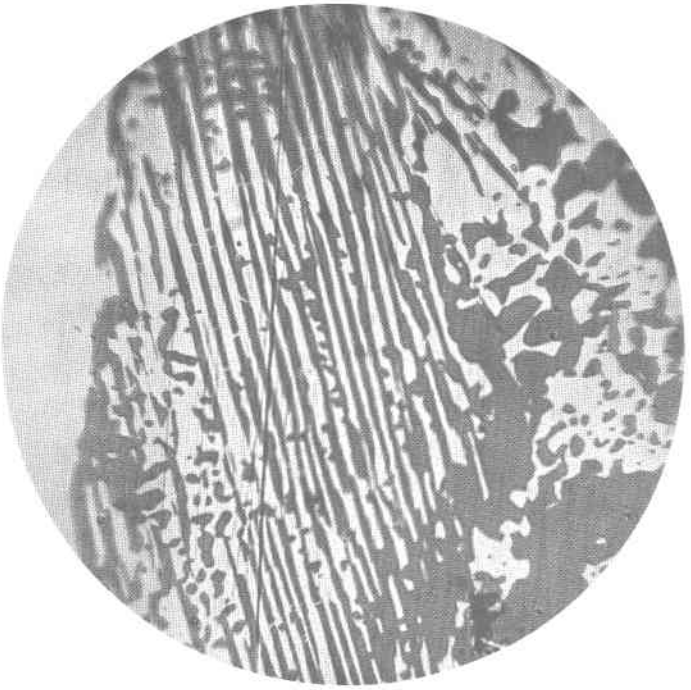


.05 mm

(B) Photomicrograph of a very highly magnified area of the section shown in (A). It may be noted that two types of structure are shown, one decidedly lamellar, and the other, normal graphic intergrowth, shows a very marked resemblance to pearlite in steel. Pearlite consists of a kind of mechanical mixture of ferrite (free alpha iron) and cementite (Fe_3C) to which Howe applied the term eutectoid. The two constituents in pearlite certainly solidify contemporaneously as the melt cools. In the case of the sulphides here shown it is not known whether or not the two were deposited contemporaneously, but it is made clear by etching the polished surface that the intergrowth is along crystallographic directions—cleavage or parting planes in the chalcocite, and that it is therefore a crystallographic intergrowth. It is also interesting to note the extremely minute lines of chalcocite crossing through the bornite and joining adjacent lamellæ of chalcocite.

White = chalcocite. Dark = bornite.



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White = chalcocite. Dark = bornite.

of the vein, and through replacement of the wall rock by vein matter. It is also probable that the openings may have been increased by earth movements, faulting, etc., along the fractures in which the veins were forming.

Deposition of the ore minerals.—The relation of the different sulphides to each other has been discussed in detail in another place in this chapter and need not be repeated here further than to state that the ore minerals, bornite, chalcocite, and chalcopyrite are of two periods of deposition. During the first of these periods the original ore minerals were deposited from deep-seated, probably hot, solutions derived from a magmatic source believed to have been the granite. The ore minerals thus deposited are the so-called hypogene minerals, and consist of bornite, chalcocite, chalcopyrite, and minor amounts of other sulphides, such as pyrite, klaprothite, argentite, etc. So far as the writer has been able to determine there was only one period of hypogene mineralization, but it was probably of considerable length, and it is not known that conditions remained unchanged or that the active solutions were the same throughout the period. One thing, however, is certain: The minerals believed by the writer to be of hypogene origin as they are found to-day invariably bear exactly similar relations to each other, entirely regardless of the mine or portion of the district from which they are taken. It must be remembered that the three important hypogene minerals, bornite, chalcocite, and chalcopyrite, and possibly some of the minor sulphides, also occur as replacement minerals of supergene origin. These, however, always have their own peculiar characteristics which are very different from those of the same minerals which are believed to be of hypogene origin. It is therefore clear that in attempting to decide to which type of mineralization any particular specimen of ore belongs, the question must be decided upon the relations of the component minerals of the ore to each other instead of upon the presence or absence of certain minerals, taking into consideration, of course, the location in the vein from which the specimen was taken. The features which the writer believes to be clearly indicative of hypogene origin of the different sulphides are the various types of complex and graphic intergrowth between the component minerals, and the relation of sulphides to gangue minerals. These have been described in detail on pp. 82-87.

During the second period of deposition, also an extended period beginning when the ores first came under the influence of the agencies of weathering and continuing until the present, the same major sulphides, chalcocite, bornite, and chalcopyrite, were deposited as were formed during

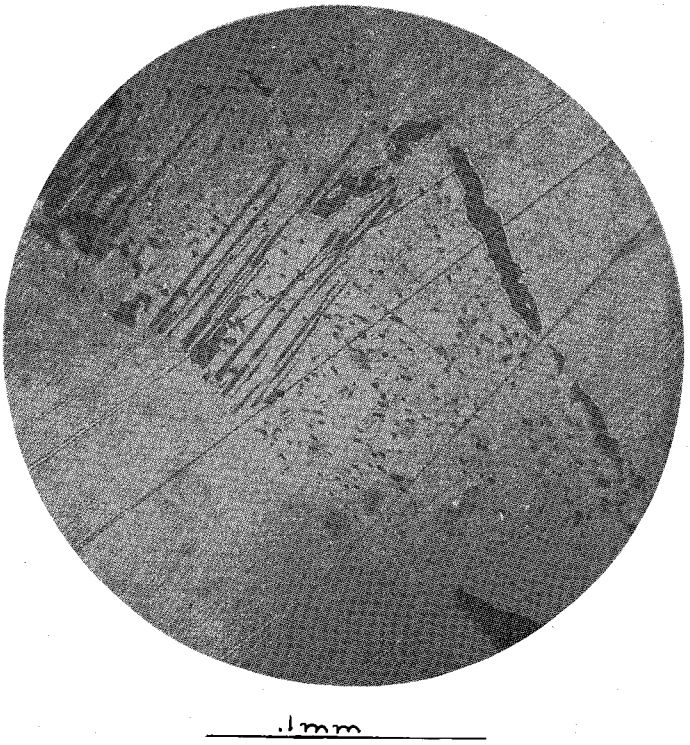
the first period of deposition. It is not known whether or not either of the minor sulphides, pyrite, klaprothite, or argentite, was formed during this period. The conditions under which these second period or supergene minerals were formed are entirely different from those of the first, or hypogene period. The supergene minerals were deposited by downward-moving meteoric waters, and are consequently limited to the upper portion of the veins, not extending below the depths reached by such waters. The minerals thus formed bear definite relations to fractures and other openings which permit the circulation of the downward-moving water, and, consequently, their relations to each other and to the minerals in which they occur are very different from those of the hypogene minerals. They always represent alterations in the hypogene sulphides in which they occur and usually are found in fractures and surrounding openings in the host mineral. The subject, however, has been discussed in detail on p. 73 *et seq.*, and need not be repeated here.

The most interesting and at the same time the most puzzling feature of the Virgilina ores are the graphic intergrowths described on pp. 82-89. Their interpretation is not only of great interest and value to the science of ore deposits, but is also of much value in forming estimates as to the continuation of the ore deposits with depth, and therefore of great value in forming estimates as to the future of the district as a whole. It, therefore, seems best to summarize the principal theories that have been offered as explanations of them.

The first theory thus presented was given by the writer[a] in his paper on the ores and minerals of the district in 1911, and it is the one to which he still holds after having made an exhaustive microscopic study of the subject. It is, that the intergrown bornite and chalcocite are both hypogene or primary minerals and that they are of contemporaneous deposition.

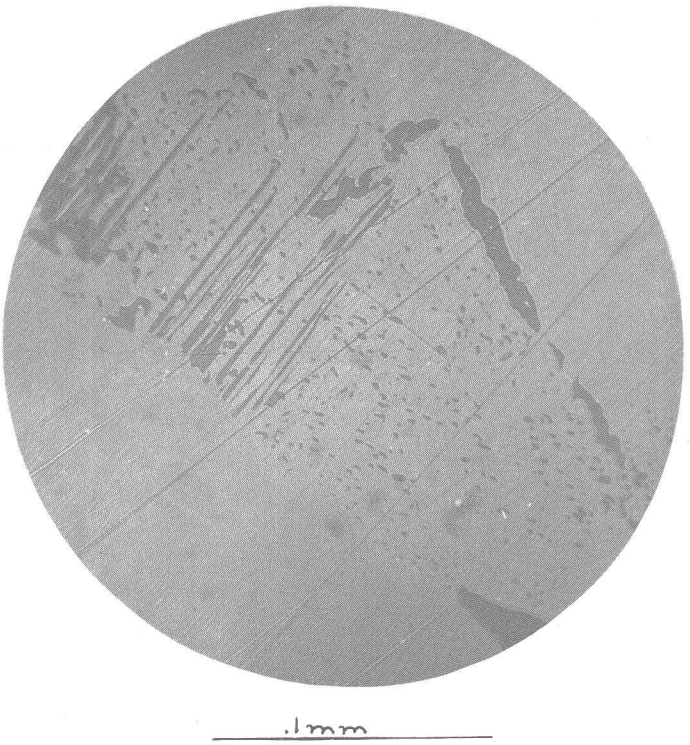
The writer believes that such crystallographic intergrowths are formed only when the component minerals are of contemporaneous deposition, and that they are similar to the same type of intergrowths in pegmatite, other sulphide intergrowths, such as sphalerite and pyrite, galena, argentite, and bismuthinite, galena and stibnite, and many others, and to the eutectic and eutectoid intergrowths of sulphides in mattes and of metals in alloys, all of which produce the same type of pattern. So far as the writer's experience has extended such intergrowths have never been found to have formed as the result of supergene agencies and processes.

[a] Laney, Francis Baker: The relation of bornite and chalcocite in the copper ores of the Virgilina district of North Carolina and Virginia, Proc. U. S. Nat'l Museum, Vol. 40, 1911, pp. 413-424; ibidem, Economic Geology, Vol. 6, 1911, pp. 399-411.



(A) Photomicrograph of a polished section of ore from Cornfield Prospect No. 2. Shows chalcocite of two distinct shades of color, one a delicate bluish gray, and the other normal. The bluish gray chalcocite is in graphic intergrowth with bornite which shows in the photographs as irregular areas, as minute dots, and in elongated rod-like forms. The two chalcocites are not clearly differentiated from each other in the photograph, but are easily distinguishable by the eye. The evidence as to the origin of such structures is not conclusive, but the writer believes the minerals were deposited contemporaneously.

Light gray = chalcocite. Dark gray = bornite.



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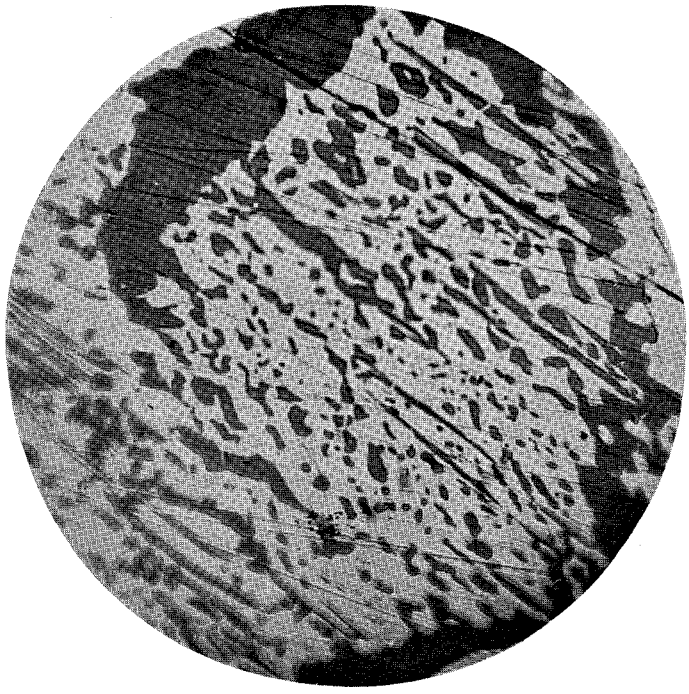

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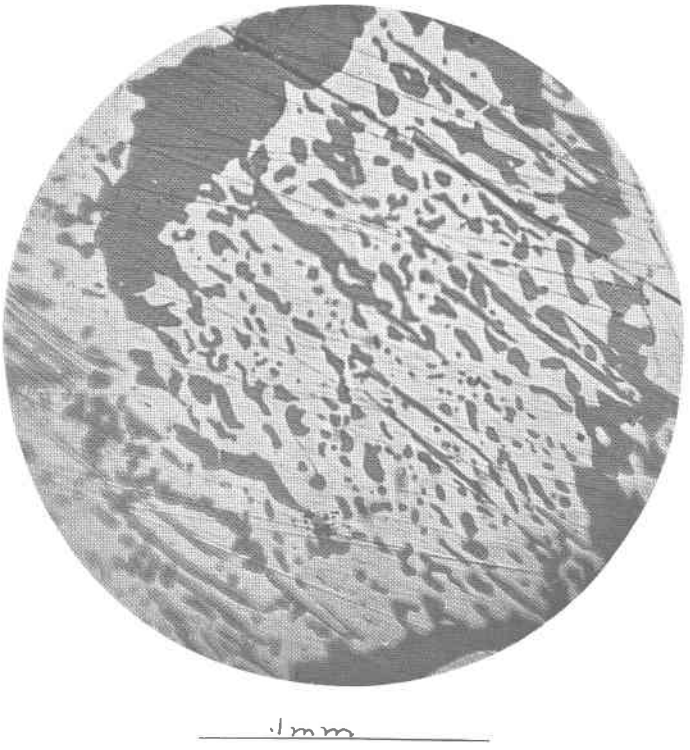
(B) Photomicrograph of another portion of the section shown in (A). Shows a different pattern of the reticulated graphic intergrowth between chalcocite and bornite.

Light gray = chalcocite. Dark gray = bornite.



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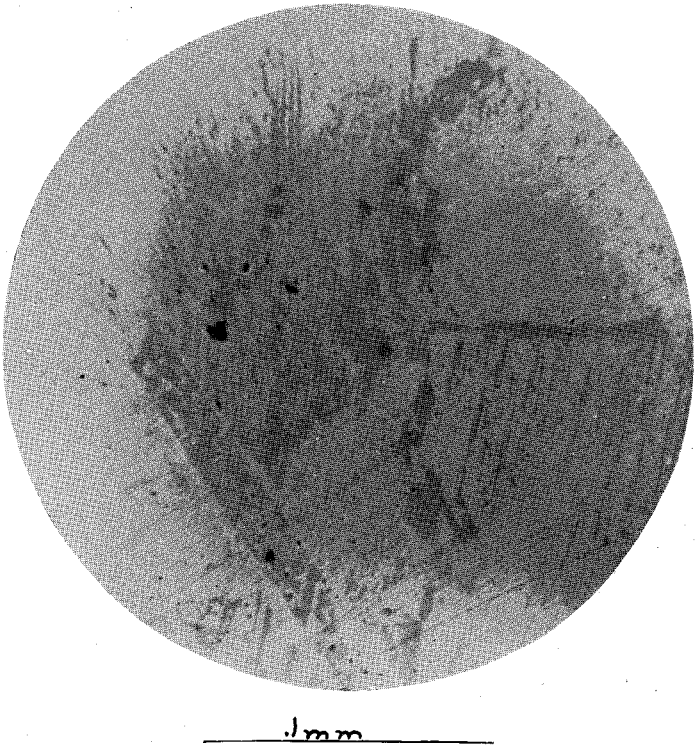
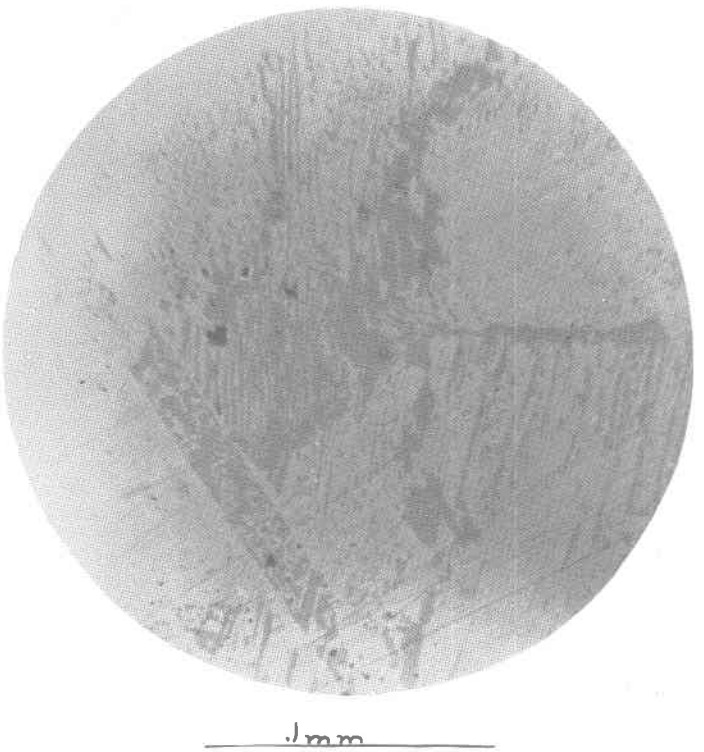


(A) Photomicrograph of a polished section of ore from Cornfield Prospect No. 1. Shows reticulated intergrowth of bornite and chalcocite. By etching the section it shows clearly that the minerals are intergrown along crystallographic directions. Such occurrences as this add to the difficulty of accounting for the formation of the graphic intergrowths as characteristic of the Virgilina ores. In the present instance there are reasons for believing them to have resulted from supergene agencies, but there is no proof that they are not of hypogene origin and that the two minerals were deposited contemporaneously.

Light gray = chalcocite. Dark gray = bornite.



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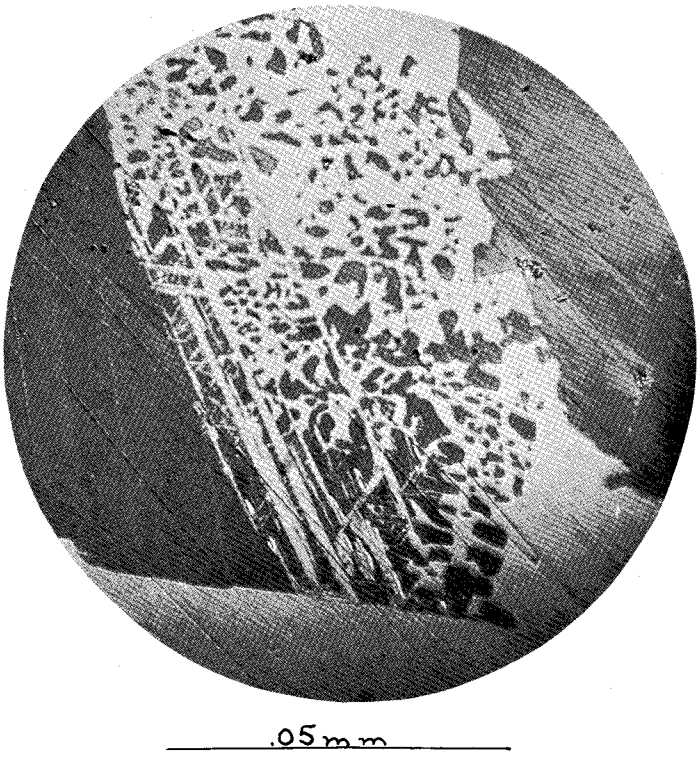
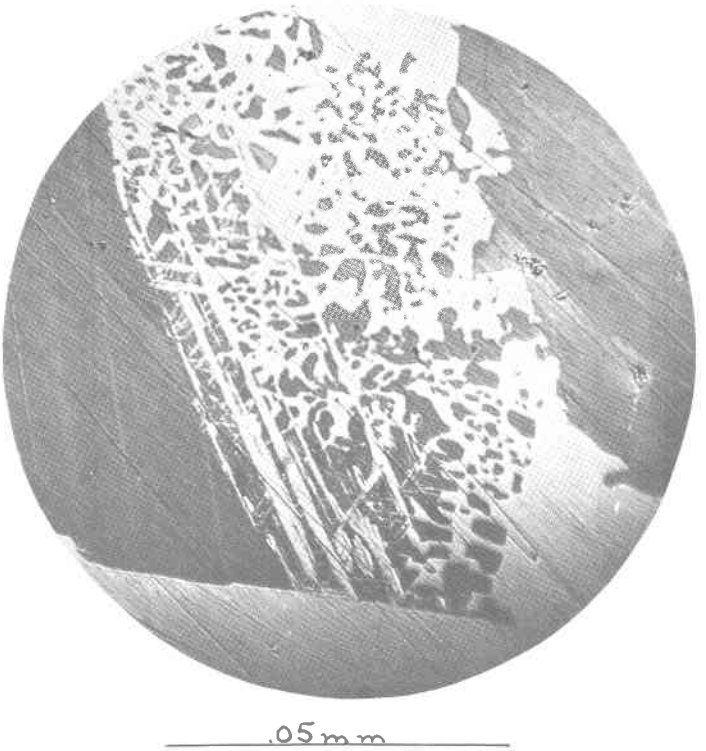


(B) Photomicrograph of a portion of the same section shown in (A), but very highly magnified in order to show the intricacy of the reticulated intergrowth. Light gray = chalcocite. Dark gray = bornite.



(B) Photomicrograph of a portion of the same section shown in (A), but very highly magnified in order to show the intricacy of the reticulated intergrowth. Light gray = chalcocite. Dark gray = bornite.

A second theory is, that the bornite in the intergrowths is a primary mineral and of hypogene origin, and that the chalcocite represents a secondary alteration of the bornite but that it is of hypogene origin. That is, the adherents of this theory believe that the chalcocite is a secondary mineral formed by deep-seated agencies.

So far as the writer can see, there is no way of either proving or disproving this theory. He has studied in great detail secondary hypogene alterations in the silver ores of Tonopah, Nev. The patterns there formed by such processes are similar to those formed in ordinary supergene enrichment. He therefore believes that the adherents of this theory must prove that such patterns can and do result from hypogene alterations in earlier hypogene sulphides before they can apply it in explanation of these intergrowths.

A third theory is that the bornite is a primary or hypogene mineral, and that all the chalcocite is a replacement of the bornite and of supergene origin.

It is felt that before the adherents of this theory can offer it they must first explain how the same agencies acting under the same conditions can produce such different and characteristic results as the chalcocite which occurs as replacement veinlets in the bornite on the one hand and the graphic intergrowths on the other. Furthermore, so far as the writer is aware, such graphic intergrowths have never been shown to result from supergene agencies.

A fourth theory, offered by Segall[a] as an explanation of certain reticulate crystallographic intergrowths in the Butte, Mont., copper ores, is that such intergrowths are the result of replacement of chalcocite along crystallographic directions by bornite.

Each of these four theories has its ardent adherents, but so far as the writer's judgment goes, neither theory has been proven nor disproven. As stated above and fully realizing the strength of the other theories, he believes that in such graphic intergrowths as those characteristic of the Virgilina ores, the evidence points more strongly toward contemporaneous deposition of the two minerals and he still adheres to that theory.

CONTINUATION OF THE ORE DEPOSITS WITH DEPTH.

The descriptions and generalizations in regard to the rocks, the veins, and the ores, and the geological structure of the Virgilina district as

[a] Segall, Julius: The origin and occurrence of certain crystallographic intergrowths, Economic Geology, 1915, Vol. 10, pp. 462-470.

given in foregoing portions of this report appear to the writer to warrant a few statements and surmises as to the continuation of the ore deposits with depth.

It has been shown that all the geological evidence in regard to the subject indicates that the veins and ores have been derived from deep-seated sources, probably from an intrusive magma entirely independent of the greenstone in which they occur. It has also been shown that the veins were developed in fractures, possibly fault planes, which extend to unknown, but certainly great, depths. When these factors are considered together it is reasonably certain that the ore deposits are by no means merely superficial phenomena and that they will extend to depths beyond the limits of mining. While there is no means of proving it, the writer regards it as reasonably certain that the intergrown chalcocite and bornite are hypogene minerals of primary deposition and therefore that there will be no change to leaner minerals with depth. It is not intended to assert that any one ore shoot will continue to indefinite depth, for such a statement would be preposterous. What the writer believes and what he intends to say is that the veins with all their irregularities as to width and metal content will probably continue to great depths. The size and value of an ore deposit as shown in reasonable development may form a basis upon which to base expectations as to what further exploration may develop. It is, therefore, the writer's opinion that if the upper 300 or 400 feet of development work in an ore shoot develops ore of commercial value, the ore thus developed will form a basis for expectations as to what further exploration would develop and that the development may be carried forward to great depths with reasonable hope of success.

THE MINES AND ORES OF THE VIRGILINA DISTRICT

DESCRIPTIVE GEOLOGY OF THE MINES AND PROSPECTS.

SEABOARD MINE.

General statement.—The Seaboard mine, owned by the Seaboard Copper Company, of Boston, Mass., is located on the west one of two approximately parallel low-lying, flat-topped ridges extending northeastward from the center of the Virgilina district. It is about four and one-half miles northwest of the town of Virgilina, located on the Danville and Norfolk Division of the Southern Railway, which is the nearest shipping point. It is reached by a good wagon road and is so located that a branch line connecting it with the main line of the railroad at Virgilina could be built at minimum expense. The country adjacent to the mine is fairly well timbered with both pine and oak, and there is an abundant supply of material for mine timber, lumber, etc. There is not an abundant supply of water for the mine, but a small stream about three-fourths of a mile southeast could be made to furnish an ample supply by the building of a dam and installing pumps to send the water from the stream to the mine. In fact, a small dam has been built at a suitable place on this little creek and the water which was used in the development of the mine was pumped from this place.

Copper is said to have been first found on this property in 1899, and between this date and 1902 two shafts, Nos. 1 and 2 of the company, were started and each sunk to a depth of about 100 feet. This early work was done by a Mr. Williams and consisted of little more than prospecting. In 1902 the property was purchased by its present owners, who at once proceeded to sink a new shaft, No. 3, and to continue work in shaft No. 2. No. 2 shaft was sunk to a depth of about 260 feet and drifts were broken off from it at the 100- and 200-foot levels, respectively. The work thus far done amounts to about 600 feet of drifts in addition to the shafts, and was all done for development purposes, and no ore was taken out except that which came from the development work.

Description of vein.—The ore-bearing ground consists of a well-defined quartz-epidote vein carrying a small amount of calcite. This vein varies in width from one and one-half to eight feet, averaging three and one-half

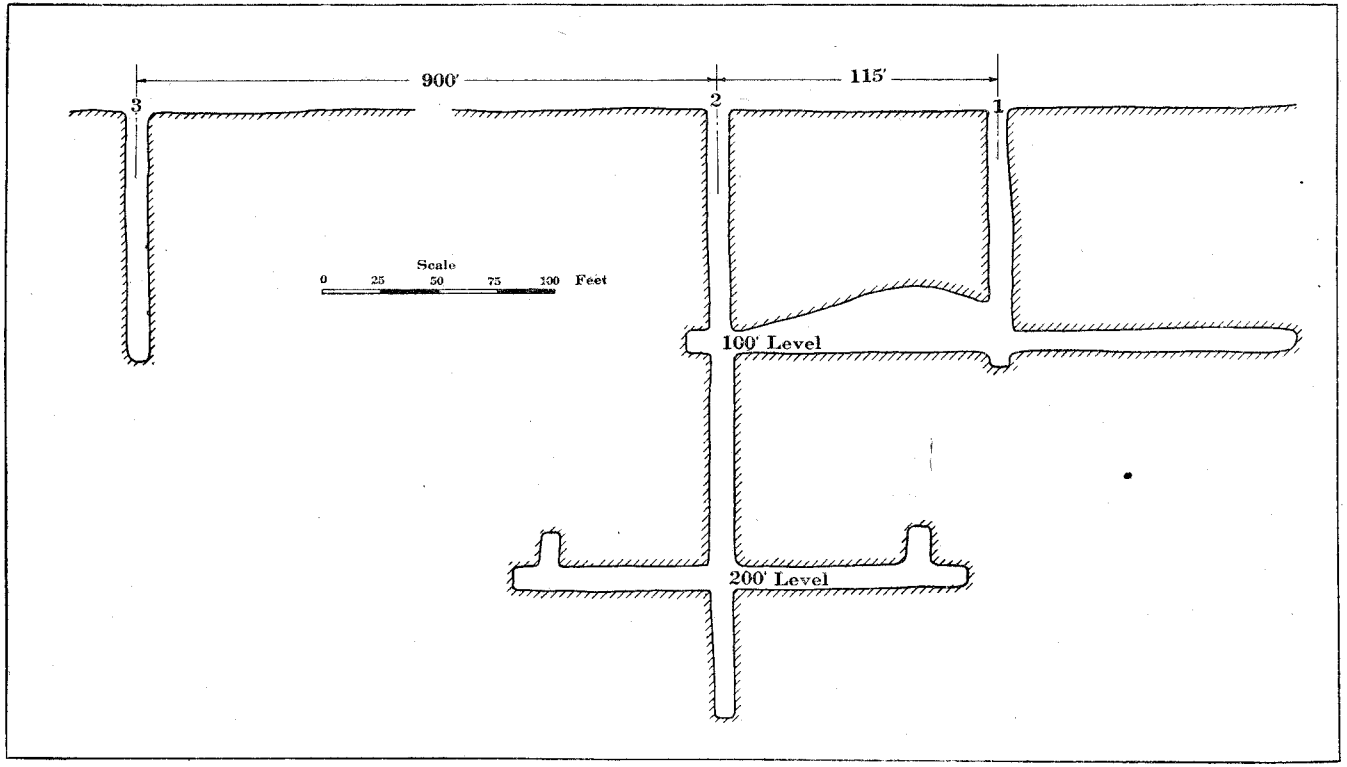


Fig. 2.—Vertical section of Seaboard mine. Surveyed by T. W. Sprague, 1909.

to four feet, and is traceable on the surface by means of quartz débris for a distance of about one and one-half miles. Three ore shoots have been located, one at shaft No. 3, one at shafts Nos. 1 and 2, and the third about one-half mile north of shaft No. 2 near the public road running west from Red Bank. Of these ore shoots only that at shafts Nos. 1 and 2 has been developed to any important extent; the others, however, especially that at shaft No. 3, appear to be fairly well mineralized and to warrant further development. In addition to this, the main vein, there is another well defined but smaller vein lying about 200 feet west. This west vein is well marked by quartz and epidote on the surface and is traceable for about three-fourths of a mile, and has been opened by a shallow shaft about 1,200 feet south of shaft No. 1. This prospect opening showed the vein to be narrow but to carry a small percentage of copper. Both veins have a strike of from 5 to 10 degrees west of north and dip about 80 degrees to the east. The schistosity of the country rock strikes approximately north and south, and it is thus seen that the veins cut the schistosity at sharp angles. They are believed to be true fissure veins and to have been developed in fractures which, as a rule, in this district have a more northerly trend than the schistosity of the country rock, though in many instances their trend is parallel with the schistosity. These veins have well-defined walls and part readily from the country rock. However, in places there is a small amount of mineralization of the wall rock at its contact with the vein. As is usually the case with veins in this region, these present many irregularities, the most important of which consist of "pinches" and "swells," both horizontally and vertically. The development at this mine has not gone far enough to show the extent of irregularities that have been noted, but there are decided "pinches" in at least two places with corresponding "swells" in two others. The veins are much more highly siliceous than the country rock, and are believed to have been derived from sources other than the rocks in which they occur. This subject, however, is discussed in the chapter on the origin of ores.

The ore shoots, so far as the development has proceeded, are well mineralized and appear to have a slight pitch to the south. The ore does not occur in any one portion of the shoot to the exclusion of all others. In some instances it is distributed rather uniformly throughout the vein. In others it is largely concentrated near one wall with only a small amount scattered irregularly through the rest of the vein, while in still others the principal values occur near the middle of the vein with only a small amount in other portions of it. There is always more or less barren material in

the vein, but it is so located that it can not be left in the ground in mining. The only structural feature affecting the developed portion of the mine appears to be a small fault which was encountered in the south end of the drift on the 200-foot level, at which point the vein appears to be cut out completely. All indications, however, are that the disturbance is slight and that the vein could probably be picked up again by drifting a few feet into the hanging wall at the end of the drift.

Ore and gangue minerals.—The ore at this mine consists of bornite and chalcocite together with a small amount of malachite in the upper portions of the vein. In certain portions of the ore shoot bornite appears to be more abundant than in any other mines of the district. In fact, the purest bornite found during the field investigations was taken from this mine. Much of the unaltered ore, however, like that from the other mines of the district, consists of bornite and chalcocite intergrown in such manner as to indicate that the two minerals were deposited contemporaneously. In the ore from the upper portions of the ore shoot much secondary chalcocite occurs in the bornite as veinlets varying from knife-edge seams to one-fourth inch in width. These penetrate the bornite in all directions and vary in size from the finest line, often scarcely visible even with the highest powers of the microscope, up to veins of pure chalcocite one-fourth inch in width. See Plate VIII (A and B). The centers of nearly all of the largest chalcocite-filled fractures are marked by sponge-like areas of some material, which in some instances appears to be quartz and limonite, and to mark the original fracture in which the chalcocite began to develop. In most cases these areas are of appreciable size and include particles of chalcocite and appear to have developed simultaneously with the chalcocite. Plate XIII (A and B).

When a polished section of ore showing these chalcocite veinlets is etched with hydrochloric acid and examined under the microscope, the material is seen to be porous and to resemble a sponge, and to be filled with minute specks of chalcocite. The boundary between these veinlets of secondary chalcocite and the bornite is generally regular, but the material within the chalcocite usually presents a somewhat feathery outline. The boundary line between the chalcocite and bornite is always perfectly clear cut and sharp, and there is absolutely no gradation of one mineral into the other. It is also clear from microscopic examination that each little vein of chalcocite in all probability started as a mere film in the fracture and grew to its present size, but how this growth took place is not made clear by microscopic

study of the veinlets. It does appear, however, that it took place at the periphery of the material already deposited, and that the veinlets increased in size at the expense of the bornite. However, the chemistry of the process has not yet been worked out. In some instances chalcocite-filled fractures in the bornite appear to be of two periods, one earlier than the other, and in such instances the more recent fractures cut across the chalcocite veinlets in the older ones. Fractures also occur in the areas of intergrown chalcocite and bornite, and in such instances the secondary veinlets cut across both the primary chalcocite and the bornite. The relations of the two minerals in such cases leave no doubt as to the secondary nature of the chalcocite in the veinlets.

The gangue minerals in this mine consist of quartz, epidote, calcite, chlorite, albite, and hematite. Quartz is by far the most important gangue mineral and makes up more than three-fourths of the vein. Calcite and epidote are present in about equal amounts, while albite, chlorite, and hematite are only sparingly developed. The greater part of the quartz is massive, and shows no tendency to form crystals. However, in some instances, especially in openings or vugs, quartz, calcite, and albite were found with good crystal development, and all were intergrown with the bornite and chalcocite. The peculiar association of gangue and ore minerals in this mine presents some features which have an important bearing on the genesis of the ores, and the subject is discussed fully in the chapter on this subject.

Development.—The development of this mine consists, as has been stated, of three shafts, Nos. 1, 2, and 3. Shaft No. 1 was the first to be sunk, and extends to a depth of 110 feet; shaft No. 2 is on the same vein, is located 113 feet south of shaft No. 1, and is the main working shaft of the mine. It is about 350 feet deep and from it two levels have been broken off, one at 100 feet and the other at 200 feet. The 100-foot level has been driven in the vein about 225 feet northward, intersecting shaft No. 1. The vein throughout this distance has an average width of about four and one-half feet and a copper content of approximately 2 to 2.5 per cent. The second level extends 105 feet north from the shaft and 90 feet south. On this level the vein is slightly narrower than at the first level, but the copper content is approximately the same. At the point where the second level was broken off from the shaft, the vein is narrow and not very promising, but at the bottom of the shaft it has widened considerably, has increased in ore content, and is much more promising.

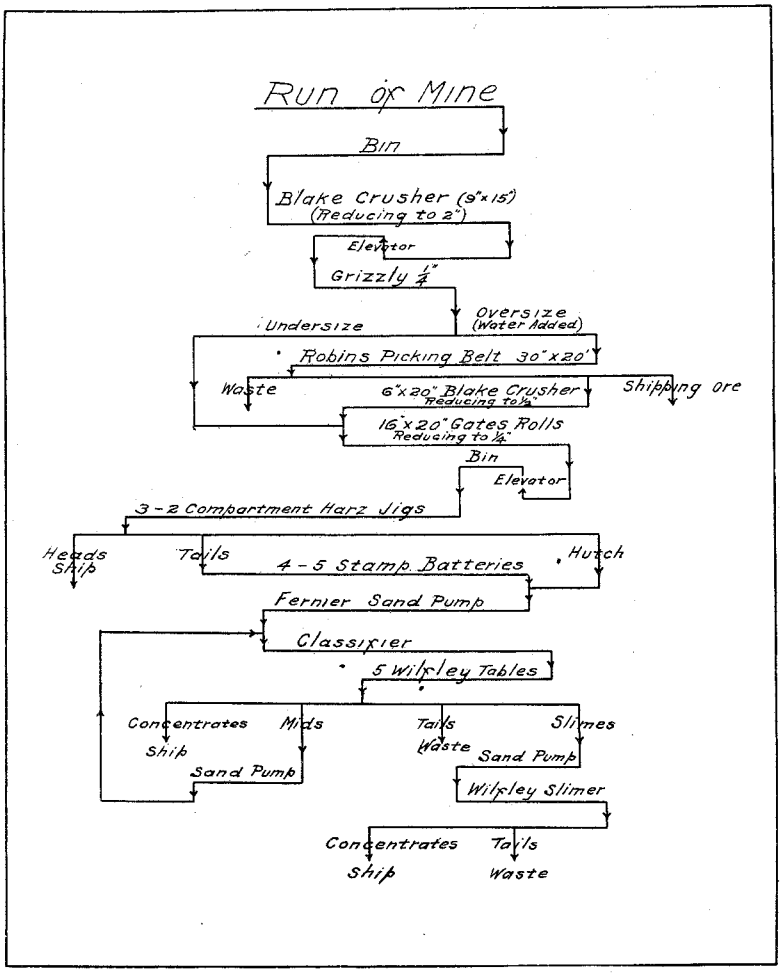


Fig. 3.—Flow-sheet of Seaboard mill as designed and constructed by A. W. Tucker, 1909.

Practically no ore has been taken from this shaft except that which was removed during the development work. Shaft No. 3 is 105 feet deep, is located about 900 feet south of shaft No. 2, and no drifting has been done. At the time of the field work this shaft was filled with water and, therefore, inaccessible. The ore on the dump, however, is entirely similar to that taken out of No. 2. No observations as to the width of this vein or the extent of the ore shoot could be made. However, it was reported that the vein is about 5 feet in width and fairly well mineralized. A generalized vertical section showing the development of the mine at the time the field work was in progress is shown in figure 2, page 96.

Concentrating plant.—It is generally agreed by those who have studied the ores of the Virgilina district that the future development of the district depends upon the ability to concentrate the ores. In order to solve the problem of concentration, which had been attacked in a desultory way at two or three mines in the district, the Seaboard Copper Company employed Mr. A. W. Tucker, of the Massachusetts Institute of Technology, and supplied him with the necessary ore for experimental work. This work, which was carried on in the laboratory of the Institute in Boston, gave satisfactory results, and in 1907 the company erected, under the supervision of Mr. Tucker, a 50-ton mill in which the ore is given the following treatment:

On being hoisted from the mine the ore passes through a rock breaker and is crushed to two inches, then passed over a picking belt from which barren material is rejected as waste, and ore approximating 10 per cent or more in copper is selected for direct shipment. The remainder is reduced to one-fourth inch by a crusher and rolls and is passed through a series of 4-compartment Harz jigs. From the jigs three products are obtained, a 50 per cent copper concentrate; a hutch product, which goes direct to a set of Wilfley tables; a middlings; and tail product, which goes to a battery of stamps and which, after being stamped through 60 mesh, is subjected to treatment on Wilfley tables. From these a 25 per cent copper concentrate is obtained. The slimes are collected and are run on Wilfley slime tables, the concentrates from which are added to that from the regular tables. No figures were obtainable which would give the total percentage of copper saved by the mill. However, in the experimental work in the Massachusetts Institute of Technology above referred to, a similar equipment to the one just described was used, and a saving of between 80 and 85 per cent of the assay value of the ore was obtained. The flow sheet of this mine, which was furnished by Mr. Tucker, is shown in figure 3, page 100.

The mill was operated only a short time, and the ore treated consisted of about 2,200 tons of second-grade material left over after hand picking. From this there was extracted about 77 tons of concentrates. Smelter returns from these were as follows: Hand-picked ore averaged 7.45 per cent copper, 1.50 ounces of silver, and .01 ounce of gold per ton, respectively. Table concentrates averaged 23.85 per cent copper, 2.89 ounces silver, and .02 ounce gold per ton.

While it is evident that the data just given are not sufficient to warrant any far-reaching statements as to concentration of the Virgilina ores in general, it is believed that they do show conclusively that a properly constructed and operated mill will concentrate the ores in a satisfactory manner, and they also indicate that such a mill should be constructed somewhat along the lines of the Seaboard mill.

BLUE WING MINE.

General statement.—The Blue Wing mine is located about one and one-half miles southeast of the town of Virgilina, from which it is reached by a good wagon road. The branch line of the Southern Railroad running from the junction about 1 mile east of the railroad station at Virgilina to the Holloway mine passes within 100 feet of the Blue Wing shaft, and thus furnishes excellent shipping facilities.

While the timber lands surrounding the mine have been cut out, there is still an ample supply of both hardwood and pine for mine timbers. At the time of the field work there was such an abundant supply of cord wood that the mine management found it a much cheaper fuel than coal.

There is only a moderate supply of water, which is derived from a small brook near the mine. In winter and spring the supply is ample, but during the late summer and fall, the dry season in the region, the brook is often dry and water for mining or milling purposes is scarce. However, it is believed that by impounding the water during the spring there could be provided at small expense a supply sufficient for all actual needs during the dry season. In case this water should fail, it is certain that an ample supply could be obtained by pumping from Aaron's Creek about one and one-half miles east of the mine.

The mine takes its name from Blue Wing post-office, long since abandoned, which was located a short distance west of the mine at the time of its opening, and which in turn received its name from Blue Wing Creek located about 2 miles west of the post-office. It is reported that during the year the mine was opened about 500 tons of high-grade ore

were taken out and shipped. The property after passing through several hands was acquired about 1895 by its present owners, the Boston and Carolina Copper Company, a Massachusetts organization maintaining offices in Boston. It has been operated spasmodically rather than steadily, and has been allowed to lie idle the greater part of the time. The causes for this idleness, so far as they could be determined, appear to have been litigation, certain transactions looking toward a consolidation of the more important mines of the district which the company was trying to effect, and the varying price of copper. There has never been a time since the discovery of the mine when it would not have been regarded at least as a very favorable prospect. The causes for so much intermission in operation are thus attributed more largely to market, financial, and other conditions affecting the operators than to the lack of ore in the mine or of promise in the prospect. The last work was done in 1909 by E. H. Westlake of the Tennessee Copper Company under an option granted by the owners of the property. Under this agreement the mine was operated, but not continuously, from July 1, 1909, to January 1, 1910, and about 3,000 tons of ore were shipped which averaged between 2 and 3 per cent of copper. During this work the shaft was sunk an additional 80 feet, giving it a total depth of 360 feet and about 400 feet of new drifts were driven.

The surface plant consisted of the housing for the shaft and the necessary machinery for operation, consisting of a steam boiler, a small hoisting engine, a good 10-drill air compressor, picking belt, and equipment including a rock breaker. There are also bins for storing about 100 tons of ore, and a repair and blacksmith shop.

Nothing in the way of concentration has been done during recent years except such sorting of ore and elimination of waste as could be done on a picking belt, which work was done efficiently and cheaply by negro women. It is reported that in the early days of the mine crude attempts were made at concentrating the ore. The plant for this purpose is said to have consisted of the necessary crushing equipment, a set of Harz jigs, and a Frue vanner. The equipment was so meager and ill adapted to the ore, and the work was done in such a desultory way, that it proved a decided failure and was soon discontinued. This failure must not be taken to indicate that the ores are not amenable to concentration, for from experimental work, and also from actual mill practice on other ores of the district similar in all respects to the Blue Wing ore, it is certain that with modern equipment and intelligent management these ores can be concentrated without difficulty.

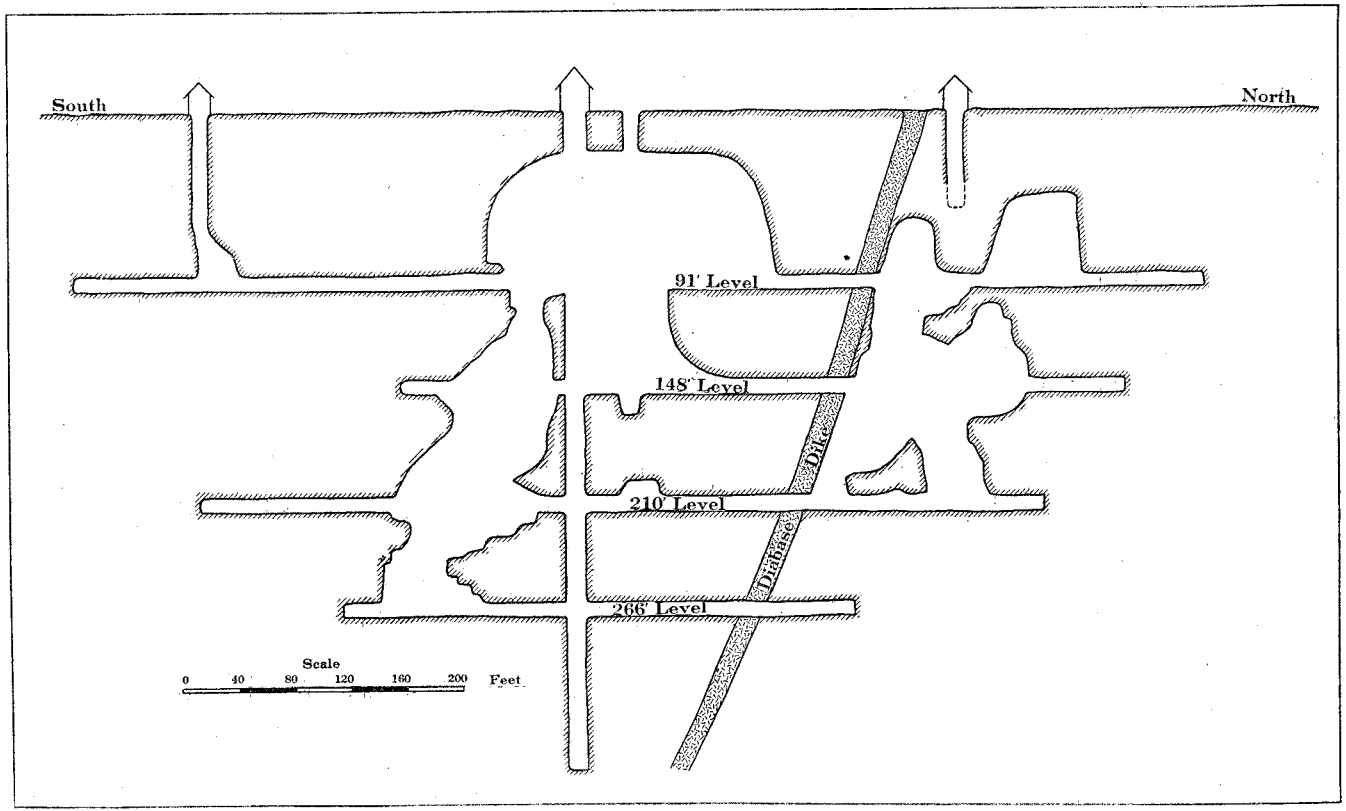


Fig. 4.—Vertical section of Blue Wing mine. From surveys by J. Parke Channing, 1905, and R. W. Lassiter, 1910.

Underground development.—The property has been tested and developed by one working shaft about 360 feet deep, 3 prospect shafts varying in depth from 50 to 125 feet and about 1,700 feet of drifts, which were broken off from the main shaft at four levels: 91 feet, 148 feet, 210 feet, and 266 feet, respectively, from the surface. Considerable stoping has also been done in what appear to be two distinct ore shoots, one at the main shaft and another immediately north of the diabase dike which crosses the vein about 120 feet north of the shaft. In the first-mentioned ore shoot the stoping extends from about 30 feet from the surface to the 260-foot level and in the second from about 50 feet from the surface to the 210-foot level. Nothing in the way of exploratory work except the shaft has been done in ground deeper than the 266-foot level, although all indications are that the two ore shoots will probably extend to a much greater depth than has been reached by any of the present workings. The vein varies from about 2 to more than 6 feet in width, averaging perhaps 4 feet, and the values are distributed irregularly through it, with sometimes portions of the walls being mineralized. Consequently, in order to be certain of obtaining all the values in drifting and stoping, it is always necessary to remove the entire vein, and, in some instances, a considerable portion of the walls. The drifts and stopes, therefore, represent at least the actual width of the vein and show the irregularities as to outline that it presented. A vertical section through the mine showing the development up to 1910 is shown in figure 4, page 104.

Only the usual and well-known methods of mining were used in this mine. Modern air drills were used in sinking and driving, and together with light stoping drills furnished the equipment for use in breaking the ore. Both the overhead and underhand methods of stoping were employed, the one being used which was most suitable for the ground to be removed. The mine apparently makes only a moderate amount of water, which was easily handled with a small Cameron pump. The broken ore was trammed to the shaft, hoisted in buckets, and dumped in a bin about 20 feet above the collar of the shaft. From this bin it was passed through a rock breaker and reduced to 2 inches, and then passed over a grizzly which removed all material less than 1 inch. The oversize went on the picking belt from which the waste rock was removed; the ore then passing into bins from which it was shipped.

Geologic relations.—The country rock at the Blue Wing mine is the typical greenstone schist of the district, and does not differ essentially

from the rock at the Holloway, Durgy, and Seaboard mines. Technically speaking, the rock is a mashed and much-metamorphosed andesitic tuff, associated with which is a small amount of normal andesitic lava which in some places is slightly porphyritic and in others decidedly amygdaloidal. The intense metamorphism to which the rock of the district has been subjected has to a large extent obliterated its original characteristics and

Fig. 5.—Ore from Blue Wing mine, showing banded structure. The white ground is calcite, with some quartz in little lenses. The solid black is bornite. The parallel lines represent schist. Scale, natural size. (After W. H. Weed.)

transformed it into a chlorite-epidote schist which varies in color from dark green to a purplish-gray. It almost invariably has a decided slaty cleavage or schistosity, which in the vicinity of the Blue Wing mine has a trend of from 20 to 30 degrees east of north and dips from 70 to 80 degrees toward the southeast. This subject, however, is discussed in the chapter devoted to the detailed description of the rocks of the district.

There is at this mine an interesting phenomenon that occurs at only one other mine in the district, namely, the Durgy mine. This is a dike of olivine diabase about 15 feet wide, which cuts across the vein some 150 feet north of the shaft. The dike trends approximately north 35 degrees west and dips about 65 degrees to the southwest. Thus, as the shaft is increased in depth, it necessarily approaches nearer the dike, and, unless the dip of the latter changes, will intersect it at a depth of about 425 feet. The intrusion of this dike followed the development of the vein and ores at a great interval of time and is believed to have had no influence in the formation of the vein or ores. The only effect noted so far as the mine has been developed consists of a slight shattering of the vein at the contact between it and the dike, and in a few places by slight displacement on the north side of the dike. This displacement is especially noticeable on the fourth level, where the vein is badly shattered and apparently displaced about 8 feet toward the east.

The vein is a typical fissure vein, and is made up dominantly of white quartz with much calcite and variable amounts of epidote, chlorite, and a few other minerals. The vein, which varies in width from 2 to 6 feet, will average about 4 feet, and, while locally it appears to follow the schistosity of the country rock, taken as a whole, it has a somewhat more northerly trend than the schistosity. It presents many irregularities in shape and form, but maintains its average width with much persistence. Within it are included many fragments and strips of more or less altered country rock, and in many instances it presents a decidedly sheeted appearance caused by the vein matter filling spaces between the torn-apart or rifted schists. As a rule, both foot and hanging walls are well defined, although in places one or the other is rendered obscure by the development of numerous layers or plates of vein matter in the rifted schist. The foot-wall is probably more clearly defined and is more easily followed in mining than the hanging wall. However, as a rule, both walls are well defined. The ores are almost exclusively confined to the vein, but there is always a varying, and in some instances a considerable, amount of ore in the wall rock near the contact with the vein. In mining it is, therefore, always necessary to keep close watch of the walls in order to be certain that no values are left. The vein possesses many irregularities in the way of pinches and swells, and contracts and widens in both vertical and horizontal directions.

Ore and gangue minerals are of contemporaneous development, and there is little or no supergene or secondary enrichment, at least none of importance from a commercial standpoint. While there is a tendency

toward segregation of the quartz and calcite in the vein, in no place has it been carried to completion, and each mineral is intermixed and intergrown with the other and with the ore.

The following minerals, exclusive of included country rock, named in the approximate order of their abundance, make up the gangue minerals of the vein: Quartz, calcite, chlorite, epidote, and hematite. The ore minerals in the order of their abundance are: Bornite, chalcocite, malachite, azurite, and argentite(?). It is not definitely known how the silver occurs in the ore, but microscopic examination of polished sections offers some evidence that it is present in the form of argentite, and that it is intergrown with the other sulphides. Ore and gangue minerals are so intimately asso-

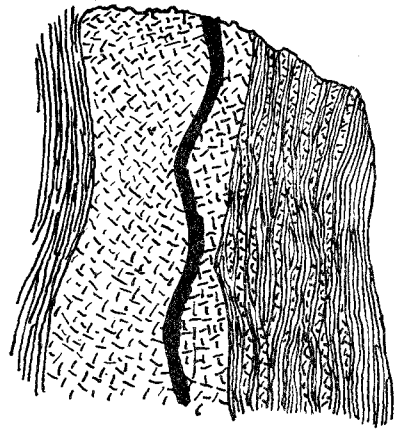


Fig. 6.—Blue Wing vein, face of 100-foot level, north. On the right is schist with stringers of quartz. In the center is calcite with some quartz and a streak of ore. On the left is calcite and quartz, then schist. (After W. H. Weed.)

ciated and intergrown with each other that there is little doubt that they are of contemporaneous development. There is a slight tendency on the part of the ore to be segregated in different portions of the veins, but in no place is it completely so, and in general a good part of the ore is found bunched here and there throughout the vein, while a smaller amount is scattered irregularly through it. There is also often an important development of ore in the schists at or near the contact with the vein. An important feature of the deposit from both a commercial and scientific standpoint is the predominance of quartz as a gangue mineral. Many carefully made estimates and analyses show that the vein carries an excess of silica varying from 60 to 70 per cent, thus making it possible to use the ore as

converter linings and as a siliceous component in smelting other heavy sulphide ores. In fact, this feature is common to all the ores of the district and forms a very important consideration in its future development. The following partial analyses of selected samples of the ore, which were made for commercial purposes, show in a general way the composition of the ore.

Partial Analyses of Selected Samples of Blue Wing Ore.[a]

	A	B
	Per cent	*Per cent*
Cu	2.73	4.10
Fe	6.10	6.50
CaO	5.65	7.10
S	0.91	1.46
Al_2O_3	6.89	1.10
MgO	0.79	0.56
SiO_2	66.84	69.00
Ag	0.80 oz. per ton	1.30 ozs. per ton

From the standpoint of genesis of the ores their highly siliceous character indicates that they are probably derived, not from the basic greenstones in which they are found, but from some extraneous, highly siliceous rock, in all probability from the granitic intrusions which occur abundantly in certain parts of the district. This question is discussed in detail in the chapter on the origin and deposition of the ores. The general character of the vein and the relation of ore and gangue to walls and country rock are well illustrated in the following sketches by Weed.[b] Figure 6 represents, natural size, a typical specimen of ore, showing banded structure caused by the inclusion of layers of schist and illustrates the distribution of ore through the gangue. Of figures 6, 7, and 8, Weed says: "Fig. 6 shows the face at the north end of the 100-foot level; Fig. 7 the roof above the stope, a short distance south of the face. Fig. 8, a sketch of the south face of the same level, shows quartz lenses holding ore and the slate-casing to the ore lenses. This south face shows on the hanging wall barren white quartz and calcite, and on the foot dark gray sulphide in slate with quartz streaks holding parallel threads or films of what looks like slate dotted with ore. Ore (harder and darker in color) also occurs in the casing. The ore body often presents a streaked or ribboned appearance, due, not to crustification or to recent movement of the vein, but to partly replaced sheets of slate."

[a] U. S. Metals Refining Company.

[b] Weed, Walter H.: Types of copper deposits in the Southern United States, Am. Inst. Min. Eng., Trans., Vol. 30, 1900, pp. 465-467.

The general tenor of the ore is well shown by the following tables of smelter returns on actual shipments of ore. These shipments were selected to represent the type of ore taken from the mine at different periods in its development. They represent the returns for ore taken out in 1899 to 1900, which is selected and cobbed ore rather than the run-of-mine, and consequently shows a much higher percentage of copper than the average of the vein. The table showing the returns for 1907 represents the run-of-mine ore with only such waste material as was removed on a picking belt, and is believed to represent the average ore of the mine.

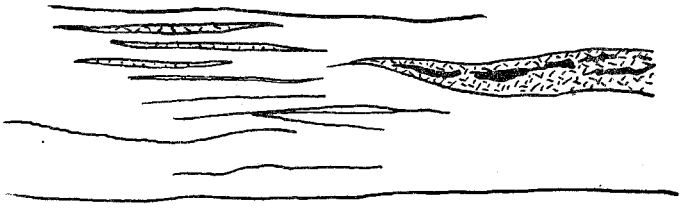


Fig. 7.—Sketch of Blue Wing vein in roof over stope above the 100-foot level, 350 feet south of shaft. On the left, calcite and a little white quartz, with dark streaks of slaty material and spots of ore. On the right, ore in dark quartz. (After Weed.)

Assays of Blue Wing Ore, 1899-1900.

Lbs. Sampled	Date	Cu. *Per cent*	Ag. *Ozs.*	Au. *Ozs.*	Assayer
42,885	May 12, 1899	11.91	N. d.	N. d.	Ledoux and Co.
43,341	June 3, "	11.31	"	"	"
46 075	" 19, "	12.40	"	"	"
50,276	July 14, "	11.70	"	"	"
43,907	" 21, "	12.38	"	"	"
43,881	Aug. 8, "	13.85	"	"	"
41,514	Sept. 9, "	12.69	"	"	"
31,705	Nov. 24, "	7.35	"	"	"
41,193	" 21, "	11.04	"	"	"
49,823	Dec. 30, "	15.64	5.55	"	"
5,289	Sept. 12, "	42.48	N. d.	"	"
54,879	" 12, "	3.76	"	"	"
39,879	" 11, "	3.56	"	"	"
66 772	Oct. 7, "	10.27	"	"	"
3,063	Dec. 30, "	44.48	13.80	.01	"
36,340	Jan. 20, 1900	6.48	N. d.	N. d.	"
54,051	Oct. 19, 1899	8.33	"	"	"

Assays of Blue Wing Ore, 1907.

Lbs. Sampled	Date	Cu. *Per cent*	Ag. *Ozs.*	Au. *Ozs.*	Assayer
44.160	July 20, 1907	6.81	2.65	.0066	Eustis Smelting Works
327,250	" 5, "	3.17	1.18	.005	"
298,184	" 9, "	3.09	1.16	.005	"
354,917	" 20, "	2.69	1.02	.994	"
337,548	" 20, "	2.69	1.00	.004	"
369,685	" 27, "	3.08	1.17	.005	"
389,027	" 29, "	2.66	1.00	.004	"
370,728	" 31, "	2.08	.80	.002	"
234,679	Aug. 5, "	2.46	.96	.005	"
198,230	" 9, "	2.47	.97	.004	"
373,814	" 9, "	2.31	.89	.004	"
345,465	" 22, "	2.39	.89	.004	"
217,191	" 22, "	2.42	.90	.004	"
322,720	" 22, "	2.67	.95	.0045	"
363,699	Sept. 1, "	2.67	.96	.005	"
221,132	" 3, "	2.96	1.07	.005	"
326,477	" 3, "	2.75	1.00	.005	"
312,586	" 9, "	3.26	1.14	.005	"
232,525	" 4, "	4.21	1.54	.015	"
309,108	Oct. 15, "	2.01	1.06	.005	"
390,117	" 15, "	2.70	.99	.005	"
368,728	" 15, "	3.31	1.14	.006	"
178,713	Nov. 6, "	5.89	2.23	.007	"

The Blue Wing vein is fairly persistent and can be traced by outcrop or by quartz débris on the surface with some interruptions for nearly half a mile. Just how much of it throughout this distance is mineralized is not known, but at least three openings at intervals of more than 1,000 feet show ore. These are the Blue Wing mine proper, the opening 1,000 feet to the south known as the Spring shaft, and an abandoned pit 25 or 30 feet deep about one-fourth mile south of the Spring shaft. Some of the surface débris between the Spring shaft and this pit shows copper stains, and it is not improbable that more prospecting would develop other more promising ore shoots. Of the four ore shoots thus far known, the two at the main shaft are most promising. The one at the Spring shaft shows good ore as far as development, which consists only of a shaft about 100 feet deep, has gone. While the average ore at this shaft does not contain as high a percentage of copper as that at the main shaft, all geological conditions, so far as could be determined, are similar, and it is not improbable that future work would develop an important body of ore at this place. This shaft was filled with water at the time of the field work and was,

therefore, not accessible for study, and the statements in regard to it are, therefore, based on an examination of the material on the dump and on reports of men who worked in the place. At the opening, about one-fourth mile south of this shaft, the conditions are somewhat different. So far as could be determined from the abandoned and caved pit, the vein is well defined but narrower, and, judging by material on the dump, contains very little calcite. The ore also differs from that at the Blue Wing and Spring shafts in that it contains specular hematite in excess of the copper-bearing sulphides. Bornite and chalcocite are present, but in all the material available for examination were found to be subordinate in amount to the hematite. Hematite occurs with the sulphides in all the mines of the

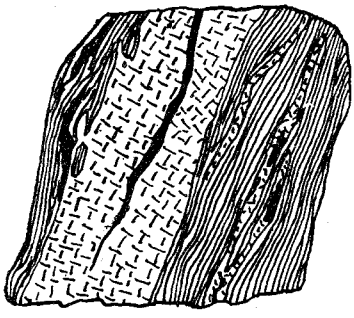


Fig. 8.—Blue Wing vein at the south face of the 100-foot level. On the right is schist carrying streaks of quartz. In the middle are barren quartz and calcite with a band of ore in the center. On the left is schist containing quartz lenses and ore. (After W. H. Weed.)

district, but only in this one prospect is it present in great abundance. Its relation to ore and gangue minerals, so far as noted, is the same in all cases, that is, intergrown and contemporaneous with them.

Only at the Blue Wing shaft has development work gone far enough to afford data on the pitch and other characteristics of the ore shoots, and even in this instance it is not extensive enough to warrant much in the way of generalization. It can be stated, however, that the ore does occur in definite ore shoots in which it shows a tendency to be segregated largely in different places in the vein, but that this segregation is in no place complete, and that smaller but important amounts of ore are distributed irregularly through the vein. It may also be stated that, so far as development has gone, the ore shoots have a pitch in the vein of about 65 degrees to the south, having, therefore, approximately the same pitch as the diabase dike which intersects the vein in this mine.

Production.—No record of the total amount of ore taken from this mine is available, but, judging from the amount of stoping that has been done and from such records as could be found, it would certainly not be placed below fifty thousand tons. It is also believed, from an examination of such smelter returns as were accessible, that the ore taken out and shipped carried an average of about 4 per cent of copper.

Future of the mine.—The part of the geologist's report on a mine which is probably of greatest interest to the owners of the mine and those interested in its development are his statements in regard to the possibilities and probabilities of the future development of ore in the mine. This, indeed, is the very part of his report that he would most gladly omit if he felt that he could do so without shirking his duty.

It is believed that the studies of the Blue Wing mine will warrant a few surmises as to its future. It is commonly stated that the only way to judge the future is by the past, and this method will be used in making statements as to the future of this mine. The geological conditions are practically the same in the vein as it is opened by the deepest level and at the bottom of the shaft as they are on the first level. To be sure, there are irregularities and variations in the amount and distribution of the ore from place to place, but as regards the really important features, such as the size and persistence of the vein, the mineralization, and the continuation of the ore shoots, etc., the conditions are practically the same in the deepest workings as they are at the first level. The vein is clearly a fissure vein, and this type of vein is always counted upon to carry good values to great depths. The value of the ore thus far taken out was in all probability not much increased by processes of secondary enrichment, and it is believed to represent values practically as they were originally deposited in the vein. Taking all these data into consideration it is assumed that one is justified in believing that the ore which has been developed up to the present time may be regarded as an example of what future development may show. It is, therefore, believed that development work should be continued with the expectation that the ore shoots will hold their value in depth, and that further ore, comparable with that already developed and taken out, will be found.

In regard to the future of this mine, Mr. J. Parke Channing, in a commercial report, stated:

"The Blue Wing mine has not been tested north and south with drifts, and it is quite probable that further development in these directions would

show other ore bodies. From the results of the various samples I am of the opinion that this mine will produce ore carrying 2 per cent copper and 8 ounces of silver with a silica excess of about 60 per cent. I assume that the mine can produce 20,000 tons of ore per annum and I am of the opinion that the cost of development will be about 65 cents per ton and that the total cost of mining, including development, will be two dollars per ton."

HOLLOWAY MINE.

General statement.—The Holloway mine is located about 3 miles south and 1 mile west of the town of Virgilina, and a short distance east of the county road leading south from the town. The wagon roads connecting the mine with Virgilina are in only fair condition, but they are so located that a small amount of work would improve them greatly. The mine is connected with the Southern Railway at Virgilina by a branch line which runs from the mine to the junction about 1 mile east of the town, thus giving good shipping facilities.

There is not a sufficient supply of water immediately at hand for carrying on extensive operations in ore dressing if such should ever be desirable. However, about 1 mile west of the mine is Crooked Creek, and approximately 2 miles east is Aaron's Creek, and, by impounding either stream at the nearest point to the mine, ample water can be obtained and supplied to the mine by pumping. The timber conditions surrounding the Holloway mine are similar in all respects to those at the Blue Wing mine. Thus there is available an ample supply of both oak and pine timber for all mining purposes.

The land on which the Holloway mine is located formerly belonged to William S. Holloway, who used it for farming purposes, and who, in 1880, while plowing, discovered the first indications of copper which consisted of the green and the blue carbonates. Mr. Holloway was somewhat interested in the copper stains and sunk a test pit to a depth of 15 or 20 feet, exposing promising rock. In 1884 the prospect was purchased by Judge A. W. Graham, of Oxford, N. C., who had a small amount of development work done and sold it in 1885 to parties by the name of McPherson and Heitman. These men started work on the quartz vein about 100 feet west of the present main Holloway shaft. They apparently did not have sufficient funds to carry on the development of the property and it was soon sold to satisfy debts incurred in the prospecting, and was purchased by W. H. Ragan, of Mocksville, N. C., and E. L. Gaither, of High Point, N. C. They did little or nothing to develop the property, and in the latter part of

1887 sold it to William M. Pannebaker, of Lewistown, Pa. Mr. Pannebaker did a small amount of prospecting, but nothing in the way of important development, and in the early part of the year 1897 sold one-half interest in the property to W. E. C. Eustis, of Boston, and leased the other half to him on a royalty basis. With this transaction the actual development of the mine began. The work was carried on actively, and it is reported that during 1899 and 1900 about 120 men were employed in and around the mine, and that the work was carried on in two shifts of 10 hours each.

In May, 1901, mining had reached to a depth of 440 feet. During October, 1901, work on these lower levels had ceased, but work was continued on the upper levels and ore was shipped until March, 1903.

In 1903 Mr. Eustis made a proposition for individual ownership of the mine to Mr. Pannebaker, by which Mr. Pannebaker finally obtained control, and in November, 1916, the mine was in possession of Mr. Pannebaker's estate, he having died in 1914. In 1905 Philadelphia parties, backed by Harrisburg politicians, became interested in the property and partially reopened the mine, retimbering shaft No. 1 to a depth of 115 feet. At this point the famous Harrisburg Capital troubles arose, the backing failed, and the work was discontinued, it is said, much against the recommendation and wishes of the persons actually in charge of the work. As a result of cutting the walls to accommodate the new timbers about 6 tons of ore assaying 8.64 per cent copper were obtained and shipped. No further work on the property has been attempted and the mine has remained closed and filled with water to the present date.

The dump of low-grade ore that accumulated during mining began to be worked over just as soon as the Eustis smelter at Norfolk, Va., was completed; and as early as December, 1899, material was shipped from these dumps to the smelter, as it was needed as a flux. Later, in 1909 and 1910, the remainder of the dump was purchased by R. G. Lassiter and shipped for use as macadam and railroad ballast.

Development.—Judging from the general appearance of the mine during the time of the field work for this report, nothing was done in the way of surface development or improvement that was not absolutely necessary in order to get out the ore and ship it. In fact, it appears that in all the work only the cheapest and poorest grade of material was used, and that this was put together in the cheapest way possible. The shaft was not housed nor properly timbered, and it is reported that not even the absolutely necessary timbering was done in the mine. At present, all that remains of such

surface plant as was put up is the railroad track, a rickety old boiler house, and a dilapidated boiler.

Taking into consideration all available data, the surface development seems to have been characteristic of the underground work. Judging from such observations as could be made and from reports of many men who worked in the mine, the object sought by the management seems to have been to take out the ore in sight just as cheaply as possible. Apparently no development work was done looking toward extending the mine, or

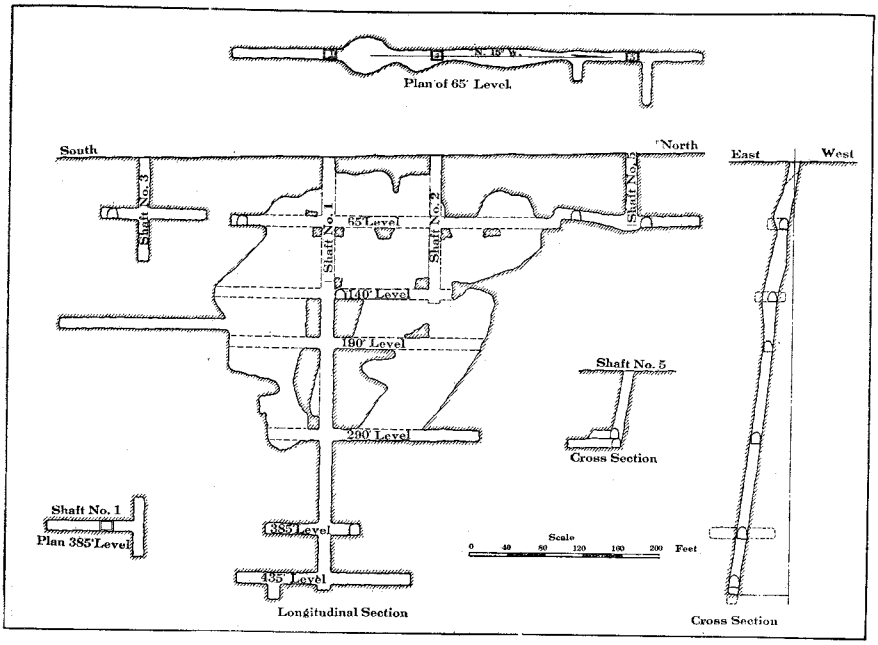


Fig. 9.—Vertical sections and plans of Holloway mine. From map made from notes by J. D. Battershill, 1903.

toward developing a future supply of ore. A single large lens of rich ore was in sight, and the object of the management appears to have been to get this out as quickly as possible. Five shafts were sunk on the property. Of these only No. 1, which is the main working shaft, was sunk to any important depth. The shaft is about 450 feet deep, and from it six levels have been broken off at 60, 140, 200, 290, 385, and 435 feet from the surface, respectively. It is an inclined shaft and follows approximately the dip of the schists, which is 70 to 80 degrees to the east. The total drifting,

all of which, except a very small amount, was necessary in getting out the lens of ore, amounts to about 1,800 feet. Practically all of the drifting was done in the vein. The mine was under water at the time of the field work and was, therefore, not accessible for study. However, such data as were available were collected, and the vertical section given on page 116 was made from a sketch of the workings by J. D. Battershill, who was superintendent of the mine throughout the whole period of its operation, and is reasonably correct. These data show that there was an irregular ore body about 300 feet long and varying from 3 to more than 100 feet in width, which has been stoped out for a width varying from 3 to 33 feet. This stoping extends from within about 30 feet of the surface to the 290-foot level. Weed[a] reports in 1900 that the mine was hoisting from 30 to 40 tons of ore per day, and states that this ore was cobbed and picked by hand and that from it 16 to 20 tons of ore were selected per day for shipment.

Geologic relations.—The rock in the Holloway mine is the typical Virgilina greenstone, both the tuffaceous and the porphyritic phases being represented. No rock is exposed at the surface in the immediate vicinity of the mine, but judging from the rock hoisted in mining the ore it is somewhat more massive and contains more epidote than the average greenstone. However, it has suffered intense dynamic metamorphism and is decidedly schistose but not to the extent of completely obliterating its original characteristics. The strike of the schistosity varies in the vicinity of the mine from 20 to 35 degrees east of north, and the dip is uniformly from 70 to 80 degrees toward the southeast.

There are two veins or mineralized fissures on the property, one, the principal vein, has a trend of approximately 15 degrees west of north, while the other, apparently not so strongly mineralized as the first, has a trend of about 5 degrees east of north, thus crossing the first vein at an acute angle. The trend of the second vein is marked by considerable quartz débris, while the first has very little in the way of surface outcrop. Little is known as to the strength of mineralization in the second vein. One shaft has been put down on it to a depth of about 80 feet, and it is reported that it produced shipping ore. This shaft was partially caved and filled with water at the time of the field work for this report and nothing as to the character of the vein could be learned from actual observation.

The principal vein, as has just been stated, is not at all well marked at the surface; in fact, there is little or no outcrop. It is clearly of the fissure

[a] Loc. cit.

type and was developed in a fracture or fissure which in trend cuts the schistosity of the country rock at an angle of about 45 degrees and which dips about 80 degrees toward the east. All the openings on this vein were filled with water at the time of the field work for this report and consequently were not accessible for study. The following account of the geology of the mine is taken from data which the writer believes to be reliable. It comes almost wholly from two sources, a report on the Virgilina district by Weed,[a] and notes and other data on the mine compiled by Miss M. Florence Pannebaker from records and reports of the mine while it was being operated under the Eustis lease, and by her kindly placed at the disposal of the writer.

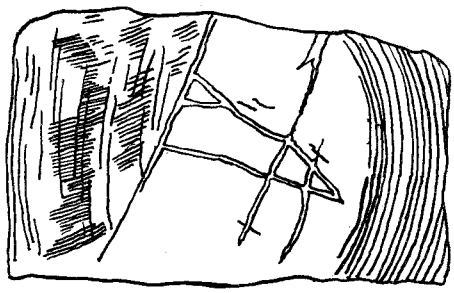


Fig. 10.—Sketch showing face of 300-foot level, south, in Holloway mine, January 26, 1900. On the left, black quartzose ore; in the center, white quartz stringers in black gangue. (After Weed.)

It appears from Miss Pannebaker's data that, in sinking shaft No. 1, the main shaft, at a depth of about 14 feet a thick mud seam was encountered beneath which was rich chalcocite ore. At 18 feet the vein was 13 feet wide with a pay streak of chalcocite ore between 2 and 4 feet wide and assaying as high as 44 per cent copper. It is also stated that, from the surface down to, and considerably below, this depth, the entire contents of the shaft averaged over 3 per cent copper, much of which occurred in the form of the green and the blue carbonates. Some shipments were made from material obtained in the sinking carrying as high as 33 per cent copper, with a number of carloads of 10 per cent average. At a depth of 112 feet, while the full width of the vein was not known, the 6 feet included in the width of the shaft averaged from 8 to 10 per cent copper. The records show that during the first year of work, spent largely in sinking

[a] Weed, Walter H.: Types of copper deposits in the Southern United States. Trans. Am. Inst. Min. Eng., 1900, Vol. 30, pp. 449-504.

Table of Settlement Returns on Ore Shipments from the Holloway Mine, 1897-1903.

Year	January	February	March	April	May	June	July	August	September	October	November	December
1897					1 Car ..... 10.67% 1 Car 10.03%	5 Cars ..... 9.07% 4 Cars ..... 9.83% 4 Cars ..... 11.19% 1 Car ..... 23.91% 1 Car ..... 33.64% 1 Car ..... 10.82% 1 Car ..... 10.55% 1 Car 10.39%	1 Car ..... 9.83% 5 Cars ..... 10.26% 1 Car 37.47%	5 Cars 8.76%	5 Cars ..... 7.46% 1 Car 38.78%	5 Cars ..... 8.29% 1 Car ..... 10.08% 4 Cars 10.15%	1 Car ..... 5.17% 1 Car ..... 5.30% 1 Car ..... 6.84% 1 Car ..... 10.15% 4 Cars ..... 9.74% 1 Car 33.50%	1 Car ..... 7.72% 1 Car ..... 9.74% 2 Cars 10.92%
1898	4 Cars 10.92%	4 Cars 10.98%	5 Cars ..... 8.90% 1 Car ..... 7.76% 1 Car 6.86%	1 Car ..... 34.79% 4 Cars ..... 7.76% 1 Car ..... 6.11% 1 Car 9.64%	3 Cars ..... 9.64% 1 Car ..... 4.84% 1 Car 34.70%	3 Cars 7.88%	1 Car ..... 7.40% 2 Cars ..... 7.88% 1 Car 33.56%	1 Car ..... 6.80% 5 Cars ..... 6.98% 4 Cars ..... 7.43% 1 Car 32.59%	4 Cars 6.80%	4 Cars 8.92%	1 Car ..... 8.92% 5 Cars ..... 9.72% 1 Car 31.21%	4 Cars 8.61%
1899	4 Cars 9.44%	1 Car ..... 10.10% 1 Car 9.44%	4 Cars ..... 10.10% 1 Car ..... 10.35% 5 Cars 12.06%	4 Cars ..... 10.35% 1 Car 9.57%	4 Cars ..... 9.57% 1 Car 39.07%	6 Cars 10.72%	Records lost.	Records lost.	Records lost.	Records lost.	6 Cars ..... 6.41% 1 Car 40.00%	6 Cars ..... 6.39% 6 Cars ..... 11.55% 1 Car ..... 28.42% 1 Car 32.26%
1900	6 Cars ..... 11.41% 6 Cars 10.44%	6 Cars 7.62%	6 Cars 6.66%	6 Cars ..... 6.80% 6 Cars 5.13%	6 Cars ..... 7.35% 6 Cars 5.47%	6 Cars ..... 4.71% 6 Cars ..... 6.25% 6 Cars 4.04%	6 Cars ..... 4.92% 6 Cars 4.66%	6 Cars 5.77%	6 Cars ..... 5.79% 6 Cars 5.05%	6 Cars ..... 4.85% 6 Cars 6.87%	6 Cars ..... 6.29% 4 Cars 4.11%	2 Cars ..... 4.11% 4 Cars 4.74%
1901	2 Cars ..... 4.74% 2 Cars 3.22%	4 Cars ..... 3.22% 2 Cars 2.64%	1 Car ..... 3.53% 4 Cars 2.64%	3 Cars 3.53%	2 Cars 3.53%	3 Cars 9.11%	3 Cars 9.11%	2 Cars 5.47%	2 Cars 5.47%	2 Cars ..... 5.47% 1 Car 2.81%	3 Cars 2.81%	2 Cars ..... 2.90% 2 Cars 2.81%
1902	1 Car 2.90%	3 Cars 2.90%	3 Cars 2.89%	2 Cars ..... 3.66% 3 Cars 2.89%	3 Cars ..... 4.71% 4 Cars 3.66%	4 Cars ..... 5.31% 3 Cars 4.71%		4 Cars ..... 6.35% 2 Cars 5.31%	6 Cars ..... 6.38% 2 Cars ..... 6.35% 1 Car ..... 5.96% 2 Cars 4.38%	5 Cars ..... 5.96% 2 Cars 4.11%	3 Cars ..... 4.23% 4 Cars 4.11%	4 Cars ..... 5.24% 3 Cars 4.23%
1903	4 Cars ..... 5.82% 2 Cars 5.24%	2 Cars ..... 5.82% 2 Cars 3.95%	2 Cars ..... 4.38% 5 Cars 3.95%	2 Cars ..... 4.38% 6 Cars 3.78%								

and drifting, there were shipped, in all, 89 cars of ore which averaged 11 per cent copper with some shipments running as high as 40 per cent.

Miss Pannebaker's records furthermore show that, so far as removed from the mine, the richest ore occurred roughly in two shoots, one a short distance south and the other about 120 feet north of the main shaft, near shaft No. 2, and that both shoots had a pitch in the vein approximating 70 degrees toward the south. The ore in both shoots was of uniformly high grade and in both the vein was very wide. According to Weed the south shoot was 33 feet wide on the first level, 75 feet below the surface south of the shaft. Other records show that this shoot farther down was stoped to widths varying from 15 to 30 feet or more. The north shoot was also of high grade ore, but was probably not stoped quite so wide as that in the south shoot where the reports mention stopes up to 30 feet in width. Between these two large shoots the vein was narrower, from 3 to 10 feet, but well mineralized. Nothing in the way of stoping was done below the fourth level although the vein was well mineralized and material removed in sinking and drifting was shipped to the smelter. The records also show that in the shaft at a depth of about 440 feet a body of very rich ore was encountered. Records of shipments made at the time this sinking and drifting were in progress and presumably from this work show an average of 9.11 per cent copper. It was reported that the drift and cross-cut on the fifth level, north, were mineralized for a width of about 60 feet and that in the drift on the sixth level, both north and south, shipping ore was obtained.

Records which might show the character of the ore produced by this mine are scarce and difficult of access, and there were no geological examinations of the ore body while the characteristic high-grade ore was being taken out. At the time of Mr. Weed's report the greater part of such ore of this type as had been developed had been removed, and much of the mine was not accessible for examination. There are also many conflicting reports regarding the mine which are generously poured into the ears of any one who, for any reason, manifests interest in the possibility of the mine again becoming a producer, oftentimes much to the injury of the mine and of the district as a whole. Because of all this and in order to render accessible such reliable information on the subject as exists, it was decided to include the following table of settlement returns on representative shipments of ore from the mine during the years 1897 to 1903. The table by no means includes all the shipments made during the period covered, but it is believed that such as are included are representative and that they

furnish a reliable basis on which may be formed an estimate of the grade and character of ore produced by the mine. The table was compiled by Miss Pannebaker from actual smelter returns in her possession and by her placed at the writer's disposal.

The vein has been prospected and more or less developed for a distance of about 800 feet, and it is reported that each of the prospect shafts showed more or less ore, and that shipping ore was taken out of both the northernmost and the southernmost developments.

The following is Weed's[a] account of this mine which, in the main, corroborates the data furnished by Miss Pannebaker:

"The vein varies greatly in width, showing the lenticular structure noticed on a small scale in the railroad cut, and, in fact, repeated in the ore-body itself. It varies from 3 feet to 75 feet, or more, in width. In general, there is a fairly defined foot-wall, showing a dip of 75 degrees. The hanging-wall is less defined; and both foot and hanging show irregularities, due doubtless to the crossing of the schists by the vein at a slight angle, and the presence of projections where the rocks are slightly harder than the usual schists. It should be remarked also that the course of the Holloway vein, north 15 to 20 degrees east, is not that of most of the veins of the district.[b]

"In the lower or third level of the mine, the vein is 12 feet wide at the south face, and shows white and gray quartz, with epidote and gray chalcocite 2.5 feet wide. Fig. 10 represents a sketch made in the mine at this level. Here the hanging-wall is rolling, and there is no defined foot-wall. It is also noticed that the quartz sends little droppers or feeders into the schists, in stringers parallel to the schistosity. This is illustrated in Fig. 11.

"On the third level, south of the shaft, the vein was lost in following the foot-wall, so that there is a short cross-cut into the country-rock. Fig. 12 shows the cross-section of the ore body on this level, to the south. In general, it is noticed that the vein south of the shaft is well-defined, and has good walls up to the first level. The quartz is cased in a soft, micaceous slate, which is not a gouge or selvage in the ordinary sense, and may be a schist forming part of the country rock. . . . On the third level, the vein pinches toward the shaft to about 3 feet, and continues with this width to the shaft and northward for a short distance, beyond which it widens to 6 or 8 feet in width. North of the shaft, the vein is broken by an inclined fault-plane, marked by a mud containing sharp angular fragments of ore and quartz, and dipping east about 30 degrees. It does not throw the vein, though it shatters the walls.

[a] Loc. cit., pp. 458-461.

[b] The author states the course of the vein is north 15 to 20 degrees east which, since by actual survey the trend is north 15 to 20 degrees west, must be a typographical error.

"The ore-body in the third level is altered along cracks showing films of green carbonates in both the ore and the white quartz. In the bottom of the shaft, however, no decomposition was observed. A prospect-drift, which has been started about 25 feet above the face of the third level, shows a black jaspery rock, with crossings of white quartz. There is no ore exposed except on the north wall, where there is a slight green stain.

"On the second level south no timbering exists, so that it was not carloads [of ore] have been shipped from this mine, which varied from shows hard, finely laminated micaceous schists, the schistosity of which makes an angle of about 30 degrees with the vein. At the north end of this level the vein shows a slaty hanging-wall, with quartz feeders running off into it. These feeders wedge off in a few feet, and usually carry ore. The quartz ore-body does not show any marked breccia; but in this, as in all the mines of the district, there are the usual thin, plated masses of decomposed schist. In general, the richer ore is found near the foot-wall. No definite association was observed between the occurrence of ore and the character of the various schists cut by the vein.

"On the first level, 75 feet below the surface, south of the shaft, the vein is 133[a] feet wide, but converges rapidly in both directions."

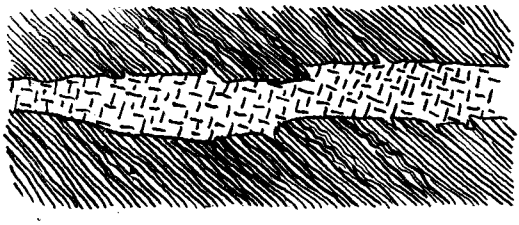


Fig. 11.—Ideal horizontal cross-section of the Holloway vein, showing quartz spurs following the foliation of the country schist. (After Weed.)

Mineralogy.—The gangue minerals, exclusive of fragments and bands of country rock included in the vein, named in the order of their abundance, are: Quartz, epidote, chlorite, hematite, and a little pink feldspar, probably orthoclase. The ore minerals in the order of their abundance are: Chalcocite, bornite, malachite, azurite, and argentite (?), cuprite, native copper, and native silver. All the minerals of the vein, except the oxidization products and a part of the chalcocite in the upper portion of the vein, which is clearly secondary, are intimately and complexly intergrown and are believed to be of contemporaneous development. Epidote occurs in this mine in greater abundance as a gangue mineral than in any other mine or prospect in the district, and calcite is probably a little less abundant than

[a] This should read 33 feet. *See* Weed, Copper Hand Book, 1916, p. 591.

in the other mines. Chlorite is plentifully present, and was probably derived from the country rock and perhaps represents altered fragments of the greenstone. Feldspar, both orthoclase and plagioclase, is sparingly present and was found in a few specimens of gangue matter on the dump. So far as was determined, the ore minerals are associated very intimately with the gangue minerals and are pretty well distributed throughout the vein. However, there is a decided tendency toward a segregation of the ore at different irregular places throughout the vein. Chalcocite is by far the most abundant ore mineral and probably represents a greater percentage of the ore than in any other mine in the district. Excepting that portion of this mineral in the upper workings of the mine, it is probably all, or practically all, hypogene or primary deposition and is believed to be contemporaneous with the bornite. Bornite and chalcocite are intergrown in the ore of this mine in much the same manner as was noted in the Blue Wing mine. However, no well-defined graphic intergrowths, such as those in the ore from the Wall mine, were noted. The general appearance of the polished section under the microscope suggests an intricately branching mass of bornite merged with a similar mass of chalcocite, the latter mineral predominating. Malachite is the more abundant of the two carbonates. In fact, azurite occurs only sparingly. They are confined to the upper portion of the vein, extending, however, in one instance near the fault plain mentioned by Weed, to a depth of 300 feet. Hematite, while widely distributed, is by no means an abundant mineral. It is not known in what form the silver occurs, but it is believed to be present as argentite. Cuprite occurs sparingly in the oxidized portions of the vein. Native copper and native silver are said to have been found as films in fractures in the oxidized portion of the vein.

Two connected shoots were partially proven, but the work in them was not sufficient to afford data for much in the way of generalization. As opened up by the workings, the ore shoots taken together are about 300 feet long in their greatest linear extension, from 5 or 6 to about 100 feet in width, and extend to a depth of at least 450 feet from the surface. Like the other ore shoots of the district, they appear to have a slight pitch to the south. The ore, while largely segregated in various portions of the vein, is also irregularly disseminated through it so that very little of the vein in the ore shoot is wholly barren. It is believed, however, from such data as were available, that segregation of the values was more nearly complete in this than in the other ore deposits of the district, and thus it was that

the operators were enabled to select a relatively greater amount of high-grade ore than was possible in the other mines that have been worked.

Whether or not there are other ore shoots in the Holloway vein is not known, since no development work of any importance has been done except in the two ore shoots already mentioned. It is, however, unlikely that there should have been only one ore shoot developed in such a strong vein and further prospecting along its strike would certainly be justified.

Production.—There were no means of ascertaining the total output of ore from the Holloway mine, but it is reported that in value, the ore taken out was worth considerably over $500,000. Weed says that at the time of his visit, in 1899, the mine was shipping from 18 to 20 tons of ore per day. Assuming that this production was maintained for 200 days during each

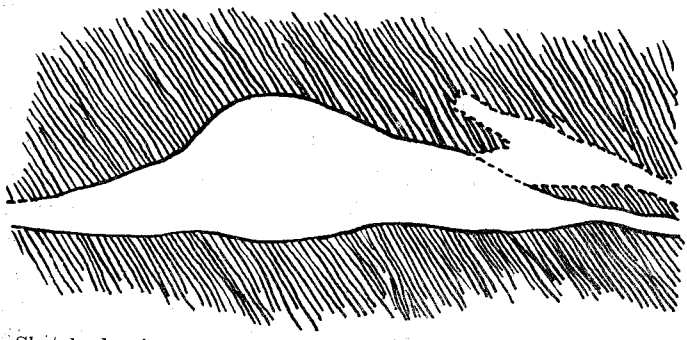


Fig. 12.—Sketch showing cross-section of the Holloway vein as seen in the 300-foot level, south. (After Weed.)

of the five years the mine was in operation, the total production would then be 180,000 tons, which figure, however, is probably in excess of the actual production. There were but little data available as to the distribution of the values in the ore shoot, but it is believed that, taking it as a whole, it ran considerably higher in copper than the other ore shoots of the district. Judging from such smelter returns as were accessible, it appears that the silver and gold content were slightly higher than in the majority of the mines and prospects of the district. In some portions of the ore shoot the ore consisted of nearly pure sulphides and carried a very high copper content, it being known from smelter returns that hand-picked ore running as high as 40 per cent copper was shipped in carloads. Weed states that in 1899 the mine yielded about 61 tons of ore of two grades, the first averaging 30 per cent or more of copper and the second over 12 per cent. It is quite

evident that these statements do not take into account the lower grade of ore and the fines all of which were discarded at that time. These, however, were shipped later and smelter returns for more than 50 carloads of them show a copper content of a little less than 3 per cent. The following table showing the production of the mine, which by no means is complete, was compiled by Miss Pannebaker from actual settlement records in her possession.

240	cars shipped prior to January 27, 1900, which averaged over 10% copper.
16,157	tons shipped which averaged over 6% copper.
10,000	tons shipped which averaged over 8% copper.
6,000	tons shipped which averaged over 3% copper.
3,185	tons shipped which averaged under 2% copper.

Future of the mine.—Taking into consideration the character of the work done at this mine and the size and importance of the ore body, it is believed that further and extensive exploratory work should by all means be undertaken. The shaft should be sunk until it passes out of the ore shoot, and further development drifts should be driven both north and south in the vein. It also should be borne in mind that the vein crosses the schistosity of the country rock; that it shows a tendency to send off feeders or stringers of ore parallel with the schistosity; that it has an irregular contour; and that its walls are "billowy" and in some instances not well defined, and a system of regular cross-cutting should be carried on in connection with the drifting. If the study of this mine has made a single point clear, it is that the ore deposit has certainly not been prospected to the extent that its size and importance would warrant. It is, therefore, believed that further development can be undertaken with a reasonable hope of finding valuable ore. As the Holloway mine stands to-day, the author regards it as one of the most promising prospects in the Virgilina district.

HIGH HILL MINE.

General statement.—The High Hill mine is located about 9 miles north of Virgilina from which it is reached by a fair wagon road. There are no railroad facilities and Virgilina is the nearest shipping point. The location of the mine is such that in case it should ever be developed to an extent that would justify it, a branch could be extended from the first siding on the Southern Railway west of Virgilina, along a ridge to High Hill at a minimum expense, which would pass the Wall and Seaboard mines and a number of favorable prospects including the Littlejohn and the Elliot.

The timber lands surrounding the mine have been closely cut over, but there is yet a supply of both oak and pine ample for all needs in operating

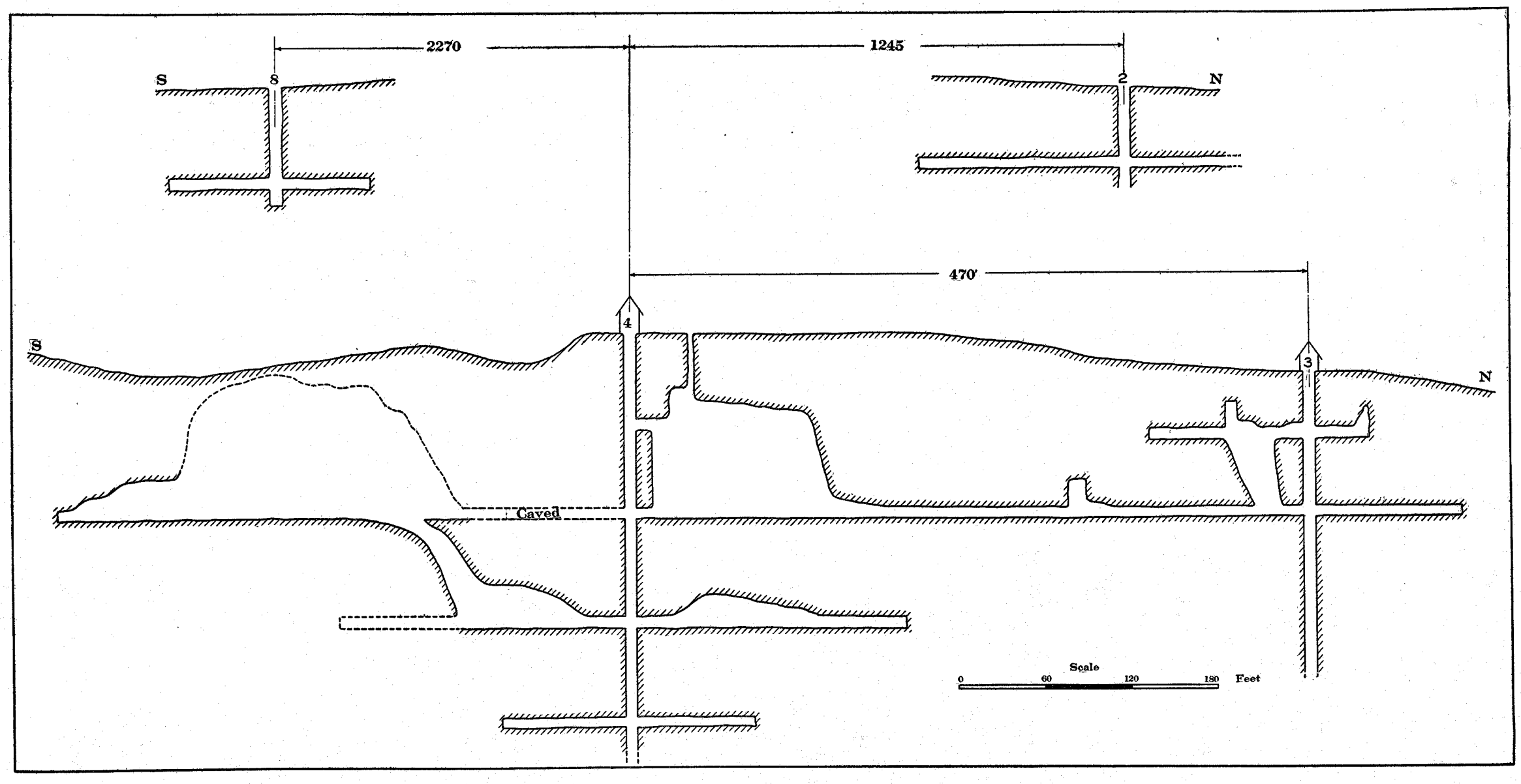


Fig. 13.—Vertical section of High Hill mine. From a survey by J. Parke Channing, 1905.

the mine. At the time of the field work an abundance of cord wood could be obtained for fuel, delivered at the mine for one dollar per cord.

Unfortunately, the mine has no immediate water supply. The water used for mining and milling purposes in excess of that made by the mine, which is very little, is obtained by pumping from Hyco River, about one-half mile northwest of the mine. When the mine and mill were in operation a pumping station consisting of boiler, 50 h. p. engine, and 18 by 9 by 12 duplex pump, and a 6-inch pipe line to the mine, were installed at a point on the river about 2,800 feet from the mine. This supplied all the water necessary in the operations.

The mine is located near the north end of a prominent ridge which extends southward toward Virgilina and attains its maximum elevation at the mine of about 200 feet above the river level.

Actual development of this mine began in 1899 and was brought about largely through the activities of Judge A. W. Graham, of Oxford, N. C., and W. T. Harris, of Virgilina, Va., who interested, Boston, Mass., capitalists in the property. Prospecting proceeded rather rapidly and in December, 1899, 14 pits and shafts varying in depth from 25 to 125 feet had been sunk in the vein. These were numbered from 1 to 14, consecutively, beginning at the north, and were so spaced as to prospect nearly 1 mile of the vein.

None of this early work except the upper part of some of the pits was accessible at the time of the field work. Taking into consideration the lack of system in the later development of the mine and the fact that none of the work is accessible at the present time it is thought best to include a few paragraphs from a commercial report by H. F. Wild, a mining engineer, who examined the property in December, 1899. In describing this development work Mr. Wild says:

"Shaft No. 4 is 125 feet deep and Nos. 1, 2, 3, 5, 6, 7, and 8 are more than 50 feet deep, No. 2 being 93 feet. At the bottom of No. 1 shaft there is a drift on the vein 180 feet to the north and 130 feet to the south connecting with and extending beyond shaft No. 2. At the 60-foot level in shaft No. 4 there is a drift 100 feet long and a stope 31 feet long and 16 feet high. To the south of the shaft is a drift 15 feet long and at the 96-foot level a drift 15 feet long. At the bottom of shaft No. 8 are two drifts on the vein each 9 feet long. This shaft is 72 feet deep. None of the various shafts has been sunk at the points which at the surface show the largest croppings of quartz, and as depth is attained the ore has increased in width and value. Surface leaching has depleted the values for some 15 or 20 feet beneath. Then the percentage of copper increases. In

drifts from No. 1 shaft the ground to the north has been stoped out and at the extreme north the drift is within a few feet of the surface (owing to the contour of the hill). The ore shows for the entire length of the drifts (in the bottom where stoped above and in roof, bottom, and elsewhere), varying from 2 to 5 feet in width, averaging about 3 feet. In shafts Nos. 1 and 2 the vein shows about the same as in the drifts down to their level and in No. 2 below the drift the vein is very wide, but as the shaft has been sunk in the foot-wall side of the vein the streak of rich ore has not been exposed. The No. 4 shaft and the drifts from it are in the foot-wall side of the vein and are all in ore, the wall on the hanging side not having been reached except at one point in the shaft where a cross-cut shows the vein to be 14 feet wide. The shaft itself is 9 feet wide and a drill hole at the bottom shows the quartz to be at least 11 feet wide. In the drifts from this shaft the ore averages over 6 feet as exposed and since the hanging wall has not been reached the real width is greater. At the bottom of No. 8 shaft the vein has pinched to about 1 foot in width, but in the drifts from the bottom, although they are only 9 feet long, it has widened out to two and one-half feet. The streak of rich ore in the quartz vein varies in extent, not always corresponding with the variations of the vein itself and occasionally it occurs in kidneys through the quartz, but I estimate from my measurement and from the proportion it forms of the ore already extracted, that the rich ore forms about one-sixth of the entire contents of the vein."

Shortly after Mr. Wild's report was made the mine was taken over by its present owners, a stock company known as the Virginia Copper Company, Ltd. This company was organized under the laws of Great Britain, but maintained, during the operation of the mine, an office in New York City. Development work was continued largely, however, at shafts Nos. 3 and 4, which were chosen as the main working shafts. These were sunk to depths of about 250 and 350 feet, respectively. Two levels were broken off from shaft No. 3, and 3 levels from No. 4. From these levels stoping was done as shown in the vertical section of this mine on page 124. This stoping was evidently very carelessly done and the shattered ground was not properly timbered, and, as a result, nearly 300 feet of ground above the first level south of the shaft caved.

Good buildings, such as shaft house, boiler and power house, office, shop, a residence for the manager, and some houses for laborers, were erected. The shaft was equipped with good machinery including hoisting engine and a 20-drill air compressor. Later, in 1901, a mill was erected and an attempt was made to concentrate the ores. So far as could be learned the equipment was very inadequate and not suited to the ore. At any rate the work was a significant failure. The equipment consisted of a rock

breaker, some screens, a picking belt, and a set of Harz jigs. The rock breaker was the only crushing machinery employed and all material too coarse for the jigs was screened out and discarded. As a result there is now at the mine a large dump of this discarded material, which, according to assays, will run nearly 2 per cent in copper. The work continued in a somewhat desultory way until the price of copper reached a very low figure when the mine was closed. In 1907 the mine was reopened and another attempt was made to treat the ores. This time the process consisted in giving the ore a sulphating roast in a specially designed furnace. This was followed by an acid leach and it, in turn, by electrolytic precipitation of the copper. An expensive plant was erected and operated only long enough to demonstrate that the method as installed was a failure. The mine was immediately closed and has not been reopened since.

Geologic relations.—The rock of the High Hill mine is the normal schistose Virgilina greenstone. The greater part of it is decidedly schistose, but here and there are areas which show the original tuffaceous character of the rock. Some of the rock is of a dark green color and is fairly massive, while a smaller amount has a decided purplish color.

The High Hill vein is one of the strongest in the Virgilina district and is clearly traceable either by a well-defined quartz reef or abundant quartz débris on the surface for a distance of nearly two miles. The outcrops rise from a few inches to 3 or 4 feet above the surface, and where there is no definite outcrop the surface is literally covered with quartz débris. So far as could be determined throughout this distance the vein varies from 2 or 3 to 12 or 15 feet in width. It is remarkably regular in trend, showing throughout its whole length very slight variations from 6 degrees west of north. The strike of the schistosity is toward the northeast and cuts the trend of the vein at angles varying from 20 to 30 degrees. These facts make it clear that this is a true fissure vein developed in a fracture formed subsequent to the metamorphism of the country rock. In this respect it is similar to the other veins of the district. Like the other veins it also presents both vertical and longitudinal pinches and swells. It appears to contain a larger percentage of quartz, and is, therefore, more highly siliceous than any other vein in the district, with the possible exception of the Durgy vein which carries an approximately equal percentage. It carries less epidote than the Seaboard and Holloway veins and less calcite than the Blue Wing. So far as could be determined both foot and hanging walls are well defined and the vein parts easily from them. In this as in all other

veins of the district there are numerous inclusions of plates or layers of country rock which, in places, give it a laminated or banded appearance.

The gangue minerals, exclusive of fragments of country rock, included within the vein, named in the order of their abundance, are: Quartz, epidote, chlorite, calcite, and hematite. The ore minerals in the order of their abundance are: Bornite, chalcocite, malachite, azurite, covellite, and argentite(?). Ore and gangue minerals are intimately intergrown and there is little doubt that they were deposited contemporaneously. In this, as in the other mines of the district, there is a decided tendency on the part of the ore to occur as segregated areas or masses throughout the vein.

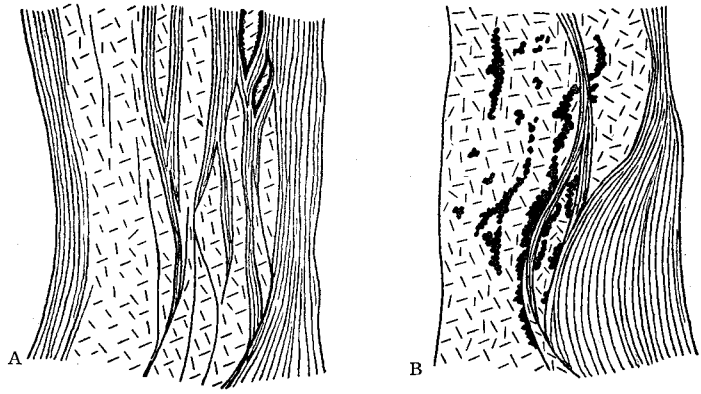


Fig. 14.—(A) High Hill vein at Shaft No. 4. North face of 60-foot level. Vein eight to nine feet wide. Ore is shown in solid black. (After W. H. Weed.)
(B) High Hill vein, north face at bottom of Shaft No. 4, as it appeared January 28, 1900. Vein from eight to nine feet wide. Ore is shown in solid black. (After W. H. Weed.)

This tendency, however, has not been carried out completely, so that no part of the ore shoot is wholly barren. The bunching of the ore is not confined regularly to any portion of the vein, but occurs in some instances near the foot-wall, in others near the hanging wall, and in still others near the center of the vein. From such data as were available at the time of the field work the run-of-mine ore from the mine will carry an excess of silica varying from 70 to 75 per cent.

As far as could be determined from the development work accessible and from such data as were available, the values occur in definite ore shoots which are believed to have a slight southerly pitch in the vein. At least three such ore shoots have been developed to a greater or less extent at shafts Nos. 2, 3, 4, and 8, respectively, but the development has not been

sufficient to furnish data for accurate statements as to their respective size. Dealing with this subject in a commercial report on this mine, made after a detailed examination of the property, J. Parke Channing says:

"It is extremely difficult to determine the length of the shoots developed, but I should say that shafts 3 and 4 would probably produce 1,000 feet of pay ground, shaft No. 8, 150 feet, and shaft No. 2, 200 feet, or a total of 1,350 feet."

In addition to this amount of pay ground which is already partially developed, the prospect pits and copper stainings in the outcroppings of the vein indicate that further development of the property will probably disclose other valuable ore shoots. But few data on the copper and silver content of the ore were available, but such as could be found indicate that a considerable quantity of high-grade ore was taken out and shipped. H. F. Wild states, in his report above referred to, that as a result of the earlier work at the mine ore as follows was taken out and shipped:

Lbs. Sampled	Cu. *Per cent*	Ag. *Ozs.*	Au. *Ozs.*
46 365	27.83	6.00	0.02
46,310	7.60	0.40	0.01
51,977	8.40	1.90	0.01
40,273	15.11	n. d.	n. d.
40,092	17.30	n. d.	n. d.
42,493	13.95	n. d.	n. d.
50,023	33.76	8.46	0.22
145,052	16.40	4.37	0.03
2,000,000 (estimate)	1.72	1.22	0.02
400,000 (estimate)	2.85	0.90	Trace

Production.—After considering the figures just given, H. A. Keller, in a commercial report on this property made in September, 1905, says:

"The total shipments of ore from this property amounted to approximately 1,414 tons (ore and concentrates), which contained an average of approximately 12.2 per cent copper with corresponding silver values. There are now on the dumps, mill tailings, and low-grade ore thrown out from the mill 8,600 tons (estimated) divided about evenly between the two. The latter goes about 2 per cent copper and the former a little over 1 per cent (according to numerous samplings and assays). Therefore there have been taken from the mine 10,014 tons of ore, which shows an average (by approximation) of a small fraction over 3 per cent copper with corresponding silver values."

Future of the mine.—The development of this vein certainly has not been extensive enough to either prove or disprove its value. So far as it has gone it shows favorable conditions. The vein is large, very persistent, and, so far as explored, reasonably well mineralized. Taking into consideration the geologic conditions of this vein, it is believed that further development work ought to be done, and that it may be undertaken with reasonable hope of success.

DURGY (PERSON CONSOLIDATED) MINE.

General statement.—The Durgy mine is located about 7 miles southwest of Virgilina. The wagon road connecting the mine with the town is kept in good condition. The nearest railroad point is the Holloway mine, which is reached by a branch track from the Southern Railway at Virgilina. This station is about 4 miles from the mine, but the wagon road is in good condition. The last hauling from the mine (in 1910) was done by a steam traction engine and heavy trucks. Well-built modern motor trucks could, at reasonable expense, easily take care of all hauling to and from the mine. There is no immediate water supply and the water needed in the operation of the mine and mill is obtained by pumping from an impounded stream about one-half mile west of the mine. Except during the driest seasons this supply is ample.

Timber has been pretty well cut off from the territory adjoining the mine, but the surrounding country is still well timbered with both oak and pine, so that there is an ample supply of timber and lumber for all mining purposes.

The land on which the Durgy mine is located was, at the time copper was discovered, the property of Theron Yancey, and the first exploratory work was done by him and under his directions. This was one of the early mines of the district and was in active operation in 1892. The vein at the places where the first shafts were sunk did not outcrop, but its presence was made known by an abundance of quartz débris on the surface. It is said that the stains of malachite in some of this material turned up in plowing were responsible for the prospecting which led to the discovery of the rich ore, consisting largely of chalcocite, and to the opening of the mine. During this early work one shaft was sunk to a depth of 150 feet and another to 88 feet. The work showed good values in the vein and it is reported that considerable ore was taken out. The mine at this time was fairly well equipped and the shaft was well timbered. A concentrating plant was erected on a small stream about five-eighths of a mile west of

the mine, and cabins and houses were built for the miners. With things in this condition the company failed, due, it is said, not to lack of ore, but to mismanagement. At the time it was known as the Yancey mine. The mine was allowed to fill with water and remained idle until 1899 or 1900, when it was purchased by a company of New Haven, Conn., men who organized the Person Consolidated Copper and Gold Mines Company. The organizers and promoters of the company, and, at the time of its organization, the owners of the property, were Fordyce Durgy and E. B. Beecher, both of New Haven.

With the organization of this company the active development of the mine began. Considerable prospecting was done on the different veins on the property and a new shaft—the present working shaft of the mine—was sunk on the main vein, and another on the so-called "Durgy vein" about 1,500 feet northeast of the main shaft was sunk to a depth of about 100 feet. A one-hundred-ton concentrating plant, described fully under the subject of "Concentration," was erected, and the mine was equipped with modern machinery, air compressor, air drills, good hoisting engine, etc. Work was continued, actively at first, but later on in a desultory way, until 1908, when the mine was closed, but not allowed to fill with water. During this work little attempt was made to keep development work ahead of actual stoping, and, as a result, when hoisting was stopped, little or no developed ore remained in the mine, although vein conditions were favorable. Just before closing the mine the company apparently saw the folly of this policy and sunk the shaft 90 feet deeper and started some drifts at a depth of 407 feet from the surface. This work showed up favorable conditions, the vein at this depth was strong and fairly well mineralized. The mine remained idle until 1910 when an agreement was made between the owners and the Tennessee Copper Company under which this company began work. The drifts were driven in the vein for about 350 feet in each direction. A considerable amount of ore was opened up in this work and about 100 feet of stoping was done on each side of the shaft. The ore taken out was shipped to the smelter at Copperhill, Tenn., where, because of its high silica content, it was used for converter linings and as siliceous material with the heavy sulphide ores from the Ducktown mines. This work was stopped in 1911 and the mine was allowed to fill with water.

The surface equipment consists of shaft house, power house, machine shop, mill, dwelling house for manager, and small houses for miners. The houses are in good repair, but the mining and milling equipment has been allowed to deteriorate.

If reports as to savings can be believed, the mill as installed and operated at the Durgy mine was not a success. These estimates, some of them based on assays of the ore as fed to mill, and tailings, indicate that, on the average, the mill did not save over 60 to 65 per cent of the values. Just wherein the cause for losses lay can not be said, but it is believed to have been partly in the cumbersome installation, partly in the care and oversight of the machinery, and partly in the inefficient methods of saving the slimes. The tailings show values in two forms: ore not freed from gangue, and ore as very fine particles or slimes; the greater part, however, being in the fine particles.

This mine has been more extensively developed underground than any other mine in the district. The two shafts, one 410 and the other 160 feet deep, make a total of 570 feet of shafting. From these shafts a total of more than 4,000 feet of drifts has been driven in the vein, and in addition a small amount of cross-cutting has been done at different places in the drifts. Practically everything accessible in the main ore shoot above the 335-foot level has been stoped out. A small amount of stoping has also been done on the 407-foot level, the deepest level in this ore shoot. A second ore shoot is indicated in the 155- and the 335-foot levels, respectively, beginning about 500 feet south of the shaft. A small amount of stoping has also been done on these levels in this ore shoot. Immediately south of the shaft the stoped ground is caved from the surface down to the 260-foot level, and much of the area north of the shaft, while not caved, is inaccessible. Timbering was not as well done as it should have been and consisted almost wholly of stulls and lagging.

Air drills and modern equipment were used in driving and stoping, and both overhead and underhand stopes were worked. The ore was in some instances roughly sorted underground and as much waste as possible eliminated before hoisting. The ore after sorting was trammed to the shaft and hoisted in a small skip. From the shaft it was trammed to bins at the mill from which it was drawn as needed.

Geologic relations.—The rock at the Durgy mine is the tuffaceous phase of the Virgilina greenstone with very large fragments, and shows more clearly its volcano-sedimentary character than at any other opening in the region. A great part of it shows the usual and normal green color, but here and there are areas that have a dark purplish color, and in a few instances fairly massive, somewhat porphyritic rock was found. In fact, some of the fragments are decidedly porphyritic in texture. The clastic nature of

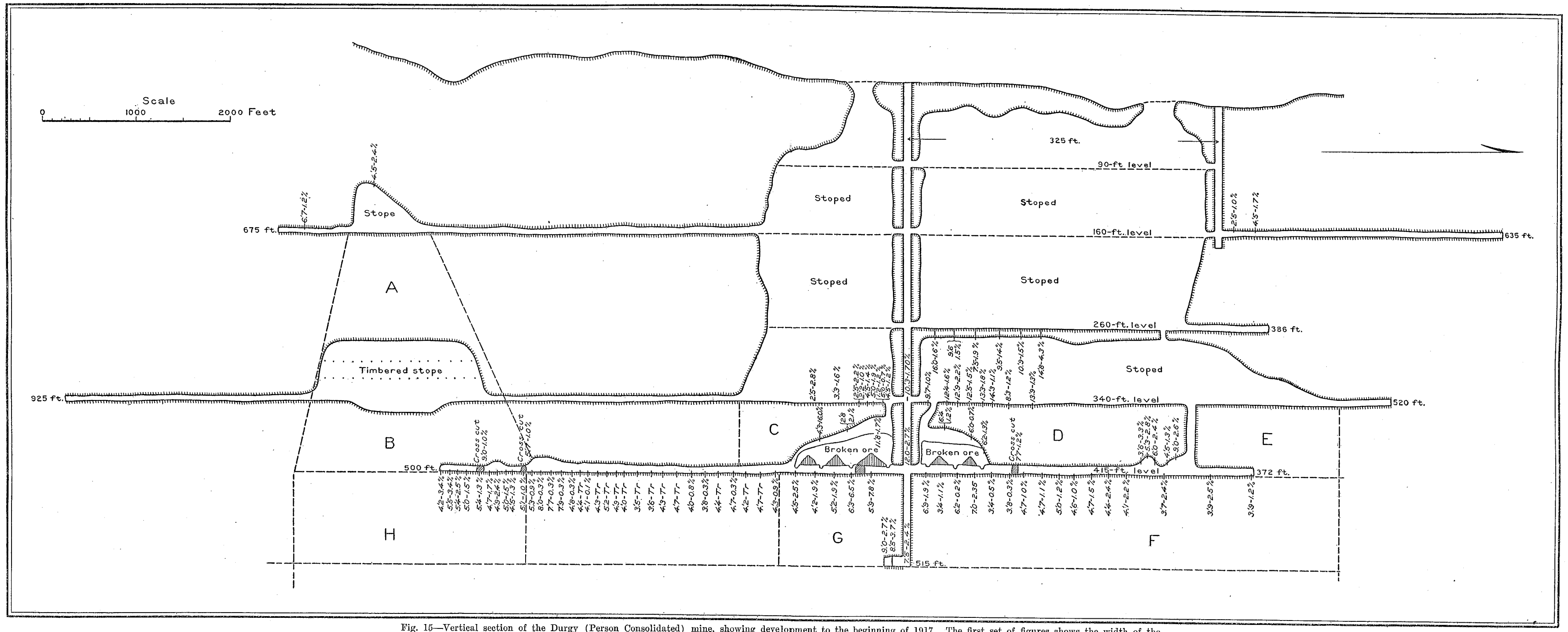


Fig. 15—Vertical section of the Durgy (Person Consolidated) mine, showing development to the beginning of 1917. The first set of figures shows the width of the vein as sampled in feet, and the second set shows the percentage of copper. This map was kindly furnished by Mr. A. W. Tucker, Salisbury, N. C.

this rock is well shown by its general brecciated appearance. The fragments are of different colors, many of them green, and a smaller number show well the purple color above referred to. As a rule all fragments have been mashed until they are decidedly lenticular in shape and somewhat like the "augen" in a gneiss. The rock for the most part is highly schistose with here and there areas somewhat massive. The schistosity strikes about 30 degrees east of north and invariably dips toward the east at angles varying from 70 to 80 degrees. Much of the rock as it lies on the mine dump slacks down to a kind of soft bluish micaceous or chloritic material. The fragments in the brecciated or tuffaceous rock are made up of all the different types and colors of the country rock, and in size vary from less than an inch to more than a foot in diameter. In some instances the large fragments are much epidotized, in others they are porphyritic, and almost invariably have withstood the forces of deformation better than the fine-grained matrix, which probably was originally volcanic ash.

There is in this mine, as in the Blue Wing mine, a prominent diabase dike, but it does not cut the vein as in the other mine. The dike, the width of which is not known and which is not exposed on the surface, forms, in some parts of the mine south of the shaft, a foot-wall of the vein. The dike is clearly younger than the formation of the vein and ore, and, so far as could be determined, has had no influence on them. The dike-rock is solid, hard, tough, and massive, and is intersected by many closely spaced joints which break the mass up into numerous polygonal blocks. When it is exposed to the air there is also a decided tendency to slack or break up into small particles. The dike appears to follow the vein for a short distance and then to pass off into the wall rock.

There are at least four, and probably more, veins on the property of this company which show the presence of copper. These are the so-called main vein on which the only work of importance has been done, the Durgy vein lying a short distance east of the main vein, the "Cross-cut" vein, about one mile southwest of the mine opening, and a small unopened vein a few hundred feet west of the main vein. They are all true fissure veins and in all important respects similar to the veins already described. One of the characteristic features of these veins, also true of the other veins of the district, is the regularity of strike and dip. Whether the vein parallels the strike of the schistosity of the country rock or not it is almost invariably regular and persistent in its trend. The predominant vein material is massive white quartz with which are minor amounts of epidote, calcite, chlorite, and fragments and plates of included schist. The veins are also

notably persistent, and it is not at all uncommon for one to be traceable, either by actual outcrop or by well-defined quartz débris, on the surface for a distance of a mile or more. Thus the main vein of this property has been traced, largely by surface débris, for nearly, if not quite, a mile. It is one of the largest and strongest veins in the district, varying in width from 6 to 18 feet or more, and, as opened in the mine, fairly well mineralized. Its strike is 5 degrees west of north, and, while in places parallel with the schistosity, taken as a whole its trend is a few degrees more northerly than that of the schists, thus showing clearly that it was developed in a fracture—possibly a fault plane, since there is no means of telling whether or not there was displacement along the line of fracture. However, like the other veins of the district, this one contains in places as inclusions many plates or laminæ of the schists which give it a kind of banded appearance. It also shows the usual vertical and longitudinal pinches and swells.

The gangue minerals of this vein listed in the order of their abundance are: Quartz, epidote, chlorite, calcite, and hematite. The ore minerals in the same order are: Bornite, chalcocite, malachite, azurite, cuprite, argentite(?), a very little chalcopyrite, klaprothite, and a small amount of gold. The hypogene ore minerals are intimately intergrown with the gangue minerals and are probably of contemporaneous development. The ore occurs in definite ore shoots and in these shows a tendency toward segregation at various places in the vein. In no place, however, is this segregation complete, so that in the ore shoot very little or none of the vein is wholly barren. The location of the bunches or areas of ore is irregular and not confined to any one part or portion of it. In some places the rich ore was found to lie near the foot-wall, in others near the hanging wall, and in still others it occurred at different places within the vein. The tendency toward segregation is well shown by the way the ore came from the mine. Three grades were produced: First, that which formed a shipping ore as it was hoisted; second, that which by hand picking or cobbing, thus concentrating from 5 to 10 into 1, could be made into a shipping ore; and, third, a straight milling ore, this last grade constituting by far the greater part of the ore, probably 75 per cent of the total. In a commercial report on this mine, made by Joseph Hyde Pratt, in 1904, the following statements are made in regard to the character of the ore:

"There is considerable variation in the value of the ore as it is mined, there being three distinct ores: (1) That which makes a shipping ore just as mined; (2) that which by hand cobbing will make a shipping ore; and (3) that which is a milling ore and runs from one to two and one-half

per cent copper, but so scattered through the gangue that there is no possibility of hand cobbing it into a shipping ore. A small amount of the ore of class 1 runs from 8 to 15 per cent copper, from 4 to 11 ounces silver, and from a trace to 0.03 ounces gold per ton. Hand-cobbed ore, which is obtained by concentrating from 4 to 8 into 1, gives a shipping ore containing from 13 to 25 per cent copper, 7 to 11 ounces silver, and 0.03 to 0.05 ounce gold per ton. The milling ore which contains from 1 to 2 and one-half per cent copper is concentrated to a product that runs 20 to 56 per cent copper, 8.7 to 22 ounces silver, and 0.03 to 0.17 ounce gold per ton. . . . There is but a small percentage of shipping ore and it is the milling ore that will determine the value of the mine."

From inspection and carefuly study of all available data, for the most part, actual smelter returns on carload shipments of ore and concentrates, on the average copper content of the run-of-mine ore, it appears that these statements of Pratt are essentially correct, and that the average copper content of all ore hoisted has been between two and three per cent.

In this mine as in all others in the district a certain amount of mineralization has taken place in the walls adjoining the vein. In mining it is, therefore, necessary always to keep close watch on the walls at the contact with the veins or values may be left.

The relation of the copper minerals of this mine is similar in all respects to that of the same minerals in the other mines of the district. Excepting a certain amount of supergene or secondary chalcocite in the upper portion of the vein, the sulphides are all believed to be primary vein minerals and of contemporaneous deposition. Bornite, which is the most abundant ore mineral, is intimately intergrown with the chalcocite and similar in all respects to the intergrowths described from the Blue Wing, High Hill, and Seaboard mines. Chalcopyrite is very rarely found, and not only is there no indication whatever that it formed the original copper mineral and that the richer sulphides were derived from it, but there is abundant evidence to show that the bornite and chalcocite are hypogene minerals, and in no way related genetically to the chalcopyrite or any other copper-bearing mineral.

The form in which the silver occurs is not definitely known, but microscopic study of polished sections of the ore indicate pretty clearly that it is present as argentite. The silver value is variable, but is usually from 0.8 to 1 ounce of silver to 2 per cent of copper. It is intimately associated with the copper-bearing sulphides and always concentrates with them. The gold content is so low that there is no way of determining definitely the

manner of its occurrence. It is known to occur in the native state in certain mines in the district and is assumed to occur in that form in this mine.

To give a correct statement of the tenor of the shipping ore and concentrates, so far as is known to the writer, the following table, in which is shown the amount of ore sampled and the assay value in copper, silver, and gold, is inserted. The figures are the actual smelter returns and formed the basis on which the smelters made payment for the ore. Some of the assays were made by Ledoux and Company, New York City, and others by the Eustis Smelting Works, Norfolk, Va. The table covers shipments ranging from 1902 to 1905, and thus shows the character of the ores as they occurred throughout a good portion of the ore shoot.

Assays of Ore and Concentrates from Durgy Mine—Smelter Returns.

Date	Ore *Pounds*	Cu. *Per cent*	Ag. *Ozs.*	Au. *Ozs.*
1902				
Aug. 23	59,774	25.56	11.99	.01
" 23	73,081	13.85	7.49	.01
Sept. 12	12,433	13.41	5.9	.02
" 12	16,096	17.66	7.79	.13
" 12	13,757	32.60	13.83	.04
Oct. 21	60,299	27.82	11.55	.01
" 24	42,029	44.91	20.	.05
Nov. 15	54,799	39.55	17.37	.065
Dec. 1	37,765	35.63	15.20	.07
1903				
Jan. 8	46,727	32.25	14.61	.075
" 28	53,836	9.56	4.49	.01
Feb. 9	51,100	24.52	.....	....
" 17	49,918	24.12	9.68	.02
Mar. 4	56,992	31.64	13.23	.075
" 19	45,400	15.22	6.34	....
" 26	54,277	29.82	11.97	.055
Apr. 24	53,757	27.20	12.06	.07
May 9	52,662	26.49	11.81	.08
" 9	31,353	23.74	10.21	.03
" 23	27,151	27.52	12.11	.07
June 4	56,241	25.73	11.30	.055
" 20	55,778	23.67	10.44	.105
July 13	21,936	24.79	11.25	.05
" 13	32,012	24.19	11.03	.05
" 24	52,597	20.37	9.69	.045
Aug. 17	54,985	21.19	10.	.045
Sept. 12	59,125	21.25	9.55	.05
" 22	46,524	20.33	9.33	.07
Oct. 8	58,144	24.04	10.92	.045
1904				
May 5	49,401	10.82	4.17	.015
" 18	44,011	10.21	4.14	.02
June 27	39,806	12.09	n. d.	n. d.
July 20	43,712	9.07	"	"
1905				
Apr. 11	24,616	19.98	"	"
" 17	31,406	41.19	"	"
May 8	49,945	38.16	"	"
" 27	32,850	18.44	"	"
" 27	22,770	37.03	"	"
June 24	51,804	39.27	"	"
July 28	29,969	13.02	"	"
" 28	23,932	38.9	"	"
Aug. 2	60,625	9.45	"	"
Sept. 14	77,166	35.49	"	"
" 14	43,723	11.14	"	"

In this mine as in all other mines of the district the values are not evenly distributed linearly throughout the vein, but occur in certain places in it as definite ore shoots. Thus far there have been three such shoots discovered in this vein, two at the main workings, and one at a small pit near where the wagon road crosses the vein about 1,000 feet south of the main shaft. Only one ore shoot, that at the main shaft, has been developed to any important extent. It is nearly 500 feet in length and extends from the surface to the deepest workings of the mine. The work thus far done will not warrant any statement as to its pitch. The small stopes on the 155- and 335-foot levels, respectively, seem to indicate a second and probably smaller ore shoot, but the work done will not justify any very definite conclusions and this may be part of the main ore shoot. Such data as are available indicate an ore shoot at the pit near the roadside about 1,000 feet south of the main shaft. The quartz and other vein matter in the dump at this pit contain good showings of the green carbonate, and a few specimens contain more or less of the sulphides, largely chalcocite. Supporting this surmise is the fact that in the heading of the 335-foot level south, carefully collected samples across the entire vein show a little over 2 per cent copper and 1.62 ounces of silver per ton. The vein is strong in this territory and all indications point to the probability of another ore shoot.

Production.—There were no means of ascertaining the total production of the Durgy mine. It has, however, been one of the largest producers of the district. It is stated in an article by L. N. White[a] that in 1901 there were on the dump and blocked out in the mine ready for stoping about 20,000 tons of ore. The mine was in operation the greater part of the time between 1901 and 1904, when J. Parke Channing made a commercial report on it. It is believed that the greater part of this ore was stoped out during the interval between these dates. In his report Mr. Channing said:

"I estimate that there is contained in the mine ready for stoping about 48,000 tons of ore containing 2 per cent copper and 0.9 ounce silver per ton."

Between the date of Channing's report, 1905 and 1911, all the ore that was blocked out ready for stoping at the time of the examination was broken and hoisted, and a considerable amount of new work including stoping was done.

[a] Mining and Metallurgy, Vol. 24, 1901, pp. 635-639.

Future of the mine.—As the Durgy mine stands to-day it is little better than a partially developed prospect. It is true that large bodies of good ore have been taken out, but development was not kept ahead of mining and as a result there is at present very little ore actually in sight. The future of the mine, therefore, depends upon the amount and grade of ore that further development will open up. Taking all things into consideration—the amount and grade of ore produced, the strong and persistent vein, the well-mineralized ore shoot which has been worked from the surface to the 335-foot level, and the two other probable ore shoots which have not been developed—it is believed that further prospecting and development work would certainly be advisable, and that it can be undertaken with a basis for a hope of rehabilitating the mine by locating valuable ore bodies.

In regard to future production from the Durgy mine Channing says:

"From a series of calculations and from an inspection of the maps, I am of the opinion that the average grade of ore to be expected from the Durgy mine will contain 2 per cent of copper and .09 ounce of silver per ton, and will contain 70 per cent excess silica. I figure that the cost of mining, including development, which I have estimated at 35 cents, will amount to one dollar and seventy-five cents per ton of ore mined and shipped.

"I am of the opinion that, from its present development, the mine can easily produce 30,000 tons of ore per annum. The vein is well defined and persistent and I believe will hold out in depth. In fact, in veins of this character I think that the better measure of their value is their capacity for production rather than the exact number of tons of ore which may be developed and in sight in the mine, this latter being entirely due to the caprice of the particular owner or manager."

There are a few items that ought to be borne in mind when considering the question of future profitable operation of this mine. They are, that the ore occurs in definite ore shoots, and that while certain portions of the shoot may contain high-grade ore, by far the greater part of the ore is low grade, probably carrying little over 2 per cent of copper, and that upon the ability to handle this milling ore satisfactorily depends the success of the operations. It will, therefore, be necessary to handle large quantities of ore and to make a high saving of the values in the mill. Further suggestions and data on this subject are given in the chapter on concentration of the ores.

DUKE MINE.

General statement.—The southernmost mine in the district is about 15 miles southwest of Virgilina and is known as the Duke mine (formerly the Tingen mine). These prospects were opened and actively worked at the time of the copper excitement in the district during the late nineties. The rock is the normal greenstone schist of the district, possibly a little more "slaty" in appearance than the usual rock. There is much epidotization and some of the rock shows the purplish color so characteristic of these schists.

Geologic relations.—There are a number of veins on this property, all of which show traces of copper. The greater number of the veins appear to follow the schists in dip and strike, but some of them clearly have a more northerly trend than the schistosity of the country rock. There appear to be the normal irregularities as to width, and pinches and swells both horizontally and vertically.

Two shafts have been sunk beyond the pit stage. These are the main or Hicks shaft, which is about 280 feet deep, and shaft No. 3, about 225 feet deep. From the Hicks shaft two levels, one at 100 feet the other at 267 feet, have been broken off. The 100-foot level has been driven in the vein about 200 feet to the northeast and about 50 feet to the southwest from the shaft. The 267-foot level has been driven in the vein about 60 feet to the northeast. No stoping of any consequence has been done. From the 267-foot level cross-cuts have been driven each way at right angles to the vein, the northwest being 240 feet long and the southeast about 120 feet. It is reported that the northwest cross-cut intersected at a distance of about 85 feet from the shaft a narrow vein carrying high values in both copper and silver, and some gold, and at a distance of about 235 feet another similar vein was found. No development work was done on either vein. Only one vein was intersected by the southeast cross-cut, this was about 80 feet from the shaft. The main vein is the typical quartz vein of the district, about 4 feet wide, but only slightly mineralized. It is said that the shaft showed good values for the first 80 feet, but that below this point the vein became lean with rich spots here and there. In its widest part this vein is about 8 feet.

Shaft No. 3 is in a narrow but well-mineralized vein, said to vary from 18 inches to 4 feet. Only one level, the 100-foot level, has been driven from this shaft. This has been driven in the vein 120 feet to the northeast and about 60 feet to the southwest. Below this level the shaft has been sunk

125 feet. From the northeast drift a stope about 70 by 80 feet has been worked out, and from the southeast drift the ore from a similar stope about 20 by 40 feet has been broken out and hoisted. The workings were not accessible for study at the time of the examination but from reports, and judging from the character of the ore and other material on the dump, the shaft must have been sunk in a small but well-mineralized ore shoot. The gangue minerals are similar in both shafts and consist of quartz, epidote, calcite, chlorite, and a small amount of hematite. The ore minerals are also similar and are bornite, chalcocite, malachite, azurite, and a little cuprite, with a few specks of chalcopyrite here and there. The bornite and chalcocite show the microscopic intergrowths typical of the ores of the Virgilina district, and are believed to be hypogene or primary minerals and contemporaneous in development.

Future of the mine.—It is believed, that, while the development work has not been very extensive, enough has been done to justify a statement in regard to the future of the mine. At least two ore shoots have been proven to a greater or less extent, one at the Hicks shaft and the other at shaft No. 3. These may be expected to continue with depth allowing, of course, for variations in value. It may be expected that the veins intersected in cross-cutting from the Hicks shaft will develop values, but more work must be done in order to prove them. The mine appears to be in fairly good condition, and, taking everything into consideration, would certainly be regarded as a favorable prospect in which more development work ought to be done. The property is said to belong to Mr. Brodie Duke, of Durham, N. C.

PROSPECTS AND PARTIALLY DEVELOPED MINES.

NORTHEAST SHAFT.

The opening on the so-called "Durgy" vein, known as the northeast shaft, is located about 1,500 feet northeast of the main shaft of the Durgy vein. The shaft was filled with water and, therefore, not accessible at the time of the field investigations, but there was, however, a considerable quantity of high-grade ore, consisting almost wholly of chalcocite, in a pile near the shaft. Judging from a small outcrop near the shaft and from such data as were available, this vein is narrow, probably not more than 3 feet in width, but well defined, and can be traced for over one-half mile by quartz débris on the surface. It is parallel to the main vein in strike, thus

cutting the schistosity of the country rock at angles varying from 15 to 20 degrees. The shaft is said to have been sunk to a depth of 100 feet, and from the bottom a drift has been broken off, but very little stoping has been done.

The ore is nearly pure chalcocite, only a very little bornite having been noticed, in a gangue predominantly of quartz with small amounts of calcite, epidote, chlorite, and inclusions of the country rock. There is here considerable evidence that some of the included schist fragments have been in part replaced by quartz. The indications are that the chalcocite is largely supergene and secondary, having replaced bornite, and it is probable that with depth the ore will become similar to that of the main shaft. But little can be said as to the value of the ore or the extent of the ore shoot. However, it is certain that the shaft is located in an ore shoot of considerable promise.

THOMAS MINE.

The Thomas mine was opened about the time the first development work was done on the Holloway mine. It was thought at that time that the two openings were on the same vein, but, so far as the writer could determine, they are on separate and distinct veins. The Holloway vein has a trend of approximately north 15 degrees west, while, so far as could be determined, the Thomas vein has a northeast trend. Furthermore the location of the Thomas mine with respect to the Holloway renders it all but impossible for the two to be on the same vein.

The early work in the place was done by W. T. Harris and Henry Hyde. Later the property was sold to Whitney and Stevenson, a Pittsburgh firm. At the time of the field work the shaft had partially caved and was filled with water. Very little could be learned as to richness and general conditions of the vein, except what could be surmised from a study of the dump. It appears that the vein where opened was not strongly mineralized and that very little ore was produced. Careful search of the dump was made for ore, but not a single specimen could be found, due, perhaps, to the care with which the operators separated the ore from the waste material. It is stated that a few tons of ore were produced and shipped.

Two interesting items were noted in regard to the material from this prospect: The decidedly porphyritic character of the rock, and the numerous inclusions of fragments and plates of country rock within the white quartz of the vein. The country rock at this place appears to be the most nearly

typical porphyritic andesite found in the district. Indeed, it was from a study of material from this place that the true nature of the rock was first recognized by Watson and Weed. The inclusion of plates and irregular fragments of country rock give certain portions of the vein the appearance of having been developed in the torn-apart or rifted schists. Some of the fragments are fairly fresh rock, others are largely changed into chlorite, while still others show evidence of partial replacement by quartz. Figure 16, taken from Weed's[a] "Types of Copper Deposits in the Southern United States," illustrates these inclusions.

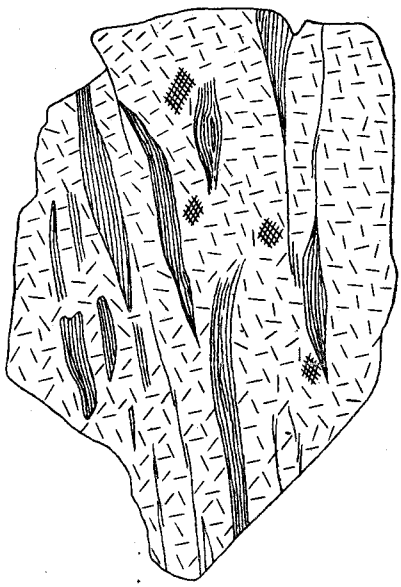


Fig. 16.—Sketch of a specimen from the Thomas vein, showing areas of schist enclosed in the white quartz. Specimen contains no ore. Three-fourths of natural size. (After W. H. Weed.)

CROSS-CUT MINE.

This so-called mine is only a shallow prospect shaft, probably 70 or 80 feet deep in a vein which outcrops rather strongly about one mile southwest of the main Durgy shaft, and which has a trend of north 30 degrees west. The schistosity of the country rock is about 30 degrees east of north, hence the name "Cross-cut" vein or mine. But little could be seen

[a] Loc. cit., p. 463.

in the way of ore or vein matter, but there were very prominent stains of malachite in some of the material on what remained of the dump. The opening is in the bed of a small stream, dry during most of the year, but running freely during the rainy season, and nearly all the material taken out of the prospect has been washed away. It is reported that so far as the work went conditions were favorable. However, the vein is small, and about all that can be said in favor of the place is that by further work there is a possibility of finding a pay ore shoot.

A short distance southwest of the Cross-cut prospect are a number of quartz veins, usually small, which show copper stainings, and prospect pits have been made in a few places, but no development work has been done. One of these veins is parallel with the Cross-cut vein. On this vein, which is crossed by the public road and the small branch at the same place, a prospect shaft has been sunk, and a small amount of country rock and vein matter has been taken out. The material carries a small amount of ore, but nothing of much promise was seen.

Between the main shaft of the Durgy mine and a small stream about one-fourth mile northwest the public road crosses two prominent and well-defined quartz veins, each of which shows copper stainings. No development work, however, has been done.

BARNES MINE.

The Barnes mine, which in reality is only a prospect showing a small deposit of copper ore, is located on the east bank of Roanoke River, in Charlotte County, Virginia, about 8 miles from the junction of this river with Dan River, and about one mile south of Mass' Ferry.

It is not known when or by whom the prospect was first opened. There are rumors and traditions that the place was opened and that ore was extracted and reduced at the mine between 1700 and 1750. There is some evidence to support the statements that the place was worked years ago, but as to the date of the working nothing is known. The statements in regard to the early work as made to the writer by John K. Taylor, of Redoak, Va., who was present when the first work known to the present inhabitants of the region was done, are as follows: In 1880 or 1881, when some men were prospecting the quartz vein on which the mine is located, they opened up an old and unknown shaft, the opening of which had been walled in and covered with soil. This shaft was 57 feet deep, and from the bottom a drift 28 feet long led into a chamber or room 84 feet long and 16 feet wide and 18 feet high or deep, the floor of which was 35 feet below

the drift. In each end of this chamber there was a well or pit, one of which was 35 and the other 24 feet deep. In this chamber were found the remains of tools such as pick axes and shovels which had been used in the work. No dump nor any other surface indications of this work were visible, except a small amount of clinkers, cinders, or slag, many specimens of which show copper stainings.

A small amount of prospect work was done in 1881, but the place was soon abandoned. In 1898 the workings were again cleaned out and a little more prospecting done. The property is owned by James A. Barnes, of Redoak, Va.

The rock is the normal greenstone schist of the region, similar in all respects to that at the other mines. The strike and dip of the schistosity are north 30 degrees and 70 to 80 degrees to the southeast, respectively. The vein is predominantly of quartz, with epidote and calcite, varies from a few inches to 4 or 5 feet or more in width, and in strike and dip appears to follow the schistosity of the country rock. The ore consists of bornite and chalcocite, carries small values in silver and gold, and is apparently similar to the ore from the other mines in the district.

A short distance north of the Barnes shaft is another prospect shaft on the same vein known as the *MacLean shaft*. The vein is narrow, and at the shaft not strongly mineralized.

McNENY MINE.

In the extreme northeastern part of the Virgilina district, a short distance southwest of Keysville, Va., there are a number of copper prospects which show rock, veins, ores, and general geologic conditions similar in all respects to those in the central and southern portions of the district. The most important and the best developed of these prospects, at the time the field work on this report was done, is known as the McNeny mine.

The McNeny mine is located on the Reese Fork of Twitty Creek about six miles southwest of Keysville and four miles east of the town of Drakes Branch. The openings, two in number, were made in a narrow quartz vein in the normal greenstone schists—altered basic volcanic tuff—similar in all respects to the rock at the High Hill, Holloway, Blue Wing, and other mines in the central portion of the district. The mine is on land belonging to a Mr. McNeny.

At the time of the field examinations for this report the mine was not in operation, the shaft was filled with water and consequently not accessible

for study. The statements here made are, therefore, based upon such data as could be obtained from an examination of the ore pile and dump, and from people who worked in the mine when it was in operation. The principal shaft is said to be about 150 feet deep, and to have been sunk in the vein. Little or no outcroppings of the vein were visible at or near the shaft, which was located in low ground near the creek. The vein is indicated on the surface both north and south of the shaft for a considerable distance by quartz débris. It appears to be narrow—from a few inches to four feet in width—and to present the usual irregularities such as pinches and swells and to follow the country rock in strike and dip.

The predominant gangue mineral is a hard, vitreous, white quartz, with a small amount of calcite, epidote, chlorite, and a little hematite. The ore minerals are bornite and chalcocite, similar to that from the other mines in relation and position in the vein, and in their relations to each other. The vein, while apparently pretty well mineralized—estimated to carry between 2 and 3 per cent copper—is so narrow that the mine from present development can not be regarded as anything more than a favorable prospect.

DANIEL'S MINE.

About one and one-half miles northeast of the McNeny mine, and probably on the same vein, are two prospect pits or shallow shafts known as the Daniel's mine. The vein is a well-defined quartz vein which shows considerable copper staining and in some of the material from the pits the sulphides still remain. The country rock, vein, ores, and their relation to the gangue, are similar in all respects to those of the largest mines in the district. The vein, however, is rather narrow, 2 to 4 feet, and with the present development the place can not be regarded as anything more than a prospect.

GILLIAM MINE.

The so-called Gilliam mine consists of a few prospect pits on a narrow but well-defined quartz vein parallel to and about one-fourth mile east of the Daniel vein. The conditions of vein, rock, and ores are similar to those at the Daniel's mine. There has not been sufficient development work to warrant any statement as to the permanent value of this prospect.

WILSON MINE.

A prospect pit in a quartz vein about three-fourths of a mile northeast of the Gilliam prospect is known as the Wilson mine. The vein is narrow,

and shows considerable copper staining, but from the small amount of work done nothing can be said as to what future work may develop. This prospect appears to be on the same vein as the Gilliam prospect, although it was not possible to trace it through from one to the other.

CRENSHAW MINE.

On Reese Fork of Twitty Creek, about a mile above the McNeny mine, are a few prospect pits known as the Crenshaw mine. These were sunk on a narrow, but fairly well-defined quartz vein, which follows the strike of the schists and which can be traced on the surface by quartz débris for about one-fourth mile. There is considerable copper staining at the prospect, which also shows some of the typical Virgilina sulphides, bornite and chalcocite. The small amount of work done will not justify any statements as to the permanent value of the place.

GROVE MINE.

About one-half mile northeast of the Wilson prospects are two or three prospect pits known as the Grove mine. The vein is narrow, but well defined and traceable on the surface for about one-fourth mile. The material taken out shows the usual type of ore of the district. Only a little work has been done and consequently nothing can be said as to its permanent value.[a]

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[a] Since the field work on this report was completed the Grove mine has been developed to the stage where it is now the largest mine and the only producer in the northern portion of the Virgilina district. It has been developed by three shafts having depths of 60, 85, and 160 feet, respectively, distributed within a distance of 300 feet along the vein. The working or 85-foot shaft, which is an incline, has a total of 650 feet of drifts turned off from the shaft at the 60- and 85-foot levels. The 60-foot shaft, also an incline, located 160 feet north of the 85-foot shaft, is connected with the latter by the drift on the 60-foot level. The 160-foot shaft, a vertical shaft sunk in the hanging wall, is being sunk to catch the vein at a depth of 200 feet.

The vein is traced on the surface for a distance of about a quarter of a mile, strikes N. 35° E. and dips 75° S. E., and varies from 4.5 to 5.5 feet in width. So far as developments have extended the vein appears to increase in width with depth. In composition and structure the vein is of the normal Virgilina type. Bornite and chalcocite are the principal ore minerals. A little chalcopyrite and the oxidized or carbonate ores, malachite and azurite, occur.

The ore is hand picked, hauled by team a distance of 1,800 feet to a spur track from the Southern Railway, and shipped to the smelter at West Norfolk. Since October 1, 1916, the total shipment of ore will probably not exceed 2,500 tons net dry weight. (From notes taken by S. Philip Holt of the Virginia Geological Survey in a recent examination of the Grove mine.)

KAY MINE.

About one-fourth mile south of Dan River and about one mile below the mouth of Bannister River are three or four prospect pits and two shallow shafts which are know as the Kay mine. The place is owned by the Kay Mine Smelting Company, an organization incorporated under the laws of South Dakota, and having an office at Omega, Va. Only a small amount of work has been done and even this in an unsystematic manner. At the time of the field work, most of the openings were filled with water and inaccessible, and there was thus little opportunity to study the veins and ores.

The country rock is the mashed and altered "sandy tuff," or Aaron slate, that is, a rock made up of basic volcanic ash and tuff with which, at the time of its deposition, there was intermixed more or less terrigenous material consisting of grains and fragments of quartz, mud, and other land waste. This type of rock is fully described in the chapter on the detailed description of the rocks of the district. It is rare indeed in the Virgilina district that ore is found in this formation; in fact, the Kay mine is the only prospect, so far as known, that is located in it. Quartz veins are about as numerous in this rock as in the Virgilina greenstone, but for some reason they do not appear to have been mineralized as they were in the greenstone.

As far as could be determined the vein or veins at this mine are neither regular nor very well defined—certainly not like the typical veins of the district. It is true that there is a considerable amount of quartz and that the greater part of the ore occurs in it, but it appears to be somewhat irregularly developed and not to lie in the usual regular veins with well-marked walls. A considerable amount of mineralization has taken place in the country rock. In fact, it appears that a very important amount of the ore occurs outside of the quartz areas.

The ore is of the typical Virgilina type—that is, it is a mixture of bornite and chalcocite. In addition to the sulphides there is a considerable development of malachite, a small amount of azurite, and here and there a little cuprite. Assays of selected ore run from about 4 to about 30 per cent copper, from 1 and 1.5 to 7 ounces of silver, and as high as .05 ounce of gold per ton. There has not been enough development work to warrant any statement as to the probabilities of there being a large deposit of ore at this place. All that can be safely said is that the work thus far done shows up a small and irregular body of ore which, unless more can be developed, will be worthless. The place must be regarded merely as a prospect until sufficient work is done to either prove or disprove the size and value of the deposit.

CHAPPELL MINE.

The Chappell mine, or rather Chappell prospect, is located almost on the bank of Hyco River about two miles west of the High Hill mine. The development consists of two shafts, 87 and 55 feet deep, respectively, and about 125 feet of drifting. Shaft No. 1, nearest the river, is 55 feet deep and from it about 25 feet of drifts have been driven. Shaft No. 2, about 150 feet south of No. 1, is 87 feet deep and from it about 100 feet of drifts have been driven. They are located in a narrow, but fairly well-mineralized quartz vein, and are both probably on the same ore shoot. Both shafts were filled with water when the field investigations were made and hence inaccessible for study. There was, however, a considerable pile of fairly high-grade ore in a dump near the shafts, and it is reported that while the vein is narrow it is well mineralized. The country rock, vein, and ore are of the usual type of the district. There is also a prospect pit about 1,000 feet south of shaft No. 2. The material on the dump at this place shows more or less copper staining, but the work is not extensive enough to determine anything in regard to its value. This is also true of the deposit as a whole. The development work has not been extensive enough to either prove or disprove the property. The best that can be said for it is that it is a fairly favorable prospect.

PONTIAC MINE.

The Pontiac mine, formerly known as the "Tuck property," is located about 6 miles northwest of Virgilina and one and one-half miles west of Moffett post-office. It is reached by fair wagon roads, and is as accessible as the High Hill or Seaboard mines. There is no immediate water supply, but there is a small stream about one-half mile northwest of the property that by impounding could be made to furnish sufficient water for mining purposes, but would have to be pumped to the mine. The timber conditions are similar to those at the High Hill or Seaboard mines. There is an ample supply of both oak and pine for all mining purposes.

The veins of this mine were located sometime between 1895 and 1900. A little later the Pontiac Mining Company, the present owner, acquired the property and began active development work which continued until 1903, when all work was stopped and the shafts allowed to fill with water. No work has been done since that date and the property has been dismantled. Two shafts were operated, one on the eastern vein which appears to have a trend of 4 or 5 degrees west of north, and known as the Glasscock shaft, and one on a smaller vein about 1,000 feet west of the Glasscock,

known as the Tuck vein, which name was also given to the shaft. The two veins are very different in character and in the ore they produce. The Glasscock vein is irregular in width, strike, and dip, contains much epidote and in places only a moderate amount of quartz; in fact, it is reported that in places there was little vein matter of any kind unless the epidotized country rock in which the ores occurred could be regarded as the vein. The ore, too, is different from the usual ores of the district, in that chalcopyrite is present in considerable quantity, making up about one-third of the ore, the other two-thirds being bornite and chalcocite. The minerals of the gangue, named in order of their abundance, are: Epidote, quartz, chlorite, calcite, and hematite, which is present only in small amount. The ore minerals in the same order are: Chalcopyrite, bornite, chalcocite, malachite, azurite, covellite, and cuprite. Covellite, cuprite, the carbonates, and a part of the chalcocite in the upper portion of the vein are supergene minerals derived from the hypogene chalcopyrite, bornite, and chalcocite. The relations of chalcopyrite, bornite, and chalcocite make it reasonably certain that the three are to be regarded as hypogene or primary minerals, at least in part primary, so far as bornite and chalcocite are concerned. Many specimens of chalcopyrite showing alterations to chalcocite and covellite, and, in a few instances, doubtfully, bornite was noted on the dump, but it is believed that much of the bornite and chalcocite is hypogene and primary, and contemporaneous with the chalcopyrite. Many irregularities such as broken ground, mud seams, varying values, and different kinds of vein matter were noted in sinking the shaft. So far as there are data on which to base possible explanations of these phenomena, it is believed that they represent breaks and joints formed at the time the fissure in which the ore occurs was formed. The vein was for the most part developed in the fissure which crosses the strike of the schists, but when the fissure was formed the schists were more or less disturbed and torn apart, and, when the vein and ores were deposited, some of the depositions and alterations took place in the broken and rifted schist in the immediate vicinity of the fissure.

This shaft is 203 feet deep and one drift was broken off at 86 feet from the surface and driven about 50 feet to the south and 20 feet to the north. Conditions as regards ore are said to have been promising, but the vein, which varies from 2 to 6 feet in width, is reported not to have had well-defined walls and to have been difficult to follow.

There was no way of ascertaining the total amount of ore produced by this prospect. A pile of good ore representing several thousand pounds

was lying on a platform at the collar of the shaft, but how much more, if any, the mine produced is not known. It is not advisable to make any statements as to the future of this property until more exploratory work is done. As things now stand the place must be regarded simply as a fairly good prospect.

The Tuck shaft is about one-fourth of a mile southwest of the Glasscock shaft and is on a separate and distinct vein. The country rock is the normal greenstone schist, but contains less epidote than that at the Glasscock shaft. The vein is narrow, varies from a few inches to about 3 feet, and appears to follow the schists in dip and strike. The most abundant gangue mineral is quartz which makes up at least 80 per cent of the total vein. The ore and gangue minerals are similar to those at the Durgy mine and their relations to each other are typical of the district. The shaft was filled with water at the time of the examination, but, judging from the ore pile and the dump, the vein while narrow seems to have been well mineralized where opened by the shaft. Until more work is done this mine, like the Glasscock, must be regarded only as a fair prospect.

PANDORA MINE.

About 6 miles north of Virgilina and about 1 mile south of Moffett post-office is a shallow prospect shaft known as the Pandora mine. No work has been done at the place for a number of years. At the time the field work was being done the shaft was filled with water, and about all the data available as to the character of the vein and the ore were a few conflicting stories told by people in the vicinity and such inferences as could be drawn from examining a small amount of material on the surface at the shaft. The rock is the ordinary greenstone schist of the district somewhat more epidotized and not quite so highly schistose as usual. The ore, a small pile of which remained at the place, consisted of bornite and chalcocite with small amounts of the carbonates, and a little cuprite occurring in both epidotized country rock and quartz. A small amount of well-crystallized plagioclase feldspar, apparently albite, was noted in some specimens as a gangue mineral associated with the ore in quartz. So far as could be determined it appears that there is no regular and well-defined vein. The shafts seem to have been sunk in epidotized and somewhat mineralized area of the country rock. Until further development work is done the place must be regarded as a prospect of doubtful value.

MORONG MINE.

The so-called "Mother lode" mine of J. G. Morong is located about three and one-half miles due north of Virgilina. The shaft which is reported to be about 150 feet deep is located on a strong and well-defined quartz vein of the usual Virgilina type, which can be traced in the surface by actual outcrop and quartz débris for more than a mile. So far as could be determined from an examination of the material on the dump and from reports of men who were familiar with the place when the work was in progress, it is believed that no ore of commercial value was found. At least there is no evidence in the material now on the surface at the shaft of any such ore. The vein shows copper stainings in a number of places, and it may be that further development work would expose more favorable conditions, but, until such work is done, the place must be regarded as merely a prospect of very doubtful value.

BAYNHAM MINE.

The Baynham prospect or mine as it is called is located about 8 miles north and a short distance east of Virgilina. It consists of a dilapidated and partially caved shaft around the collar of which is a small dump consisting of schistose greenstone—the usual country rock—and a small amount of vein material, quartz, epidote, chlorite, etc., some specimens of which carry a little ore of the usual Virgilina type. The place has long since been abandoned and no data, other than that obtainable from the dump, were available as to the conditions of vein and ore. It is, therefore, regarded as a prospect of doubtful value.

ANACONDA MINE.

The Anaconda mine is located about one and one-half miles north of Virgilina on the east side of the public road, near the colored schoolhouse. It has not been operated for a number of years, and at the time of the field examination for this report was filled with water and not accessible for study. Very little authentic information in regard to it could be obtained from the people in the district, but the consensus of such data as could be obtained indicates that the shaft was sunk on a small but high-grade shoot of ore. The ore taken out was shipped and the greater part of the waste or barren rock hoisted has been hauled away for use in road building. However, such material as remained indicated that the mine had produced some good ore. Weed,[a] in his report on the Virgilina district, says of this mine:

[a] Loc. cit., p. 464.

"The ore is a mixture of glance and gray copper in quartz. The dump shows bright green schist largely impregnated with epidote. Some seven carloads [of ore] have been shipped from this mine, which varied from 3 per cent of copper in the first carload to 12 per cent in the last five carloads shipped. . . . The vein can not be said to have had a very extensive trial, and the ore thus far extracted has come from but one shoot."

THE CORNFIELD PROPERTY.

Situated in the southeast part of the Virgilina town site are two or three prospect shafts belonging to the William M. Pannebaker estate and known as the Cornfield Property. They were opened a number of years ago when mining was at its height in the district, but for some reason were soon abandoned and were not reopened until in the late fall of 1915. The shafts are only a short distance apart and are in the typical Virgilina greenstone, but the ore in each shaft is decidedly different from that in the others. They are designated "Cornfield No. 1," "Cornfield No. 2," and "Native shaft." The ores from the respective openings are so different that each will be described separately.

Cornfield No. 1 shaft when cleaned out was found to be about 55 feet deep and about 6 by 6 feet in the clear, and enlarged to about 9 feet at the bottom. The ore, consisting largely of chalcocite with only a small amount of bornite, occurs in a gangue of quartz, calcite, and a little epidote and chlorite, and in the country rock. There is, so far as the development has progressed, no well-defined vein, although there is a decided tendency for the ore to be segregated in different places in the mineralized portions of the rock. The writer did not have an opportunity of seeing the prospect after it was reopened, but, judging from data and specimens of the ores and rock which were kindly furnished him by the owners, it appears that this is certainly one of the promising prospects of the district and that it ought by all means to be given the attention which it deserves. In the notes furnished by the owners of the property it is stated that the whole width of the shaft, 9 feet, is more or less mineralized—all good milling ore, with a streak of chalcocite and bornite nearly four inches wide in one place.

The ores from this prospect are of more than ordinary interest in that they contain some of the finest examples of graphic or crystallographic intergrowths of bornite and chalcocite that were found in the district. These are described in detail and photomicrographs of them are shown in the chapter on the origin of the ores, and the descriptions need not be repeated here. The evidence afforded by these ores seems to the

writer to indicate very clearly that there are two generations of chalcocite—one of hypogene origin and contemporaneous with the bornite, and one of supergene origin and younger than the hypogene sulphides in which it occurs. Only the normal and usual minerals were found in these ores.

Cornfield No. 2 shaft is located about 400 feet east of No. 1 and in the same type of rock, but the ores are different in that they contain in addition to the usual bornite and chalcocite a large amount of chalcopyrite and an appreciable amount of pyrite which in the Virgilina district is an exceedingly rare mineral. This shaft was sunk entirely within a mineralized area of the country rock. While the ores thus far found in this prospect are not so promising as in the other shaft they are certainly worthy of further exploration. The ore minerals are chalcopyrite, bornite, chalcocite, malachite, azurite, klaprothite(?), pyrite, argentite, native copper, and cuprite. There are apparently two generations of both chalcopyrite and chalcocite, one of hypogene origin and one of supergene origin, and therefore younger than the hypogene mineralization. These relationships are discussed and illustrated in the chapter on the origin of the ores, and the discussions need not be repeated here further than to state that fine examples of the alteration of bornite to chalcopyrite were found.

The "Native shaft" is located in the southern part of the town site only a few hundred yards south of the Baptist church and a short distance east of the wagon road leading south from the town. This shaft is in the northern portion of an epidotized and mineralized belt of the Virgilina greenstone of varying width and extending southwestward along the strike of the rocks for about two miles, in which the ore, consisting of native copper, cuprite, and the carbonates, occurs for the most part in silicified and epidotized portions of the greenstone instead of in definite fissure veins as is usual in the Virgilina district. These deposits, if not exactly like Weed's[a] Catoctin type of copper deposits, are very much like them. In fact, Weed himself places them in the Catoctin class. This subject is discussed in detail in the chapter on the detailed description of the ores.

The ore in the "Native shaft" consists of native copper, cuprite, and the carbonates in a gangue of epidote and quartz, the copper occurring for the most part in the quartz, but to a less extent in the country rock and in the epidote. There is no well-defined vein in the usual sense of the term, and the ore is found as granular and crystalline metallic copper in irregular

[a] Weed, Walter H.: Types of copper deposits in the Southern United States, Trans., Am. Inst. Min. Eng., Vol. 30, 1900, pp. 498-504.

silicified and epidotized areas of the country rock and in short narrow quartz veinlets. The cuprite and the carbonates which are regarded as alteration products from the copper are disseminated through the country rock in the vicinity of the deposits. It is also probable that a part of the metallic copper occurs in the same manner, but, if it does, it was not discovered during the field work upon which this report is based. At the time of the field work this shaft was filled with water and not accessible for study. Very little of the ore which had been taken out was available for study, but such specimens as could be found consisted of native copper in quartz and epidote, together with cuprite and the carbonates as oxidation products. The shaft is reported to be about 60 feet deep and to have been sunk through ore. It is also said that a good part of the ore taken out in sinking was shipped to the smelter as high-grade ore. The shaft was cleaned out in the late fall of 1915, and the owners state that both quartz and epidote carry the ore which consists of the minerals just mentioned, and that there is no regular and well-defined vein, but that the quartz and epidote areas and veinlets which carry the ore are irregular in size and occurrence. This is one of the most promising of all the native copper deposits in the district, even though it has not been developed beyond the stage of a mere prospect. In the immediate vicinity of this shaft there are a number of silicified and epidotized areas of the greenstone which show more or less mineralization. On this account it would seem that this is as good a place as could be found in the whole district in which to try out, by well-directed development, the native copper deposits.

PANNEBAKER PROSPECTS.

About one-half mile south of old Blue Wing post-office, and a short distance west of the road and on the line between Person and Granville Counties, North Carolina, W. M. Pannebaker opened in the summer of 1907 a number of prospect pits in some epidotized outcrops of country rock containing irregular areas and stringers of quartz, which showed copper staining. In some places native copper and cuprite occurred with the malachite within a few feet from the surface, and in some of the pits considerable areas of well-mineralized rock were found. No sulphide minerals were noted. The primary mineral appears to have been native copper which was disseminated through the country rock, largely as thin plates in the planes of schistosity and as irregular grains and elongated areas in the quartz and epidote. The cuprite and the carbonate were derived from the native copper by oxidation. So far as could be determined the native

copper occurs in zones or areas in the country rock rather than in definite, well-defined quartz veins, and while the mineralization is extensive no deposits rich enough to mine have been opened. It is impossible to make, with any degree of certainty, any predictions as to the future of these deposits of native copper. It is certain that in many places the metal is widely disseminated through the rock, but, until further exploratory work is done, all such occurrences must necessarily be regarded as prospects of unproved value.

Native copper occurs in two other prospect pits, one only a short distance southwest of those just described, and the other at the roadside about 1 mile south of the Thomas mine. In both of these places the country rock is amygdaloidal and native copper and cuprite occur in the amygdules. Otherwise the conditions are similar to those at the Pannebaker prospects. Neither prospect developed a promising ore body. These deposits are also of the Catoctin type.

ANNIE MAUD PROSPECT.

About one-half mile south of Old Blue Wing post-office and a short distance east of the county road is a small prospect which is said to have produced some promising ore of the Holloway type, that is, the ore is largely chalcocite in a gangue in which quartz is subordinate to epidote. This shallow pit is known as the Annie Maud mine and is owned by the Wm. M. Pannebaker estate. So far as could be determined, the vein, as it is exposed in the prospect, is narrow, but it appears to be rather persistent and has been traced by quartz débris on the surface for considerable distances both northeast and southwest of the prospect. In fact, two other openings have been made in what, so far as could be determined, is the same vein. One of these, known as the Fourth of July mine, is located about one-fourth mile northeast of, and the other, an unnamed prospect pit, is about the same distance southwest of, the Annie Maud opening. The work thus far done is not sufficient to either prove or disprove the value of the prospect.

ENGLE PROSPECT.

The shallow pits and shafts about 1 mile northeast of the Gillis mine are known as the Engle mine. The work was done in a small but fairly well defined and narrow quartz vein which appears to be an extension of the Gillis vein. Considerable copper-stained quartz was exposed and a small amount of the usual sulphides, chalcocite and bornite, was found, but nothing of commercial value was developed.

GILLIS MINE.

The copper ores at the Gillis mine were discovered and the mine opened in 1852 or 1853. It is, therefore, one of the earliest worked copper deposits in the United States. It was examined by Ebenezer Emmons, State Geologist of North Carolina in 1854, and in his "Geology of the Midland Counties of North Carolina"[a] he described the mine and stated that two shafts had been sunk to a depth of 80 feet, the south one showing 5 feet of vein and the north one 18 inches. He also noted that the expected change of chalcocite to chalcopyrite with depth did not occur in this mine. The vein does not present a prominent outcrop and appears to be narrow—about 3 feet wide on the average. It is difficult to trace on the surface, but appears to trend 10 degrees east of north and to dip about 70 degrees to the southeast. The rock is the normal Virgilina greenstone. The vein is composed largely of quartz, but contains appreciable amounts of calcite, epidote, chlorite, and a little hematite. The ore minerals are bornite, chalcocite, malachite, azurite, chrysocolla, tenorite(?), and cuprite. Emmons states that "vitreous copper" (chalcocite) occurred in a continuous belt 2 to 4 inches wide nearly pure. The mine has been closed for years and no data further than those given were available.

COPPER KING MINE.

A prospect shaft about 100 feet deep, known as the Copper King mine, is located about three and one-half miles southwest of Virgilina. There is apparently no well-defined vein, and the ore occurs in an epidotized portion of the country rock in which more or less quartz has been deposited in irregular areas or masses and in lenses and stringers. Aside from the excessive epidotization, the rock is the normal Virgilina greenstone. The gangue minerals are epidote, quartz, calcite, chlorite, plagioclase (probably albite), and a little hematite. The ore minerals are bornite, chalcocite, klaprothite, malachite, azurite, and cuprite, which in some instances occurs in the form of the so-called "plush copper ore" or chalcotrichite. The sulphides are intimately associated with all the gangue minerals. One specimen was found in which well-terminated albite crystals nearly an inch long and more than one-fourth inch in thickness were embedded in massive sulphides. The sulphide masses are always composed of an intimate intergrowth of bornite and chalcocite.

[a] Emmons, Ebenezer: Geology of the Midland counties of North Carolina, 1856, pp. 344-346.

At the time of the field work there was a small body of good ore in a short drift which had been started from the bottom of the shaft, and there were a few thousand pounds of high-grade ore on a platform at the collar of the shaft. As conditions were at the time of the examination, there had not been enough development work done to warrant any surmise as to the future of the mine, and until such work is done the place must be regarded as a promising though unproved prospect. It belongs to J. H. Morong, of Virgilina, Va.

COPPER WORLD MINE.

The Copper World mine is about one and one-fourth miles southwest of the Gillis mine and apparently on the strike of the Gillis vein—at least if the strike of the Gillis vein be produced along its regular trend southwestward it would reach the Copper World shaft. The rock is the normal green and purplish schist of the district. The vein does not outcrop, but judging from material on the dump it is the normal type of vein of the district, that is, white quartz with epidote, calcite, and chlorite. The ore is an intimate mixture of bornite and chalcocite with oxidized minerals near the surface. The only reliable information available in regard to this mine is by Weed,[a] who says:

> "The Copper World was first opened in 1882. The present owner, Colonel Stiff, has sunk a shaft, 60 feet deep, with drifts at 30 and 60 feet. It is equipped with a small steam hoist and well timbered. The vein shows the usual white quartz with some epidote, encased in gray and purple schist. But one ore shoot has been crossed, from which 8 to 10 tons of high-grade glance ore has been stoped and shipped."

FOURTH OF JULY MINE.

A prospect shaft about two miles south of Virgilina is known as the Fourth of July mine. Just why it is called a mine or why the shaft was sunk was not made clear from an examination of the material on the dump, which consists of normal greenstone schist with a few bunches of quartz here and there which in places show a slight amount of copper staining. So far as it was possible to determine there is no vein at the place.

ARRINGDALE MINE.

A few prospect shafts and pits were sunk a number of years ago on some fairly well-defined quartz veins about two and one-half miles northwest of the Durgy mine. These are known as the Arringdale mine. The work was soon abandoned, and, judging from the material in the various

[a] Loc. cit., p. 463.

dumps, with most excellent reasons. It is true that some of the material shows a slight amount of copper staining, but certainly not sufficient to warrant one in sinking a shaft.

LITTLEJOHN MINE.

About one-fourth mile west of the Seaboard vein are a number of closely spaced veins, some of which show considerable copper staining in the outcrop. The property including these veins was recently purchased by the Littlejohn Copper Company, of New York, and in one of the most promising of the veins three prospect shafts were started. These are all shallow, the deepest one being about 100 feet in depth, but they each show a narrow well-defined vein with considerable mineralization, the ore consisting largely of chalcocite with only a very little bornite. No assays of the material taken out were available, but from the general appearance of the vein it seems that further prospecting would certainly be justified. At least nine veins showing copper stainings, outcrop on the property owned by this company, and the most prominent of these veins are traceable by quartz and epidote débris as well as outcrops on the surface for considerable distances, in one instance at least two miles. They are, however, for the most part narrow and of doubtful value. As far as could be determined their strike appears to be parallel with that of the schistosity of the country rock.

ESTHER MAY PROSPECT.

In the Seaboard vein where it is crossed by the county road about one-fourth mile north of the Seaboard mine is a small prospect pit known as the Esther May mine. The pit is only a few feet deep, certainly not deep enough to either prove or disprove the property. The material on the dump shows a small amount of ore similar in all respects to the Seaboard ore and the prospect so far as could be determined is on the main Seaboard vein.

WALL MINE.

About three-fourths of a mile north of the Seaboard mine are two or three prospects known as the Wall mine. The country rock at these places is the tuffaceous phase of the Virgilina greenstone similar to that at the Seaboard mine. The vein, so far as could be determined, has a considerably more northerly strike than the schistosity of the country rock. At the time of the field investigation for this report this mine was not in operation. The shaft was filled with water and there was, therefore, no

opportunity for underground examinations. It is reported, however, that the vein is narrow, averaging not more than 2 feet in width, but that it is well mineralized. The material on the dump shows that the ore consists of bornite and chalcocite in a gangue composed dominantly of quartz, considerable epidote, and a small amount of calcite with a little chlorite. Only one opening of any importance was made in this vein. It is reported that the shaft was sunk through a depth of 135 feet and that a drift about 100 feet long was driven from the bottom of the shaft.

The ore from this mine when examined under the microscope proved to be the most interesting of the whole district in that it presented the best examples of crystallographic intergrowths of bornite and chalcocite that have ever been found.

A typical case of such intergrowth is illustrated in Plate XVII. At a magnification of 40 diameters these areas resemble very closely the intergrowths of quartz and feldspar in a micropegmatite, or the intergrowths of the constituents in certain alloys. At the highest magnification used, that of 575 diameters, this resemblance is even more pronounced. When an area of such intergrowth is etched deeply enough to bring out the cleavages distinctly the chalcocite is seen to be composed of numerous medium-sized individual grains, the cleavage lines of which could be seen to extend from one side of the grain to the other, interrupted here and there by the filaments of bornite. This type of texture is regarded as strong evidence that the two minerals crystallized at the same time. This subject is discussed in greater detail in the chapter on the genesis of the ores.

GOLD MINES AND PROSPECTS.

General statement.—All the copper ores of the Virgilina district carry small but variable values in gold. The usual values of the concentrates and ores in gold as shipped to the smelters vary from a mere trace up to 1.30 ounces per ton. It is also reported that "colors" of gold may be found in many stream beds and other places in the district. However, so far as was determined during the field investigations for this report, there is only one area included within the district as shown by the accompanying map (Pl. I) which shows the presence of gold in sufficient quantity to warrant prospecting for it. This is an area about 2 miles wide extending from about 2 miles to 6 miles northeast of Virgilina. The southern half of this area, which contains many irregular quartz veins and stringers, stands a little higher than the surrounding country and is known as Gill's Mountain.

It is said that nearly any stream in this area, by panning, will show from one to many colors of gold, some of which is fairly coarse. A number of prospect pits have been sunk and many cross-cuts made in the area, with the hope of locating valuable deposits. Many of these show gold, but it is nearly always present in too small amount to be of any commercial value. While many of these veins and stringers show pyrite and gold it is very seldom, indeed, that they show any of the copper-bearing sulphides. Of all the pits and cross-cuts in this territory only three show indications that might possibly warrant further prospecting. It also seems probable that these three are all on the same vein, at least in the same mineralized zone. These, beginning with the one farthest south, are: The Poole and Harris Prospect, the Red Bank Mine, and the Luce and Howard Mine.

POOLE AND HARRIS PROSPECT.

About one and one-half miles south of the Red Bank mine are a number of shallow pits and cross-cuts in a quartz vein which in places shows rather favorable pannings. Only very little surface work has been done and no assays are available nor other data that would afford any quantitative information. As conditions are, the place can not be regarded as more than an undeveloped prospect.

RED BANK MINE.

The Red Bank mine is located about four and one-half miles northeast of Virgilina, and about one-fourth of a mile north of the wagon road leading from Red Bank store to Hitesburg. It was the only gold mine in active operation at the time of the field work. In fact, it is the only gold mine thus far developed to any important extent in the whole region. The veins were discovered and active development was begun in 1903 by H. C. Crowell. Very soon after the discovery, W. T. Harris became associated with Mr. Crowell in the development work. These men carried on the work until 1905, when they sold the property to its present owners, the Virgilina Mining Company, with headquarters in Buffalo, N. Y. The surface plant consists of a small stamp mill, ore bins, crusher, air compressor, boiler, and engine all well housed. All the ore thus far taken out was handled by the stamp mill and amalgamating plates. Much of the gold has been proven to be very fine and consequently the slime loss has always been considerable. To avoid this the company purchased a cyaniding outfit, but for some reason did not install it.

The underground development consists of two shafts, one about 50 and the other about 200 feet deep, and about 650 feet of drifts. The first level at a depth of about 70 feet extends 370 feet south and 120 feet north of the shaft. The second level extends about 90 feet south and 100 feet north of the shaft. Considerable stoping has been done, but little or none of it extends below the 70-foot level. All drifting and development work has been confined to the one vein.

The country rock is the usual greenstone schist of the district. The green- and purplish-colored types of the rock are both present and its tuffaceous nature is plainly visible upon close examination. It appears that the rock is probably more highly schistose than at the other mines. The vein is of the fissure type and appears to follow the dip and strike of the schistosity of the rock in which it occurs. It varies in width from a few inches to 6 feet, averaging perhaps three and one-half feet. The walls are well defined and the vein is easily followed. Much silicified country rock is included in the vein and much of it has a decided reddish color resembling jasper, due probably to the development of hematite in the siliceous material.

It is said that the richest values were found in the reddish portions of the vein. The upper portion of the vein seems to carry only two metallic minerals, gold and hematite, but with depth a small amount of pyrite began to come in. The values are not evenly distributed throughout the vein, but they occur in a well-defined ore shoot, only one of which has been developed, although others of more or less promise are known to exist. Even in the ore shoot the values are "spotty" and in places the vein carries very little or no value. No properly made assays were available, and it is therefore not possible to make any statement in regard to average value of the ore per ton. However, it is reported that up to date (1912) the mine had produced a total of $22,000 worth of gold.

It is not known why the mine has been allowed to lie idle so much—whether due to lack of suitable ore or to the management. H. C. Crowell, who is familiar with the workings, says that there is a good body of average grade ore in sight, but that much of the gold is too fine to be saved on amalgamating plates and that this fact is responsible for the idleness.

Not much can be said with any degree of certainty as to the future of the mine. Certainly some high-grade ore was taken out, but it is not known how much remains unbroken. Until more development work is done the place must be regarded as a favorable, but unproven, prospect.

LUCE AND HOWARD MINE.

A prospect on a hill about one-fourth of a mile northeast of the Red Bank mine and apparently on the same vein is known as the Luce and Howard mine. The metal sought was gold which occurred in small quantity in quartz veins and stringers in the schists. The place was not in operation at the time of the field examinations for this report and the workings were not accessible. So far as could be determined from examinations of material on the dump, conditions are somewhat similar to those at the Red Bank mine. Three shafts have been sunk to depths varying from 75 to 100 feet, but little or no stoping is said to have been done. A small stamp mill and concentrating machinery have been installed, but no data were available as to the success of the mill. It is reported that much of the gold is very fine and as a consequence very difficult to save by amalgamation.

UTILIZATION OF THE ORES.

GENERAL STATEMENT.

There are three ways of utilizing the Virgilina ores: (1) Ship the run-of-mine ore, less such waste material as can be eliminated from a picking belt, direct to the smelter for use as converter linings or as a siliceous material for fluxing heavy sulphide ores or concentrates. (2) Concentrate the ores and ship the concentrates. (3) Extract the metals from the ores in a plant erected in the district for the purpose; such plant might consist of a smelter or be equipped for roasting the ores and concentrates and leaching the valuable metals from the roasted material.

SHIPMENT OF ORE WITHOUT MILLING.

The location of the district and the type of ore produced are favorable to the first-mentioned way of utilizing the ores, that is, ship the roughly picked ore direct to the smelter for use as siliceous material. The district is not far removed from a number of smelters, and, if reasonable freight rates can be obtained, the hand-picked ore, carrying from 4 to 8 per cent of copper and 70 per cent excess silica, could undoubtedly be shipped at a profit. The nearest smelter is the Virginia Smelting Company, at West Norfolk, Va., only 147 miles distant. This smelter at the time of the field work was treating large amounts of roasted pyritic copper ore, "spent pyrites," from Canadian points, and the management was more than anxious to have siliceous ores to serve as flux with the heavy iron ores.

Very reasonable freight rates were in force between Virgilina and Norfolk and if proper contracts could have been made which would have assured the smelter a steady and regular supply of siliceous ore, and, at the same time had assured the miner a steady and fair market for his ore, it is reasonably certain that the whole output of the district could have been disposed of to this smelter. In fact, the greater part of the output was handled by this smelter.

In case the Norfolk smelter could not handle the ores, the smelters in New Jersey and the Tennessee Copper Company's smelter at Copper Hill, Tenn., are within reach. They are farther away and the success of shipping to these markets would depend upon the kind of freight rates that could be obtained. All these smelters are buying silica for use as flux, and it is believed that by assuring the railroad of regular and large shipments of ore, the price for the excess silica in the ores would almost, if not quite, meet the transportation charges and thus enable the operator to deliver the actual copper ore to the smelter free of, or for a very small, freight charge. These smelters, especially the one at Copperhill, Tenn., have used many shipments of ore from the Virgilina district. Indeed, in 1909 and 1910, the Tennessee Copper Company did considerable exploratory work in the district for the purpose of ascertaining whether or not a sufficient supply of siliceous ores could be obtained for their smelter. The project failed, but it is said not from a lack of ore, but because of exorbitant prices demanded for property.

In order to sell Virgilina ores in this way to the best advantage it will be absolutely necessary for the district to be able to deliver steadily and regularly a reasonably large tonnage of fairly uniform ore. There is probably not a mine in the district, when operated as a single unit, that can meet such conditions, but if a number of the most promising mines and prospects would combine in marketing their ores the conditions could be met very easily. It seems perfectly evident that the only way to operate the mines on the basis of greatest profit to the individual owners is to consolidate them, at least so far as selling and shipping the ore is concerned.

MILLING THE ORES AND SHIPMENT OF CONCENTRATES

Sufficient experimental work, and actual milling of the Virgilina ores on a commercial basis, have been done to demonstrate beyond any question that they are readily amenable to concentration. This statement is made with full knowledge of the failure of both the High Hill and Person Consolidated mills to give satisfactory results. It is perfectly clear to any

one familiar with the construction, equipment, arrangement, and management of these mills, that the causes for failure lay within the mill and its management and not within the ores. Every mining engineer of any standing who has examined properties in the district has either strongly recommended concentration or remarked that the ores are favorable for concentration. The important minerals of ore and gangue together with the specific gravity of each are given in the following list:

Ore Minerals	*Specific Gravity*
Bornite	4.90 to 5.40
Chalcocite	5.50 to 5.80
Argentite[a]	7.20 to 7.36
Chalcopyrite[b]	4.10 to 4.30

Gangue Minerals	*Specific Gravity*
Quartz	2.65 to 2.66
Calcite	2.71
Epidote	3.25 to 3.50
Chlorite	Under 3.00
Average rock	About 3.00

It is seen that there is a difference in specific gravity of 1.7 between the average bornite, the lowest important ore mineral, and the average of epidote, the highest important gangue mineral. In good milling practice it is possible to separate without great difficulty minerals having a difference of little more than .5 in specific gravity. It is, therefore, clear that so far as the relative specific gravities of the gangue and ore minerals are concerned there is nothing to interfere with successful concentration.

There is, however, one feature that complicates the problem and one which must be seriously considered in any attempts to concentrate these ores. This is the brittleness of bornite and chalcocite, the principal ore minerals, and the toughness and hardness of epidote and the hardness of quartz, the principal gangue minerals. Consequently, there will be a strong tendency for the ore minerals to crush very finely and form a great deal of slime, which will be lost in the milling process unless careful measures are taken to save it. The best way to save slimes in ore dressing by gravity methods is not to make them; therefore in treating these ores every precaution must be taken to prevent the formation of slimes. In planning a method of treatment for these ores, this question must be given first and foremost consideration. Then, in spite of every precaution, a certain

[a] It is assumed that the silver in the ores occurs in the form of argentite.

[b] Chalcopyrite occurs in appreciable quantities in only two mines or prospects in the district—the Glasscock shaft of the Pontiac mine, and the Cornfield No. 2 prospect.

amount of slimes will be formed, so that no process could be considered adequate which did not include apparatus for collecting and saving slimes. One of the fundamental principles of ore dressing is never to crush the ores any finer than is absolutely necessary to free the valuable minerals from the deleterious or worthless material. In applying this principle to the Virgilina ores there is both a fortunate and an unfortunate feature. The fortunate one is the fact that in most of the deposits the ores are pretty well bunched or segregated in fair-sized areas, and can be saved without exceedingly fine crushing. The unfortunate feature is the fact that this segregation was not carried to completion and as a consequence there is a great deal of vein through which the ore is finely disseminated and which therefore must be crushed very finely. Therefore, in devising a system of treatment means must be provided for taking out as much ore as possible without crushing and to crush only what is absolutely necessary and then not any finer than is absolutely necessary to free the values from the gangue. This makes it necessary, in order to treat any of these ores to the best advantage, to provide a picking belt which takes the ore from a rock breaker in which it is broken to about 2-inch size but no finer. From this belt three products will be obtained—a shipping ore, a milling ore, and much barren quartz and country rock. A picking belt is regarded as essential to any equipment for dressing these ores.

The mill equipment of the High Hill, Person Consolidated, and Seaboard mines has been described in the paragraphs relating to these mines and will not be repeated here. Of these mills only the Seaboard was a success. Before erecting this mill, A. W. Tucker, at that time manager of the Seaboard mine, carried out a great deal of experimental work on the ores, with the object of determining the best type of treatment for them. This is the only work of its kind thus far attempted with the ores from the district, and it seems best to quote briefly from Mr. Tucker's report of his work.

"The tests were made on ore from the Seaboard mine in the ore dressing laboratories of the Massachusetts Institute of Technology, Boston. The total amount of ore used was a trifle under two tons. It had been crushed at the mine to 2-inch size and all high-grade ore taken out. By high-grade ore is meant all ore running 10 per cent copper or over. This was done to take the place of a picking belt which is essential to any mill in the district. Much work was done on the ore for two purposes: First, to determine the fineness to which the ore must be crushed in order to produce the greatest percentage of saving in the simplest manner; and, second, to determine the adaptability of various machines to the concentration of this particular ore. Under such conditions it is readily seen that a negative result would

be nearly as valuable as a positive one. From the results obtained the proper mill to install can be determined easily, but the individual test or run has little value by itself. Three complete runs or tests were made. They are as follows:

"In the first test the ore was crushed and then reduced to 5-mesh by putting it through one set of rolls. This 5-mesh product was fed direct to a 3-compartment Harz jig, containing 12-mesh bottom screens and allowed to make its own bed. The hutch product was run in a one-spigot classifier which gave two products, heads and tails. The jig tails, jig middlings, and the classifier tails were mixed and run through a gravity stamp mill having a 14-mesh screen. The stamp mill pulp was classified and the various sizes run on Wilfley tables. The mud from the jig was added to that from the Wilfley tables and run on a Wilfley slime table. This test showed a total saving of 81.09 per cent of the total copper in the ore, distributed as follows: Jig, 48 per cent; Wilfley table, 27 per cent; Wilfley slime table, 6 per cent. The original ore assayed 2.78 per cent copper, hence the ratio of concentration was 14 to 1.

"The second test was one of graded crushing with rolls through 8 mesh. The material was classified in a 4-spigot classifier, Spigot No. 1 went to the jig, the middlings being run on gravity stamps having a 20-mesh screen. Spigots Nos. 2, 3, and 4 were treated in the usual manner on Wilfley tables, the overflow going to a Wilfley slime table. This test was made on ore assaying 3 per cent copper. The saving was 88.22 per cent of the copper and was distributed as follows: Jig, 52.61 per cent from treatment of material from spigots Nos. 2, 3, and 4; and overflow, 15.10 per cent; treatment of jig middlings, 20.51 per cent. In this test, however, all products assaying 10 per cent or over were called heads without further concentration and the ratio of concentration would therefore be low.

"In the third test the two-inch material as received from the mine was fed directly to gravity stamps having a 14-mesh screen. The pulp was classified and run on Wilfley tables; 79.30 per cent of the total copper content of the ore was saved as follows: Wilfley tables, heads, 60.54 per cent; round table, heads, 6.43 per cent; and Wilfley slime table, 12.33 per cent. The original ore assayed 2.80 per cent copper. The test showed the round table to be almost worthless as a machine to follow Wilfley tables. If these tables had been followed by a Wilfley slime table as in the other tests the extraction would probably have been higher.

"It was also found that the gold and silver values concentrate with the copper."

The mill at the Seaboard mine, which was built and operated by Mr. Tucker after he had completed the experimental work on the ores, was, so far as can be determined, very successful, but did not make as high a saving as was made in the experimental runs. The flow sheet on page 100 shows the equipment of this mill.

CONCENTRATION BY FLOTATION.

While flotation has not been tried on the Virgilina ores, it has been practised with such great success throughout the world upon many ores far more difficult to treat than these that there is absolutely no doubt that, if given a fair trial, it will prove to be as successful here as elsewhere. In fact from the writer's knowledge of the subject he is certain that it is the most promising of all available methods of concentrating the Virgilina ores. Its advantages over other methods of concentration for these ores are so evident that it really seems unnecessary to discuss them except in a general way. The most patent advantage is in the handling of slimes. The worst feature of all other methods of concentration is the difficulty of saving the slimes. The condition of the ore is such that in order to free the values from the gangue, it is necessary to crush it very finely and this can not be done without making a large amount of slimes. Because of this it is necessary in considering any method of concentration to include a method of treating the slimes. Flotation thus far is the only really successful method known of treating such material.

Another very important fact in regard to flotation is the flexibility of the process. It can be used alone or in combination with table concentration with equal facility. Thus, if it is desired to use ordinary gravity concentration for everything except slimes and to treat them by flotation, it can be done easily and economically. A flotation machine large enough to treat the slimes from a 50-ton mill will cost but little more than a slime table for the same purpose, and it will not require a great deal more operating power. It is also just as practicable and certainly more economical to arrange to do all the concentration by flotation as by ordinary methods, or by a combination of the two.

Finally the item of cost of installation and operation of a suitable concentrating plant is believed to be greatly in favor of flotation. The greatest expense is that of crushing machinery, and this has to be met in either case regardless of the method of concentration used.

It is not the intention of the writer to go into the question of flotation in detail. In fact, such a discussion would be out of place in a geological report. All he desires to do is to call the attention of the operator in the district to the importance of the subject and to suggest that it be given careful consideration.

SMELTING ORE IN THE DISTRICT.

The last of the three ways of treating the ores, smelting or extracting the metals from them in the district, is considered the least feasible of all. There are many reasons for this conclusion, among which may be mentioned the following: There is not only no readily accessible fuel supply but no supply of material suitable for flux. It would, in all probability, be less expensive to ship the ore or concentrates to a smelter than to pay transportation charges on fuel, material for flux, and general supplies. It does not appear probable that the district will ever produce large quantities of ore—probably not enough to supply a large metallurgical plant. Small copper smelters are usually not very satisfactory and they generally are more expensive to operate than large plants in proportion to the amount of metal produced.

It is realized that there is a possibility of treating these ores by hydrometallurgical processes, and that such processes might eliminate certain of the obstacles in the way of smelting operations.

It is even true that a process for extracting the copper from the ore by acid leaching and recovering it by electrolytic precipitation was installed and operated a short time in 1907 at the High Hill mine. The process and results were kept secret, but it is well known that from a commercial standpoint the plant was a failure. The process so far as it could be learned consisted in giving the crushed ore a sulphating roast in a specially constructed reverberatory furnace, leaching the roasted ore with dilute sulphuric acid, and finally precipitating the copper electrolytically.

In considering any method of treating as well as mining the Virgilina ores the prime factor must be to keep expenses down to the minimum. The two methods just considered are of necessity expensive and on this account, if for no other reasons, are not considered feasible.

The first two ways mentioned of utilizing the ores, shipping the hand-picked ores to smelter or of milling the run-of-mine ore, less such waste as can be easily eliminated from a picking belt, are both considered feasible, and it is recommended that they be given careful consideration by any one contemplating operations in the Virgilina district.

SUMMARY.

Of the three methods of handling the Virgilina ores that have just been discussed, namely, shipping the hand-picked ore, concentrating the ore and shipping the concentrates, and reducing the ore to metal in the

district, the second one appears to the writer to be the most feasible. This is also the conclusion reached by most of the men who have at different times operated mines in the district, as well as it is the opinion of the best mining engineers who have written commercial reports on the district. Unless straight flotation be adopted a fairly complicated equipment will be required in the treatment of these ores, and in order to secure the greatest efficiency it will be necessary to handle as large quantities of ore as possible. A large mill will, therefore, be necessary. Taking into account the small size of the individual deposits, it appears that it would be little short of actual folly for each individual mine to erect a concentrating plant. The cost of erecting and operating the mill would be almost, if not quite, prohibitive. The writer believes that the most satisfactory as well as the most economical plan would be some scheme of coöperation between the different operators in the district whereby there could be erected a centrally located mill large enough to handle all the milling ores from all the mines. Such a mill could be located on Aaron's Creek near the railroad. Each mine could install and operate a picking belt so that it would be necessary to haul only the concentrating ore to the mill.

As regards transportation it seems probable since motor trucks have been developed to such a high degree of efficiency that they could be satisfactorily employed for the purpose.

It seems desirable before discontinuing this subject to quote a summarized statement of the recommendations given by Mr. H. A. Keller in a commercial report on the district a few years ago. This was written before flotation had been developed to such a high degree of efficiency, but it is still worthy of the most careful consideration by any one contemplating mining in the Virgilina district.

"(1) The ore should be crushed at the shaft and the high-grade smelting ore saved and the waste eliminated from a picking belt before the ore goes to the mill.

"(2) The ore should be jigged as coarse as possible in order to avoid crushing or pulverizing the small bunches of pure minerals—thereby avoiding as much slime loss as possible.

"(3) The jig tailings must be recrushed and concentrated further.

"(4) Some satisfactory treatment must be provided for slimes."

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GEOLOGIC MAP
OF THE
VIRGILINA DISTRICT
OF
VIRGINIA AND NORTH CAROLINA

TRAVERSE BY
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GEOLOGY BY
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JOEL H. WATKINS

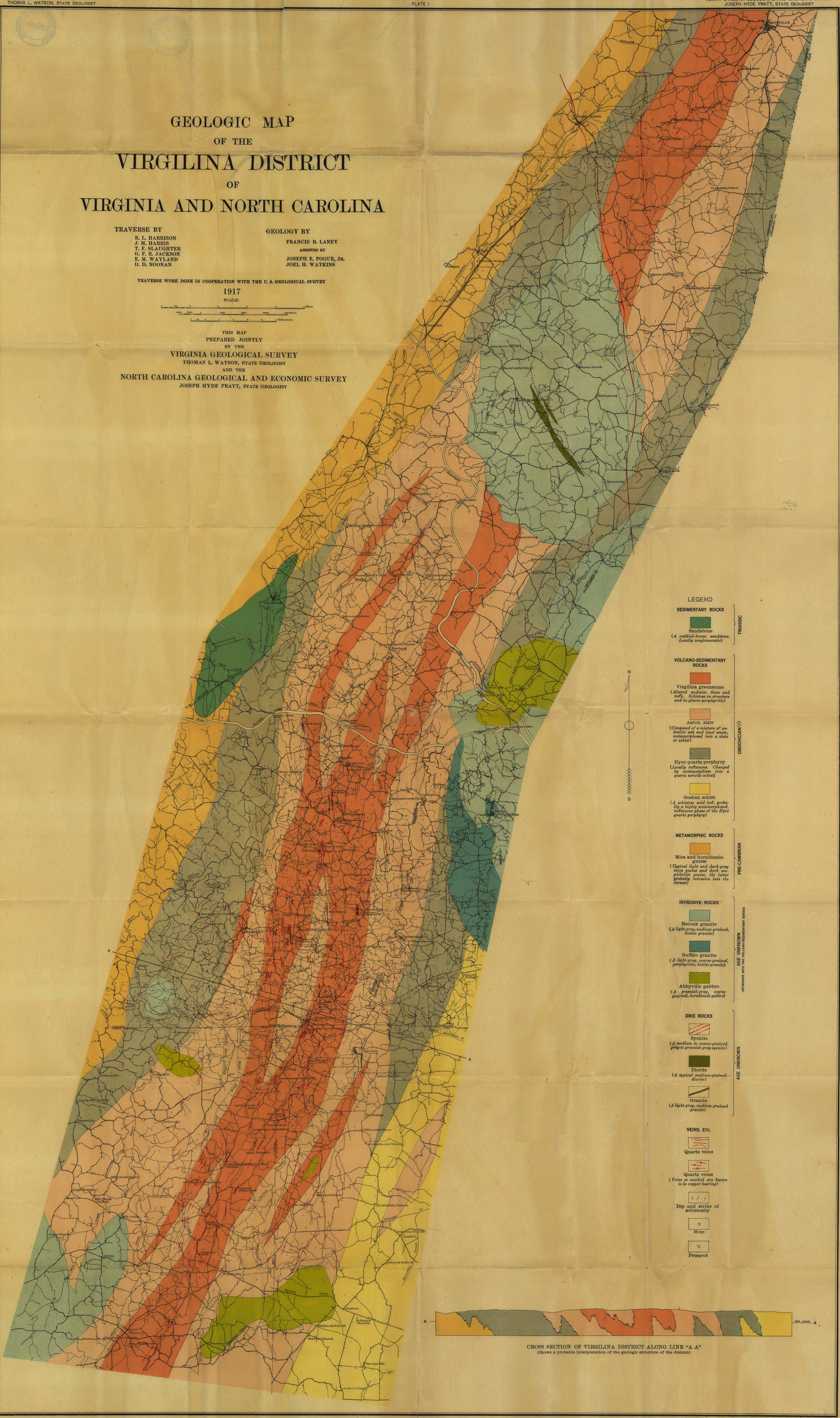
TRAVERSE WORK DONE IN COOPERATION WITH THE U. S. GEOLOGICAL SURVEY

1917

SCALE:

1 ½ 0 1 2 3 4 Miles
6000 2000 0 6000 8000 12000 18000 Feet
1 ½ 0 1 2 3 4 5 Kilometers

THIS MAP
PREPARED JOINTLY
BY THE
VIRGINIA GEOLOGICAL SURVEY
THOMAS L. WATSON, STATE GEOLOGIST
AND THE
NORTH CAROLINA GEOLOGICAL AND ECONOMIC SURVEY
JOSEPH HYDE PRATT, STATE GEOLOGIST



CROSS SECTION OF VIRGILINA DISTRICT ALONG LINE "A A"
(Shows a probable interpretation of the geologic structure of the district)