THE RELATION OF BORNITE AND CHALCOCITE IN THE COPPER ORES OF THE VIRGILINA DISTRICT OF NORTH CAROLINA AND VIRGINIA.

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INTRODUCTION.

The copper ores of the Virgilina district consist almost wholly of bornite and chalcocite. The level of ground water is from 50 to 75 feet below the surface, and the zone of secondary alterations does not appear to extend below 250 feet. The important mines of the district are from 350 to 500 feet deep, and the ore from the deepest levels contains almost as much chalcocite as bornite. If a specimen from the upper levels of almost any of these mines be examined in detail it will be found to consist of the two minerals in such relations that no hesitancy is felt in pronouncing much of the chalcocite secondary and more recent than the bornite. If, however, a specimen be taken from the deeper levels the two minerals are seen to be so intricately intergrown that no other conclusion than that they are genetically contemporaneous seems possible. These facts have led some observers, notably L. C. Graton,[1] to suppose that chalcocite occurs in these mines as a primary mineral. Chalcocite has been almost universally regarded as a mineral of secondary origin, i. e., derived from some leaner copper-bearing sulphide. Its manner of occurrence as heretofore observed left little doubt as to its secondary nature, and there grew up a belief that the mineral is always secondary. The chalcocite of the Virgilina district therefore appeared to offer an exception to the generally accepted conclusion, and with the hope of throwing some light upon the genesis of this mineral, an extended microscopical examination of these ores was undertaken.

The field work upon which this investigation is based was done while the writer was employed by the Geological Surveys of North Carolina and Virginia, and a detailed report on the geology of the district is now being prepared. The U. S. National Museum fur-

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[1] U. S. Geol. Survey, Min. Res. 1907, Pt. 1, p. 620.

nished a metallographic microscope and equipped it with an improved lighting device especially for this work, and the photomicrographs illustrating the paper were made in the photographic laboratory of the Museum by Thomas W. Smillie.

The specimens herein described are the property of the U. S. National Museum.

GEOGRAPHY AND GEOLOGY.

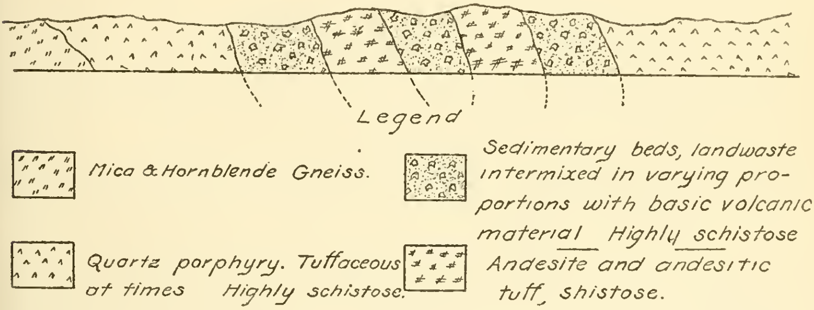
Before entering upon a description of the ores a brief sketch of the geology of the district will be given.

Location.—The Virgilina copper district is located near the eastern border of the Piedmont Plateau in Person and Granville counties, North Carolina, and Halifax and Charlotte counties, Virginia, each State including approximately one-half of the ore-bearing area. It takes its name from the village of Virgilina, a station on the Southern Railway situated on the State line near the center of the district, and about 160 miles west of Norfolk and 45 miles east of Danville. The most important ore deposits occur on two approximately parallel flat-topped, though somewhat conspicuous, ridges which trend from 15 to 20° east of north, and which have very gradual slopes. The maximum elevation is at Virgilina, 540 feet above sea level. The relief is not pronounced, varying from about 300 feet up to the maximum above stated, but the country is decidedly hilly. Rainfall is rather heavy, especially during the winter and spring, and streams are numerous.

Geology.—The rocks of the district are highly schistose, and are popularly known as slates. They are of two distinct types—greenstone schists, and quartzose sericitic schists or gneisses. Into these schistose rocks have been intruded large masses of granite, and less important bodies of more basic material, probably gabbro. Also here and there throughout the area occur small diabase dikes. The intrusive rocks are not schistose, but are closely jointed.

A close examination of these schists reveals their character—a great series of volcano-sedimentary rocks of two types—a basic rock, andesite, and one highly acid in character, a quartz porphyry. Of the andesite there are three types—porphyritic, amygdaloidal, and tuffaceous, and of the quartz porphyry only two—porphyritic and tuffaceous. Closely associated with the greenstone schists and grading directly into them, are heavy beds of highly schistose greenish rocks differing from the tuffaceous portions of the andesite only in that they contain varying amounts of land waste intermixed with the basic volcanic material. These range from fairly well-marked sandstone and fine conglomerate on the one hand to typical andesitic tuffs entirely free from terrigenous material on the other. The relative position of these two phases of the greenstone indicates that at the beginning of the volcanic activity there was a period when the volcanic material was not equal to the land waste, and thus were deposited beds of sandstone and conglomerate with only a small amount of volcanic ash. As the activity increased, the amount of land material grew proportionately less and less, until at the time of maximum vulcanism it became nothing, and the normal volcanic beds were formed. As this activity began to diminish, the former conditions began to reassert themselves, and the beds deposited consisted to a greater or less extent of land waste. The following is a somewhat idealized cross-section through the middle of the district at right angles to the schistosity. This section is approximately that exposed along the Southern Railway from a point about ten miles west to about eight miles east of Virgilina.

The andesitic tuff passes by regular gradation into the sandy and conglomerate rock, so that in the field even where exposures are the best it is not possible to draw a sharp boundary line between the two.



CROSS-SECTION OF VIRGILINA DISTRICT AT RIGHT ANGLES TO THE STRIKE OF THE SCHISTOSITY, APPROXIMATELY ALONG THE SOUTHERN RAILWAY.

It is possible that the sandy beds may have been formed from the rapid erosion of unconsolidated volcanic ash beds as well as by the commingling of similar material with land waste at the time of eruption. Thus in either case it is clear that with an increase of the volcanic material the resulting rock would more nearly approach the true basic tuffs, while with a decrease of this it would approximate more nearly a normal sediment—a conglomerate, sandstone, or shale as the case might be.

The andesite and the andesitic tuff, especially the former, are the most massive of the older rocks of the region. The andesite is of two types, porphyritic and amygdaloidal, both of which are mashed and decidedly schistose. The amygdaloidal phase is not abundant, and is usually so highly metamorphosed that it is easily confused with the tuffaceous phase. All the ore deposits thus far developed, and in fact all the prospects as far as known at present, with a very few exceptions, are located in the andesite or the andesitic tuff.

The quartz porphyry is, for the most part, especially on the western side of the area, a typical rock of its kind, but much mashed and highly schistose. The phenocrysts are largely of feldspar, with a variable and usually an inferior amount of quartz. The basal and the upper, and at times other portions of this rock, are to a greater or less extent tuffaceous. This is especially true of the eastern area, where by far the greater portion is probably a very fine tuff. No workable ore deposits have been found in this rock.

The age of these rocks is not known; they have generally been regarded as pre-Cambrian. They appear to be somewhat similar to tuffaceous rocks intimately associated with the slate deposits lying northeast of the Virgilina district. These slates have recently been described by Watson [1] and Powell and shown to be early Paleozoic. It is believed that further study may determine the volcano-sedimentary rocks of this district to be of the same age.

Granite.—This is the youngest intrusive rock of the region except the diabase dikes, and is also the most important. Three prominent areas of it are included within the district, one in the southwest corner near Mill Creek post office, North Carolina, and another in the east-central portion at and surrounding Buffalo Lithia Springs, and the third and largest one, northwest of Redoak post office, Virginia. This area of granite extends almost across the region of volcano-sedimentary rocks and cuts out the ore-bearing horizon for a distance of 4 or 5 miles. It is apparently massive, and therefore shows nothing of the prominent schistosity of the other rocks. In all the occurrences it is a rather coarsely granular, highly quartzose rock, and in places, especially at Buffalo Lithia Springs, it is decidedly porphyritic. Like all the other granites of the southeastern United States, it contains a large amount of plagioclase in proportion to the orthoclase, and shows well its quartz-monzonitic character. This rock is of especial interest since all the field evidence obtainable points toward the conclusion that it is the source of the ores, and that they and the veins are closely connected genetically with its intrusion. In this relation it is further considered in the paragraphs relating to the origin of the ores.

Structure.—From the cross section above given, what the writer considers a probable structure of the district is readily seen, that of a closely compressed syncline, the axis of which has a strike of from 10 to 30° east of north, and which is inclined so that it has approximately the same dip as the schistosity—from 70 to 80° toward the southeast. It is believed that at the beginning of the formation of the series there was a great outpouring of acid lava—the quartz porphyry upon the mica and hornblende gneiss as a basement. This

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[1] Thos. L. Watson and S. L. Powell. Fossil evidence of the age of the Virginia Piedmont slates. Amer. Journ. Sci., ser. 4, vol. 31, 1911, pp. 33–44.

was followed by a period of quiescence, marking the beginning of the outpouring of the basic lava—the andesite. During this time the regular agencies of erosion were active, and the results were the beds of land-waste intermixed with basic volcanic ash. The vulcanism increased, and there followed the great beds of andesite and andesitic tuff. Finally the activity decreased and a period similar to that at the beginning of the basic activity followed, and during this time the upper beds of sandy tuff were formed. This marked the close of the volcanic activity as far as any record in the rocks goes. Following this the beds were complexly folded, much mashed, and the present schistosity largely developed. This was followed, probably after a long period, by the intrusion, first of the gabbro, later of the granite, and then, as phenomena concomitant with the coming in of the granites, the fracturing of the greenstone schists and the formation of the veins and the development of the ores.

VEINS AND ORES.

Veins.—The veins are composed dominantly of quartz with locally a considerable amount of epidote and calcite. (See pl. 63.) In width they vary from small stringers not more than a few inches up to 15 or 20 feet. They always have well-defined walls and are probably true fissure veins. As is always the case with such veins, these present many irregularities, most prominent of which are the numerous pinches and swells, both horizontally and vertically. In places they are reduced to little more than a mere stringer of quartz between two well-marked walls, while again they may locally swell out to several times their average thickness. In length they range from a few hundred yards to 4 or even 5 miles, and in many instances may be traced these distances by actual outcrop or by abundant quartz débris in the soil. Vertically they are also continuous, and aside from the irregularities in width they are as well defined in the bottom of the deepest shafts as at the surface. The size of the vein and the prominence of the outcrop form no criteria as to the richness of the mineralization. Often the richest ore bodies have been found under a very insignificant outcrop, and as often the strongest exposure at the surface is barren or very lean. The average strike of the veins is more northerly than the schistosity of rocks in which they occur, and while at times they follow the schistosity for short distances their average strike intersects it at acute angles. The fractures in which the veins have formed are therefore regarded as having been made subsequent to the development of the schistosity in the country rock. The ore is not evenly distributed throughout the veins, but is concentrated locally into definite ore shoots. These present the usual irregularities and as a rule appear to have a slight southerly pitch in the vein.

Ores.—Though apparently preferring the quartz, the ore is so intimately associated with all the gangue material as to make it almost certain that all were deposited contemporaneously. (See pl. 64.) The copper-bearing minerals are bornite and chalcocite, with the oxidized products derived from them. Chalcopyrite is present in such small and varying amounts that unless careful search is made it will not be found at all, and it is apparently no more abundant in one portion of a mine than in another. Certainly there is no increase with depth in the amount of this mineral. In fact the mine which shows it most abundantly is only about 150 feet deep, and here it was as abundant in the first sulphides encountered as in those in the bottom of the shaft. In two of the deepest mines—the Holloway, 450 feet in depth, and the Durgy, about 400 feet—it is so rare that one can hardly find it.

Chalcocite occurs in two very distinct relations with the bornite; secondary to and filling fractures in the bornite, and intergrown, sometimes clearly crystallographically, with it. Bornite is the most important mineral in all the mines in the district except the Holloway, in which it is subordinate to chalcocite. It appears, too, from even a casual observation of the ores that there has been considerable shattering since their original deposition. This is especially prominent in the ore from the Seaboard mine, which furnishes the purest bornite in the district. In the fractures in the bornite from this mine, be they ever so minute, are developed veinlets of chalcocite, which penetrate the bornite in all directions, and vary in size from the finest line, often not visible to the unaided eye, but perfectly clear under the microscope (pl. 67, fig. 1), up to areas a quarter of an inch in diameter (see pls. 65 and 66). In the center of many of these chalcocite-filled fractures are films of quartz which evidently mark the original fracture in which the chalcocite began to develop, thus showing that at the beginning of or prior to the development of the chalcocite, there were solutions carrying considerable quartz. In the interior of some of the largest quartz veinlets thus formed there occur particles of chalcocite so related to each other as to indicate a growth of the quartz since the beginning of the deposition of the secondary chalcocite (see pl. 66). Also in a few instances the vein of chalcocite when deeply etched presents a kind of spongy skeleton of quartz appearing as if quartz and chalcocite were deposited simultaneously. The boundary between these veinlets of chalcocite and the bornite is exceedingly irregular, usually presenting a somewhat feathery outline, though always perfectly distinct and clear-cut. There is absolutely no gradation of one into the other. There is certainly a growth of the chalcocite, but how it takes place is not made clear by the microscopic study of the veinlets. It appears, however, that it takes place at the periphery of the material already deposited, but the chemistry of the process has not been worked out. Where fractures of two periods are present, both are often filled with chalcocite, that in the younger fractures cutting across the veinlets in the older ones. Fractures also occur in the intergrown chalcocite and bornite, and in such instances the secondary veinlets cut across both the primary chalcocite and the bornite. The relation of the two minerals to each other in the case in hand leaves no doubt as to the secondary nature of the chalcocite. This type of chalcocite, as far as observations have extended, is confined to the upper portions of the veins and was not found in sections of ore from the deeper mines. It was found, however, in the upper portions of all mines from which sections were examined, and in many instances a single section would show excellent examples of both types of chalcocite. (See pl. 68, fig. 1.)

The other type of ore is entirely different. Both minerals are present in every section examined, sometimes the bornite predominating, and at others the chalcocite. They are intimately associated with each other, but each has its own definite boundaries, cleavage, and other physical properties, with absolutely no indications that one is secondary to or derived from the other. In a number of sections the chalcocite predominated over the bornite, and in such instances the indications seemed to be that the bornite was the first to crystallize. It occurs in irregular areas, sometimes separated and again connected, lying in a larger area of chalcocite. In other instances the two are present in approximately equal amounts, and there is nothing to indicate that one is older than the other. In other occurrences, as in the ore from the Blue Wing mine, the two minerals are present as small areas or grains and in approximately equal proportions. In these sections the appearance is as if a sponge of bornite while growing had been merged with another similar sponge of chalcocite, the association being so intimate and so complex that there is no way of accounting for it except on the basis of contemporaneous deposition (see pl. 67, fig. 2). In the case of the sections in which the bornite appears to have been formed earlier than the chalcocite, it seems as though when the ores were being deposited, the solutions were first saturated, as it were, for bornite, and this mineral began to crystallize out, the iron possibly being the determining factor. This continued until by a reduction of the bornite molecules in the solution, the eutectic point for both bornite and chalcocite was reached, and these two minerals crystallized out simultaneously, and in many places solidified as crystallographic intergrowths. The chalcocite is rather coarsely crystalline, and the etch figures show that the larger areas are made up of numerous interlocking grains, which stand out distinctly and have no definite crystallographic relation to each other. The cleavage, as brought out by the etching, is apparently in two directions at right angles to each other, one more prominent than the other, one possibly prismatic and the other basal.

The crystallographic intergrowths are the most interesting and also the most conclusive as to the contemporaneous deposition of the two minerals. These are by no means rare, having been found more or less perfectly developed in ore from all the mines except the Seaboard. At a magnification of 40 diameters these areas resemble very closely the intergrowths of quartz and feldspar in a micropegmatite. At the highest magnification used, 220 diameters, this resemblance is even more pronounced. In these intergrowths the minerals present perfectly sharp and clear-cut boundaries, with absolutely no indication of gradation of one into the other—boundaries just as sharp as between any minerals in an igneous rock (see pl. 68). When an area of such intergrowth was etched deeply enough to bring out the two cleavages distinctly (pl. 69, fig. 1) the chalcocite proved to be a single grain or crystal, the cleavage lines of which could be seen extending 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 proof that the minerals crystallized at the eutectic point of a solution, and it is, therefore, conclusive evidence that in the case in hand bornite and chalcocite were deposited contemporaneously.

It is realized that while these minerals are contemporaneous, they both may be secondary after some leaner copper mineral. There are certain reasons for suspecting such conditions, the most prominent of which is probably the long period of erosion which the region has undergone since the ore deposits were formed. This long erosional interval would afford time for conditions of oxidation and enrichment to penetrate to exceptional depths in the ore bodies. With this idea in mind careful observations were made as to the depth of the zone of alteration as far as the same could be determined, and the conclusion is that it rarely if ever extends below 175 or 200 feet, the impermeability of the veins limiting the downward circulation. They and their walls are all exceedingly dense and impervious to water, and the mines all furnish a surprisingly small amount of water, of which by far the greater part comes from the upper 100 feet of the vein. As an example of the tightness of the vein, it may be mentioned that when the Blue Wing mine was unwatered about two years ago, it was found that the air pressure had held the water out of an upraise which had been started from the 266 feet level. The vein rocks were so tight that the air could not escape even though it was under a pressure of about eight atmospheres. Under such conditions as these, circulation of meteoric waters must necessarily be at a minimum. This tightness of the vein is characteristic of practically all the ore deposits of the Piedmont and Southern Appalachian regions.

The relations of ore to the gangue, and of the gangue minerals to each other are strong evidence against the assumption that the two sulphides are secondary minerals. It has been stated before that the ore is so complexly and intricately associated with the gangue minerals that no other conclusion than that of contemporaneous deposition seems tenable. If chalcocite and bornite of the intergrown type are secondary minerals, the whole vein, gangue and all, is secondary.

The minerals of the deposits, both gangue and ores, as a group, with the possible exception of the chalcocite, if they can be said to be characteristic of any one portion of a mineral vein, would probably be typical of the deeper vein zone.[1] These are, so far as has been determined, quartz, calcite, epidote, chlorite, specularite, bornite, chalcocite, a very little chalcopyrite, albite, and orthoclase. It must be stated that feldspar of any kind in direct association with the sulphides is rare, but good examples were found at the Seaboard mine, where the feldspar is a plagioclase, probably albite; at the Holloway mine, where both plagioclase and a pink feldspar, which is apparently orthoclase, occur; and at the Copper King mine, where the feldspar is albite. Feldspars, however, are very abundant in many of the veins, especially in lean or barren portions. In such occurrences the mineral is generally albite or an acid oligoclase. In certain portions of the veins at the gold mine near Redbank, Virginia, and Holloway mine in North Carolina, pink feldspar occurs in association with quartz so as to strikingly resemble a pegmatite. This is generally not closely associated with the ore, but at times, especially in the Holloway mine, it carries a small amount of the sulphides. It usually is found in barren portions of the vein or as stringers running off from the vein into the country rock.

Origin of the ores.—The origin of these ores is a more difficult question than one might at first suspect, and is as important as difficult. The country rock is by far too basic to have afforded the vast amount of quartz in the veins. Neither can the underlying quartz porphyry be looked to as the source, since this rock is also older than the veins and is itself cut by numerous quartz veins similar in all respects to those in the andesite and the andesitic tuff, except that they contain but little or no calcite and epidote and probably no copper ores. Some source, therefore, outside of and much younger than the country rocks must be looked for. The only rock in the region which apparently meets the conditions is the granite. This granite is highly quartzose, younger than the rocks in which the ore deposits occur, was not in-

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[1] Waldemar Lindgren, Relation of ore deposition to physical conditions, Economic Geology, vol. 2, 1907, pp. 105–127.

W. H. Emmons, A genetic classification of minerals, Economic Geology, vol. 3, 1908, pp. 611–627.

truded until after a strong schistosity had been imposed upon the andesitic rocks, and is a type of magma the intrusion of which is frequently attended by more or less mineralization in the intruded or adjacent rocks. It is also well able to furnish the acidic material of the veins, and in its effects upon the intruded rocks, through hydrothermal metamorphism, could very well have been responsible for the development of the calcite, epidote, and probably the chlorite. In fact, it appears to be the only rock in the region that could have furnished the feldspars of the veins or have been responsible for the pegmatite-like character of certain portions of some of the veins. It is, therefore, believed that the deformation attendant upon the intrusion of the granite produced the fractures in which the veins now are, and that the filling of these, both gangue and ores, was supplied by the granitic magma, and that it came in as a phenomenon attendant upon or immediately following the intrusion.

As to the conditions of the deposition, there is little or no positive evidence. Since the ore deposits are confined to the more basic facies of the schists, it may be surmised that the basic character of the rock was a factor of prime importance in the deposition of the ores.

SUMMARY AND CONCLUSIONS.

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 vein, younger 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, clear 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 mineral, by processes of secondary alteration.

EXPLANATION OF PLATES.

PLATE 63.

Fig. 1. Typical vein. Exposed in railroad cut near Christie, Virginia. The irregularities here shown are exhibited by nearly every vein that has been opened in the district.

2. Outcropping of a large but barren quartz vein near High Hill Mine. Few of the vein outcrops are as pronounced as this one.

PLATE 64.

Fig. 1. Photograph of a specimen from the Wall mine showing relation of ore and quartz. The vein was "split" at the point where this specimen was taken and the piece here figured represents the entire width of one portion of the vein.

Dark areas=ore.
White areas=quartz.

2. Tracing made from a polished surface of a specimen from the Wall mine showing the relation of the ore to the quartz. Natural size.

Black=ore, chalcocite, and bornite.
White=quartz.

The relationship here shown is typical of all the mines in the district. The ore and gangue appear to be contemporaneous.

PLATE 65.

Secondary chalcocite in bornite. × 10. Seaboard mine. This photograph shows a mass of bornite penetrated in all directions by a mesh or network of chalcocite which has formed in minute fractures in the bornite. This is typical of all the secondary chalcocite studied, the only difference being the stage of development. This one is farther advanced than any of the others shown. The white line in the center of many of the chalcocite veinlets is quartz. Running diagonally across the specimen is a recent fracture which cuts bornite and the older veins of chalcocite. In this chalcocite is also seen to be developing.

PLATE 66.

Fig. 1. Secondary chalcocite in bornite. × 40. Seaboard mine. Similar in all respects to section shown in Plate 67, fig. 1, only the development of chalcocite is farther advanced. The same feathery line of contact between the two minerals is evident. In the center of the chalcocite areas are seen films of quartz which apparently mark the original fracture in which the chalcocite developed.

2. Secondary chalcocite in bornite. × 40. Seaboard mine. Similar to fig. 1, but shows more clearly the relation of the chalcocite to the bornite. In one of the fractures in the bornite there is seen a stringer of quartz, the dark area running vertically through the section. On each side of the quartz, between it and the bornite, there is a considerable development of chalcocite.

PLATE 67.

Fig. 1. Secondary chalcocite in bornite. × 40. Seaboard mine.

Irregular lines=chalcocite.
Other portion of section=bornite.

This figure shows an incipient stage of the development of secondary chalcocite in minute fractures in bornite. The little lines of chalcocite are well defined, but present an irregular or "feathery" line of contact with the bornite.

Fig. 2. Intergrowth of bornite and chalcocite. × 40. 266 feet level, Blue Wing mine.
Dark areas=bornite.
Lighter areas=chalcocite.

There does not appear to be any marked crystallographic relationship between the two minerals in this section as in those shown in Plate 68. The appearance is that of a spongy mass of bornite merged and intergrown with another similar mass of chalcocite.

Plate 68.

Fig. 1. Intergrowth of bornite and chalcocite. × 40. Wall mine.
Dark areas=bornite.
Lighter areas=chalcocite.

A typical example of crystallographic intergrowth of bornite and chalcocite. Such intergrowths are believed to form only at the eutectic point of a solution and are strong evidence that the two minerals were deposited contemporaneously.

2. Crystallographic intergrowth of bornite and chalcocite. × 220. Wall mine.
Dark areas=bornite.
Lighter areas=chalcocite.

This is an area of the finely intergrown portion of the section shown in fig. 1, highly magnified, and shows that the relationship of the two minerals is a typical crystallographic intergrowth.

Plate 69.

Fig. 1. Intergrowth of bornite and chalcocite. × 220. Wall mine.
Stippled areas=bornite.
White areas=chalcocite.

This is a deeply etched section of the two minerals and shows clearly by the etch figure, the lines at right angles to each other in the chalcocite, that the portion of this mineral here seen is a part of a single individual crystal, and also brings out the crystallographic relations of these two minerals.

2. Intergrowth of bornite and chalcocite. × 40. High Hill mine.
Stippled areas=bornite.
White areas=chalcocite.

The peculiar lines in the chalcocite areas are the etch figures and show the coarsely granular condition of this mineral.

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Typical Veins of the Virgilina District.

For explanation of plate see page 523.

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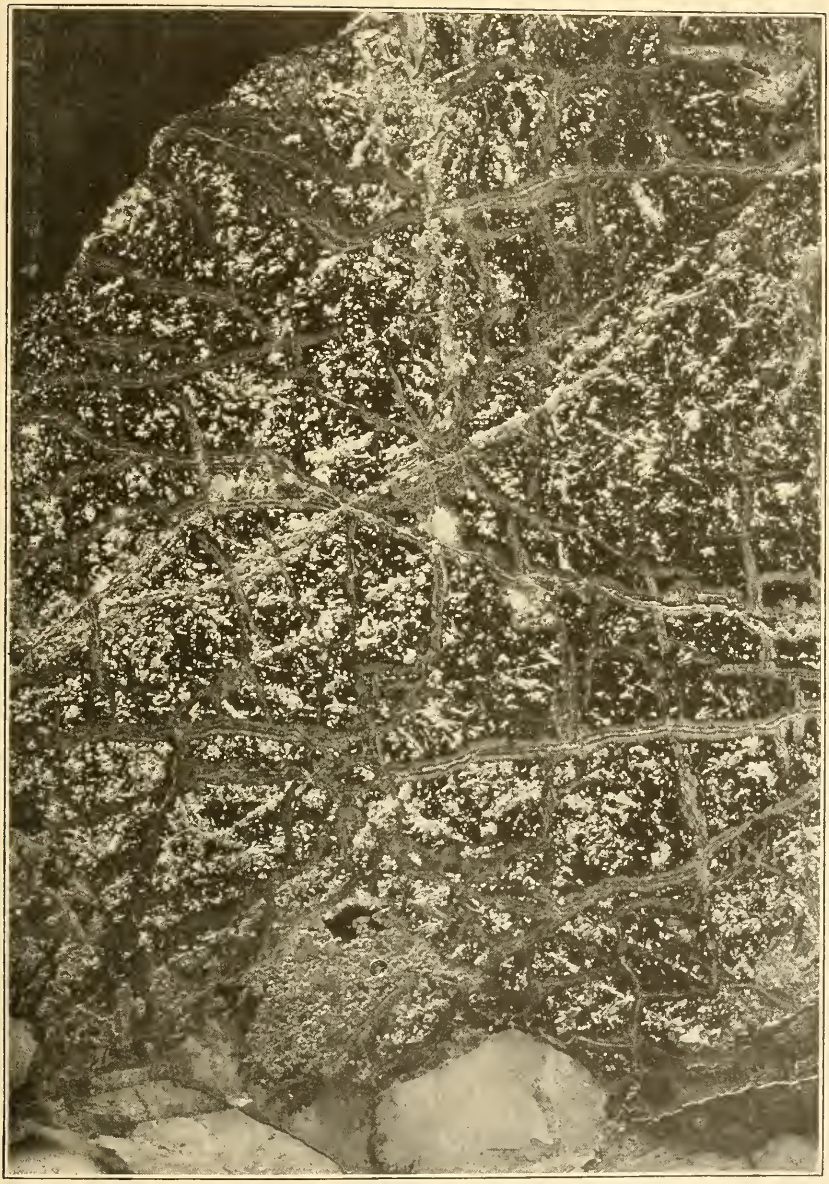
Ore in Quartz, Wall Mine.

For explanation of plate see page 523.



Secondary Chalcocite in Bornite Seaboard Mine.

For explanation of plate see page 523.

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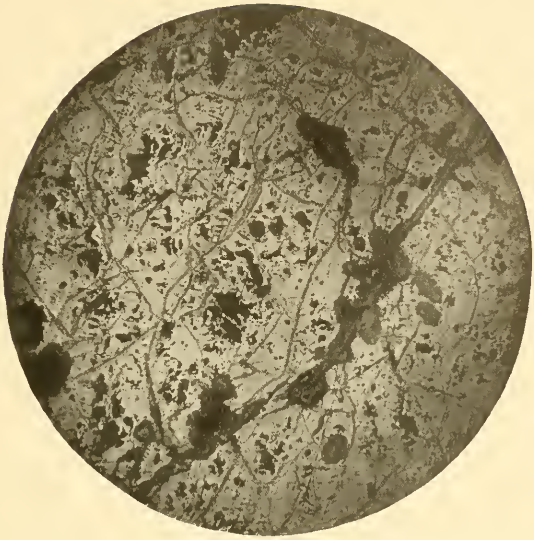
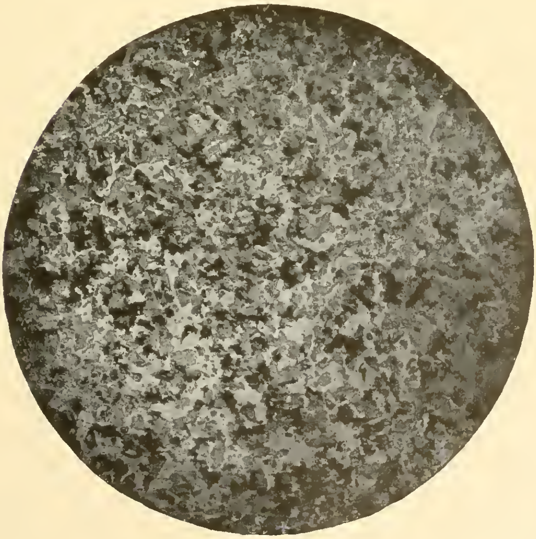
SECONDARY CHALCOCITE IN BORNITE, SEABOARD MINE

FOR EXPLANATION OF PLATE SEE PAGE 523.



SECONDARY CHALCOCITE AND BORNITE, SEABOARD MINE.



INTERGROWTH OF BORNITE AND CHALCOCITE, BLUE WING MINE.

FOR EXPLANATION OF PLATE SEE PAGES 523 AND 524.

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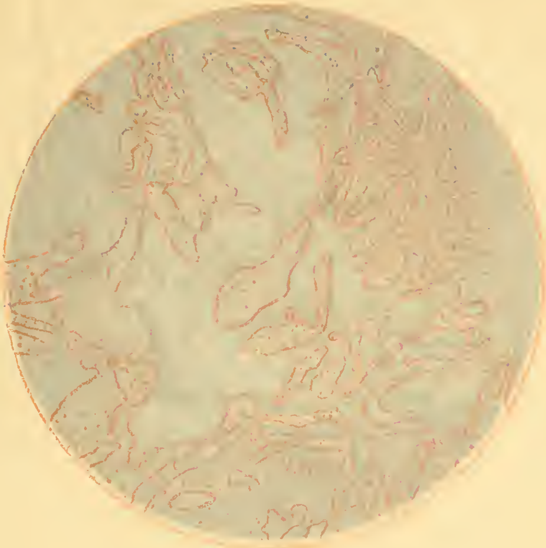
Crystallographic Intergrowth of Bornite and Chalcocite, Wall Mine.

For explanation of plate see page 524.



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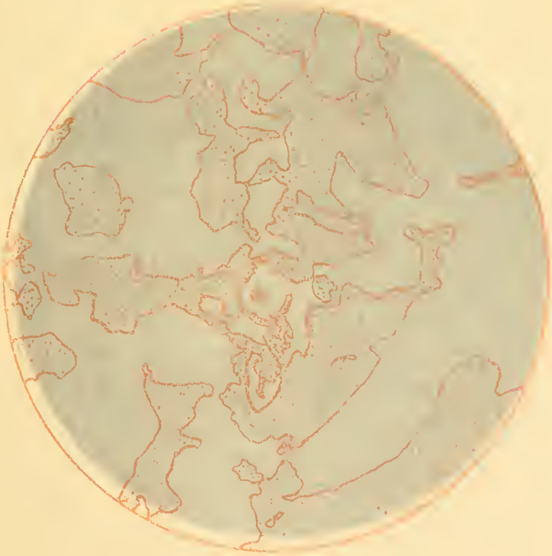

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[illegible]

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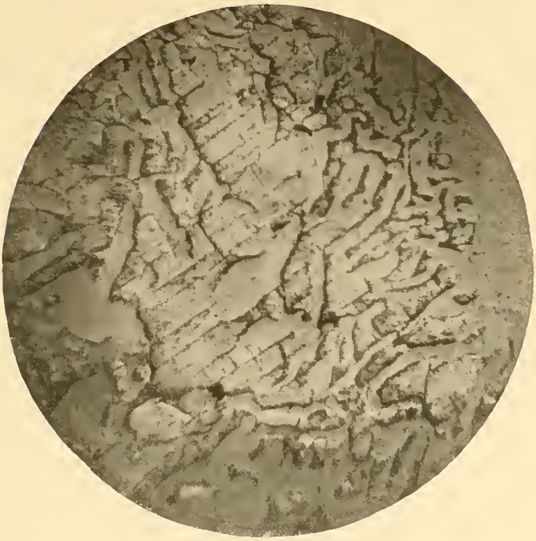
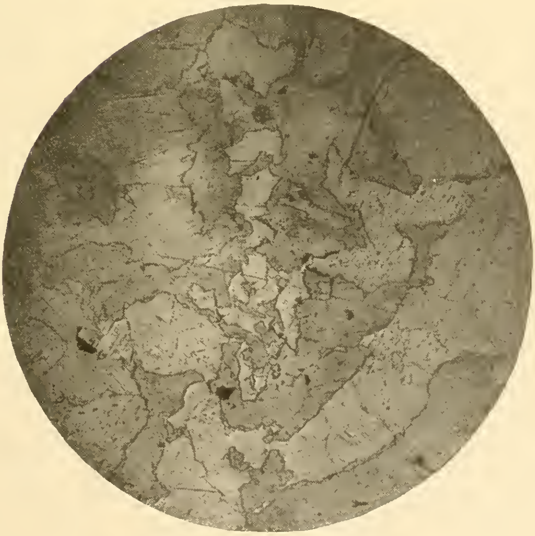


1



2

INTERGROWTH OF BORNITE AND CHALCOCITE.

FOR EXPLANATION OF PLATE SEE PAGE 524.