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PRELIMINARY REPORT
GEOLOGY OF THE ORANGE COUNTY COPPER DISTRICT, VERMONT

By W. S. White, and J. H. Eric

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PRELIMINARY REPORT
GEOLOGY OF THE ORANGE COUNTY COPPER DISTRICT, VERMONT

By W. S. White and J. H. Eric

ABSTRACT

The Orange County copper district in east-central Vermont includes an area about 20 miles long and 5 miles wide, elongate north-south. It contains three important mines, the Elizabeth, Ely, and Eureka-Union. The district yielded important amounts of copper before 1882, mostly from the Ely mine, but has since been only a small and intermittent producer. Total production is estimated to be between 50 and 60 million pounds of copper.

The district contains highly deformed stratified rocks of Ordovician or Devonian age. The western part is underlain by a series of calcareous schists known as the Waits River formation, and the eastern part contains dominantly quartz-mica schist. Needle amphibolite, probably of volcanic origin, and coarse garnet schist beds are locally important stratigraphic markers. All the rocks are highly metamorphosed.

The bedding is intensely folded on a large and small scale, and a well-developed cleavage lies essentially parallel to the axial planes of major and minor folds. The folds generally plunge less than 30° N-N.E.

The cleavage itself is deformed on a large and small scale. The copper district lies on the east flank of a broad cleavage arch whose axis lies parallel to and a few miles west of the district. Minor flexures or "rolls" in the cleavage are common in the central part of the district, and the Ely ore shoot lies within and plunges parallel to the axis of one such "roll." Faults that cut and deform cleavage as well as bedding also contain sulfide deposits.

The ore is a mixture of pyrrhotite with subordinate chalcopyrite and sphalerite. The average copper content of ore at the different mines ranges from 2 to over 3 percent. Principal gangue minerals are quartz, feldspar, mica, hornblende, and carbonate; these minerals represent, for the most part, unreplaced constituents of the country rock.

The ore bodies are lenticular and generally lie parallel to the cleavage of the wall rocks. The Elizabeth mine workings are confined to a single large body, but the other two large deposits are composed of several small bodies that overlap like shingles on a roof. The two largest ore deposits, Elizabeth and Ely, are definitely elongate shoots, and their elongation is closely parallel to the plunge of minor

folds in their vicinity. It is suggested that the Eureka-Union deposits may be connected to a similar shoot at moderate depth, and this possibility could readily be tested by drilling.

Geologic factors that should be considered in connection with geophysical prospecting are discussed, and a number of favorable areas for geophysical prospecting are described.

Detailed descriptions of individual mines and prospects, excluding the Elizabeth mine, which has been described in an earlier report, follow the general discussion.

INTRODUCTION

The Orange County copper district in east-central Vermont contains three important mines, the Elizabeth, Ely, and Eureka-Union (Pike Hill), and a number of small deposits and prospects. The location of the district and mines is shown in figure 1.

Members of the Geological Survey, United States Department of the Interior, studied the district in 1942 and 1943 as a part of the Survey's program of providing geologic information that will aid in developing known deposits of strategic minerals and in the search for new deposits. The mines were examined in detail and a geologic map of the district (pl. 1) was prepared. The senior author was ably assisted in all phases of the field work by J. H. Eric, I. G. Sohn, and T. W. Amsden. G. H. Espenshade of the Geological Survey contributed much helpful guidance as well as material assistance for five weeks at the beginning of the project.

The Bureau of Mines, United States Department of the Interior, conducted drilling programs at the three important mines, partly in cooperation with the Geological Survey. The project engineers in charge of this exploration were H. P. Hermance and J. E. Bell. Mr. Hermance, in particular, has been most helpful in many problems involving cooperative effort.

G. R. MacCarthy of the Bureau of Mines began resistivity and self-potential investigations in the district in June, 1943, and some of the results of this work are used in a discussion of the search for new deposits in the district by geophysical methods.

Mine maps and other information supplied and many gracious courtesies extended by Mr. H. M. Kingsbury and Mr. J. A. Norden of the Vermont Copper Co., Inc., are gratefully acknowledged.

GEOGRAPHY

The copper district lies in a country of rolling hills with an average relief of 500 feet and a maximum relief of 1,800 feet.

Two-thirds of the region is wooded and the remainder is open farmland.

Most places are within a mile of travelled roads; very few of the roads are paved. All parts of the district are within 9 airline miles of the Boston and Maine railroad.

Water in brooks and streams can generally be found within a mile of all points, but electrical power for mining operations would, in general, have to be obtained by extending existing lines for as much as 8 miles.

Housing in the region presents serious problems where more than a few individuals are concerned.

Many trees blown down during the hurricane of 1938 will, in places, reduce the efficiency of most types of exploration by factors greater than 50 percent.

GEOLOGY

Lithology

The rocks of the region are highly deformed and metamorphosed sediments of Ordovician or Devonian age. The eastern part of the district is underlain by more or less quartsose mica schists, and the western and northern parts contain calcareous schists. The boundary between these formations (fig. 2 and pl. 1) may be traced for many tens of miles in a course roughly parallel to the Connecticut River.

The calcareous rocks belong to the Waits River formation, and include calcareous quartzite, calcareous mica schist, and thinly interlaminated mica schist and quartz-mica schist. The average carbonate content of the formation as a whole is 35 percent or less. The rocks are interbedded with one another in all proportions and the thickness of individual beds ranges from a fraction of an inch to at least 20 feet. Non-calcareous members several hundred feet in thickness are distinguished in plate 1. The thickness of the formation must be many thousands of feet.

Gile Mtn fm

The non-calcareous schists, referred to in this report as the "schist formation," apparently overlie the Waits River formation. The rocks of this formation are dominantly quartz-mica schist, with subordinate mica schist, kyanite-mica schist, and micaceous quartzite. There are several calcareous members that contain rocks identical with those of the Waits River formation.

Banded needle amphibolite, probably of volcanic origin, forms at least one thick well-defined stratigraphic unit in the district. This member lies close to the boundary of the two formations described above, and its outcrop is shown in plate 1. Other thin layers of amphibolite, some of which may be intrusive, are locally common but not abundant throughout the schist formation; a few are found in the Waits River formation.

Exceptionally coarse garnet schist is closely associated with some of the amphibolites of the district. The garnets in this rock have an average diameter of 1 inch and a maximum diameter of about 2 inches. Beds up to 50 feet in thickness lie between the large amphibolite member mentioned above and the adjacent schists. Other garnet beds, some of which are associated with small layers of amphibolite, are shown in plate 1.

Except for outcrops of pegmatite mapped west of Pike Hill (pl. 1) and a few coarse amphibolites that are believed to be of igneous origin, no intrusive rocks were found in the district. A large area north of the district is underlain by granitoid rocks that were intruded after the major deformation of the stratified rocks.

Small pods, lenses, and veins of quartz make up as much as 12 percent of the more micaceous rocks, and a smaller proportion in the more quartzitic.

Metamorphism

The minerals that now make up the stratified rocks were largely formed from the original sedimentary materials by intense heat during a period of regional metamorphism. This metamorphism was closely related to the intrusion of the granitoid rocks north of the area, and reached a stage of maximum intensity after the major deformation. The ore deposits were probably formed at a late stage in the metamorphism, and the gangue minerals of the sulfide deposits are identical with the metamorphic minerals of the surrounding rocks.

Structure

Major structural features

The rocks of the district are highly folded and locally faulted, and the stratified rocks all have a well-defined cleavage.

The bedding is closely folded on a large and small scale. The larger folds are shown by the regional outcrop pattern (pl. 1 and fig. 2) and locally by reverse patterns of the minor folds in the bedding on opposite limbs of the major folds. These minor folds, which range in size from less than an inch to many feet across, can be found in most of the outcrops in those parts of the area characterized by major folds, but are not abundant in the southern and east-central parts of the district. The axial planes of both major and minor folds are roughly parallel to the regional trend of the cleavage (fig. 2). Almost all the folds plunge north to northeast at angles generally less than 30 degrees. A few exceptional folds in the Elizabeth open cut and in the area immediately south of it have horizontal axes or axes plunging gently south.

The cleavage of the rocks, formed by parallel orientation of a majority of the micas, is roughly parallel to the axial planes of folds in the bedding and generally intersects the bedding at a low angle. Where minor folds are few, bedding and cleavage may be essentially parallel.

The attitude of cleavage is relatively uniform within small areas, but on a regional scale appears to form a broad arch whose axis lies a few miles west of the district. Within the district the attitude changes from steep dips and nearly north-south strikes in the southeastern part of the area to gentler dips and northwesterly strikes in the northern and western parts of the area, as brought out in figure 2.

Subordinate structural features

The structural elements that are of most evident importance from an economic standpoint are subordinate to the larger regional features. In this class belong certain minor faults and a group of flexures or rolls in the cleavage.

Faults.—Four faults have been recognized in the area. The vein zone at the Elizabeth mine (shown on pl. 1 by the line of pits and trenches) lies along a reverse fault parallel to cleavage, and a small mineralized reverse fault extends south from the main Ely ore shoot (pl. 2). A fault with north-south strike and unknown dip was mapped in the vicinity of the Cookville mine (pl. 1, fig. 6). The vertical stratigraphic displacement, down on the east side, is apparently about 1,000 feet. The fourth fault lies south-southeast of Gilman Hill (pl. 1). The dip is not known and the displacement is probably only a few hundred feet.

Cleavage rolls.—Local changes in strike of the cleavage, here referred to as "cleavage rolls" to distinguish them from folds in bedding, are characteristic of the vicinity of the Ely mine, where one is of fundamental importance in localization of the Ely ore shoot. In long narrow areas, up to 5 miles in length and half a mile in width, trending N. 25° E., the average strike of the cleavage is 20 to 70 degrees more westerly than the regional strike in the vicinity. These areas are shown, probably in over-simplified form, in plate 1.

The cleavage rolls have been studied in most detail at the Ely mine. In plate 2, which shows the attitude of cleavage in the vicinity of this mine, there are at least three well-defined narrow zones, trending about N. 20° E., in which the strike of cleavage is more westerly than elsewhere. The center line of one such zone lies about 700 feet west of the main shaft entrance, a second one crosses the shaft entrance, and the third lies about 1,200 feet east of the shaft entrance. Each roll may be considered, structurally, as a pair of folds, an anticline east of a syncline, although the amount of curvature is small in comparison with that of the folds in the bedding of the region (see fig. 3). The average plunge of the rolls is 23° N. 30° E. Near the mine there are many small rolls in the cleavage which duplicate on a small scale the major rolls. The observed trend of the zones and the average plunge of the rolls suggests that the axial planes of the rolls dip eastward at angles of about 70 degrees.

The average plunge of the axes of typical minor folds in bedding and of intersections of cleavage and bedding in the vicinity of the Ely mine are similarly oriented. The average of the 55 linear elements plotted in plate 2, including both fold axes and cleavage-bedding intersections, is 23° N. 36° E.

Inasmuch as the cleavage that lies more or less parallel to the axial planes of the folds is itself deformed in the rolls, the rolls are clearly later than and distinct from the folds.

One of the rolls has apparently been of major importance in localizing the Ely ore shoot. The upper workings lie within an area of more westerly strikes, and only small stringers are found outside of this area. The plunge of the shoot, 25° N. 34° E., is almost exactly parallel to the plunge of the roll. Such similarity can scarcely be coincidence, and emphasizes the importance of this roll in forming a favorable environment for ore deposition.

In addition to these large cleavage rolls, drag folding of cleavage on a smaller scale is noteworthy along the faults at the Elizabeth and Ely mines. Such drag folds are likewise quite distinct from the common folds in bedding. Drag folds in the cleavage up to 10 feet across typically lie adjacent to the fault southeast of the main shoot at the Ely mine (fig. 3 and pl. 6). The top of the main ore shoot at the Elizabeth mine abuts against the trough of a large syncline in the cleavage on the hanging wall. This syncline plunges from 5° to 20° N.NE., and is roughly parallel to the average orientation of minor folds in bedding in the vicinity.

ORE DEPOSITS

History and production

For many years prior to 1882, when the Ely mine closed down after 28 years of continuous operation, Vermont was among the foremost copper-producing states. Ore suitable for smelting was produced at all the mines by hand sorting and heap roasting. About 70 percent of the total copper from the district, mostly from the Ely mine, was obtained in this manner. Only higher grade ores, averaging at least 3 percent copper, were profitably worked, and the mines with lower grade ore were only intermittent producers.

Since 1882 there have been many attempts to concentrate the ore from the Vermont mines with more modern methods, but none has been successful in maintaining anything approaching continuous operation. High mining cost in these relatively small deposits and lack of a market for the byproduct pyrrhotite have been the chief obstacles to cheap production of copper.

The estimated production (and grades) of the mines of the district is summarized in the following table:

Mine	Tons ore mined 1/	Av. grade	Pounds copper
Elizabeth	250,000	2.2	10,500,000 2/
Ely	500,000	3.5	35,000,000 2/
Eureka	60,000	2.5	3,000,000
Union	?	?	5,600,000 2/
Total	900,000 3/		54,100,000 2/

1/ Does not include an estimated 150,000 tons mined for copperas, 1793-1875 or later.
2/ Plus or minus 5,000,000 lbs.
3/ Union production assumed to be 90,000 tons.

The above table does not include a few small shipments of ore that may have been made from the Orange, Gove, South, Cookville, and Smith mines.

Composition of the ores

The ore deposits are bodies of massive and disseminated sulfide that have wholly or partly replaced the typical schists of the region. The principal metallic mineral is pyrrhotite (Fe_nS_{n+1}), which makes up about 50 percent of the ore as mined. Copper, which occurs almost wholly in the mineral chalcopyrite ($CuFeS_2$), is present in proportions that vary from traces at some prospects to over 3 percent in the ore of the Ely mine. There are traces of cubanite ($Cu_2Fe_4S_6$) in the ore. Sphalerite (ZnS) is common at all the deposits, but generally averages less than 1 percent of the ore. A little pyrite exists at all the deposits, and magnetite was found at the Orange and Cookville mines. Magnetic fractions of Elizabeth ore, consisting almost wholly of pyrrhotite, contain about 0.1 percent cobalt, according to spectrographic analyses by K. J. Murata of the Geological Survey. Nickel makes up less than 0.01 percent of the ore. There are traces of gold ahd silver.

The gangue minerals are, in general, simply the unreplaced minerals of the country rock. The amount of introduced gangue material is quantitatively negligible, and except for some added carbonate, tourmaline, and feldspar, the only notable wall rock alteration is a local increase in the grain size of some minerals. The principal gangue minerals are quartz, feldspar, muscovite, biotite, hornblende, and carbonate. Quartz probably makes up an average of 40 percent of the gangue.

There appears to be an orderly sequence of mineral formation in the deposits, beginning with the growth of the minerals of regional metamorphism and ending with the deposition of sulfides. The sulfides are therefore believed to have been deposited in the closing, low temperature stages of the regional metamorphism.

Relation of ore deposits to lithology

Sulfide minerals occur in all the important types of rock found in the district and are not concentrated in any particular stratigraphic horizon nor in any one type of rock. Copper may be more widespread in small amounts in amphibolite than in any other rock, but no ore bodies are known in amphibolite and, at the Elizabeth mine, there are indications that amphibolite may be an unfavorable host rock for large-scale replacement. In general, loci of sulfide deposition and differences between deposits are determined by the structure rather than the composition of the host rocks.

Structure of the ore deposits

Classification of the deposits on a structural basis is somewhat arbitrary, because the deposits have more similarities than differences. In all deposits where the structure is known, the ore is found in those places where maximum permeability probably existed at the time of ore deposition. The deposits are all tabular and made up of groups of irregular veins, stringers, or lenses of massive sulfide, separated by layers of wall rock containing more or less disseminated sulfide. With only minor exceptions, the deposits as a whole and most of the veins or stringers are essentially parallel to the cleavage of the wall rock. There is great variety in the thickness, continuity, and the amount of pinching, swelling, and coalescence of individual stringers. In the largest and best ore bodies, however, such as can be seen now only at the Elizabeth mine, the individual veins or stringers are large, close together, and coalescent, and the wall-rock partitions separating the stringers are thin, irregular, and discontinuous, or occur only as scattered "inclusions" in the massive ore. All gradations are found in the district from these large massive bodies to sparsely mineralized deposits containing several small pod-like stringers scattered through several tens of feet of rock. The margins of ore bodies are generally marked only by a gradual feathering out of sulfide stringers.

At the Ely and Eureka-Union mines, the deposits consist of overlapping lenses that lie one above the other like shingles on a roof (pl. 4 and fig. 4). The dip of the individual lenses is slightly less than the dip or plunge of the ore deposit as a whole. At Ely the individual lenses average about 300 feet long down the plunge, and the lower end of one body overlaps the one below by an average of about 50 feet (see pl. 4). The Elizabeth ore body is essentially a single unit, possibly splitting up at the north end. Recent drilling by the Bureau of Mines, however, indicates the existence of a new parallel shoot, somewhat smaller than the main shoot and down the dip of the fault from it.

Although the ore deposits are so similar that, except for local differences in wall rock and the attitude of ore bodies, a limited exposure in one mine might readily be confused with one from any other, some of the deposits differ structurally in important respects from others. The deposits may be classified, insofar as their structure is known, on the basis of concordance or discordance with the country rock, on the basis of the presence or absence of an important fault in the space now occupied by the ore, and on the basis of the presence or absence of a well defined shoot.

The sulfide ore bodies of the district are essentially parallel to the cleavage of the adjacent wall rocks, with the exception of minor deposits at the Cookville mine and along the fault southeast of the main Ely ore shoot. The sulfides at the Elizabeth and Cookville mines, in the Ely adit, and possibly at the Smith mine lie along fault planes, but no well-defined continuous fault was found along any of the other veins. The two largest ore deposits of the district, Ely and Elizabeth, are well-defined shoots plunging parallel to the important linear elements of the region. The Ely ore shoot occupies a pronounced flexure or roll in the cleavage (fig. 3), and plunges nearly parallel to the plunge of the roll. At the Eureka-Union mine, the mine workings and drill holes suggest the existence of two irregular, partly connected, tabular ore bodies that lie in essentially the same vein zone dipping 35° E., but the elongation of the stoped areas is more nearly down the dip than parallel to the plunge of minor folds. At all the smaller mines and prospects in the area, subsurface data are not available or are inadequate to define the structural relations and outlines of sulfide bodies.

In summary, considering the ore deposits in terms of their relative importance, about 85 percent of the total copper from the district has been produced from the Ely and Elizabeth ore shoots, which lie parallel to the plunge of the local minor folds, and most of the remainder from the Eureka and Union mines, where the ore bodies are less well-defined.

Relation of ore deposits to regional geology

No definite correlation has been established between the distribution of ore deposits and the major structure and disposition of the lithologic units. The deposits are found in all types of rock and have several types of structural control. The ultimate source of the sulfide-bearing solutions probably lies at a considerable depth, and most of the factors contributing to the present distribution of the ore deposits cannot be definitely established. Although it is possible at some places to show why a certain type of structure afforded a favorable environment for ore deposition, it is not possible to determine from surface exposures how or where solutions obtained access to this structure in depth or why an almost identical structural environment in another place has not been mineralized. Nevertheless, a few observations can be made regarding apparent relations between the distribution of known ore bodies and the larger geologic features. These observations are highly speculative because they are based on statistically inadequate data, but they suggest a hypothesis that might be a valuable guide to prospecting.

An arc can be described through the major mines (Pike Hill, Cookville, Ely, Elizabeth) that has a pattern somewhat similar to and sub-parallel to the trace of the important Monroe fault (fig. 2), 5 to 10 miles farther east, and more nearly parallel to the axis of the cleavage arch a few miles to the west. This arc may reflect a deep "basement" structure from which mineralizing solutions emanated.

The contact of the schist formation with the Waits River formation is very irregular and intricately folded where it passes thru the Orange County copper district (see pl. 1 and fig. 2) but is comparatively straight north of the district. The Ely mine, and probably also the Elizabeth and Eureka-Union mines, lie on or close to the axial planes of major folds whose flanks converge toward the southeast, as shown by the outcrop pattern of formation boundaries. It is not known at present whether or not this relationship is coincidental, but the existence of such a relationship suggests that other points where the axial planes of similar major folds intersect the arc described above may have been favorable loci for ore deposition.

Origin of the deposits

The sulfide minerals were deposited at high temperatures, probably from hydrothermal solutions that originated at depth directly or indirectly from the intrusion of igneous rocks such as those exposed north of the district. No direct means are available of determining the depth at which sulfide deposition took place, but any attempt to restore the folded structures of the region above the present surface shows that the surface of the land at the time of deformation must have lain many thousands of feet above this present surface. Evidence that the ore deposits were formed during the last stages of the regional deformation, and thus at considerable depths, is consistent with the high-temperature mineral assemblages and the lack of mineral zoning in the deposits, as well as with the lack of low-temperature wall-rock alteration adjacent to the deposits.

Deposition of the sulfides appears to have been controlled almost entirely by physical environment rather than by the chemical composition of the wall rocks. Places favorable for ore deposition existed along faults or shear zones, as at Elizabeth and in flexures in the cleavage, as at Ely. At these two mines most of the copper was deposited in elongate areas, probably of greater permeability or lower pressure than the surrounding rocks, that are oriented parallel to the regional plunge of fold axes and were probably determined directly or indirectly by the same forces that produced the folds. Where such linear control was lacking, sulfides were deposited irregularly through the rocks, largely along cleavage planes, forming concordant tabular deposits with irregular outlines, as at the Eureka-Union mine.

POSSIBILITIES FOR FUTURE EXPLORATION

Extensions of known deposits

Extensions of known deposits can best be proved by diamond drilling or development workings, aided in some places by geophysical exploration. The Elizabeth vein zone is, perhaps, still the most promising deposit in this respect. The lower end of the main shoot has not yet been found and recent drilling has shown that there is at least one other parallel shoot on the same fault plane. Unexplored ground on the fault at great depth below the mine, at shallow depth north of the mine, and below 300 feet for almost a mile south of the mine may contain other shoots. Furthermore, surface indications of significant mineralization at the old South mine and midway between the South mine and the Elizabeth open-cut have not been adequately tested. On the basis of present knowledge, the large amount of amphibolite and hornblende schist along the vein zone south of and below the Elizabeth mine may be unfavorable for development of large ore bodies in these directions.

The Ely ore shoot is not known to terminate at the bottom of the present workings, but the cost of exploring and developing the probable downward continuation of the shoot would be very high compared to expectable gains. Recent drilling by the Bureau of Mines and examination of exposures in the main adit suggest that there is probably no workable ore body on the fault plane near the surface immediately southeast of the main Ely ore shoot.

The ore bodies at the Eureka and Union mines appear, from past records and recent drilling, to be largely worked out. The only favorable unexplored ground adjacent to the mines lies a few hundred feet northeast of the bottom of the Union mine where a northward-plunging cleavage roll was found by surface geological mapping after drilling was completed. An ore shoot may exist in the anticlinal portion of this cleavage roll, a position analogous to that of the main ore shoot at the Ely mine (see fig. 3). If such a shoot exists, it might represent the main locus of ore deposition, and the deposits now mined out might represent the dissipated upward leakage from this shoot.

The sulfide deposits at all the smaller mines and prospects in the district are too poorly exposed and generally too small or lean to warrant exploration by diamond drilling, and they are therefore considered in connection with the regional search for new deposits by geophysical methods.

New deposits

As a preface to a discussion of the search for new deposits, it should be stated that an ore shoot comparable to that at the Ely mine could exist safe from discovery beneath the glacial drift at all but a negligibly small number of places in the district.

Exploration for new deposits of massive sulfide ore under shallow cover can be attempted most easily by geophysical methods guided by geological information. A program of geophysical exploration in the district was begun by the Geophysical Section, Bureau of Mines, under the direction of G. R. MacCarthy. Test traverses at the Elizabeth mine showed that a magnetometer is not sufficiently influenced by the sulfide ore to give satisfactory results. Self-potential measurements, however, showed a close relation to the known distribution of ore, and resistivity measurements were somewhat less satisfactory.

Some general characteristics of the deposits must be considered in geophysical exploration and particularly in following up geophysical work by drilling.

The ore deposits are tabular, and with a few minor exceptions are parallel to the average strike and dip of cleavage in the adjacent rocks.

The largest ore bodies are definitely elongate, and the direction of plunge is essentially parallel to the axes of the local minor folds. In most of the district, these folds plunge slightly east of north, but in the vicinity of the Ely mine the direction is nearly northeast. The angle of plunge ranges from 5 to 35 degrees.

A large deposit plunging nearly down the dip of the cleavage may have relatively short horizontal dimensions, of the order of 100 to 300 feet, but a deposit plunging nearly parallel to the strike of cleavage may have a strike length of more than 1,000 feet.

Self-potential measurements should be made wherever practicable over known deposits to establish controls for exploratory work. In the absence of control data isopotential patterns over typical ore bodies can only be inferred. Isopotential lines over a truly large ore body should be expected to describe a pattern that is definitely elongate parallel to cleavage or a fault plane. It is possible that most of the current generated by the chemical activity of an ore body may be discharged at one or two points at the top rather than from the whole upper edge, but this is not known to be true of the Orange County deposits; positive evidence is wanting. Some centers of electrical activity in which the maximum potential difference was over 800 millivolts have been explored by drilling at the Dimond property, on a hill 1 mile south of the Ely mine. The isopotential lines surrounding the centers form nearly circular rather than long narrow patterns, and drilling on and near the centers failed to reveal more than a few traces of sulfide. In order to profit from this experience, future drilling programs might be restricted to those centers of activity which lie in distinctly elongate areas of negative anomaly, should any such be found.

Drill holes planned to explore an elongate area of negative anomaly should first be located to intersect a line drawn from the center of the anomaly in the direction of plunge of minor folds of the area. Unless there is definite evidence to the contrary, the possible ore body may be assumed to lie in a plane that strikes and dips parallel to the cleavage in the vicinity.

Specific areas recommended for geophysical exploration

The fundamental causes for localization of ore deposits within the district as a whole are unknown and it is therefore necessary to point out a rather large number of areas which are favorable for prospecting. These areas, chosen largely on the basis of the structure of the rocks, can be stated to be the most likely places to search for concealed ore deposits, but no area can, for obvious reasons, be guaranteed to contain ore.

Viewed broadly, the most favorable parts of the area for finding ore are probably near or between known large deposits. No reasons are known at present why large ore bodies may not lie outside the district, but, empirically, areas within the district and particularly within an elongate area one or two miles wide that includes the Elizabeth, Ely, Cookville, and Eureka-Union mines would seem to afford the best opportunities. This assumption is favored by the rough parallelism between this area and the major late-stage structural elements of the region.

Areas considered most favorable for geophysical exploration are shown on the geologic map (pl. 1), and are described in the following paragraphs in groups according to what is believed to be their relative merit.

Highly recommended areas

Areas north and south of Elizabeth mine.—The Elizabeth vein and its possible extensions to the north and south of its known limits probably afford the best possibilities in the district. Poor exposures and the fact that the folding in the cleavage, which might be useful in locating an ore body, is restricted to the mineralized parts of the vein make it difficult to predict the position of new ore bodies on the basis of surface geology without actually finding ore, or to set definite limits to the amount of exploration that seems advisable. The Elizabeth vein from the north end of the Elizabeth mine to the South mine should be traversed at closely spaced intervals, probably not exceeding 200 apart, and the traverses should be carried at least 500 feet from the vein both east and west. The projections of the vein should probably be explored for at least a mile along the strike, regardless of results, and favorable results might encourage continuation to a greater distance. Initial traverses to search for and test extensions of the vein probably should not be more than 500 feet apart, and their length should be increased in proportion to their distance from the ends of the known vein.

Areas of westerly strike.—Cleavage rolls, such as that which controls the Ely ore shoot, are common in an elongate area extending from a point at least 3 miles north-northeast of the Ely mine to a point about 2 miles north-northeast of the Elizabeth mine (pl. 1). The total area underlain by rocks with more westerly strike includes many square miles, and in a limited program of regional geophysical exploration, traverses covering all of the cleavage rolls would not be advisable, particularly if the most favorable parts do not appear to contain new ore deposits. The best areas for exploration of cleavage rolls appear to be the following:

The group of rolls in the immediate vicinity of the Ely mine (pl. 2), particularly the roll lying about 1,200 feet east of the main shaft entrance, should definitely be explored. This latter roll shows extraordinary curvature and lies close to a known sulfide ore body.

Points at which the arc that includes the Elizabeth, Ely, Cookville, and Eureka mines intersects the axial planes of large folds (see p. 10) should definitely be explored where they lie within or close to cleavage rolls. Two areas that contain such points are (1) an area about a quarter of a mile square north of the road intersection a mile west of Center Hill, and (2) the top and north slope of a ridge 1 mile north of Ely mine. No rolls were found in the latter area, but outcrops are poor and there are many rolls to the south and east.

Part of an elongate area of westerly strikes lies just east of Miller Pond. This area, which is roughly between the Ely and Elizabeth mines, might well be explored from a point a mile or more north of Miller Pond to its southern end. Part of this area that lies 1¼ miles west of West Fairlee and south of the Dimond property is considered especially favorable.

The rolls north and, to a lesser degree, west of Miller Pond are favorable for the same reason as the preceding. Several local inhabitants described a prospect pit in sulfide on the slopes west of Miller Pond, but this was not found. Geophysical work west of Miller Pond would be hindered by moderate and locally severe "blow down." Except for a small area just north of the pond, and near the roads southwest of the pond, most of this area is considered less favorable for efficient prospecting than the areas described in the two preceding paragraphs.

Recommended areas

Areas classed as "recommended" might well be explored geophysically after a part, possibly half, of the exploration of cleavage rolls had been completed if results on the rolls were not satisfactory. The area of rolls at the Ely mine, and the more accessible areas just north, east, and for some distance south of Miller Pond should be explored before the "recommended areas."

Area north of Ely mine.—An area north of the Ely mine is worth exploring because of the possibility that the mineralized fault that lies southeast of and intersects the main ore shoot may continue north beyond the shoot.. Two small prospects a half mile N. 20° W. of the main shaft entrance show traces of pyrrhotite. The area is mostly rather open woods with some cliffs.

Vicinity of Eureka and Union mines.—An area south of the Eureka mine, and including the Smith mine, deserves exploration. Numerous trenches in the area between the Eureka and Smith mines show sparsely scattered sulfide, but considerable potential ground between the mines is unexplored, particularly west of the line of trenches. There has been no exploration of the vein zone more than 500 feet south of the Smith mine. This area is heavily wooded, and contains considerable "blowdown."

There might be an ore shoot near the surface along an east-west line at about coordinate 800 S. between coordinates 200 and 400 E. (pl. 7), as suggested on p. 27. A north-south traverse on coordinate 300 E. should be run.

Drilling results at the Union mine were discouraging, but the shallow ground north of the Union mine along the projected outcrop of the vein zone (not outlined on map) is almost unexplored and might warrant a few traverses. The area is wooded.

Cookville mine.—The fault on which the Cookville mine lies is believed to afford excellent opportunities for discovery of an ore body by geophysical methods. The vein is probably only a foot or so in width in the open cut, but is moderately rich in copper. It is comparable in many respects with the area of leaner veins along the fault south of the Elizabeth mine. The fault trace for many hundreds of feet north of the open cut, in a position analogous to that of the main Elizabeth ore body, is covered with glacial drift, possibly several tens of feet deep locally. The glacial cover has prevented any attempt to explore this promising ground. This area is mostly open pasture with minor woods.

The area south of the open cut, continuing the analogy with the Elizabeth mine, is less favorable than the northern area, but still deserving of attention.

Area north of Strafford.—An area lying on the east side of the valley one mile north of Strafford village is recommended for exploration because of the rocks it contains. A small test pit exposes a coarse grained altered amphibolite, made up almost exclusively of a pale hornblende typically found associated with copper mineralization in the region. Glacial boulders of this rock, some of which contain disseminated chalcopyrite, were found scattered in the till as far south as Strafford village. Exposures near the pit are inadequate to define the possible limits of an ore body, but the unusual amount of pale hornblende suggest the desirability of geophysical exploration. The area is a steep open pasture.

Orange and Gove mines.—Sulfides occur at scattered points in the vicinity of the Orange and Gove mines within a few feet or tens of feet of the northern boundary of a persistent layer of needle amphibolite. This zone, not outlined in plate 1, might be profitably explored geophysically between the two mines and for some distance beyond to the east and west. The sulfide veins, where exposed at the mines, are only a foot or two in thickness, and there is no structural evidence to permit prediction of a large ore shoot. The location of the zone is well defined stratigraphically, and the area is largely open pasture.

Less favorable areas

Certain areas less favorable than those described above might warrant eventual investigation by geophysical methods. The chances of finding an ore body in these areas is considered to be far greater than at random points in the district, such as might be located by drawing straight lines between mines.

Area south of Gilman Hill.--An area for exploration is shown just south of Gilman Hill on plate 1. This area contains locally erratic strikes in the cleavage of needle amphibolite, three test pits in which the rocks contain traces of chalcopyrite, and a probable fault. The area is mostly open pasture.

Area west of Cookville mine.--From a half to one and a half miles west of the Cookville mine along the north contact of a large body of needle amphibolite there is a sharp change in the strike of the cleavage (pl. 1 and fig. 2). This change suggests a structural discordance that might be followed by an ore body, but the area must be considered as a "wildcat" location. The contact follows the base of a very steep wooded slope.

DESCRIPTION OF INDIVIDUAL DEPOSITS

Elizabeth mine

The Elizabeth mine has been described in detail in a report 1/

1/ White, W. S., Geology of the Elizabeth Copper mine, Vermont: U. S. Geol. Survey, report in open files, pp. 1-9, 3 plates, 1943.

available for inspection in the files of the Geological Survey. Maps accompanying this report may be obtained upon written request to the Director, Geological Survey, Washington 25, D. C.

Ely mine

The Ely mine (pl. 2), also known as the Vershire or Copperfield mine, lies almost 2 miles northwest of the village of West Fairlee. The property can be reached by public road, but the entrance to the shaft is about three-quarters of a mile from the road, and not accessible by automobile. The workings above the level of the main adit and a lower adit are still accessible, but all other workings, including over 90 percent of the main shaft, are flooded. It is owned by the Vermont Copper Co., Inc.

Production

Copper was discovered at the Ely mine in 1821, but little was mined before 1854. The production, so far as known, and the periods of idleness that followed the first important operations are given below.

Ely Mine

Year	Tons ore raised
1854	134
1855	198
1856	137
1857	246
1858	314
1859	789
1860	1,452
1861	1,812
1862	2,224
1863	1,430
1864	880
1865	1,420
1867	4,920
1868	5,650

Year	Pounds Copper
1870	943,461
1872	1,200,000±
1876	1,646,850
1880	3,186,175
1882	360,000
1883-1888, idle	
1889	147,000
1890	633,000
1891	1,031,624
1892	1,200,000±
1893-1899, idle	
1899-1901 Development	
1902-1903 Production small	
1903-present. Mine idle	

In 1918, about 300,000 pounds of copper from the dumps were sold as flotation concentrates.

From 1854 to 1882 a profit apparently could not be made when the price of Lake copper fell much below 25¢ per pound. In the period 1889-1892, the average price was 13.35¢, but it is not known how profitable the enterprise was. The purchase price of the mine, mill, and smelters in 1888 was very modest compared to their original cost.

Geology

The important geologic features of the mine and the location of workings are shown with a topographic base in plate 2. Plates 3 and 4, respectively a plan and section of the main workings, are largely reductions of two drawings kindly loaned the writer by P. S. Smith, supplemented, where possible, by data obtained from surface and underground mapping. Plate 5 is a reproduction of part of plate 3, showing the location of numerous geologic sections (plate 6) made in the workings above the main adit level.

The country rock is quartz-mica schist, generally garnetiferous with subordinate mica schist, micaceous quartzite, kyanite schist, and hornblende schist or amphibolite. Sillimanite schist was found on the hill just west of the mine. The attitude of the cleavage in the neighborhood of the mine is shown in plate 2. Areas in which the strike of cleavage is more westerly than the average constitute the cleavage rolls described on page 6. The bedding is highly folded, and generally trends more northerly and dips more steeply east than the cleavage. The axial planes of the folds are more or less parallel to the cleavage. The plunge of the axes of minor folds and of the intersections of bedding and cleavage are shown in plate 2. The axes of cleavage rolls and the axes of the minor folds are essentially parallel, and both approximate the plunge of the main ore shoot.

The ore is a mixture of pyrrhotite and chalcopyrite, with minor sphalerite. The average grade is between 3 and 3.5 percent copper.

The main ore shoot, which lies in the middle of a broad roll or flexure in the cleavage (fig. 3, pl. 2), consists of a series of long narrow ore lenses oriented parallel to the cleavage of the wall rock. Individual lenses may be 20 or 30 feet thick in the middle, but the average is about 10 feet. The central part of the lenses was apparently mostly massive sulfide with minor thin intercalations of schist. Only the margins of ore bodies can now be examined, but the cross-sections of the workings drawn parallel to the strike (pl. 6, sections A-A' to J-J') suggest the outlines of the bodies. Their lateral margins exposed in the workings show tapering and feathering out into a number of thin veins or stringers separated by barren schist (pl. 6). The strike length of the ore lenses, shown roughly by the width of the stopes in plan (pl. 3), ranges from 50 to almost 250 feet. The pitch length of individual ore lenses is generally not over 300 feet, according to Smith.1/ The lower end of one ore lens

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1/ Smith, P. S., The copper sulfide deposits of Orange County, Vermont, unpublished thesis, Harvard University, p. 128, 1904.

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generally overlies the upper end of another in the manner of shingles on a roof. The average overlap is 50 feet.2/ When the lower end of

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2/ Idem, p. 131.

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an ore lens was reached in mining, the upper end of a new one was always found by sinking a winze for 20 or 30 feet through lean or barren schist. An attempt to reconstruct the outlines of some of these lenses for the purpose of illustrating the overlapping lens structure is presented in plate 4. The outlines of lenses are constructed wholly from the written descriptions of Smith and others, supplemented by an interpretation of certain workings shown on the plan (pl. 3), and are only diagrammatic. The dashed lines do not necessarily represent workings, and the elevation of the lenses with respect to the shaft are assumed, except for the "Black Stopes," which were surveyed. The shaft follows a series of stopes throughout most of its length, but apparently it passes through barren rock between some of the lenses. The total length of the main shoot, as mined up to the present time, is 3,380 feet, measured parallel to the shaft.

Parts of the main adit and the small stopes southeast of the main ore shoot follow a mineralized thrust fault on the adit level. The trace of the fault on the adit level is shown in plate 5. It dips about 42° E. There is locally a pronounced drag fold in the cleavage adjacent to the fault (pl. 6) on both hanging and foot walls, and the direction of curvature shows reverse fault movement. A vein of sulfide with a maximum thickness of 2 feet and an average thickness of less than a foot lies on this fault. In a few places there are thin stringers or groups of stringers that branch from the main vein and follow the cleavage of the hanging wall. Bureau of Mines drill holes E-2 to E-5 showed most abundant traces of sulfide at points where the holes intersected the projection of this fault (pl. 4 and p. 21). The small sulfide vein, locally up to 5 feet in thickness, exposed in the adit south of and below the main adit, may lie on the same fault, although the dip there is only 30° E. The position of the fault at the surface, calculated by projection from the underground workings, is shown in plate 2.

Exposures in the small stope at coordinates 8680 N., 6860 E. suggest that the fault plane may decrease slightly in dip and bend more towards the west at its northern end. Projection of the fault plane up the dip in the cross-sections (pl. 6, sections D-D' to F-F') suggests that the fault plane may continue with slight curvature through the workings known as the "Back stopes," as shown in figure 3, or between the "Back stopes" and the main ore shoot above. The fault is evidently parallel or nearly parallel to cleavage where it lies within the cleavage roll.

The fault may bear a close relation to the Ely ore shoot. The pitch of the shoot is parallel to the plane of the fault, and the shoot lies close to the intersection of the fault with the axial plane of the roll. Whether or not the fault served as a feeder for the main shoot cannot be readily determined, but the close structural connection between the fault and the ore shoot is important, particularly as providing a pattern which might be a useful guide in prospecting for ore bodies in this or other similar districts. The area in which a mineralized fault crosses a cleavage roll may be at or close to an ore shoot.

Two vertical faults were mapped in the adit (pl. 5). The fault planes contain up to a foot of breccia and abundant coarse calcite. The displacement along the eastern fault may be less than a foot, but along the western, the mineralized reverse fault is clearly displaced. Assuming vertical movement, the east side has dropped 10 feet with respect to the west. These faults are probably the same as some, at least, of the planes shown as "dike walls" on the old mine plan (pl. 3).

In addition to the workings connected with the main shaft, there are a number of minor workings nearby. Largest of these is an adit, caved at the entrance, 650 feet south of the main adit. Begun sometime before 1859, this adit was planned to give access to the main ore shoot in depth, but it was abandoned about 1863 when the main shaft had already been carried below this level. Between coordinates 7730 N. and 7775 N., this adit follows an irregular zone containing a few thin stringers of sulfide. Between 7775 N. and 7850 N. the sulfide vein is better defined and has a maximum thickness of about 5 feet, tapering to the north and south. The vein strikes N. 15° E. and dips about 30° E., parallel to the cleavage of the schists. The ore was stoped up to the surface in this interval, and a winze of unknown depth was sunk in the widest part. The remainder of the adit to the north contains only a little scattered sulfide, and appears to lie east of the mineralized zone. A long crosscut driven northwest from the adit along the strike of the cleavage is all in barren schist and amphibolite except for the first few feet.

A vertical shaft 71 feet deep was sunk in barren rock 70 feet east of the entrance to the main adit; it was started about 1864 as an air shaft to the lower adit, but was never completed.

Two steep to vertical prospect shafts, probably of the order of 100 feet deep, were sunk near the roast beds about 1896. Both show abundant amphibolite on their dumps, and many fragments from the more northerly show abundant tourmaline and coarse pyrrhotite. At coordinates 8260 N., 6320 E., a shaft 80 feet long, sloping 35 degrees towards the northeast, shows some scattered sulfide and a little massive sulfide in schist and amphibolite fragments on the dump.

Tabulation of drill hole data

Significant data from diamond drill holes at the Ely mine are tabulated below. The location and bearing of holes are shown in plates 2 and 3, and the inclination of the Bureau of Mines holes in projection are shown in plate 4. The inclinations of company holes, drilled underground about 1901, are given below. Assay data for the Bureau of Mines holes were kindly furnished in advance of publication by Mr. H. P. Hermance, project engineer.

Bureau of Mines holes (all inclined 80° at collar)

Hole	Interval (ft.)	Assay (% Cu)	Sulfides observed in core
E 1	Bottom 500'		No sulfide
E 2	202.5-208.5	(S) 0.15 1/	Trace 193.6', trace 204.4'
	236.5-238.5	(S) 0.14	Trace sulfide at 231
	281.5-286.5	(S) 0.15	Trace 279.4', 283.3'-283.8
	291.5-296.5	(S) 0.44	Trace 287.6', trace 288'
	298.5-301.5	(S) 0.15	296.5-297.8', Fault?
	301.5-309.5	(S) 0.06	Trace 302.2', 303', 303.6', 307'
	Bottom 321.5		

Hole	Interval (ft.)	Assay (% Cu)	Sulfides observed in core
E 3	299.3–300.3	0.04	Tourmaline-pyrrhotite
	335.0–340.0	0.06	Scattered veinlets
	345.3–346.3	0.06	Vein quartz with sulfide
	417.1–417.4		Traces sulfide
	452.4–457.4	(S) 0.66	Trace 442.7', 444.1', 446.5'
	459.2–460.3	6.03	Chalcopyrite stringers with pyrrhotite. 459.4–462.4'
	Bottom 503.7		Fault?
E 4	53.0–56.2		
	73.8–75.3	0.03	Traces pyrrhotite, little chalcopyrite
	83.9–87.4	0.10	Tourmaline-qtz, little sulfide
	110.7–113.3	0.55	Amphibolite, disseminated sulfide
	115.7–117.0		Sulfide veinlets, mostly pyrrhotite to 113.6'
	132.7–134.2	0.29	Estimate 2% copper
	Bottom 190.5		Veinlet. Fault?
E 5	199.7–207.7	0.04	Disseminated sulfide
	240.6–240.8	0.09	Rich 2" vein. Fault?
	Bottom 300.5		

1/ (S) means sludge sample, generally inaccurate indication of grade and position. Location of sulfide stringers represented is given under core observations.

Company drill holes in mine, ca. 1901

Hole	Inclination	Log, as given
DH-1	30°	0–18', dike wall; 18–51, vein matter; 51–82, rock.
DH-2	42.5°	0–5', ore; 5–10, dike wall; 10–43', ore; 43–56', vein matter; 56–60', rock.
DH-3	42.5°	0–6', rock; 6–7', ore; 7–11.5', dike wall; 11.5–16.5', ore; 16.5–29', rock.
DH-4	42.5°	0–12', rock and ore; 12–22, dike wall; 22–34', ore; 34–49'; rock.
DH-5	75°	0–10', rock and ore; 10–42', rock.
DH-6	23°	0–42', rock; 42–43.2', ore; 43.2–48.9 rock; 48.9–49.7', ore; 49.7–130.3, rock.

Hole	Inclination	Log, as given
DH-7	27°	0.62.5', rock.
DH-8	35°	0-56.5', rock.
DH-9	No data	

Ore reserves and possibilities

There are virtually no measured ore reserves at the Ely mine. A few indications of continuity, however, are given by the diamond drill holes put down in the mine. Drill holes DH-1 to 5 suggest that the vein has been displaced downward about 15 feet on the east side of the line labelled "dike wall." If it is assumed that the ore cut by three of the holes lies in a single vein, the ore is found to be up to 6 feet thick, and to strike N. 5° W. and dip 36° N.E. The block of ground outlined by the holes contains about 500 tons of ore. It is reasonable to assume that, neglecting the slight displacement along the so-called "dike wall," which has apparently discouraged extensive exploration, the ore shoot continues down the plunge in much the same manner as above. More thick lenses may well exist below. The principal obstacle to further development is the high initial cost of exploring and reaching the ore.

Drilling by the Bureau of Mines near the top of the shaft and to the south, and examination of the workings above water level indicate that there are probably no large mineable ore bodies at or near the level of the main shaft, either on the fault plane southeast of the main shaft, or left along the lateral margins of the main shoot. Hole E-4 intersects the projection of the fault plane at a point down the plunge from the small ore body exposed in the lower adit, and suggests that no well-defined shoot exists there.

Pike Hill mines

The Pike Hill mines (pl. 7) include the Eureka (Corinth), Union, and Smith (Bicknell) mines on the east side of Pike Hill in Corinth. The Eureka and Union mines are 3.7 miles south of Waits River village, and 2.8 miles north-northwest of Cookville. The Smith mine is a small opening half a mile farther south. The two important mines are only 0.3 miles from a public road, and all are directly accessible by wagon road. Part of the Eureka mine above the adit level is accessible where not caved, but the Union mine is mostly flooded. There are large open cuts on the vein above the stopes, and numerous trenches between the Eureka and Smith mines. The property containing the Eureka and Union mines is owned by the Vermont Copper Co., Inc.

Production

Copper was discovered at the Eureka mine at least as early as 1846. The known production and the periods of idleness are given below:

Union mine

1866-1881	31,504 tons of ore, presumably hand sorted, averaging 8.5-10 percent copper.
1881 to present	Idle

Eureka mine

1863-1864	369 tons ore
1866	1,755 tons ore
1868-1904	Idle
1905	131,911 lbs. Cu.
1906	304,377 lbs. Cu.
1907	425,367 lbs. Cu.
1907-1915	Idle
1915-1916	42,000 lbs. Cu.
1918	509,654 lbs. Cu., 2056 oz. Ag.
1919 to present	Idle

Little is known of the history of the Smith mine.

Geology

General description.—The country rock in the vicinity of the Pike Hill mines is calcareous quartz-mica schist with subordinate mica schist. Hornblende schist and amphibolite were observed only on the dumps of some of the trenches near the Smith mine.

The bedding is highly folded; generally it trends slightly more easterly and dips more steeply than the cleavage, although at most places the deformation has been so intense that the two structures are essentially parallel. The minor folds plunge almost north at angles ranging from 5 to 15 degrees. The average strike of the cleavage is N. 30° W. and the average dip is about 35° E. Measurements of cleavage attitude on virtually all the outcrops near the mines are shown in plate 7.

East of the principal mines, the axis of a broad roll in the cleavage plunges about 20° N. 5° E. East of the Eureka mine, this roll, made up of an anticline east of a syncline, is very pronounced, as suggested in figure 3, although structural data are relatively scanty there. The amount of curvature decreases to the north and south, and south of the Eureka open cut and east of the Union mines there is only a slight deflection of the average cleavage strike. The Eureka and Union ore bodies lie on the western limb of the synclinal portion of the roll (fig. 3).

The ore at all the mines consists of a mixture of pyrrhotite and chalcopyrite, with subordinate sphalerite. Pyrrhotite probably makes up 40 to 50 percent of the ore mined. A weighted average of the copper content of 58 channel samples collected between 1903 and 1918 at the Eureka mine is 3.74 percent, equivalent to almost 11 percent chalcopyrite. The average ore mined in 1918, however, contained only 2.34 percent copper. A weighted average of the copper content of 23 channel samples collected in 1903 from the margins of the Union ore bodies is 3.15 percent. The samples from the Union mine average 3.5 feet in length, and it may be inferred, therefore, that they were taken to represent grade of sulfide rather than grade of mineable widths of ore. Sphalerite is about one-eighth as abundant as chalcopyrite in the Bureau of Mines drill holes.

Eureka and Union mines.—The Eureka and Union ore bodies consist of a number of ore lenses whose general shape may be inferred from the outlines of workings to be roughly elliptical in plan. The lenses are roughly elongate in a direction slightly east of north, and their average length, about 175 feet, is approximately twice their average width. Weed 1/ states that the average thick-

1/ Weed, W. H., Copper deposits of the Appalachian states: U. S. Geol. Survey Bull. 455, p. 33, 1911.

ness is 8 feet. The central part of the ore lenses now mined out, was probably largely massive sulfide. Along the margins, the ore lenses feather out into a number of thin sub-parallel veins (fig. 4, section A). The lenses as a whole and their constituent veins and stringers lie essentially parallel to the cleavage of the rocks.

The Eureka and Union ore bodies lie within a single narrow vein zone whose upper surface is defined by the structure contours of plate 8. The contours are drawn on the top of the mine workings, as shown on old blueprints, and at the top of the highest massive sulfide encountered in drill holes. Within the vein zone, the individual ore lenses overlap one another like shingles on a roof. Section C in figure 4 is a diagrammatic representation of the arrangement of ore bodies in the Eureka mine, suggested largely by the shape of the workings. Wendt 2/ gives a similar section repre-

2/ Wendt, A. P., Pyrites deposits of the Alleghenies: Eng. and Min. Jour., vol. 41, p. 409, 1886.

senting the overlapping ore bodies of the Union mine. The overlap is in the direction of the dip, as at the Ely mine. The ground between ore lenses may be barren schist, or may contain scattered veinlets and disseminated sulfide. Locally two lenses may be connected across the cleavage by a series of discontinuous small stringers en echelon, as illustrated in section B, figure 4.

The part of the vein zone that contains the richest ore bodies is defined by the outline of the workings of the Eureka and Union mines (pl. 8). The vein zone between the two mines contains only thin veins of sulfide. Holes drilled in the vicinity of the mines suggest that a definite boundary to the mineralized zone more or less follows the southeast edge of the Eureka workings and passes through the lowermost Union workings. Practically no sulfide has been found on the east side of this line. The boundary is nearly parallel to and just west of the trough of the syncline shown in figure 3. Drill holes EU 5 and 6 and P 8, all drilled approximately in the trough of the syncline, showed little or no sulfide. The structure contours of plate 8 show a slight curvature in the southern workings of the Eureka mine, suggesting that these marginal workings lie close to the trough of the syncline.

Three holes north of the Union mine, drilled to determine whether or not there might be a single ore shoot plunging north-northeast through the two mines, encountered very little sulfide. Hole EU 11, just north of the bottom of the Union mine, contained the largest amount of sulfide, namely 2 veins 1.5 feet thick separated by 5 feet of schist.

The only evident relations of the ore deposits to geologic structures are their parallelism with cleavage and their apparent termination along a line nearly parallel to local linear elements, particularly the axis of the adjacent synclinal roll. Three other features of the deposits warrant attention, namely, the lean vein zone between the two mines, the apparent elongation of the two ore bodies, as suggested by the workings, plunging more nearly down dip than local fold axes, and the apparent absence of mineable ore bodies north of the Union mine. These features bear no significant relation to the major structure of the area and permit no analogy with the other two large mines of the district. If certain assumptions are made, however, a satisfactory explanation for the distribution of ore can be offered, which could be used as a guide for future exploration.

A comparison of cross-sections of the Ely and Eureka mines in figure 3, drawn at right angles to the plunge of minor folds and rolls in the cleavage, is suggestive. The Ely ore shoot, which is continuous for at least 3,380 feet down the plunge, lies in and just west of the crest of the anticlinal portion of a roll in the cleavage. The Eureka mine, on the other hand, lies on the west limb of the synclinal portion of a similar, but more accentuated roll. The maximum formation of potential openings would normally be expected where the Ely shoot occurs, and definitely would not be expected where the Eureka vein lies. The possibility is suggested, therefore, that the site of major ore deposition at Pike Hill actually lies at and just west of the crest of the anticline and that the vein that has been explored to date represents only sulfides deposited by solutions that leaked out of the main channel. The ground along the anticline (see pl. 7) has not been explored. If a major ore shoot at the cleavage horizon of the known ore bodies follows the crest of the anticline, it would crop out along an east-west line at about coordinate 800 S. between coordinates 200 and 400 E, between some old trenches. The Eureka and Union ore bodies may, however, represent the entire upper extensions of a major ore shoot, in which case no ore might be found in the crest of the anticline above the elevation of or south of the bottom of the Union mine.

Choice of a precise target for exploration is difficult because the dip of the axial plane of the anticline is not known. The crest in depth, therefore, may lie west but probably lies east of the crest at the surface. A preliminary hole might be tentatively planned to intersect the "cleavage horizon" of the vein zone at coordinates 1000 N. and 600 E. It should be noted that hole EU 11, 250 feet west of the recommended spot was by far the best of the holes drilled north of the Union mine.

Area south of Eureka mine.—The Smith mine workings consist principally of a small inclined stope, about 50 feet across down dip, and 70 feet long. It is connected to the surface by a 50-foot adit and an irregular opening in the back. At the north end, close to the outcrop, there is a 40-foot drift, and a winze, now flooded, was sunk for about 40 feet down the dip of the vein below the stope north of the adit.

The schists contain sulfide through a thickness of at least 20 feet. The sulfide occurs disseminated in the schist and as scattered small stringers that dip about 30° E., parallel to the cleavage. There appears to be a principal sulfide vein immediately below a well-defined hanging-wall parting that may be a fault plane. The parting strikes N. 55° W. At the north end of the drift, this sulfide vein is about six feet thick and contains very minor chalcopyrite but is only a foot or two thick elsewhere in the walls of the mine. Other stringers, one of which follows another parting, branch off into the footwall and possibly into the hanging wall.

The ore examined in the workings and on the dumps is probably of about the same grade as the other Pike Hill mines. The few places at which the deposit could be examined failed to disclose a mineable thickness of good ore, either massive sulfide or schist with abundant chalcopyrite, but the fact that the stope is 8 to 10 feet high suggests that the ore mined was of good width.

Five drill holes were put down in 1916 just north of the Smith mine (pl. 7). They revealed only sparse sulfide, but the intersections in the holes suggest the attitude of the vein zone in this southern area. The zone appears to strike about N. 5° E. and dip 35° E., and appears to cut across the cleavage at a low angle.

There are over 40 small pits and trenches in the area between the Smith and Eureka mines and south of the Smith mine. These have all caved and slumped, and only a few exposures of bedrock remain. Inspection of the rocks thrown out, however, reveals that no massive sulfide and only a small amount of disseminated sulfide were encountered in any of them. The disposition of trenches shows a keen understanding of the structure of the area. They follow very closely the trace of a theoretical curved surface that is sub-parallel to cleavage and passes through the Union and Eureka mines toward the Smith mine. This surface has a large "ridge" plunging north where it follows the roll east of the Eureka mine.

If the Union, Eureka, and Smith mines lie in a single plane that has no significant curvature, this plane would outcrop as much as 400 feet west of the line of trenches at coordinate 1500 S.; it would pass below the bottoms of drill holes S1, 2, 3, and 5, and through sparsely mineralized schist in hole S4. It is not known, therefore, that the mines do not lie in such a plane, and that there are no ore bodies between the Eureka and Smith mines.

Tabulation of drill hole data

Significant data from diamond drill holes at Pike Hill are tabulated below. The Bureau of Mines holes were all drilled S. 75° W. at an angle of 80° with the horizontal, except for hole EU 2, which was started at an angle of 60 degrees. All the company holes, drilled in 1916 and 1917, were inclined at 60 degrees to the horizontal. The holes around the Eureka mine were drilled S. 75° W., and the holes near the Smith mine were drilled due west. Assay data for the Bureau of Mines holes were kindly furnished by H. P. Hermance, and records of the old drill holes are from the files of the Vermont Copper Co., Inc.

Bureau of Mines holes

Hole	Interval (ft.)	Assay (% Cu)	Core observations
EU 1	69.2-70.2	2.85	Chalcopyrite 69.2-69.4',
	70.2-72.4	0.05	70.0-70.2. Mixed sul-
	72.4-74.6	0.76	fides 72.6-74.8'
	74.6-77.4	0.10	Schist
	77.4-80.1	1.07	Sulfide on edges of quartz vein
	80.1-85.0	0.15	Sulfide 82.3-83.0'

Bureau of Mines holes (continued)

Hole	Interval (ft.)	Assay (% Cu)	Core observations
EU 1	85.0-85.5	2.19	Sulfide
	85.7-92.7	(S) 0.43 1/	Core ground up
	92.7-102.7	(S) 0.85	Most of core ground up
	102.7-113.7	(S) 3.80 2/	Poor recovery, very minor sulfide in core
	Bottom 145.5'		
EU 2	172.3-173.6	0.47	Part disseminated sulfide
	173.6-175.4	1.11	Massive sulfide
	Bottom 210'		

1/ (S) means sludge sample, generally omitted where core recovery was good.

2/ Some of the copper in this sample may have come from a ground up bit. Diamonds in the destroyed bit were set in copper alloy.

Hole	Interval (ft.)	Assay (% Cu)	Core observations
EU 3	59.0-65.0	0.45	Patchy sulfide
	65.0-70.2	1.36	Patchy sulfide
	70.2-71.8	0.50	Micaceous quartzite
	71.8-72.9	1.32	Patchy sulfide, vein quartz
	72.9-83.4	—	Micaceous quartzite
	83.4-87.7	0.62	Largely pyrrhotite
	87.7-89.7	1.23	Schist and sulfide
	89.7-95.5	0.18	Pyrrhotite 92.9-93.3'
	95.5-96.8	3.76	Massive sulfide
	Bottom 125'		
EU 4	148.3-151.0	0.49	Trace sulfide at 148.3', 148.5'
	151.0-156.9	0.33	Sulfide, mostly pyrrhotite, 149.6-150.8', 154.8-155.3'
	159.9-160.1	0.80	Disseminated sulfide
	Bottom 190'		
EU 5	No sulfide, bottom 240'		
EU 6	213.9-215.6	3.36	Much sulfide in schist
	215.6-222.0	0.17	Dissem. sulfide 221.0-221.6'
	222.0-233.1	—	Quartz-mica schist
	233.1-234.6	0.66	Sulfide, some disseminated
	234.6-237.0	0.12	Quartz-mica schist
	237.2-240.1	0.30	Mostly pyrrhotite
	Bottom 497'	Hole drilled deep to test foot of vein.	

Bureau of Mines holes (continued)

Hole	Interval (ft.)	Assay (% Cu)	Core observations
BU 11	343.9–345.4	0.94	Sulfide
	345.4–357.9	—	Trace sulfide 347.2', 357.7'
	357.9–361.4	0.36	Disseminated sulfide, vein quartz
	361.4–363.3	1.69	Massive sulfide
	363.3–367.9	0.12	Micaceous quartzite
	367.9–369.3	6.20	Massive sulfide
	Bottom 396.2'		
BU 12	220.0–221.6	0.02	Massive sulfide, mostly pyrrhotite
	221.6–223.0	0.27	Disseminated sulfide
	Bottom 314.8'		
BU 13	311.2–311.7	0.12	Patch sulfide 311.5'
	382.0–382.9	0.12	Patch sulfide 382.8'

Company holes near Eureka Mine, 1916–1917

Hole	Interval	Description of core
P 1	161.0–179.0	Scattered sulfide
	179.0–188.6	Fair ore
	Bottom 232.5'	
P 2	146.3–148.0	Low grade
	148.0–150.0	Fair ore
	150.0–153.9	Barren
	153.9–158.0	Good ore
	158.0–166.3	Low grade, streaky
	Bottom 187.0'	
P 3	71.3–76.9	Good ore
	76.9–86.0	Barren
	86.0–87.0	Fair ore
	87.0–89.7	Barren
	89.7–101.0	Good ore
	101.0–102.6	Fair ore and quartz
	102.6–105.0	Good ore
	105.0–108.7	Spotty ore, fair grade
	Bottom 133.0'	
P 4	196.0–196.7	Ore
	Bottom 250'	

Company holes near Eureka Mine, 1916-1917 (continued)

Hole	Interval	Description of core
P 5	138-144	Little mineralization
	144-146	Fair ore, mostly pyrrhotite
	146-149	Barren
	149-153	Low grade
	Bottom 180'	
P 6	80-81	Estimated 3% Cu
	81-82	Barren
	82-85	Estimated 2% Cu
	85-104	Barren
	104-107	Less than 1% Cu
	107-116	Barren
	116-120	Low grade
	Bottom 150'	
P 7	No data	
P 8	All schist, bottom 325'	

Company holes near Smith mine, 1916

S 1	181-181.2	Ore
	Bottom 209'	
S 2	145-145.4	Pyrrhotite
	Bottom 196'	
S 3	140-149.8	0.18% Cu
	149.8-152.6	0.88% Cu
	152.6-154.8	0.20% Cu
	154.8-167.6	Barren
	167.6-170.0	1.53% Cu
	170.0-172.0	0.90% Cu
	172.0-177.0	Barren
	177.0-180.5	0.20% Cu
	Bottom 198'	
S 4	96-106.5	Estimated 0.5% Cu
	106.5-121.0	Barren
	121.0-121.7	Estimated 4% Cu
	121.7-147.5	Disseminated sulfide
	147.5-155.5	Estimated 1% Cu
	Bottom 190'	
S 5	75-79.5	Estimated 3% Cu
	Bottom about 125'	

Ore reserves and possibilities

Except for drill hole EU 1, sludge samples from which may have been salted by a ground-up copper bit, none of the holes show sulfide equivalent to 6 feet of 2 percent ore. Measured reserves of ore mineable at present are therefore negligible, except for a few hundred tons of ore left in pillars and the margins of workings. The ore taken from the Eureka mine in 1918 shows a progressive drop in the average grade from 2.58 percent copper in July to 1.96 in December, suggesting exhaustion of the best ore in sight.

Unless further exploration along the lines suggested above reveals the existence of a new ore body, there is no reason to expect any noteworthy production in the future.

Orange and Gove mines

The Orange and Gove mines lie about 1.75 miles northeast of the village of Strafford, and about 4 miles north of the Elizabeth mine. The deposits are on the land of Mr. Glenn Titus of Strafford, but the mineral rights on the Orange mine, at least, are owned by Mrs. Reynolds, widow of the last operator. The locations of mines and prospects are shown in plate 1 and figure 5.

The Gove mine, which Mr. Titus states was last worked during the Civil War, consists of a small open cut and an inclined shaft of unknown depth, now filled with water. The size of the dump indicates that about 10,000 cubic feet of rock were removed. The Orange or Reynolds mine, also flooded, was worked briefly during the last war, and the remains of a shaft house and small mill, built sometime before 1911, are still standing. The workings consist of an inclined shaft 110 feet deep and a 70-foot drift on the 100-foot level. The dump is only slightly larger than that at the Gove mine. A few bags of unshipped concentrates at the Orange mine give some indication of the type of ore mined. Three small prospect pits and a prospect shaft were also dug in the area.

The ore deposits are in needle amphibolite that lies stratigraphically a few hundred feet below the top of the Waits River formation (fig. 5). A bed up to 50 feet thick of mica schist with abundant large garnets lies between the amphibolite and the calcareous rocks to the north. The rocks strike about N. 55° W. and dip 30° to 40° N. Cleavage is essentially parallel to the bedding, but shows a more constant orientation. Regional geologic mapping suggests that the rocks are overturned.

The ore is an aggregate of pyrrhotite and chalcopyrite, as at the other mines in the district. Pyrite is abundant in small patches and veinlets at the Gove mine, but is not closely associated with the chalcopyrite. Pyrite is negligible at the Orange mine and adjacent prospects, but a little magnetite was found on a dump nearby. Massive sulfide, largely pyrrhotite, forms the principal vein material, but much of the chalcopyrite is disseminated or occurs as tiny stringers in the adjacent host rock. The average copper content of the massive sulfide is estimated to be 1 percent or less. Sphalerite is nearly as abundant as chalcopyrite, and the average zinc content of the vein material is probably about the same as the copper content.

The principal gangue minerals are quartz, feldspar, and hornblende. Carbonate is generally present in small amounts, and a little tourmaline is found locally. Some of the sulfide at the Orange mine is disseminated in coarse garnet-biotite schist.

The ore occurs in veins that lie parallel to and a few feet or tens of feet south of the northern boundary of the amphibolite. The vein appears to lie on a small thrust fault at the top of the Gove shaft, and its relation cannot be determined elsewhere. Dump fragments at the Orange mine indicate that some sulfides are actually found in the garnet-mica schist to the north at this point. Exposures are inadequate to determine whether the sulfide vein at the Orange mine and adjacent prospects is continuous with that at the Gove mine, but the few observations that can be made suggest that the ore deposits lie in a single narrow poorly defined zone that only locally contains significant amounts of sulfide.

The thickness of the massive sulfide layer at the top of the Gove shaft ranges from three inches to three feet. The wall rock contains small stringers and disseminations of sulfide within a foot or two of the vein. The veins are narrower where observed in the prospect pits, but that in the Orange mine could not be examined. The vein zone may contain several branching veins, more or less parallel to one another, as at the Ely and Pike Hill mines.

The shape and structural relations of the deposits developed by the mines is not known. There does not appear to be any well defined structural control of ore deposition, and the distribution of sulfides along the general vein zone may be very patchy, analogous to the similar but larger deposits at Pike Hill.

There are no appreciable measured or indicated ore reserves in the vicinity of the mines. A very small tonnage of sulfide, probably averaging less than 1 percent each of copper and zinc over a 6-foot stoping width, may be inferred from surface exposures and examination of the dumps.

Cookville mine

The Cookville mine is 0.9 miles south of Cookville (Corinth P. O.). The workings, shown in figure 6, consist of a 250-foot open cut and trenches, probably dug at about the time of the Civil War. A 15-foot shaft was sunk near the middle of the open cut shortly before 1900. The open cut has an average depth of about 7 feet. The walls of all the workings have slumped badly, and exposures are poor.

The open cut appears to follow a sulfide vein, but only a little disseminated sulfide was actually seen in place. The slumped rock and dirt in the bottom of the pit presumably covers the vein. Fragments of ore on the dump are typical massive sulfide, dominantly pyrrhotite with subordinate chalcopyrite. Layers of magnetite in amphibolite were found in dump fragments. The average copper content of the massive sulfide is probably about 1 percent, but some schist with disseminated sulfide appears richer in chalcopyrite. The sulfide zone is at least 1 foot wide locally, but the average width is not known.

The wall rocks are calcareous mica schist and a composite rock made up of layers of hornblende schist and muscovite schist. This composite rock, probably of volcanic origin, is the host rock of practically all the sulfide. The contact between the calcareous and non-calcareous rocks was not seen, but the distribution of the rocks, as shown in figure 6, indicates that the contact is a fault. The fault appears to lie just west of the south end of the open cut, and inside the remainder of the cut. It strikes N. 12° E., and dips steeply, but the direction of the dip is not known. The average strike of the fault to the north and south appears to be more nearly north-south (pl. 1).

The sulfide vein, defined by the open cut, lies partly on the fault and partly on a plane that diverges from the fault to the south.

The rocks thrown out of the shaft near the middle of the open cut are massive fine-grained diorite, composed largely of stubby hornblende crystals with random orientation. This diorite is probably intrusive, but was not observed in place. A large body of the same rock was found on the steep slope west of the mine (pl. 1).

The ore in sight is negligible. The importance of the deposit lies solely in the evidence it gives of a mineralized fault. For although the part of the fault opened by the workings of the Cookville mine may contain only minor sulfide, other parts may lie in or adjacent to workable ore bodies. The area north of the mine, which, by analogy with the Elizabeth mine, is most favorable for such an ore body, is deeply covered by glacial drift for a distance of several hundred feet. Ore bodies might also be found to the south along the fault.

A tunnel of unknown length was driven into barren calcareous schist on the slope west of the mine. The tunnel was driven to find ore indicated by a divining rod.

Dimond property

The Dimond property includes the top and the south and east sides of the hill 1 mile south-southeast of the Ely mine. The Dimond house is 6,900 feet S. 15° W. of the Ely shaft. Chalcopyrite was once found in a pit, now covered up, 400 feet north of the house, and in another pit, also covered, 1,600 feet N. 29° W. of the house. There is needle amphibolite at both localities.

Large negative electrical anomalies have been discovered on the property by self-potential determinations made by G. R. MacCarthy of the Bureau of Mines. The area was prospected geophysically because the projection of the fault southeast of the Ely mine intersects a cleavage roll east of the house. The centers of electrical activity are shown in plate 1 and figure 7.

Extensive drilling has been undertaken by the Bureau of Mines to determine the source of the currents, but nothing capable of producing the observed potential differences (over 800 millivolts at the center of the anomaly 1,400 feet N. 25° W. of the Dimond house) has been found to date.1/ A map of the property (fig. 7), based on the same grid as plate 2, shows the attitude of the cleavage, the plunge of small rolls in the cleavage, and the location of the centers of activity and drill holes. Hole 13, drilled to intersect a point down the plunge of the minor rolls from the center of the largest anomaly, encountered sulfide at two places. The hole was drilled toward the center of activity at an inclination of 65 degrees with the horizontal at the collar. There is a vein 5 to 15 millimeters thick of pyrrhotite with a little chalcopyrite at 314 feet and a zone with many tiny anastomosing veinlets of the same material between 321.6 and 322.3 feet. The other holes, which were drilled principally to test the ground directly below the centers of activity, found nothing of significance except for a stringer of graphite at 93 feet in Hole E 10.

1/ November 1, 1943.

Minor prospects

In addition to the deposits described above there are many small prospects within the Orange County copper district. A large number of these, shown in plate 1, were visited during the field work, but two that are known to exist could not be found. There are undoubtedly a few other prospects that were neither found nor called to the writers' attention.

The locations of prospects and summary descriptions are listed as follows:

(1) 1,400 feet S. 80° E. of Eureka mine adit. 20-foot (?) shaft. Hornblende-garnet rock. Gossan fragments; no sulfide seen.
(2) 1,400 feet N. 30° W. of Cookville mine. Deep shaft. Needle amphibolite. Traces of pyrrhotite and chalcopyrite.
(3) 2,500 feet N. 86° W. of Cookville mine. Large deep shaft, two uncompleted adits; claimed to be a silver mine. Quartz-mica schist and black mica schist. Traces of pyrrhotite and chalcopyrite.
(4) About a mile E.N.E. of Vershire, near top of steep wooded slope. Small prospect showing chalcopyrite. Prospect not found.
(5) 4,100 feet N. 20° E. of Mill village and 4,750 feet N. 31° E. of Mill village. Two small prospect pits in quartz-mica schist. No sulfide seen in exposures.
(6) 2,750 feet N. 20° W. of the Ely shaft. Two small shafts and a short caved adit. Needle amphibolite band about 75 feet wide. Coarse pyrrhotite veinlets; no chalcopyrite seen.
(7) 7,850 feet N. 89° W. of the Ely shaft. Large pit in coarse hornblende schist. Sparsely disseminated pyrrhotite, traces of chalcopyrite.
(8) Southeast of Gilman Hill, 1,400 feet S. 62° E. of entrance to a private road on south side of West Fairlee-Strafford road at height of land; 400 feet south of Strafford-Vershire town line. Small shaft in amphibolite and coarse garnet schist. A little coarse pyrrhotite, tourmaline. An outcrop of amphibolite 150 feet south has pyrrhotite and tourmaline.
(9) 1,400 feet south of (8). Pit 10 feet across. On fold in coarse garnet schist between calcareous schist and needle amphibolite. Disseminated pyrrhotite and traces of chalcopyrite.
(10) 2,900 feet S. 12° W. of (8), 1,550 feet S. 22° W. of (9). 15-foot inclined shaft in coarse garnet schist. Scattered pyrrhotite, traces of chalcopyrite in small concordant fault zone.
(11) South of Gilman Hill, 2,750 feet S. 34° W. of entrance to a private road on south side of West Fairlee-Strafford road at height of land. Well just behind abandoned farmhouse. Calcareous schist. Traces of pyrrhotite.
(12) Slope west of Miller Pond. Pit showing chalcopyrite. Pit not found.
(13) 3,850 feet N. 82° E. of Orange mine. Three small pits. Needle amphibolite. Pyrite veinlets.
(14) 5,950 feet N. 89° W. of Gove mine. Small pit. Altered amphibolite. Disseminated pyrrhotite and chalcopyrite.
(15) 7,500 feet N. 79° W. of iron bridge in Strafford village. Small shaft. Needle amphibolite. Pyrrhotite and chalcopyrite veinlets.
(16) 1,150 feet S. 86° W. of (15).

CONCLUSIONS

On the basis of a geologic study of the Orange County copper district, a program is outlined that offers hopeful possibilities for the discovery of new ore bodies by geophysical exploration and diamond drilling.

Geophysical investigation of highly recommended areas should be carried out to the extent suggested on page 15. The discovery of one or more large self-potential anomalies, preferably showing marked elongation parallel to the cleavage, should be sufficient grounds for investigating all recommended areas.

Favorable results of geophysical exploration should be followed up by diamond drilling, preferably after interpretation of the results in the light of detailed study of the local geology. In addition, hopeful possibilities for the discovery of ore bodies by diamond drilling at Pike Hill and the Dimond property are apparent on the basis of geologic and geophysical data already available.