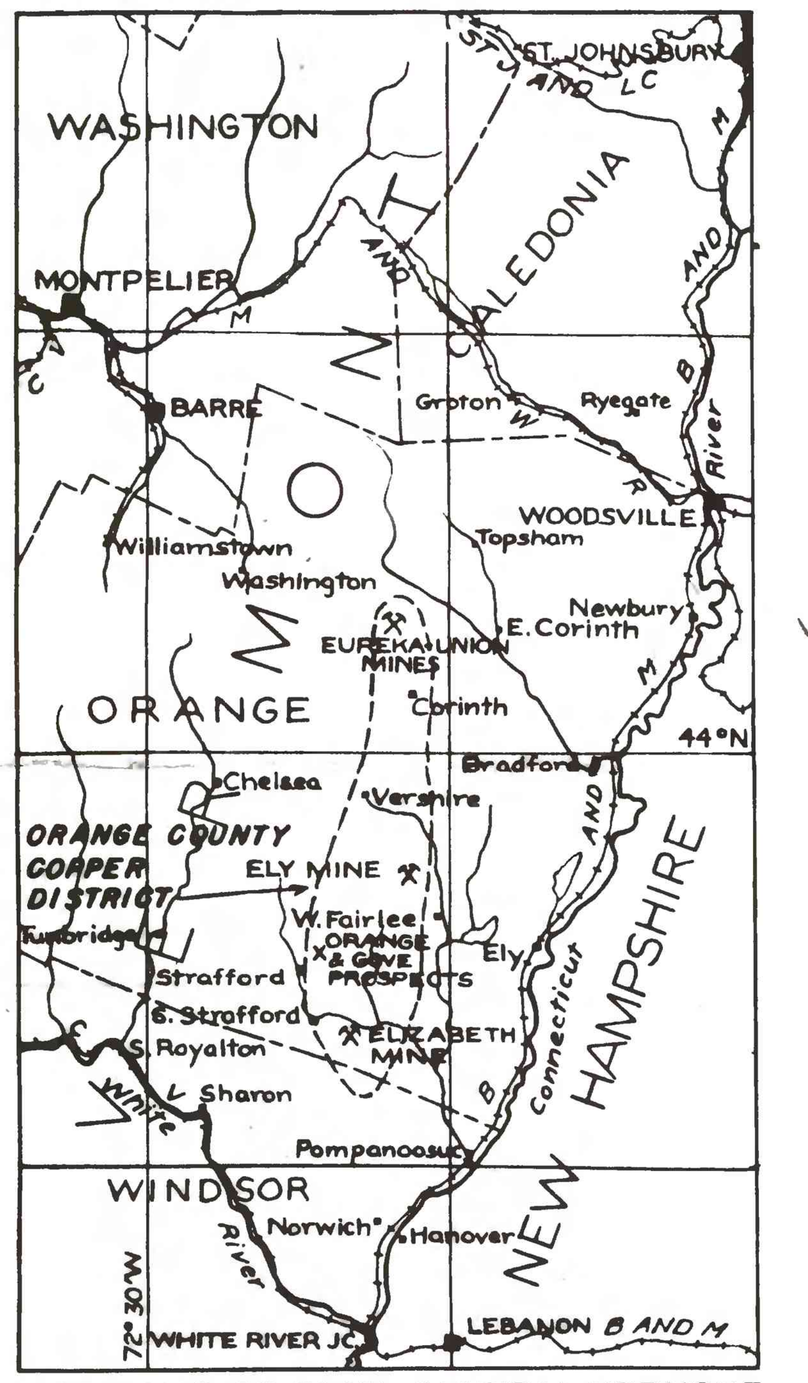
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

STRATEGIC MINERALS INVESTIGATIONS
PRELIMINARY MAP FIGURE 1



INDEX MAP OF EAST-CENTRAL VERMONT
SHOWING LOCATION OF COPPER MINES
0 10 20 Miles

Elizabeth Copper Mine

GEOLOGY OF THE ELIZABETH COPPER MINE, VERMONT

The newly reopened Elizabeth copper mine lies 1½ miles southeast of South Strafford, Orange County, Vermont. It is owned by the Vermont Copper Co., Inc., organized in 1942 for the purpose of developing this and other old mines in Orange County. A new 500-ton mill is under construction, and the mine is being newly equipped and developed for mining.

The mine was examined during the winter of 1942-43 by Walter S. White, John H. Eric, and I. Gregory Sohn of the Geological Survey, United States Department of the Interior, in the course of a comprehensive study of the Orange County copper district. The investigation is part of the Survey's program of providing geologic information that will aid in developing known deposits of strategic minerals and guide the search for new deposits. A brief preliminary account of the Elizabeth mine is presented here, in advance of a more complete report on the whole district. The Bureau of Mines, also of the Interior Department, conducted a drilling program at the mine in cooperation with the Survey, and the results thus obtained have been utilized in preparing this report.

From records of production since 1917, and from the extent of the older workings, the total production from the property is roughly estimated at 400,000 tons of sulfide ore. The 94,000 tons mined since 1917 contained on the average 2.2 percent of copper.

The rocks in the vicinity of the Elizabeth mine are metmorphosed sediments, probably of Ordovician or Devonian age. They are mainly quartz-mica schist, consisting essentially of quartz, muscovite, and biotite in various proportions, all gradations being found between schist with a little quartz to nearly pure quartzite. Small garnets are common in these rocks, and crystals of kyanite occur locally. There are also layers, up to 50 feet in thickness, of a schist that contains abundant hornblende crystals in addition to quartz and biotite. This rock locally grades into schist without hornblende, and for 2,000 feet north of the South mine (pl. 1A) the rocks mapped as hornblende schist contain a good deal of schist without hornblende. Associated with the hornblende schist is a coarse-grained garnet-muscovite schist which commonly contains long crystals of altered hornblende. A gneissic rock containing abundant rounded crystals of oligoclase feldspar is exposed in the open cut and in the southern workings of the Elizabeth mine.

The rocks have been highly deformed. The bedding is much folded, small folds being superposed upon large ones, and a well-developed schistosity strikes nearly north and has an average dip of 63° E. The bedding strikes more nearly northeastward than the schistosity and dips more steeply. The folds plunge for the most part gently northward, although some folds have horizontal axial planes, or even plunge southward. (Pl. 1A, in the open cut and to the south.) The rocks are so uniform and the schistosity so well developed that the bedding has had no important mechanical effect on the localization of the vein zone and the ore shoots.

The Elizabeth vein is in a fault that was formed after the schistosity was developed. The fault is presumably a reverse fault, but the direction and amount of movement on it are not known. The footwall of the vein is parallel to the schistosity of the underlying rocks; the schistosity of the hanging wall has been warped, probably by drag along the fault. A broad synclinal roll in the schistosity, locally broken off by a small reverse fault on its east limb, lies close to the top of the main ore body (see cross sections, pl. 3), and similar rolls of smaller size were seen locally within the ore body. The axes of these rolls generally plunge 5°-15° N. Ore deposition has been controlled by the fault zone and by the drag folds.

The ore at the Elizabeth mine consists of a massive aggregate of pyrrhotite and chalcopyrite with a gangue of quartz, silicates, and carbonate. Most of the ore mined in 1929-30 is said to have consisted of quartz, feldspar, mica, pyrrhotite, and chalcopyrite named in order of abundance. About 0.5 percent zinc, in the form of sphalerite, is commonly present, and small grains of pyrite are locally associated with vein quartz. Carbonate is abundant in places and tourmaline is common. Pale actinolite or tremolite was often seen, and hornblende may be abundant where the wall rock is hornblende schist.

Except for the carbonate, tourmaline, actinolite, and a small part of the vein quartz, the gangue minerals appear to represent unreplaced wall rock. Massive sulfide without gangue grades into schist with scattered grains of pyrrhotite or chalcopyrite, and vestiges of schistosity, inherited from the wall rock, are common even in the most massive sulfide. The composition of the vein material may be influenced by that of the adjoining wall rock. The drill cores obtained by the Bureau of Mines suggest that the hornblende schist was not readily replaced by sulfides. Where hornblende schist forms both the hanging wall and the footwall of the vein zone, as in holes BM 12, 18, and 21, there are only a few scattered thin veins and disseminations of sulfide. In holes BM 7 and 13, which went through good ore, hornblende rock lies on the hanging wall, but the unreplaced country rock within the vein zone is schist without hornblende. On plate 1B the intersection of the westernmost band of hornblende schist with the hanging wall of the vein zone is plotted from drilling data. The lower part of this intersection is probably unfavorable for ore deposition.

The sulfide seems to follow a braided fault zone, which is known to be mineralized for a strike length of about 1½ miles and for a vertical range of over 1,000 feet. Only a small part of the zone, however, contains ore of mineable width and grade. The vein zone proper is rarely greater than 80 feet wide, and the greatest width of mineable ore observed is 65 feet, though a greater width may have been mined in some parts of the open cut now covered by dumps.

At a few places along the vein, as in the Elizabeth mine, the mineralization was sufficiently concentrated in relatively narrow channels to produce, by replacement of the hanging wall, ore shoots of economic width and grade. The vein zone at such places generally contains little or no unreplaced schist and has sharp contacts with the enclosing wall rocks. In most parts of the Elizabeth mine, the footwall is well defined and consists of a smooth plane, showing no indications of fault movement, above unaltered and uniformly dipping schist. Immediately above the footwall there is either massive sulfide or as much as 6 feet of strongly altered schist, containing tourmaline, carbonate, actinolite, and disseminated sulfide. On the hanging wall, at many places, the schist is in sharp contact with massive sulfide and is virtually unaltered; at other places the boundary is transitional and marked by interfingering of schist and sulfide stringers, abundant disseminated sulfide in the schist, and, locally, intense alteration of the wall rock. The average horizontal width of the vein in the Elizabeth mine is about 12 feet.

The ore shoot followed in the mine pitches about 15° N. The top of the ore body is closely related to the synclinal roll formed by drag on the hanging wall, as shown in sections B-B' and D-D', plate 3. This roll appears to have diverted the copper-bearing solutions moving up the dip of the vein, causing them to move upward at a low angle towards the south and concentrating the flow in the part of the vein immediately below the roll. The average width of the vein beneath this roll is about 20 feet. The synclinal roll becomes smaller and ceases to act as an important channelizing agent at the depth of the 500 level, which it intersects at about 12980 N. (see pl. 2). North of the intersection, well above the roll, there are many stringers, whereas the parts of the vein above the roll, in the upper parts of the mine, are barren. The veins or vein aggregates near the north end of the 600 level are locally of mineable width, and some of the small stringers are very rich; but, because of the erratic distribution of the sulfide veins, considerable exploration will be necessary to develop substantial ore bodies in this ground. The thick veins of good ore penetrated by the old drill holes DDH 19 and 20 (see pl. 1B), however, seem to justify further exploration down the pitch.

The lower boundary of the ore shoot is an assay wall, along which the vein pinches to a foot or two in width, or splits up into a number of scattered stringers too low in grade to mine.

Within the main ore body, far below the top, there are some pinchings and swellings not controlled by a synclinal roll. One thick pod of ore, up to 25 feet in width, whose structural relations are somewhat uncertain, was mapped in three places—at the south end of the 600 level, near the inclined shaft in the northern part of the 500 level, and in the sublevel just south of the 500 level stopes (pl. 2). It pinches markedly to the north and south. The large ore body indicated by holes BM 7 and 13 is believed to be limited along its lower margin by the unfavorable hornblende schist in the hanging wall. Evidence is inadequate to determine the presence or absence of a synclinal roll along the upper boundary.

In the South mine—a long pit, largely filled with water—some massive sulfide is still exposed in the hanging wall. Holes DDH 1 and 2, drilled into the vein nearby, failed to intersect mineable ore, but there may be an ore shoot of small tonnage pitching about 35° north between the drill holes.

About 1,100 to 1,700 feet north of this pit, the presence of a shallow ore body of unknown dimensions is suggested by meagre surface exposures in old trenches and by drill holes DDH 3 and 4. Because of a thin surficial zone of secondary chalcocite, no satisfactory sampling could be done in the trenches without considerable blasting to obtain unenriched material. The longest trench, however, exposes over 40 feet of massive sulfide and schist with abundant disseminated chalcopyrite. In other trenches and small pits the exposures are poor, but some massive sulfide can be seen in the walls and dumps.

The first exploratory work at the Elizabeth mine should be directed toward the development of the main ore shoot down the pitch, and of the new ore shoot indicated by holes BM 7 and 13, which appears most probably to extend up the pitch. Much additional ore might be developed in one or both of two directions—down the pitch to the north, or down the dip. Extension down the pitch holds the greater promise, despite the unfavorable tendency toward splitting up of the vein noted on the 600 level. Presumably the main ore shoot of the Elizabeth mine was formed, in the place where it is, largely because solutions moving up the dip of a fault zone were diverted and concentrated beneath the trough of a fold plunging gently north. The existence of another such fold and diversion channel, and of another such ore body directly down the dip is very doubtful, as the fold would have prevented access of solutions to the known shoot. The ground above the best part of the Elizabeth shoot, is barren presumably for a similar reason. Below the north end of the explored part of the Elizabeth shoot, however, where mineralization appears to have been less intense, the south end of a similar shoot might be found at considerable depth. Should future development down the pitch encounter a zone in which the vein is absent, there might well be another shoot further down the dip, though perhaps at prohibitive depth. Smaller ore shoots, also, such as that revealed by holes BM 7 and 13, might lie beneath the southern part of the main Elizabeth shoot. But as the vein zone between the Elizabeth and South mines is everywhere mineralized, though only sparsely, the chance of finding a shoot as large as the Elizabeth shoot in the Elizabeth vein is not considered good.

It is barely possible that there are other large shoots at some distance south of the South mine, and at shallow depth north of the present workings, where the fold at the top of the main shoot either disappears or ceases to act as an impermeable barrier. These possibilities can best be tested by geophysical methods for in both areas the cover of glacial drift is too deep for trenching.