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I

MINERAL INDUSTRIES

Reopening of the Vermont Copper Mines

ELBRIDGE C. JACOBS

The outstanding event of geological interest in Vermont at the present time is the reopening, by the Vermont Copper Company, Incorporated, of the Elizabeth Mine, near South Strafford, Orange County. Furthermore the company is giving attention to the Ely and Pike Hill mines, north of the Elizabeth, and to minor prospects which also occur along the copper-bearing belt extending north and south over a known distance of approximately twenty miles, with a view to their rehabilitation. This enterprise was undertaken for the patriotic purpose of increasing our country's sorely needed supply of copper. In this time of "all out" war the task of bringing a long-idle mine into production, with its attendant selection of an efficient scientific personnel, procurement of priorities for the necessary materials, the giving of contracts and the coördination of the whole effort, is a formidable one. To this task Mr. George A. Ellis, ex-Governor Stanley C. Wilson, and their associates have given unsparingly of their time and efforts.

Activities along the copper belt date back as far as 1793 when the outcrop of the Elizabeth ore body was first discovered, followed in 1821 by the finding of the Ely lode in Vershire and, in 1866, of the Pike Hill deposits in the northern part in Corinth.

The Ely mine, in the central part of this belt, was the largest producer of copper and was the scene of many early events of historical and economic interest. It was here, and to a lesser extent at the Elizabeth mine, that copper production held the lead in the United States until the Michigan copper mines with their rich ores, and later the Montana deposits, gained precedence during the latter part of the last century. The significant feature of the Ely occurrence was that the ore was mined continuously to a depth of 3,400 feet along the gently-pitching orebody, or to a vertical depth of about 1,500 feet below the surface. It is worthy of note that at the Eustis mine, located just across the border from Vermont, in Canada, and possibly along the extension of the Vermont copper belt, a somewhat similar deposit of copper ore was mined down to a vertical depth of 5,240 feet. At the Elizabeth and Pike Hill mines, however, mining operations have been carried to vertical depths of only a few hundred feet.

These facts and other characteristics of the type of mineralization represented has led to the belief by engineers of the Company that the present exploration in progress at the Elizabeth Mine, and now being planned at other

localities, may result in much deeper mining, particularly in view of the modern methods of mining that are being adopted and supervised by skilled operators who have been brought from leading mining districts of the western states.

Several attempts have been made to reopen these mines since they were abandoned some forty years ago, but these in all cases have led to failure with the collapse in the price of copper, largely because of the small scale of the operations and the use of makeshift and inadequate equipment, as well as the lack of cooperative interest in keeping a potential industry alive in the State in times of adversity.

In the early days of production the extraction of the copper was possible only by roasting the raw ore, after hand picking or cobbing, and subsequently smelting the roasted product. Since that time revolutionary improvements have been made not only in mining methods (from hand to machine drilling, for example), but also in mechanized transportation, while the entire milling of copper ores has been radically changed by the introduction of selective flotation for the mechanical concentration of the copper mineral (chalcopyrite) intimately associated with barren iron sulphides (pyrrhotite) and silicates which constitute the ore as mined. In more recent years this flotation treatment has been further improved to make it possible cheaply to separate the copper-bearing minerals in the form of a high-grade concentrate, containing 25 to 30 per cent copper, that can be shipped to smelters and refineries in the New York area for the final extraction of the copper.

The present Vermont Copper Co., Inc., was organized with private capital in April, 1942, to make a systematic, thorough study of the Vermont copper belt and to develop and equip meritorious sections of it. This company has acquired full ownership of the three areas which had been the principal producers of copper in the past.

While the primary motive for this undertaking was to supply copper for the war needs, it was desired in addition to do something of real constructive value for the State by reviving an old industry in a manner which would have a reasonable chance of becoming a permanent asset. The officers are: J. V. W. Reynders, of New York City, Chairman of the Board; George A. Ellis of New York City and Bennington, Vermont, President; Stanley C. Wilson, of Chelsea, Vermont, and A. E. de Villermont of New York City, Vice-Presidents; Edward A. Ellis of Castleton, Vermont, Treasurer. The capital stock of the company is \$500,000: 4,000 shares of \$100 preferred and 10,000 shares of \$10 common.

Preliminary geological investigations were carried on early in the spring of 1942 by Mr. H. M. Kingsbury, Mining Geologist of the American Smelting and Refining Company, who was loaned to the Vermont Copper Company for the purpose. While a student at Harvard Mr. Kingsbury first became acquainted with the Elizabeth Mine in 1909, as a member of that University's mining school summer camp. Since then he has been primarily responsible for the explorations of widely scattered and now well-known copper and precious metal deposits in many countries, including Russia, Africa, India and New Guinea.

After extensive investigations last summer, both underground and on the surface, by Government experts, a contract was entered into by which the Vermont Copper Company agreed to re-equip the mines and to produce and deliver to the Federal Government 16,500,000 pounds of copper.

Messrs. R. S. Cannon and L. W. Currier, representing the U. S. Geological Survey and Mr. J. E. Bell, representing the U. S. Bureau of Mines, made early visits to the district and, in co-operation with Mr. Kingsbury, made recommendations to their respective departments to assist in the study and testing of the district. Plane-table mapping was conducted during the fall by field parties of the U. S. Geological Survey under the direction of Mr. W. S. White, while aerial photographs were made in October by the Topographical Branch. These studies are being carried through the winter months and will be continued next summer.

In addition Prof. Charles G. Doll, of the Geological Department of the University of Vermont, assisted by Mr. Carl Lucarini, also of the University, spent a part of last summer in making a study of the structural geology of the region and will resume the work in 1943.

The U. S. Bureau of Mines has recently established a new Northeastern District, with headquarters at Hanover, New Hampshire. Mr. J. H. Bardill is in charge of this office as District Engineer. The Bureau of Mines is taking an active part in exploratory work in the region and Mr. Bell, the Bureau's Project Engineer, assisted by a crew of samplers, is supervising an extensive diamond drilling and sampling campaign. The drilling is being done by the Pennsylvania Drilling Company, who have had three crews at work at the South Strafford mines and will continue this work through the winter. It is also planned to make geophysical examinations of the copper belt in order to discover possible new ore bodies.

Before the contract with the government was made, the company began early last spring and continued through the summer the preliminary arrangements to reopen the Elizabeth mine where easily accessible ore reserves were known to exist. The caved portion of the timbered entrance to the main haulage adit into the mine was cleared and the old mill building was torn down to make way for modern mine and mill structures. (Plate I.) The sites for these buildings were cleared of timber and excavations started. A large amount of planning was necessary to accommodate the personnel required for construction and operation. Houses remaining on the property and suitable dwellings in the vicinity of the mine were acquired and extensive repairs made to render these habitable through the cold winter months. It is expected that around 125 men will be employed when the mine is producing. Additional accommodations and a boarding house near the mine are to be provided. A new electric power line was required and a right of way for the construction of this line, seven miles in length, was obtained to connect the mine with the Central Vermont Public Service Corporation's nearest source of power at Union Village. This right of way has been cleared and the new line is now in the course of construction and should be completed by the end of January. The line will furnish about 1,200 kw. but is being constructed for 4,000 kw.



Plate I. Conditions at the Elizabeth Mine, January, 1943. *Above*, new buildings under construction. *Below*, the adit entrance to the workings in Copperas Hill.

to provide for possible future expansion. The voltage on this line is to be 33,000, but will be stepped down at the mine sub-station to 2,200 and 440 volts for the electric motors and to 110 volts for lighting at the mill plant and in the mine.

Early in October engineers under the direction of Mr. J. W. Thompson, of the Galigher Co. in Salt Lake City, Utah, arrived to design and commence construction of mine and mill buildings, make the necessary arrangements for tailings disposal and for the water supply which will be pumped from the Ompompanoosuc River, three-quarters of a mile distant. Mr. J. A. Norden, also from Utah, has been engaged as General Manager for the Company and has taken charge of equipping, unwatering and putting the mine into condition for the delivery of 500 tons of ore daily to the mill. This has required the re-timbering of the entrance section of the adit and the enlarging of this adit to accommodate the increased 36-inch-gauge track and larger ore trains for electric haulage than were used during previous smaller scale operations. H. M. Kingsbury, as Consulting Mining Geologist, has been retained in charge of exploration and geological studies of the district.

A new office, 30 by 31 feet; together with a warehouse, 30 by 59 feet; machine shop, 30 by 30 feet; compressor building, 30 by 60 feet; and change house for the miners, 64 by 50 feet, are nearing completion and mill construction is now well under way. (Plate I.) It is planned to have both the mine and mill ready for production early in the spring of 1943.

The mill, which will have a daily capacity of 500 tons, is being built on the hill slope about 650 feet north from the mine entrance. The mill will include separate structures: the crusher, flotation, thickener and filter buildings, and assay and mill superintendent's office. In general the mill operation will consist of primary and secondary crushing to reduce the ore to about one-half inch size. This crushed ore will then be elevated by conveyor belt to a fine-ore storage bin at the head of the flotation building in which will be installed a new Marcy ball mill and Aikens type classifier. The product from this fine-grinding unit will pass through conditioning cells and then into Agitair scavenger, rougher, and cleaner cells from which the copper concentrate will go to a thickening-tank and thence to an Oliver-filter. From the Oliver-filter the copper concentrate, containing about 10 percent moisture, will go to the concentrate bin from which it can be loaded by gravity into trucks for shipment twelve miles to the railroad station at Pompanoosuc and from there transshipped by the Boston and Maine Railroad to the New York area for smelting and refining.

When in operation the mill will produce from fifty to sixty tons of copper concentrate daily, containing 25 to 30 percent copper. At the present time the road and bridges between the mine and the Pompanoosuc station are being improved by the State, through a grant of \$75,000 given by the Federal Aid for Roads, to permit the use of trucks to carry loads of from ten to twenty tons.

The U. S. Bureau of Mines,¹ as the result of examinations made by its expert, Mr. James E. Bell, concludes that:

¹ The Elizabeth Mine, Orange County, Vermont; War Minerals Report No. 2, Bureau of Mines (November, 1942).

1. The Elizabeth Mine can produce copper at the annual rate of 6,000,000 pounds, starting early in 1943.
2. Because of urgent war requirements for additional copper, prompt resumption of operations should be expedited through financial aid and other assistance from the Federal Government.
3. Additional prospecting by diamond drilling is warranted.

HISTORICAL SKETCH OF THE COPPER MINES

Unfortunately the copper industry in Vermont produced no historian and so what records there are are fragmentary and more or less inaccurate. W. H. Weed, formerly of the U. S. Geological Survey, wrote two articles¹ about the mines and to these frequent reference has been made. Mr. James Tyson, Jr., of South Strafford, has contributed valuable information concerning the Elizabeth Mining Company which he incorporated; Mrs. Ethel C. Harding, of Vershire, has kindly consulted the town records as they concern the Ely Mine; while Prof. Evan Thomas, of Burlington, who held a pastorate in Vershire Center from 1880 to 1889, has given the writer details of happenings at Copperfield during a part of its varied history. Ex-Governor Wilson, and Mr. H. M. Kingsbury of the Vermont Copper Company have made contributions and criticisms which are invaluable. This historical matter has proved so intriguing to the writer that he has been impelled to present it, with the thought that readers may find much of interest in this phase of Vermont history.

THE MINE AT VERSHIRE

This working was best known as the Ely Mine and was the largest and most famous of the group. It lies in the southeast corner of Vershire, near the now abandoned mining village of Copperfield.

Weed states that the ore was discovered here in 1821 by farmers who were attracted by the oxidized appearance of the outcroppings. Explorations led to the formation of the Farmers Copper Company, who opened up a body of good ore and smelted it in a crude furnace. Operations were carried on with more or less success and interruptions.

This company was apparently succeeded by the Vershire Copper Mines which was owned by Henry Barnard, J. I. Bicknell, J. E. Smith, Samuel Mitchell, Fulton Cutting, and L. L. Lombard. Later, The Vermont Copper Mining Company was chartered by the Legislature and organized in 1853 by this same group. The capital stock of this company was \$500,000: 100,000 shares at \$5 par value. Of these, 96,000 shares were issued to the six organizers and the remaining 4,000 shares were sold at par to provide working capital. The company used uneconomical apparatus in the development and operation of the mine and apparently made but little money.

The name of Smith Ely, of New York City, first appears as a stockholder in the records of 1863. In 1864 he held 2,588 shares of stock and was elected

¹ Notes on the Copper Mines of Vermont; Bull. 225 U. S. G. S. (1904) and The Copper Deposits of the Appalachian States; Bull. 455 U. S. G. S. (1911).

president in 1865. The affairs of the company were not prosperous and Ely was able to pick up the shares of most of his associates at bargain prices, while he acquired an extensive acreage around the original holdings of the company. A keen business man, he soon brought the property into a condition of fame and prosperity. The Ely Mine, as it came to be called, became practically a family affair. During one year of his régime a dividend of \$100,000 (20 percent of the par value of the stock) was paid, while salaries to himself and other members of his family were for those days, large. It is said that at one time Smith Ely was offered \$1,250,000 for the property but refused it.

Many stories are told of the palmy days of this mining camp: of the great prosperity of Copperfield, as the mining village was called (the name still appears on the Strafford topographical quadrangle), and its several hundred inhabitants, of the desert condition of the region, caused by sulphur dioxide fumes from the roasting beds; of the changing of the name of the township to Ely, in 1880, owing to the efforts of the picturesque E. Ely Goddard (a grandson of Smith Ely) who represented the town in the Legislature, drove his coach-and-four and entertained lavishly; of the three-day "Ely war," in 1883, when the miners rioted because of over due wages and the militia was called out to restore order. The crash came on July 3, 1883 and the company became bankrupt.

To go back somewhat, Smith Ely, in 1882, had deeded the property, with the exception of the company store, to E. Ely Goddard and F. M. Cazin who therefore were the owners when the enterprise collapsed. In September, 1883, Judge Samuel L. Gleason was appointed receiver and the next year the Court ordered the property sold at auction. F. M. Cazin bid it in for \$36,000, but assigned his interests, in 1888, to Otto K. Krause, of New York City, who proceeded to rehabilitate the mine. The plant was remodeled and a 100-ton concentrator was installed at a cost of \$53,000. In spite of the large investments and considerable production the enterprise was short lived, the plant was shut down in 1892, and the Vermont Copper Mining Company, as it continued legally to be called, again went into receivership.

On December 8, 1899, George Westinghouse, of electrical fame, bought the property and expended a large amount of money in experimenting with new methods of ore treatment but without success. In January, 1917, the property passed to Agnes P. Bennett. It was transferred, indirectly, to the Vermont Copper Company in April, 1942.

At some time after the Westinghouse occupation, owing to the heavy taxes imposed by over zealous assessors, the plant was demolished, the miners' houses removed or torn down, and the village of Copperfield ceased to exist.

During the first world war H. W. Bennett formed a company called the Ely Associates, who built a flotation mill in 1918 and worked over the Ely dumps. The mill was operated for ten months and, during this time, worked over about 19,000 tons of dump material, which averaged 1.34 percent copper; recovery was 67 percent.¹ Due to various circumstances, including a poorly-

¹ War Minerals Report 2.

designed mill, the use of second-hand machinery, and the inaccurate sampling of the dumps, the company soon ceased operations and another chapter in the long history of the mine closed.

PRODUCTION

According to Weed, the average composition of the Copperfield ore was: copper, 3.31% ; iron, 30.39% ; sulphur, 14.71% ; insoluble matter, 36.57%.

The same writer gives the production of the mine, under its various owners, as follows:

Copper ore shipped. 1854-1860.....	3,270 tons
1861	1,812 tons
1863	1,430 tons
1865	1,430 tons
Total	7,942 tons

Metallic copper produced in 1870, 943,465 pounds.

Amount of pig copper produced from 1872 to 1882, 25,000,000 pounds.

Copper produced in 1890, 7,500,000 pounds.

Assuming an average of 3 percent copper in the "Copper ore shipped," we get a total of over 33,400,000 pounds of copper produced by the Copperfield mine.

THE ORE

The ore at Copperfield is chalcopyrite (CuFeS_2 , sulphide of copper and iron) disseminated in pyrrhotite (Fe_7S_8 , one of the sulphides of iron) and containing some pyrite (FeS_2) sphalerite (ZnS , sulphide of zinc) and from 0.44 to 1.28 Troy ounces of silver per ton.

Again quoting Weed, the ore bodies consisted of several overlapping lenses, "en echelon," with their long axes "striking," or extending, north and south, "pitching," or slanting downward to the north at an angle of about 25 degrees with the surface, and "dipping," or sloping, about 24 degrees easterly. These lenses averaged 100 feet in horizontal extent, 10 feet in thickness, and from 100 to 300 feet along the "dip." The total depth is unknown, but the inclined shaft, which was probably driven parallel to the "pitch," was 3,400 feet long. This would give the vertical depth of the end of the shaft below the surface of 1,580 feet.

DEVELOPMENT

The upper lens was opened by an inclined stope,¹ sunk in the ore and worked by the underhand-stoping method. The stope was 3,386 feet long; the average width, about 100 feet; average height, about 10 feet. When one lens pinched out, a "winze"¹ was sunk to the top of the underlying lens which was then opened up and mined. This happened four or five times in the history of the mine. Further details are lacking.

¹ See p. 15.

REDUCTION WORKS

In smelting sulphide ores a large part of the sulphur must be eliminated. This was done in the old days by burning (roasting) the ore in heaps or within rectangular walls, open on top, called stalls. Of course the roasting increased the copper content of the ore—and killed the vegetation in the immediate vicinity of the roast-beds, giving the "desert condition" mentioned above. The roasted ore was then smelted to a "first matte" (a double sulphide of copper and iron). This first matte was then presumably reroasted, further to increase the copper content, and again smelted to impure, "black-copper" which was then ready for the refinery. Details of these processes as carried on at Copperfield are fragmentary but Weed states that the ore was first smelted in twenty-four-brick "reverberatory"¹ furnaces, of a type that was developed at Copperfield and was called the Vershire furnace. Later, water-jacketed blast furnaces² were employed in place of the reverberatories.

In 1901, while visiting the mines and smelting works at Freiberg, Saxony, the writer met a metallurgist who, many years before, had been employed at Copperfield during the Ely régime. He talked interestingly of the old days at the Ely smelter.

Plate II, taken from the 1901-02 Report of the State Geologist, Prof. George H. Perkins, gives an interesting view of the smelter buildings as they existed during the prosperous days of the Ely mine.

THE CORINTH MINES

This old group of mines lies in Corinth Township, some eleven miles north of Copperfield, on a continuation of the mineralized belt, with the same character of ore but in a more gneissose country rock. The ore bodies make up a series of lenses which lie at different depths "en echelon." The group includes:

1. THE UNION MINE

Again quoting Weed: "The Union mine was first opened in 1866. Production from then up to 1881, inclusive, amounted to 31,504 tons of ore, averaging about 9 percent of copper." (Whether the ore was that rich or was sorted, or "cobbed" to bring up the copper content is not stated.) In 1878 the property was bought by Smith Ely, who shipped the ore to the Copperfield smelter. In 1879 and 1880 a total of 5,712,604 pounds of "fines," carrying 2.7 to 4.5 percent of copper were so shipped. In 1879 the first Vermont Copper Company was organized by the same interests, and mining and shipping were continued till 1889.

¹ A reverberatory furnace consists of a long, narrow basin or hearth, separated from the combustion chamber, at one end, by a low partition, called the fire-bridge, and ending in a chimney at the other end. The roof of the hearth pitches downward towards the chimney so as to concentrate the heat. A sea of flame, from the long-flaming coal, passes across ("reverberates") the ore, spread upon the hearth and mixed with such fluxes as may be needed, and smelts it to matte by radiated heat.

² A blast furnace, generally speaking, is an upright cylinder, constricted at its lower end to form the crucible, which is water-jacketed. Above the crucible a blast of air is driven through several radial openings, called tuyères intensifies the combustion of the fuel and by its reducing action, the copper, iron, and sulphur contents of the ore form a "matte." Ore, fluxes, and coke, in proper proportions, are mixed and fed into the upper part of the furnace, which is kept full, while the resulting matte and slag collect in the crucible: the matte above and the slag below. These products are drawn off at intervals and the matte is further treated.

DEVELOPMENT

Weed states that the property was developed by an inclined shaft 900 feet long, or 766 feet below the adit level. Down to a depth of 300 feet four overlapping ore lenses (or shoots), were worked by winzes sunk from the main lens. Selected ore showed 8.15 percent of copper, 0.3 ounces of silver per ton, and a trace of gold. The lenses had a north-south direction ("strike"), sloped ("dipped") 30 degrees easterly, and had an average thickness of eight feet.

2. THE CUPRUM AND EUREKA MINES¹

The ore bodies of these mines lie south of the Union; the Cuprum, near the summit of Pike Hill. Nothing seems to be known about the beginnings of the Cuprum but in 1860 it was taken over by the Corinth Copper Company who sunk an inclined shaft in the ore body and opened it up to the north and south. An adit,² 1,000 feet long, was driven at the lower level to intercept the lode and this, when found, was called the Eureka mine (*Eureka*, Greek for "I have found it"). The adit met the upper (Cuprum) lens near its lower end, where it was pinching out, and, this proving discouraging, very little work was done on it, chief attention being given to the thicker part of the lens. This was worked intermittently till 1889. Weed states that selected samples of the ore contained 19.65 percent copper and 0.76 ounce of silver per ton.

In 1904 Knox and Allen, mining engineers of New York City, acquired the property for private interests and started further development work. This showed that there was another lens lying in line with the strike of the Cuprum but about twenty feet below it. This new lens was opened up and a body of high-grade ore discovered. The combined length of the two bodies proved to be about 900 feet. A third lens was subsequently found below the second.

Mining operations were started on a large scale in both the Cuprum and Eureka lodes. The high-grade ore was hand sorted (cobbed) and shipped to New York smelters, while the lower grades were stored for future mill treatment.

The Pike Hill Mines Company³ was incorporated in 1906, with James G. Pirie, president; Ernest M. Bowen, vice-president; and Harry G. Hunter, general manager.

The company's freehold included the Union, Cuprum, and Eureka properties, aggregating 215 acres, together with the mineral rights of an additional 185 acres. The equipment included hydroelectric power, compressor, coarse crushers, Hardinge mill, a 100-ton flotation plant, Oliver-filter, etc.

PRODUCTION

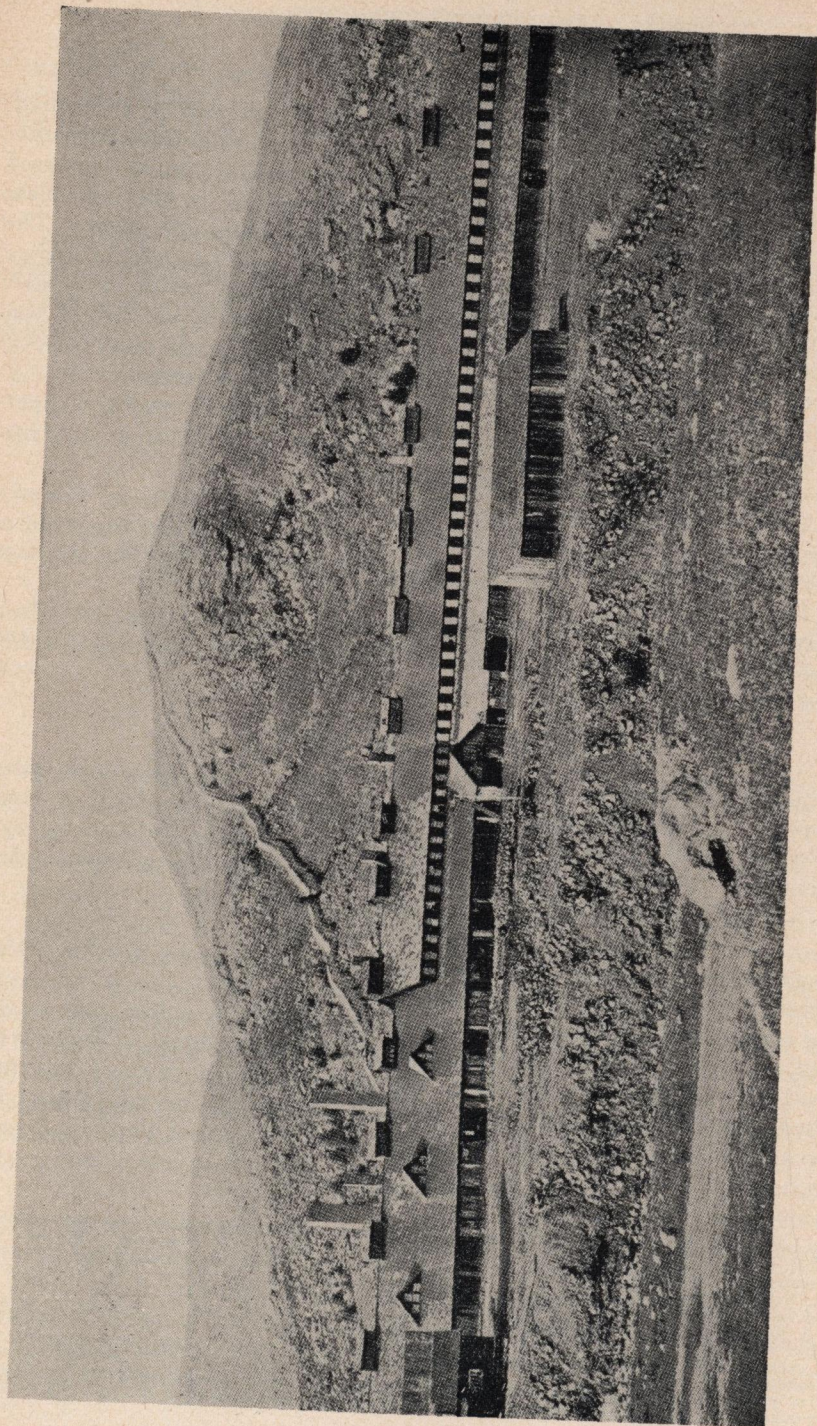
Production in 1905 was 131,911 pounds of copper; in 1906, 304,377 pounds of copper and 1,698 ounces of silver; in 1907, 425,367 pounds of copper and 2,292 ounces of silver.

¹ E. C. Jacobs: Copper Mining in Vermont; 10th Rep. Vt. State Geologist (1915-16).

² See p. 15.

³ From the Mines Handbook, vol. 18, part 1 (1931).

Plate II. The old Ely smelter building at Copperfield. The Ely Mine entrance is near the top of the hill, From The Vermonter.



For reasons not stated the company was inactive from November, 1907, till October, 1915. Then experiments with the Wood flotation process were carried on. In 1916 Mr. Hunter informed the writer that the experimental runs were satisfactory and that this type of concentration would be adopted. The Handbook states that the flotation plant was completed in 1917. Production in the following year was 509,654 pounds of copper and 2,056 ounces of silver. Presumably this resulted from the shipment of the concentrates to a smelter.

The mines were closed early in 1919 owing, no doubt, to the fall in copper prices with the end of the year.

As far as the writer is informed the Corinth mines have been idle ever since. They were purchased by the present Vermont Copper Company in 1942.

MINING OPERATIONS AT SOUTH STRAFFORD

These mines form the most southerly group on the mineralized belt, already noted, and are situated in Copperas Hill,¹ one and one-half miles south of South Strafford village and about seven miles south by east of Copperfield.

The ore which, like that of the northern deposits, consists of chalcopyrite disseminated in pyrrhotite, was first used for the manufacture of copperas ($\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$, hydrous iron sulphate), in 1793. It was mined in the open cut at the south end of the great ore body which was later to be worked for copper. This open cut, some 1,200 feet long, was known as the Foster-Cleveland property and, from its ore, copperas was manufactured and shipped by teams to Boston for many years.

On June 9, 1830, Isaac Tyson, Jr., bought the mineral rights north of the open cut and began mining operations. From then to 1883 the ore was heap-roasted and smelted for copper in reverberatory furnaces. It is said that seven smelters were built at different times and some 250,000 tons of ore were treated.²

In about 1881 James W. Tyson, Sr. (then president of the Tyson Mining Company of Baltimore, Md.), acquired the property in fee and incorporated the Elizabeth Mining Company (named for his wife). Being refused entrance to his mine through the Foster-Cleveland land, he sank a shaft near the southern end of his property and mined the ore, which was "cobbed," or selected, to bring the copper content up to 4 or 5 percent, and shipped to smelters in Connecticut. Later, under the management of his son, James W. Tyson, Jr., two water-jacketed furnaces were erected to produce copper matte and this was refined in a reverberatory furnace to "black copper" of 96 to 98 percent purity.

In about 1885, after the failure of the French Syndicate, which had apparently maintained an artificial price for the red metal, copper dropped to eight cents a pound and maintained a low level for many years. The company failed, James W. Tyson, Jr., was appointed receiver and, in 1907, he sold the Elizabeth

¹ There is another Copperas Hill, in Shrewsbury, Rutland County, where copperas was once manufactured from the iron pyrite deposits there.

² Taken from Sidney A. Mewhirter's Report to the National Copper Corporation (1930).

Mine to August Heckscher of New York City. Heckscher also acquired the Foster-Cleveland and other properties in the neighborhood. He started operations under the name of The Strafford Mining Company but later discarded that designation and incorporated the Anham Realty Company (named for his wife and daughter). Mr. Heckscher built the dam on the White River, below Sharon Station, and a power plant and lines to carry the electricity nine miles over the ridges to the mine, but these were destroyed by the flood of 1927. At one time, Heckscher was experimenting with an electric process of smelting, one which had been successfully used by the New Jersey Zinc Company, but for some reason it was not a success.

During the period of the Heckscher activity, according to Mewhirter, "Pyritic smelting was tried¹ in a 300-ton blast furnace, but this was destroyed by fire in 1909, a few months after being blown in. Another blast furnace, of 200 tons capacity, was built the same year and operated for two weeks, when the main flue collapsed and smelting operations were again discontinued. A branch railroad was also projected at this time."

"More systematic underground development was started during this period, including about 9,000 feet of diamond drilling to prove the continuity of the ore body. But after the last smelter failure the property remained idle until 1916, except for some diamond drilling in 1912-13." "In 1916 pyritic smelting was again attempted, under the direction of (Professor) G. A. Guess, of Toronto. After a thirty-six-hour run a spout failed and operations came to an abrupt stop. Since there was no spare spout on hand smelting was not resumed and this marked the end of attempts to smelt this ore."

"In 1916-18 (during the first world war) some diamond drilling was done and, in the latter year, the old magnetic separation plant was remodeled into a 100-ton flotation plant by the General Engineering Company. A six-foot by 22-inch Harding mill, Door Classifier and Callow cells (rougher and cleaner) were installed. The plant operated with this equipment till April, 1919, when a second unit was added to raise the capacity to 200 tons a day. (Mr. N. O. Lawton was the mining engineer during this period.) Considering the status of differential flotation at this time, the results were very satisfactory, but the drop in copper prices after the war caused the property to be shut down."

"After remaining idle till 1925 the property was leased to The American Metal Company, of Vermont, who added a 16-cell Minerals-separation machine to the equipment. About 20,000 tons of ore were mined and 1,756 tons of 18 percent copper concentrates were shipped during a six-months run. Again the drop in copper prices prohibited further profitable production at the existing scale of operations and the company cancelled its lease."

"In 1928² the National Copper Corporation was incorporated, with LeRoy M. Gross, of New York City, president; Frederick W. Foote, vice-president; Sidney A. Mewhirter, manager. In the fall of 1928 this company took over

¹ Pyritic smelting employs the sulphur of the ore as a partial or total fuel and so avoids roasting as a preliminary to ordinary smelting.

² The Mines Handbook (1931).

the property on a twenty-year lease. "After remodeling the mill and installing new machinery in the grinding section, operations were started in April, 1929, and continued till June, 1930, when the drop in copper prices (following the business collapse) necessitated a shut-down. The 50,000 tons of ore mined and milled during this period may properly be considered as an experimental test run to determine a basis for permanent operations when copper should recover its normal price. The run also provided a basis for estimating the possibility of sulphuric acid manufacture from the pyrrhotite in the ore."

PRODUCTION

In his report, Mewhirter wrote: "It has been estimated that 330,000 tons of ore have been removed from the Elizabeth-Foster-Cleveland mines since mining operations began in 1793." In a personal communication Mr. Kingsbury reduced this figure to 320,000 tons and stated that this tonnage came mainly from the underground workings of the Elizabeth mine. These 330,000, or 320,000 tons, included about 20,000 tons mined during the American Metal Company's operations on the Elizabeth ore body and 50,000 during the National Copper Company's lease. James Tyson, Jr., is the authority for the statement that the ore mined during his régime did not average more than 3 percent copper. Using his figure the total copper content of the 320,000 tons of ore would amount to 19,200,000 pounds.

As one reads the history of operations on the Elizabeth ore body he is impressed with the many vicissitudes that attended reduction and marketing operations. It would seem that the mine has never had a fair chance to show its commercial possibilities.

THE ORE

Like the Copperfield and Corinth ore bodies, the Strafford lode consists of chalcopyrite disseminated in pyrrhotite, a small amount of zinc, as sphalerite, and silver up to 0.2 Troy ounce per ton. Mewhirter states that 7,000 tons mined during March, 1930, gave the following analysis:

Copper	2.29%
Zinc	0.32%
Iron	36.40%
Sulphur	23.02%

The average copper content of 60,000 tons, mined in 1929-30, was 2.11 percent. He calls attention to the value of the sulphur and iron as sources of sulphuric acid and iron sinter. The ore body is present in the form of great ore shoots, lying concordantly with, or penetrating, the country rock. This country rock is, generally speaking, a quartz-biotite schist, containing also garnet, sillimanite, rutile, pyrrhotite, calcite, and other minerals. The strike of the lenses is north-east; the dip, 60 to 65 degrees easterly; and the pitch, about 25 degrees to the northeast. The Elizabeth lode can be traced for about a mile along the strike.

DEVELOPMENT¹

The Elizabeth mine has been opened by two shafts,² a series of levels, stopes,³ raises,⁴ and an adit,⁵ or entrance level.

The shaft which James Tyson, Sr., sank in 1881 was abandoned and an adit (Plate I) was driven from a point near the mill, westward into the mountain side to cut the 'D' level and provide a haulage route for the mine cars. This adit was seven feet by nine feet in section and 1,360 feet long, with an average grade, easterly, of 2.25 degrees. A 28-inch-gauge electric locomotive hauled the loaded mine cars to the ore bins at the mill. The old workings above the 'D' level connected with the Foster-Cleveland open cut and provided additional access to the mine. The 'D,' also called the "225-foot," and "the haulage," level extended 620 feet south of the adit entrance and 230 feet north. The larger part of the ore thus far mined has come from above this level.

"On the 'D' level, 25 feet north of the adit entrance, a 30-degree inclined shaft was sunk 810 feet, to a point of 330 feet vertically below the 'D' level. From this shaft levels were driven at 90 feet (the 'E' level), 220 feet ('G' level), and 310 feet ('H' level) vertically below the haulage level. The 'E' level has been driven 400 feet to the south and 140 feet to the north of the shaft. Raises (or winzes⁶) connect it with the haulage level. The 'G' level has been driven 190 feet south and 290 feet north. In the north section some stoping has been done and 'raises' driven to a sub-level, between the 'E' and 'G.' Since the 'E' level does not extend over the 'G' to the north, no raises connect them. The bottom ('H') level, extends 900 feet north of the shaft ending in a 'face' containing narrow veins of high-grade ore. A horizontal diamond drill hole had been driven 250 feet north into this face. When operations ceased, June, 1930, a raise to connect 'H' level with that next above was being driven, preparatory to stoping operations."

From the south end of the haulage level to the north end of the lowest level the horizontal distance is 1,800 feet.

Some 3,000 feet of diamond drilling was done underground and about 13,000 feet, from the surface, the latter to delimit the ore body.

ORE RESERVES

Mewhirter's Report gives the following estimated tonnage so far developed (blocked out) in the mines: Positively developed (ore "in sight"), 233,000 tons, analyzing 2.7 % copper, 31.60% iron, 18.7% sulphur. Ore estimated as the result of diamond drilling: in the Elizabeth Mine, 530,000 tons, analyzing 2.25% copper, 24.35% iron, 13.50% sulphur; below the Foster-Cleveland open cut, 802,000 tons, showing 1.35% copper, 26.0% iron, 15.0% sulphur. Total

¹ Most of this information has been taken from Mewhirter's Report.

² Shafts, in mining parlance, are openings driven downward, either vertically or slopingly into or near an ore body. Levels run horizontally from the shaft into the ore body at various distances below the surface.

³ Stopes are step-like excavations driven in the ore for the purpose of mining it; overhand stopes are driven upward; underhand, downward.

⁴ Raises are short shafts driven from below, from one level to another, upward.

⁵ An adit is a tunnel open at only one end.

⁶ A winze is a short shaft connecting levels or driven to the surface for ventilation.

reserves, thus far indicated, 1,565,000 tons, averaging 1.76% copper, 26.25% iron, 15.10%, sulphur.

In April, 1942, the newly incorporated Vermont Copper Company bought the Foster-Cleveland and Elizabeth mines. Extensive drilling operations on Copperas Hill, now in progress, are very satisfactory and the success of the new company seems assured.

ESTABLISHED MINERAL INDUSTRIES

The six basic mineral industries of the State: asbestos, granite, limestone, marble, slate, and talc, have been variously affected by war conditions.

The asbestos industry has been extremely active during the past two years, with the Vermont Asbestos Mines, a division of the Ruberoid Company, running three shifts. Asbestos is an essential war mineral and is in great demand, especially for brake linings and brake blocks for mechanized war equipment, but also in the construction of buildings for the army and navy and in moulding compounds. An enormous tonnage of asbestos-bearing serpentine is being quarried and milled on Belvidere Mountain, while the old Gallagher property, to the east, which was acquired several years ago, is being developed for future use. Vermont is the largest producer of asbestos in the United States.

The granite business is holding up surprisingly well. In 1941, the latest year for which data are available, the industry was, as regards output, better than in 1938, 1939, and 1940. The number of operators remained the same, the number of days worked increased, while the average daily wage increased about 5 percent.

The lime business, judging from the only report that has been received, is operating at about 80 percent of normal, this largely due to conditions in the paper industry which uses a great deal of Vermont lime.

The Vermont Marble Company has gone extensively into war production work and, for this purpose, has reorganized its marble-cutting machinery for the manufacture of machine tools, engine bed-plates, winches, and submarine parts. The company's subsidiary, The White Pigment Corporation, has been extensively developed.

The slate industry is at a low ebb and is operating at only about 10 percent of normal. Most of the quarries are closed. Slate is not a war industry and building restrictions are severe.

The talc companies are operating at 75 or 80 percent of normal. One company reports that about half its product is going into materials for the war effort—paint, paper, roofing, textiles, etc.—while another concern finds a market for its product in the coated-wire and cable industry. The critical condition of the rubber situation has greatly restricted the use of Vermont talc.

Vermont possesses in the Bennington region one of the largest kaolin deposits in the East. It is, unfortunately, contaminated with fine, graphitic matter which, so far, has not yielded to beneficiation. The clay has been used by the General Electric Company for insulator purposes and, by other concerns, for the manufacture of face-brick. When the present bauxite deposits,

which are the chief source of aluminum production, are exhausted or depleted, it is probable that kaolin will be used in their place; hence our deposits may be considered reserves for the future.

Mr. Leon Bushey, of Monkton Ridge, continues to produce a small tonnage of kaolin which is largely used by the Rutland Firebrick Company.

THE QUEST FOR NEW SOURCES OF MINERALS

MICA

An extensive search for mica (muscovite) for war purposes has been made but without success; it is doubtful if we have any good deposits in the State.

FELDSPAR

In Grafton Township Mr. A. F. Moriglioni discovered an enormous deposit of feldspar on the land of Mr. O. K. Rounds, which is on the Bartonsville Road, five miles from Chester. This is a pegmatite deposit containing only a small amount of quartz and very little mica. The feldspar is pink and white, with an iron content (the mineral pyrrhotite) of about 1.29 percent, which is too high for ceramic purposes. It might find use for soap powders and other purposes.

POULTRY GRIT

A good deal of poultry grit is used in Vermont and it has been obtained from dealers outside the State: from the Mica Crystal Company, of Warren, N. H., and from dealers in the West. But there is no good reason why the grit cannot be made from Vermont rocks. The Wells-Lamson Quarry Company, of Barre, is now offering a product made from their granite waste.

The Mica Crystal Company of Warren, N. H., is grinding a biotite-mica-gneiss for their grit. Probably an equally good gneiss, which occurs in large quantity along the road from Chester to Grafton, could be used.

QUARTZ

Mr. Frank B. Howard, of Randolph, owns a large deposit of very pure, translucent quartz which has been passed upon by New Haven, Conn., dealers and found acceptable. The only question is the freight rate, and this is a serious one for many Vermont mineral products; for naturally dealers will favor nearby sources of supply unless the more distant sources are of sufficiently superior quality.

QUARTZITE

The Cheshire Quartzite formation, which extends from western Massachusetts up along the Green Mountain front, is a very dense, gray, rock which, cut into blocks of the requisite size, should make an excellent abrasive for Hardinge or other grinding mills. There is an excellent outcrop along the road from East Middlebury to Ripton which could be used for this purpose.

QUARTZ SAND

In places the Cheshire quartzite is found disintegrated into very pure, white sand for which uses should be found: for abrasives, glass making, and other purposes. Swan and Baker, grocers, of East Dorset, own a large deposit of this sand and there are other deposits in the neighborhood.

MANGANESE

The largest deposit of manganese ore ever found in Vermont is that at East Wallingford. The ore consists of iron and manganese minerals occurring in pockets of yellow, gray, and white clay. The ore was worked for its iron contents as early as 1820 and smelted at Troy, N. Y. The Carnegie Steel Company worked the deposit, which became known as the Kinny-Cobble Mine, for manganese in the late 1880s and early 1890s, and shipped probably 20,000 tons. How much ore still remains underground has not been determined but, since the U. S. Geological Survey, which is acquainted with the deposit, has not thought it expedient to investigate the deposit, it is doubtful if it could be successfully rehabilitated.

In South Lincoln there is surface evidence of manganese mineral (probably wad) on the land of Mr. C. C. Hubbell. This deposit was investigated by the U. S. Bureau of Mines, whose report has not been made public. It is of doubtful value. Several other small deposits of manganese minerals have been brought to the writer's attention but have not been investigated. It should be borne in mind that the investigation of an ore deposit is an expensive undertaking so that, in order to be successful, the deposits must be large and rich enough in economic minerals to warrant the outlay.

TALC

In Bridgewater Center, on Freestone Hill, there appears to be an enormous deposit of talc. Surface showings are of low grade, but such deposits generally improve with depth. However, this one is four or five miles up a country road from the highway and is probably too distant from a railroad to have commercial possibilities.

ZINC - LEAD ORES

Sixty-five or seventy years ago a deposit containing galena and sphalerite was mined on Lyon Hill, Leicester; a shaft was sunk some fifty feet deep and an unknown amount of ore was mined. During the summer and fall of 1941 the St. Joseph Lead Company, of New York, did extensive core-drilling from Lyon Hill eastward to the Fay farm. They found good ore but the width of the vein did not warrant further investigations.

IRON ORES

In the first half of the last century a good many small iron ore deposits were worked and the ore smelted in several small, stone furnaces: The Granger

Furnace at East Pittsford; Conant's Furnace, in Forestdale, near Brandon; the Tyson Furnace (built by Isaac Tyson who first opened the Elizabeth Copper Mine, at South Strafford) in Ludlow; and the Pittsford Furnace. Some of these old furnaces are still standing and are metallurgical curiosities.

Deposits of iron ore were worked in Stamford, east and west Bennington, Shaftsbury, Manchester, Wallingford, Tinnmouth, East Pittsford, Brandon and Forestdale, Plymouth, Cuttingsville, Chittenden, Ludlow, and perhaps in other places. To what extent these deposits were exhausted could not be told except by unwatering the old shafts (and probably retimbering them) and exploring the workings—expensive operations. If Federal aid can be obtained the most promising deposits, notably those at Pittsford and Ludlow, will be examined during the coming field season.

SCHOOL COLLECTIONS OF MINERALS AND ROCKS

The State Geologist has gathered and, with the aid of N. Y. A. students, has prepared some fifty sets (twenty specimens each) of common minerals and rocks, very largely from Vermont sources, for distribution among the high schools and academies of the State. Each set will be accompanied by an explanatory pamphlet. Distribution now awaits suitable boxes with compartments for the specimens, in order that they may not get lost. Such boxes have been promised by the Department of Education but have not been received.