
Vermont's Elizabeth Copper Mine: The Tyson Years, 1880–1902

by Johnny Johnsson

The Elizabeth Copper Mine in South Strafford, Vermont, has an appealing history. Its story begins with the initial discovery of a sulphide ore body in 1793 and concludes with its final closing in 1958. Accounts of early smelting operations during the 1830s, as well as more recent mining operations conducted during and after the Second World War, have been researched and published previously.¹ Yet another little-recognized period of operations occurred when members of the Tyson family and their associates attempted to develop the mine into a significant producer from about 1880 to 1902. This paper recounts some of their hardships and several of their successes in developing the mine and smelting its difficult pyrrhotite ores, including their use of chromite-refractory lined water-jacketed furnaces.

Copperas and Copper, Early Developments

The rusty gossan outcrop of a massive iron sulphide ore body on Copperas Hill near South Strafford, Orange County, Vermont, was reportedly discovered during the annual maple sugar harvest in 1793. In 1809, investors formed the Vermont Mineral Factory Company to manufacture ferrous sulphate, then known as copperas. Manufacturers used copperas in the production of dyes and inks and as a mordant in the tanning industry. The Vermont company roasted and then leached piles of pyrrhotite ore with water, while gathering sulphate-enriched rainwater runoff from the mine in a central gully cut in the bedrock. The operation collected the resulting liquids in wooden troughs, transferred them to vats lined with sheets of lead, then boiled them down until the copperas crystallized. Workers packed this coarse, green, crystallized material into barrels for shipment, mostly to Boston. U.S. President James Monroe recognized the importance of this industrial undertaking, visiting the works during his tour of New England in 1817.²

The mine's ores contained irregular quantities of copper-bearing chalcopyrite. Therefore, the copperas manufactory was also able to recover some copper value from its leaching solutions by precipitating cement copper onto scrap iron. Around 1830, the company erected small furnaces for smelting roasted copper ores, using charcoal for fuel and waterpower from the adjacent Ompompanoosuc River to generate an air blast. At about the same time Isaac Tyson, Jr., the Baltimore Quaker chromium industrialist, became a partner in the copper venture with the Binney family of Boston. Tyson and his young family made the long move from Maryland to Vermont by steamboat and stagecoach.³

In 1833 and 1834, Tyson supervised the copper-smelting operations, including production by eight small German-style furnaces. As early as December 1833, Tyson conducted pioneering experiments in one of his furnaces, using anthracite coal and a hot-blast apparatus to smelt copper. He was granted a patent for his process in April of 1834, but could not sustain the copper enterprise financially in the uncertain economy of the 1830s. Although the establishment produced a substantial amount of copper by the standards of the day, it ceased smelting copper

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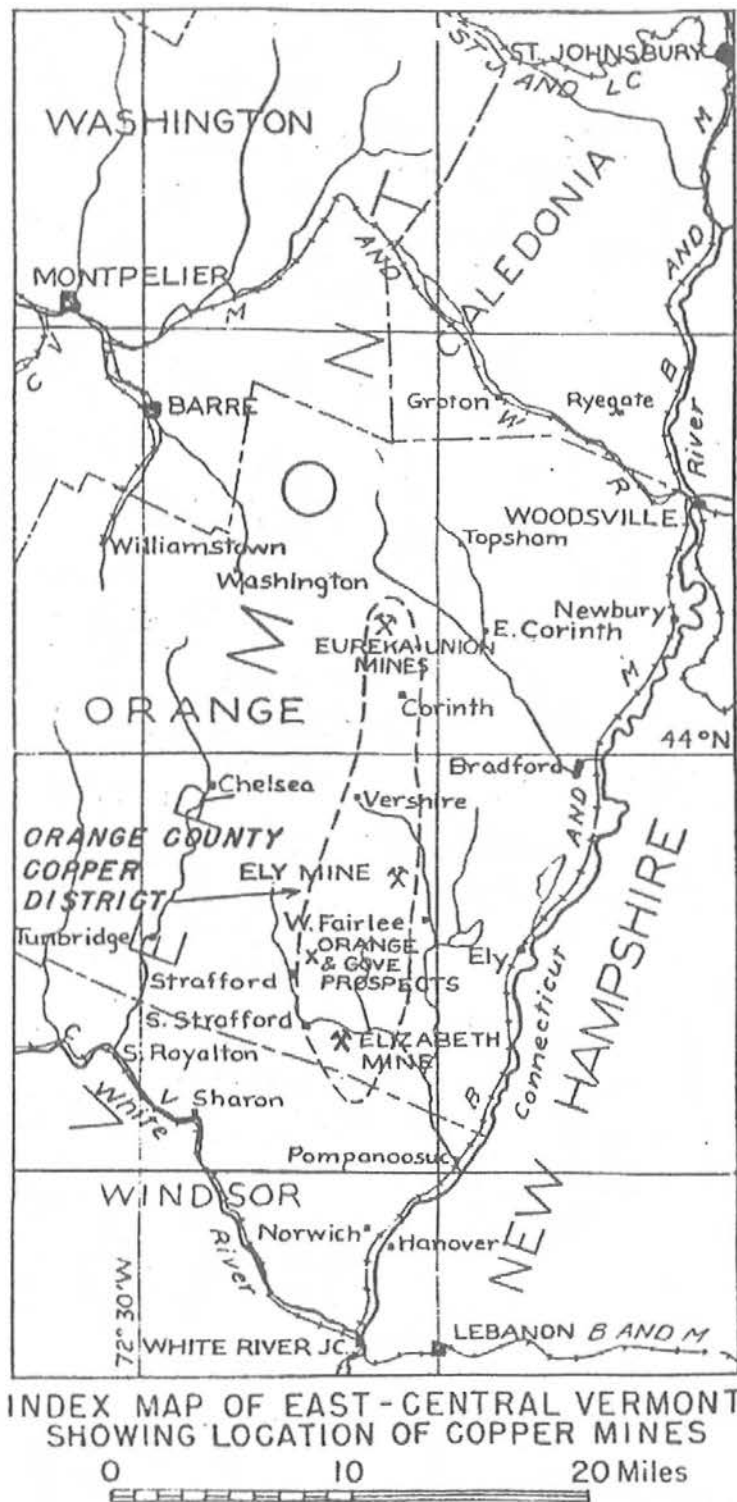


Figure 1: Location Map. The Elizabeth Mine is located in the southern part of the Orange County copper district in east-central Vermont. (W. S. White and J. H. Eric, *Preliminary Report on the Geology of the Orange County Copper District, Vermont*, (Washington: U.S. Geological Survey, 1944), Figure 1.)

by 1839. Still, the Tyson family retained their ownership of a half-interest in the mineral rights to a portion of the extensive ore deposit on Copperas Hill.⁴

Isaac Tyson, Jr. died worth nearly a million dollars in 1861. He had trained two of his sons, James Wood Tyson and Jesse Tyson, in the copper and chrome businesses. They had learned how to conduct assays and how to negotiate mineral leases and business deals. Both became skilled in applying technology to mining and ore processing. Being Quakers, both attended Haverford College near Philadelphia, Pennsylvania, between 1841 and 1843. They also served as trustees over the family's estate and as officers in the various companies created to continue the business enterprises initiated by their father. Jesse, born in 1826, played a minor role in the copper business. His main focus was on the Baltimore Chrome Works, where, as president and



Figure 2: Marble bust of Isaac Tyson, Jr. (1792-1861). (Courtesy of James W. Tyson, IV.)

majority stockholder, he continued the domination of the chromium chemicals industry begun by his father. James, two years younger, became president of the Mineral Hill Mining Company and the Tyson Mining Company, producers of copper ore and chromite, respectively. James had gained valuable experience in his youth working in his father's hot-blast iron furnace, established at Tyson, Vermont, in 1837. Through the 1850s he managed the Elba Furnace near Sykesville, Maryland, which his father had purchased for him, casting car-wheel iron for the Baltimore & Ohio Railroad.⁵

Establishing the Elizabeth Mining Company

When most of the copper and chrome mining enterprises in Maryland declined, James Tyson turned his attention back to South Strafford, Vermont. In 1872 he purchased the remaining half-interest in the mineral rights to the Blaisdell Lot on Copperas Hill from the Binney heirs for \$500. As the price of copper approached twenty cents per pound in 1880, James Tyson began acquiring other nearby properties with mineral or operational potential, eventually amassing more than 500 acres of land. He used his own money initially, but later supplemented that with funds from the Tyson Mining Company. In 1881, Tyson and his fellow investors incorporated the Elizabeth Mining Company to mine and smelt copper ores. Capitalized at half a million dollars, 100,000 shares of stock were issued at a par value of five dollars, but these were closely held by the family trust. James Tyson named the company for his wife of thirty years, the former Elizabeth Dawson of Philadelphia. (Such business and familial relations between prominent Baltimore and Philadelphia Quaker families were common during the nineteenth century.) Tyson's brother Jesse and his sons Mordecai and Isaac were officers and stockholders in the enterprise.⁶

William Glenn, another incorporator of the Elizabeth Mining Company, was a former Confederate colonel and military engineer who served as the company's mining engineer and metallurgist. He was a proven expert in chrome mining and chromium chemicals, and quickly developed an acumen for

copper smelting. Born in Norfolk, Virginia, in 1840, Glenn had started his career as a chainman on the B&O Railroad at the age of fifteen. He subsequently proved himself while working under one of the B&O's attorneys, John H. B. Latrobe, who was also Isaac Tyson's attorney and close personal friend. Glenn was promoted rapidly by the railroad, eventually supervising the construction of a section of track through the mountains near Cumberland, Maryland. His study of mineralogy during this period led him to become a mining engineer, and after the Civil War he accepted a position with the Tyson Mining Company. Later he worked for both the Elizabeth Mining Company and the Baltimore Chrome Works, and served on the board of managers of the American Institute of Mining Engineers in 1902.⁷

In late 1880, James Tyson discussed the title of his Blaisdell Lot property with the owners of the adjacent Vermont Copperas Company property (also known as the Foster-Cleaveland tract). He wanted to make certain that they did not have a valid adverse-possession claim on his property due to encroachment during the forty years it lay idle. Like his father before him, Tyson was convinced that the major ore vein continued at depth beneath this key parcel, even as far north as the Ompompanoosuc River. Glenn and Tyson traveled to Boston to negotiate with the principals of the Vermont company, businessman William H. Foster and attorney John D. Bryant. Tyson exchanged two small parcels of land and paid \$1,000 to Foster and Bryant to help settle the outstanding issues peaceably. He also contributed \$100 toward construction of a new reservoir, while guaranteeing them a continued source of water from dams constructed in their workings supplemented by a nearby well on one of his farms. Meanwhile, Tyson began developing his mine by sinking several shafts through barren rock on Copperas Hill to reach the pyrrhotite ore body. He charged some development expenses from early 1881 to an account with the Strafford Mining Company, an unrelated entity that was mining and smelting ore from the adjacent Foster-Cleaveland parcel to the south.⁸

Tyson employed John Vial, one of his key Cornish mining captains from Maryland, to conduct the underground development work. Born in Camborne,



Plan of the Copperas Works, Strafford, Vt.

Figure 3: Plan of the Copperas Works in Strafford, Vermont. (Charles T. Jackson, *Final Report on the Geology and Mineralogy of the State of New Hampshire*, (Concord: Carroll & Baker, 1844), 189.)



Figure 4: James W. Tyson (1828-1900), founder and president of the Elizabeth Mining Company. (Courtesy of Webb L. Nimick.)



Figure 5: Elizabeth D. Tyson (1828-1888), for whom the mine was named, seated on the porch at the Buena Vista Farm, c. 1887. (Courtesy of Webb L. Nimick.)

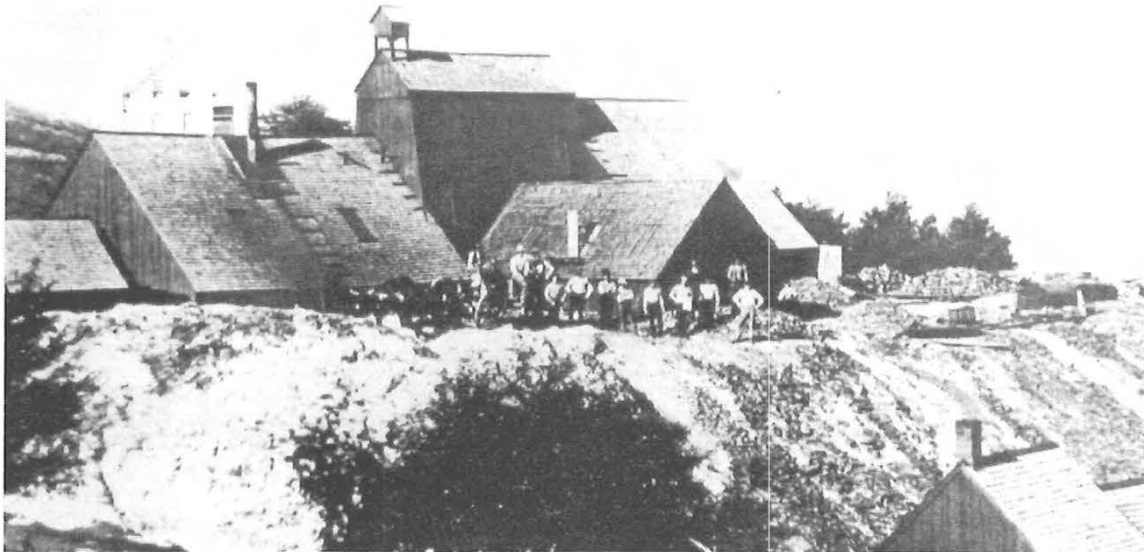


Figure 6: Elizabeth Mine buildings of the 1880s on Copperas Hill. These buildings housed the hoisting and crushing machinery for the Tyson Shaft, as well as the dressing floors where copper ore was sorted by hand. (Collamer Abbott Papers, University of Vermont.)



Figure 7: Vermont copper historian Collamer M. Abbott at the site of the 1880s-era roasting beds on the west slope of Copperas Hill. (Photographed by the author, June 1994.)

Cornwall in 1826, Vial had emigrated in 1844. By 1850, he was working in Isaac Tyson's Mineral Hill Mine, eventually becoming its superintendent. Several shafts at Mineral Hill were even named after him. In mid-January 1881, during the initial shaft development at the Elizabeth Mine, Glenn concluded in a letter to James Tyson that, "John must now be down about 70 ft., and about at the point where he sh[oul]d cut the vein. . . . He ought to let daylight thro [sic] very early in next month." Nearly twenty years later, a Tyson letter recounted how Vial had once developed a "fine run of ore," using his keen skills to avoid copper ore containing too much silica. He reportedly died of miners' consumption in 1895 and was buried in a Methodist cemetery near Mineral Hill in Carroll County, Maryland, where he had raised his family.⁹

Developing the Mine and the First Smelting Campaign

The Elizabeth Mining Company developed several primary levels in their mine, using a ladderway for access, with two working shafts, and a shallow adit. Miners hoisted buckets of ore to the surface for manual sorting, called hand-cobbing. In 1882, the company equipped the Tyson Shaft with a 20-by-24-inch steam hoisting engine, using a boiler and an engine transferred from two of the Tyson Mining Company's inactive chromite mines in Maryland and Pennsylvania. The hoisting apparatus also sometimes served to dewater the mine, hoisting buckets of water instead of ore. Fortunately, the mine was fairly dry and did not require pumps. Mine records reveal that employee George Cook received \$1.50 per day to run the hoisting engine—a typical wage at the mine. The company used a horse-powered whim at its No. 2 Shaft. Company records show both a 300-pound capacity hoisting bucket and an 1,800-pound bucket. The larger bucket served at the Tyson shaft because of the greater power of the steam engine. After crushing mine-run ore to less than two inches in size in a second-hand, 10-by-17-inch Blake jaw crusher and passing it over 30-degree iron screens with 1 1/8- and 1/8-inch openings, workers selectively cobbled the ore to 2½% to 4% copper.¹⁰

That material was then trammed in one-ton cars

and wagons to a level area set aside for roasting. There, the ore was heap-roasted in 24-by-50-foot beds to drive off as much sulphur as possible and oxidize the iron content. In the open roasting beds, workers placed a nine-inch layer of four-foot long, partly-seasoned, three-inch diameter hardwood on the ground. They then added coarse ore in layers to a thickness of seven feet, followed by one foot of the previously sized ore, known as "ragging," and covered the whole pile with a few inches of ore fines. A worker then ignited the wood at the base of the heap and the fire spread slowly throughout the ore pile. Workers controlled combustion by adding fines to any point in the heap that appeared to be too hot, taking care not to allow the pile to fuse together. After about two weeks, the burning of the sulphur in the ore became self-sustaining and required little maintenance for the remainder of the eleven weeks necessary to complete roasting. Each heap yielded approximately 350 tons of roasted ore, suitable for smelter-feed. Workers tended a number of such roasting beds, working with shovels and rakes amidst heavy sulphur fumes. Eyewitnesses expressed more concern about the damage roasting fumes caused to vegetation than their possible health effects on workers and residents, as common belief held that such fumes did not harm humans, but were actually healthful.

Glenn and Tyson adopted this productive method of roasting pyrrhotite ores from William H. Long, employed at the nearby Ely Mine in Copperfield, who had worked a nine-hundred foot roasting bed effectively in such a manner. The Tysons maintained a longstanding relationship with the Long family, who were very experienced copper smelters. In fact, William Long's father, Daniel, had worked closely with Isaac Tyson, Jr. in South Strafford during the 1830s before being employed by the Revere Copper Works in Boston. William's brother Joseph is believed to have been responsible for naming Ely, Nevada, after wealthy New Yorker Smith Ely, whose mining interests extended from Vermont to White Pine County, Nevada.¹¹

The Elizabeth Mining Company also erected a 48-inch diameter, water-jacketed, cupola furnace near the roast beds by a small stream called Blaisdell

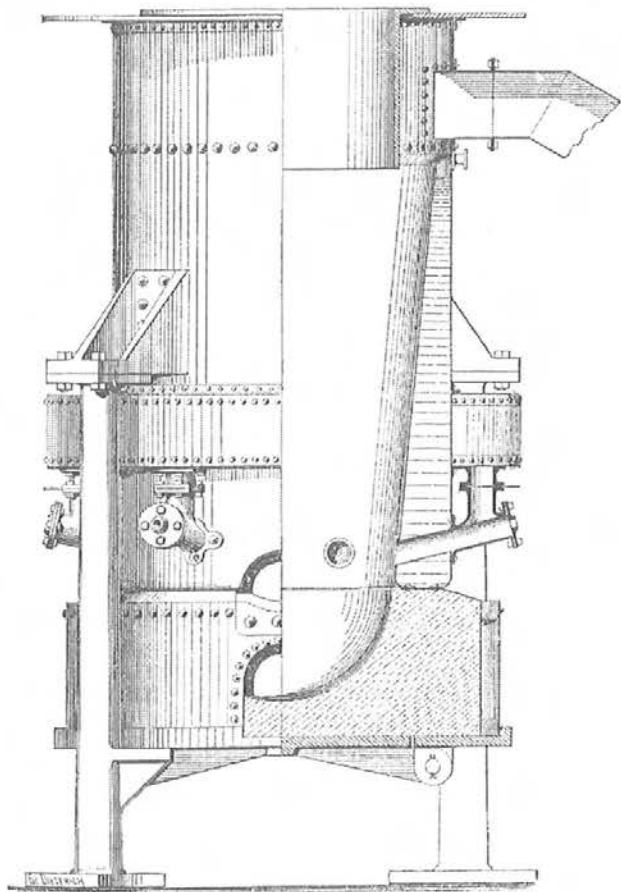


Figure 8: A typical water-jacket smelter of the 1880s. (Arthur F. Wendt, "A Blast Furnace with Bosh Water-Jacket and Iron Top," *Transactions of A.I.M.E.* 13 (1885): 33.)

Brook, since renamed Sargent Brook. During the summer seasons from 1882 to 1884, the company smelted nearly forty tons per day of the roasted ore in the small furnace, producing a twenty percent copper matte. This product was shipped to the Orford Copper & Sulfur Co. in Bergenport, New Jersey. In early 1884, the Elizabeth Mining Company received \$2.30 per unit—equivalent to about 9.8 cents per pound of copper—when refined copper stood at about fourteen cents per pound. A portion of the matte underwent further roasting and smelting on site, upgrading that product to sixty percent copper matte and yielding some pig copper. The pig copper was shipped to Birmingham, England for use in making high-quality brass pins. For smelter fuel, the company sometimes used byproduct gas coke purchased from the Boston Gas Light Company for \$2.75 per ton. On one occasion, they burned Con-

nellsville coke from Pennsylvania using an ore-to-coke ratio ranging from seven to nine parts of ore to one part coke. A No. 4½ Baker blower, powered by a twelve by twenty-four inch steam engine, provided seven ounces per square inch of air to the six furnace tuyeres, each of which was two and three-quarters of an inch in diameter.¹²

Production at that time was measured in "copper tons," equal to 2,352 pounds, although coke consumption was recorded in 2,000-pound short tons. Known also as the Cornish mining ton, a copper ton was a weight equal to 21 hundredweight of 112 pounds each.¹³ For many years, East Coast smelting companies, which had deep Welsh roots, used this unit of measure in purchasing ores for their furnaces in Baltimore, Boston, and elsewhere.

In 1882, Tyson and Glenn experimented with chromite sand as a hearth bottom because they had discovered that the acidic melt of their smelting ore steadily destroyed their silica brick refractories. They probably obtained chromite for their trials through their ties to the Baltimore Chrome Works. However, since most of the Maryland and Pennsylvania chrome mines were closed by this time, the ore may have originated in California or Turkey. Unfortunately, the fine chromite particles used to line the hearth did not bond well to each other and were eroded away by the heavy molten matte. This initial failure in using chromite as a refractory lining set the stage for success nearly two decades later. Glenn carefully documented the ore charges, fuel consumption, and matte and slag assays. When the furnace operated well, slag assays were less than 0.5% copper. He subsequently discussed the cost efficiency of water-jackets in *The Engineering & Mining Journal* in response to James Douglas' statement in *Mineral Resources of the U.S. 1883* that "the data are not yet available for determining the consumption of fuel in water-jackets and brick furnaces respectively." Glenn reported that heating the water between the internal crucible and the outside shell of the Elizabeth's furnace consumed fourteen percent of the coke fuel. He also promoted the use of a "filter charge" to charge a blast furnace as a way to prevent the ore fines from smothering the combustion process. This technique consisted of carefully layering

the coarse, medium, and fine roasted ores on top of a layer of coke fuel. This practice yielded a twenty percent improvement in furnace capacity.¹⁴

Henry M. Howe, Boston copper metallurgist and officer of the American Institute of Mining Engineers, published a bulletin in 1885 reviewing current copper smelting practices for the U.S. Geological Survey. The following year he visited the Elizabeth Mine and served as a consultant, recommending a series of development steps which he believed would enable the mine to become a major producer. Howe suggested driving a long, deep adit from the east to open up and prove a large reserve of ore dipping to the north. The ore above the adit level could readily be mined using gravity, while an incline driven from the adit would continue development down dip. He recommended either stages of semi-pyritic smelting—which used the combustion of sulphur in the ore to contribute heat to the smelting process—in a larger blast furnace to produce black copper contain-

ing around ninety percent copper, or Bessemerizing the ore to produce high-grade matte. But the deepening slump in copper prices during the mid-1880s caused a suspension of operations at the site.¹⁵

The Second Smelting Campaign and Transportation Limitations

Mining and smelting operations were again conducted quietly from 1888 to 1890, the price of copper having been artificially elevated to seventeen cents per pound due to world copper market manipulations by the French Secre-tan Syndicate. James Tyson's youngest son, James W. Tyson, Jr., participated more and more actively in the management of the Elizabeth Mine during this campaign. The mine peacefully employed twenty-five to thirty workers, in sharp contrast to the labor unrest experienced several years earlier at the financially-troubled Ely Mine in nearby Copperfield, Vermont.

Elizabeth Furnace Campaign from May 12 th to Sept. 2 ^d 1884.													To Jan 2352 lb Matte = 2352 Coke = 2000								
1884		Furnace Work				Smelting							Expenses		General Expense	Matte Cost for Ore	Matte Assay %	Average Reg. assay %	Ore Roasting		
Date	No. Charges	Tons Ore	Tons Ore	Tons Matte	Coke @ \$9.00	Ore @ \$6.00	Furnace Labor	Furnace Fuel	Engine Fuel	Tramway Ore	Ore Shovel	Total Cost to Matte	Total	Labor					Fuel	Total	
May 12 to 15	641	26.8	161.1	19.39	241.20	966.60	115.80		36.00	31.24	15.00	1405.84	4.00	72.35	26.172	0.50					
" 19 - 24	643	27.88	174.6	22.15	260.92	1047.60	127.30	5.00	35.00	25.67	15.00	1506.49	8.00	68.08	26.5	0.50					
" 20 - 31	653	26.5	158.9	24.91	238.80	953.40	125.36	5.25	30.00	28.80	15.00	1596.37	7.87	56.04	26.74	0.57					
June 2 - 7	669	27.56	170.66	30.00	248.00	1023.96	126.80	5.50	36.00	30.39	15.00	1485.69	12.25	49.62	25.9	0.51					
" 4 - 13	531	25.16	135.5	24.70	199.44	813.00	116.07	8.12	36.00	24.36	11.87	1208.86	12.50	46.49	25.72	0.45	31.66				
" 16 - 21	656	26.28	165.4	27.11	236.52	992.40	118.46	33.75	36.00	29.90	15.00	1457.63	3.62	53.74	24.08	0.52	15.14				
" 24 - 28	570	23.68	158.8	37.23	215.12	952.80	121.60	14.50	36.00	35.97	12.50	1356.49		50.92	25.2	0.59	15.45				
" 30 July 5	578	15.92	98.0	11.00	143.28	589.00	68.70	7.00	24.00	17.14	7.50	855.65		47.53	19.9	0.47	4.80				
July 21 to 26	751	29.50	198.1	36.96	268.20	1188.00	118.22	9.00	36.00	44.65	11.75	1683.42	3.40	40.58	25.0	0.43	3.42				
" 28 - Aug 2	656	27.00	179.4	36.20	243.00	1076.40	105.40	21.62	36.00	27.81	15.00	1525.23		41.89	19.6						
Aug 4 to 9	661	26.84	179.9	40.00	241.86	1079.40	108.39	17.00	36.00	31.32	15.00	1528.67		38.22	20.55						
" 11 - 16	747	30.75	203.25	46.00	276.75	1219.50	120.98	19.50	48.00	34.39	15.00	1734.12		38.44	20.12		1.15				
" 18 - 23	784	31.25	214.75	50.00	290.55	1285.50	116.65	24.05	48.00	38.82	18.37	1824.67		36.49	18.9		4.60				
" 25 - 30	633	26.80	172.25	42.24	238.00	1033.50	105.17	27.64	36.00	32.61	15.00	1455.42		35.24	17.76		1.15				
Sept 1 and 2	214	11.43	45.66	1.57											8.56						
Corrections		+4.22	-16.21		19.45	102.87	278.96	36.03	12.35	12.00	5.50	2.50	0.45.01								
					+6.36		-97.26		30.79				-24.67								
		9172	385.55	2400.06	4465.45	3469.95	1625.93	210.31	551.79	438.37	206.49	20903.20	55.44								
References: a. There were statements of 2 tons Ore more than reported. b. 16.21 " Ore less c. produced 6.36 " Matte " d. Corrections made necessary by these & e. Work consumed was 123% coke at \$9.00 and 70% for furnace fuel and near 57% coal at \$10.00 for the boiler for 1100 ft. of 12" and 14" fl. 25" and 30" as indicated. f. Cost of material necessary for 300 c.																					
Campaign at Matte Smelting July 7 to 20 th 1884 Material Used: Two 65.46 Raw Ore, 2 nd Metal 22.30 Roasted Matte 23.80 Furnace Coke Two 10.5 liquors of 60.6% dry assay 38.5 " " 72.2 " 35.50 " " 97.04 " "																					

Figure 9: A portion of metallurgist William Glenn's detailed smelting records from 1884. (Tyson Family Archives, South Strafford, Vermont.)



Figure 11: The Tyson Adit (1,340 feet long) was completed in 1898 and served as the mine's main entrance until final shutdown in 1958. (Photographed by the author, June, 1994.)



Figure 12: The Elizabeth Mill, c. 1902. The mine's adit is located to the far left. Ore cars can be seen near a slanted roof over storage bins to the left of the mill. The buildings in the foreground from left to right are a barn, a laborer's house, and a combined office and storehouse. A portion of the roasting beds are visible to the far right. (Courtesy of Collamer M. Abbott.)

a market price of twelve cents per pound for copper was minimum price at which the mine could operate. The mine shipped the matte produced during this era to the American Metal Company in New York for further smelting. A portion of the matte was also apparently sent to Baltimore or held in inventory for shipments made several years later. This matte assayed 6.2 ounces of silver and 0.007 ounces of gold per ton, indicating some potential for profit from byproduct, although the Tysons were never able to take advantage of this.¹⁸

The distance from the mine to the nearest railroad increased transportation costs, thus diminishing profitability. The Vermont Central Railroad station in Sharon was the closest to the mine, but it was eight miles distant over a steep mountain. When hauling product to the Boston & Maine's station at Pompanoosuc in the Connecticut River Valley, teamsters covered nearly ten miles of winding roads, mostly down grade. It cost three times as much to transport a ton of material from the mine to the Pompanoosuc Station as it did to ship it from Pompanoosuc to New York or Boston. During the railroad boom of the early 1890s, James Tyson judged that a railroad line constructed up the valley of the west branch of the Ompompanoosuc River would foster business growth and development in the area. His Elizabeth Mining Company "offered to bind itself to pay for the freightage of 3,000 tons of ore, coke, etc., monthly if a railroad is built up the valley, past the site for smelting works recently purchased." Unfortunately for the mine and for other potential businesses near South Strafford, no railroad ever came to the region.¹⁹

Further Mine Development Fosters New Smelter Operation

The Elizabeth Mine remained mostly idle from 1890 to 1895. The repeal of the Sherman Silver Purchase Act not only caused a slump in metal markets, but precipitated a sustained economic recession that lasted until the onset of the Spanish-American War in 1898. As the economic outlook improved, the Elizabeth's owners commenced developing the mine along lines of Professor Howe's rec-

ommendations, driving an adit some fourteen hundred feet through barren rock into the footwall of the vein. Adit work started in November of 1895, and miners excavated two hundred feet during the first six months. The company soon acquired a 10-by-10-by-14-inch Rand air compressor and a Sullivan air drill to quicken the pace of development. The performance of the Sullivan drill pleased its operators. The final months of work on the adit progressed at a rate of seventy to one hundred feet per month. The 459 feet driven from October 1897 through March 1898 cost \$18.61 per foot.

Miners reached the vein on 15 June 1898, and the completed adit, six feet wide by six and a half feet high, helped drain and ventilate the mine and aided in the gravity mining of several hundred thousand tons of ore. With minor modifications this adit served the mine for sixty years. For a short time optimism ran high, as samples from the "Dow Vein" assayed at greater than ten percent copper. The ore, rediscovered on the 180-foot and 270-foot levels, was hoisted to the surface in nearly 1,800-pound loads. It was described as "clean yellow sulphuret and mundic with little slate." John Vial had originally encountered this high-grade zone on the 180-foot level and then had lost it. The Tysons sold this high grade ore to the Lewisohn Brothers copper interests in 1896.²⁰

By 1899 copper prices were once again booming because of market factors related to Amalgamated Copper's aggressive acquisitions. In response, the Elizabeth Mining Company began constructing a larger smelting plant northeast of its mine. The price of copper peaked at nineteen cents per pound during the spring, so the company continued selling its richer copper ores to market to generate favorable cash flow, shipping them by rail and barge to the Mountain Copper Company's smelter in New Jersey. The Tysons purchased a larger 14-by-22-inch Rand compressor to power more drills further inside the mine. They built a new mill, equipping it with a 300-ton-per-day, 20-by-15-inch Robinson Rea Challenger crusher, as well as picking belts or revolving tables to assist in the efficient hand sorting of their chalcopryite-bearing ores. The Tysons also contracted with the Atlantic Works of East Boston

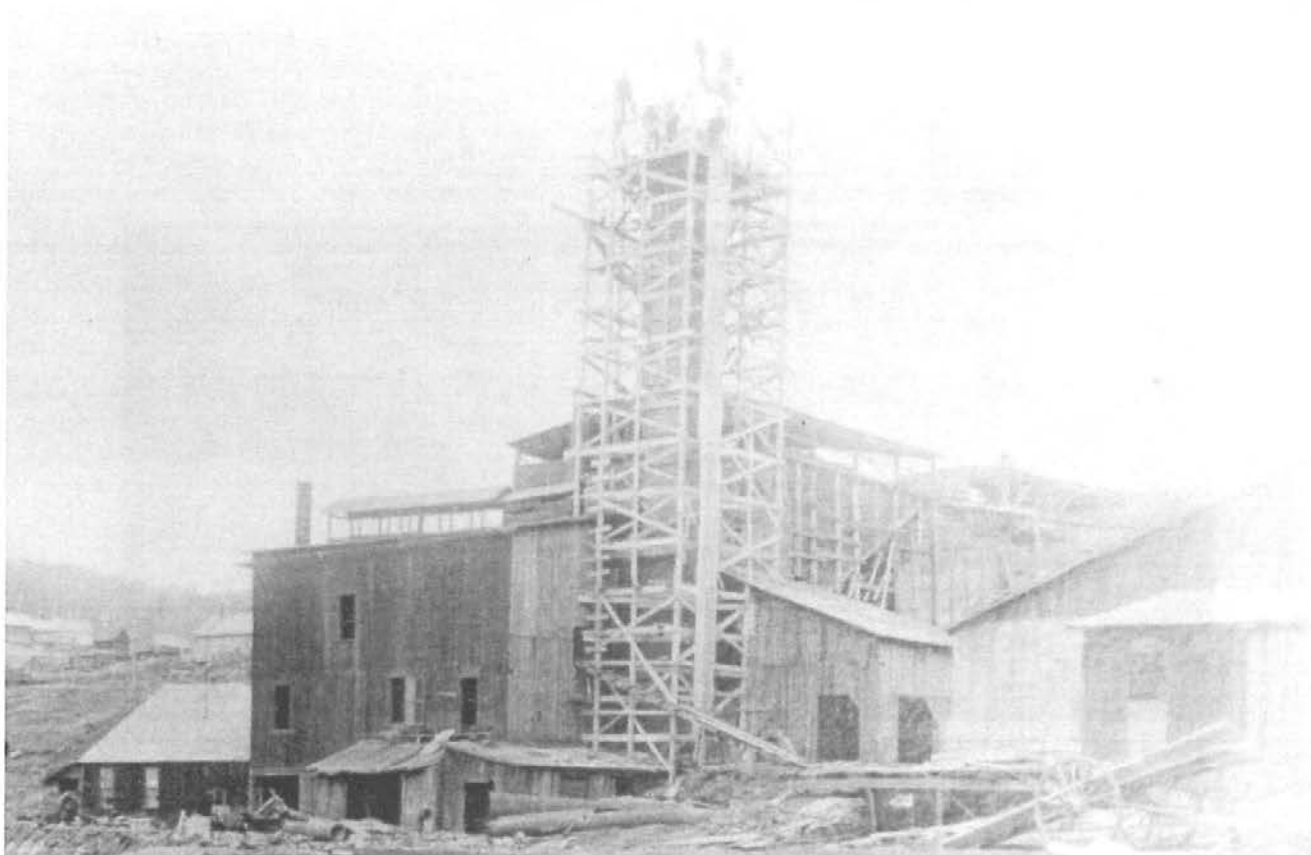


Figure 13: Erecting the stack for the blast furnace, c. 1900. The building to the right housed the reverberatory furnace. (Collamer Abbott Papers, University of Vermont.)

to fabricate a 150-ton blast furnace equipped with a No. 7 Rooté blower. This rectangular furnace featured fourteen tuyeres of five-inch clear opening. In an adjacent building they installed a new ten-ton reverberatory furnace to produce blister copper.²¹

The roasting beds were carefully laid, following the advice of copper expert Edward D. Peters, with two parallel rail tracks, one elevated on a trestle. Peters was intimately familiar with the Vermont copper mines. He had leased the Foster-Cleveland tract in 1880 and had provided metallurgical expertise to the Ely copper furnaces in 1882. Peters wrote that

as the whole advantage of heap-roasting lies in its extreme cheapness, every precaution should be taken to save expense in the handling of the ore. It is an excellent arrangement if the ore-car from the mine or dressing-house can be brought on a trestle over a

long line of roast heaps, while the track which leads to the furnaces runs parallel to these and on a still lower level. By this arrangement, the expenses of roasting can be reduced to a minimum, as the cars from the mine can be dumped directly upon the heaps, requiring only a little spreading into shape, and when the ore is to be carried to the furnaces it can be shoveled or wheeled from the heaps directly into the car, the top of which should be on a level with the ground on which the piles are built."²²

Thus a plant layout located on a hillside used gravity to significant advantage. An article in *The Boston Globe* reported favorably on the renewed operations at the Elizabeth Mine and other Orange County mines.²³

James Tyson, Jr., following his father's example, lived and worked full-time in Vermont, managing

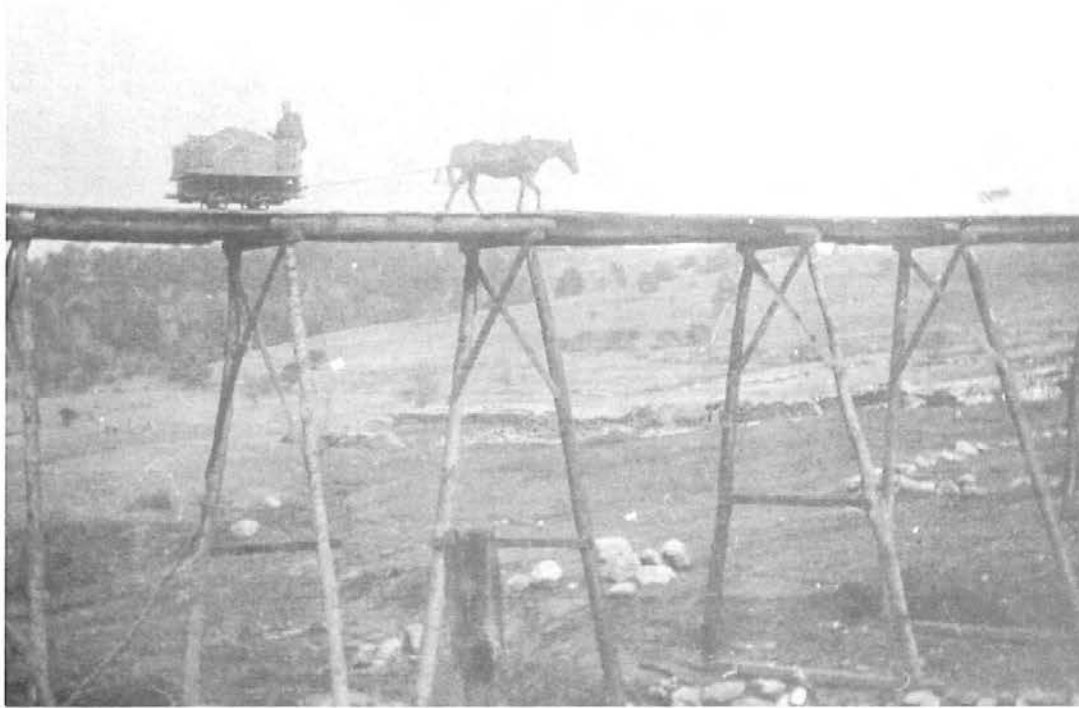


Figure 14: The horse is probably pulling a car of waste rock on this trestle above Copperas Brook, c. 1900. (Collamer Abbott Papers, University of Vermont.)



Figure 15: Elizabeth mine and mill buildings viewed from the hillside above, c. 1902. The dark building in the center foreground is a blacksmith shop, located next to a small roof covering the adit entrance. The miners' "dry" is the next building to the right near a small stable, both of which are in front of the trestle seen in Figure 14. (Courtesy of Collamer M. Abbott.)



Figure 16: An overview of the Elizabeth mine complex on Copperas Hill, c. 1902. The mill buildings are left of center. Smoke from heap roasting is possibly visible near the roasting bed trestle in the center. The blast furnace is barely visible to the far right. (Courtesy of Collamer M. Abbott.)

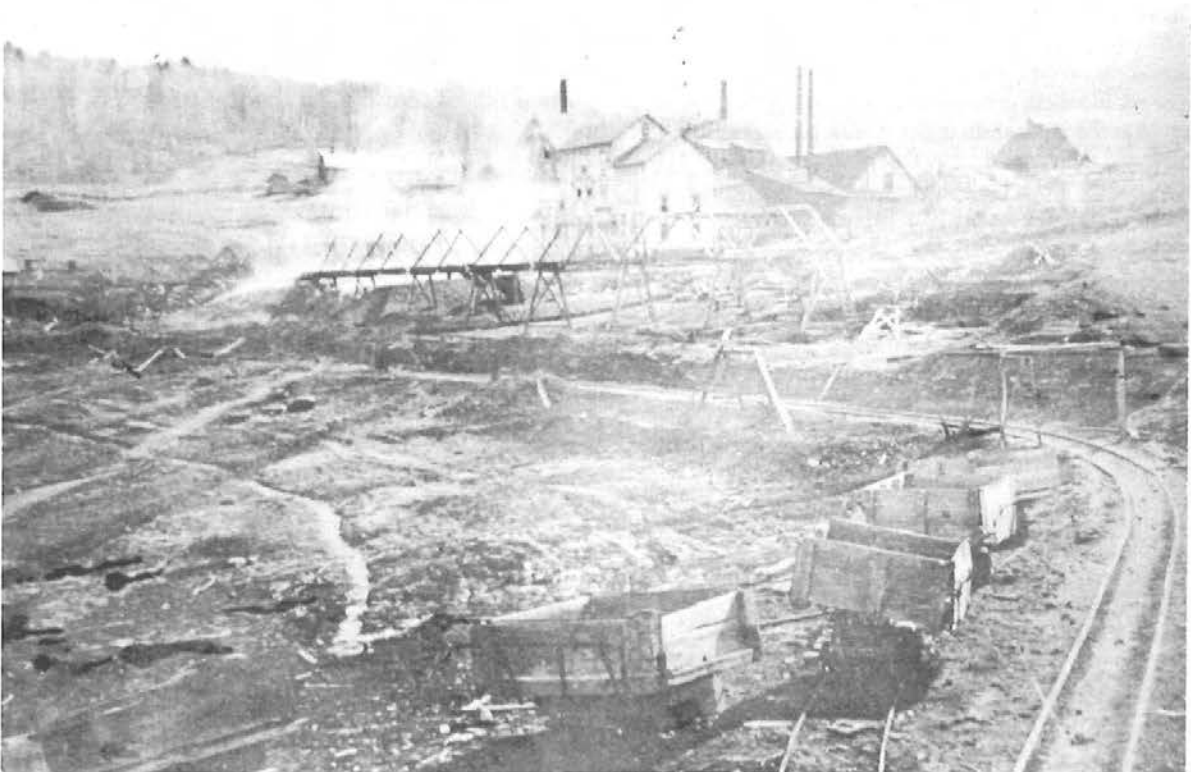


Figure 17: Active heap-roasting at the Elizabeth Mine, c. 1902. Smoke from the roasting beds near the left end of the trestle partially obscures the mill building. The trestles and track run parallel to the roasting beds and the wooden side-dump ore cars in the foreground were used to charge the cupola blast furnace located near the photographer's vantage point. (Collamer Abbott Papers, University of Vermont.)



Figure 18: Photograph of James W. Tyson, Jr. (1861-1946), the youngest son of James W. Tyson and the most active in copper mining and smelting. He managed the Elizabeth operations from 1897 to 1902, served at the mine again under August Heckscher in 1907, and then consulted in Ducktown, Tennessee from 1909 to 1912. He resided at Buena Vista Farm in South Strafford, Vermont. (Courtesy of Webb L. Nimick.)

the Elizabeth Mining Company's operations. After receiving his formal education at Haverford and being involved in some of the earlier mining campaigns, he gained further experience in the Pittsburgh steel industry. He and his family resided in a large white brick house at Buena Vista Farm, located just down the country lane from the Elizabeth's operations. James Tyson, Sr. often directed company business from Baltimore because he had been in poor health for several years and could travel north only in seasonable weather. Bookkeeper H. "Lee" Hatch and Captain Dow frequently mailed reports to the senior Tyson to keep him informed about operations at the site.²⁴

Innovations Amid Difficulties

After James W. Tyson died at the end of 1900, James Tyson, Jr. continued to operate the Elizabeth's mine and smelter as best he could. He received little support from Baltimore save that offered by faithful metallurgist William Glenn. The Elizabeth Mining Company was often short of working capital and behind in its payments. Thousands of tons of ore lay tied up for months on the roasting beds, with several dollars per ton of costs already incurred. The company sought cash advances on ore and matte shipments in order to meet monthly payrolls and other expenses. The principal stockholders of the Eliza-

Figure 19: James W. Tyson purchased the old Dow farm from William Bond in 1882 and renamed it Buena Vista Farm. Photograph c. 1880. (Courtesy of Webb L. Nimick.)



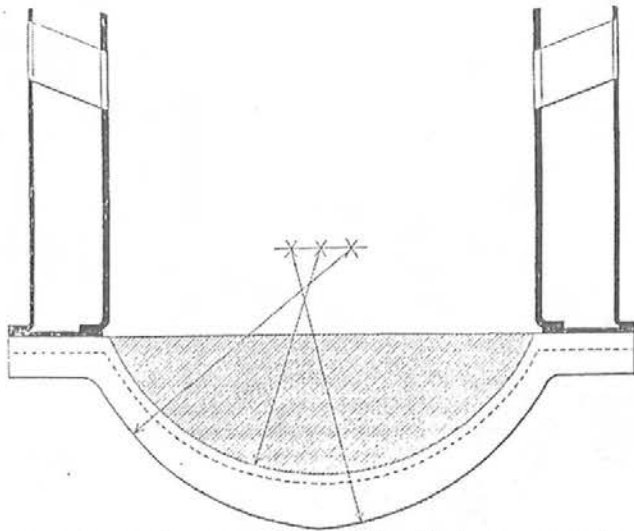


Figure 20: Idle blast and reverberatory furnaces viewed from the east. The smelter appears somewhat dilapidated, likely dating this photograph to the 1910s. The small building in front of the blast furnace with the water tank is the engine house for the blower. At the upper left lies a building believed to house matte crushing equipment, minus the stack visible in Figure 23. (Collamer Abbott Papers, University of Vermont.)

beth—various Tyson family members—had been trying for some time to sell the mine for cash, as the company was indebted to other family businesses for several hundred thousand dollars. Several potential buyers sought unsecured options but were turned down. The company even declined a reported six hundred thousand dollars offered by industrialist George Westinghouse. Westinghouse then purchased the nearly exhausted Ely Mine in nearby Copperfield, Vermont, and spent a million dollars on an unsuccessful experimental smelting plant at that site.²⁵

The Tysons continued to operate the mine and smelter, hoping to enhance the value of the property and its significant ore reserves. Smelter product was consigned to the Bridgeport Brass Company and shipped to the Nichols Chemical Company Refinery on Long Island, New York, for refining. As the price

of copper declined from seventeen to thirteen cents through 1901, the asking price for the mine followed suit. Since the company was now part of a family legal squabble and under the control of receivers and creditors, there were no serious offers to purchase the property. Copper smelting at the works was sometimes hindered by lack of suitable fuel. On several occasions late deliveries of gas coke, or coke that was too wet or too fine, caused the furnaces to be shut down. Transportation to and from the remote location in the Green Mountains remained unreliable and expensive. Teams of horses hauled cobbled ore or matte the ten miles down muddy mountain roads to Pompanoosuc Station, returning with either fuel or supplies. Sledding in winter often proved to be an easier means of transportation. When spring weather arrived, the teamsters switched from runners to wheels. Oxen were sometimes employed for particu-



Cupola, Smelting Copper-Ore. Vertical Section, Showing Chromite Lining.

Figure 21: William Glenn's diagram of the chromite furnace bottom. (William Glenn, "Chromite as a Hearth-Lining for a Furnace Smelting Copper-Ore," *Transactions of A.I.M.E.* 31 (1902): 376.)

lar hauling duties.²⁶

It was under such difficult conditions that Tyson and Glenn, experimented successfully with several innovations. One of their innovations was to use chromite refractory linings in the hearth of their 3-by-10-foot, water-jacketed furnace. This time, in contrast to their failed attempt in 1882, they used both large and small pieces of chrome ore and hammered them into place. They successfully built this interlocked chromite bottom to their cupola furnace in 1899. It functioned well for more than twenty-six weeks, whereas the deterioration of a typical silica brick lining mandated weekly replacement. Glenn enthusiastically shared this accomplishment at the 1901 American Institute of Mining Engineers meeting in Richmond, Virginia, recommending it for all copper smelters. He asserted that he was "warranted in saying that any copper-smelting cupola or blister-furnace ought to have a chrome-ore lining, as an absolute economic necessity. And I do not see why such a lining would not be the ideal thing for a converter."²⁷

Tyson also used blocks of fifty-two percent chromic-oxide Turkish ore in the bridge wall of the Elizabeth's reverberatory furnace, and along the slag line of the furnace hearth. This material resisted

wear quite well, again proving the effectiveness of the chromite. To Glenn, such a lining appeared

rude and unskillful when looked upon after completion. . . . But especially at night—when through the charging-door one sees the glowing bridge-wall as if formed of blocks of snow or piled-up white cumulus clouds, and the whitish blocks of chrome-ore along the slag-line—the structure grows artistic, because beautifully fitting. For no matter what temperature may be attained, or how biting the corrosive and vicious slags may become, yet these chrome-ore blocks cannot be successfully attacked. When the copper has been tapped out of its hearth the furnace may be recharged immediately, while it is hot, and not (as is the case with other linings) after it has grown cold by reason of an interval of three hours, required for repairs.²⁸

Today, a century later, chromite refractories have been abandoned for many uses because of hazardous waste concerns. Nevertheless, chromite remains a preferred refractory material in certain applications, such as reverberatory copper furnaces.

Another Elizabeth company innovation involved the process of copper converting. Tyson, assisted by Glenn and his smelterman, a Mr. Everett from Canada, devised a way to eliminate the slow, laborious, and energy-wasting steps of crushing and roasting the matte. They successfully reduced their matte in their small reverberatory furnace, converting it directly to blister copper by aiming a blast of superheated steam and air, with entrained sand for silica, onto the surface of the molten charge. They used waste heat from the smelter flue to generate the steam, with flue dust being captured in a chamber. In January 1902, the three men sought a patent for their process, but were disappointed when their application was denied. Thomas Roberts of Baltimore and others already held patents covering related processes, although these remained unproven practically.²⁹

In 1896, Roberts, undoubtedly familiar with Welsh smelting practices at the Baltimore Copper

(No Model.)

T. ROBERTS.

PROCESS OF REDUCING AND REFINING COPPER.

No. 568,700.

Patented Sept. 29, 1896.

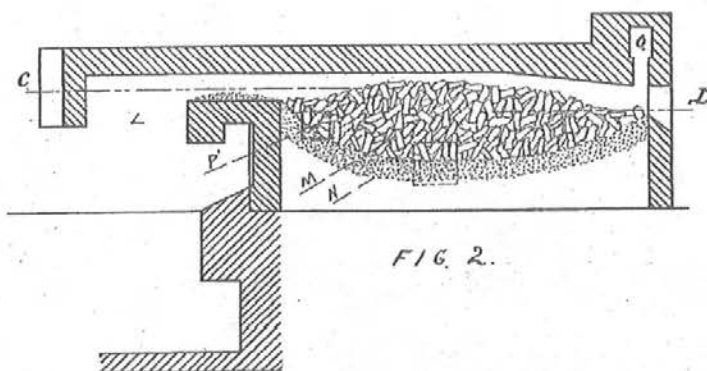


FIG. 2.

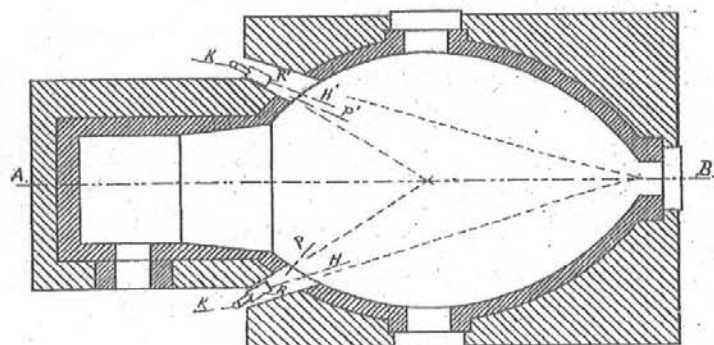


FIG. 1.

WITNESSES:

Frank E. Finamore

David G. Roberts.

Thomas Roberts INVENTOR.

BY William W. Varney

his ATTORNEY.

THE METAL PETERS CO., BALTIMORE, MD., U.S.A.

Figure 22: Illustration accompanying Thomas Roberts' patent for a process of reducing and refining copper using a steam-air blast on the surface of molten reverberatory furnace contents. (United States Patent Office, Letters Patent No. 568700, 29 Sep. 1896.)

Works, had designed and patented a refining system that included introducing a steam-air blast via two pipes. During the "poling" step of adding green wood to the reverberatory furnace contents for final conversion, he advocated directing such a blast upon the surface on the molten charge to promote agitation and hasten the process. The distinctive feature of the Elizabeth practice seems to be the entrainment of sand in the steam-air blast of the tuyeres to foster the rapid development of slag in the boiling

furnace contents. In his 1902 *Copper Handbook*, Horace J. Stevens referred to this as the "reactor process." The durability of the chromite refractory lining enabled the Tyson process to succeed, meaning that the metallurgical staff of the Elizabeth Mine were able to produce blister copper in two steps instead of three. They handled slag using wheeled pots or buggies typical of the period and also applied flowing water in a trough to granulate the slag and wash it away. Despite their success, continued finan-

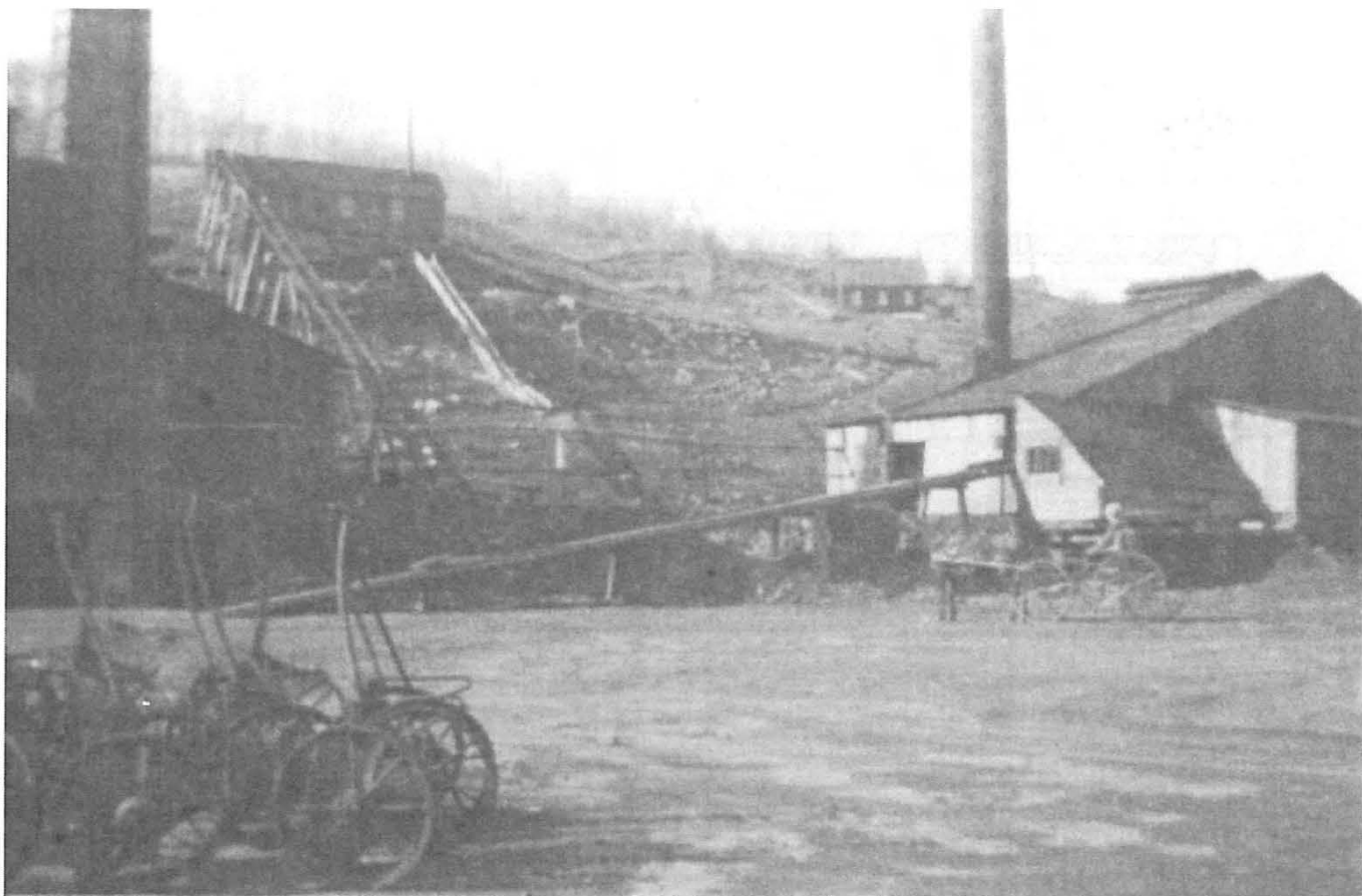


Figure 23: The Elizabeth Smelter, idle in the early 1900s. Slag pots lie in the foreground. To the left is the blast furnace with an inclined trestle leading to the reverberatory furnace on the right. This short incline probably replaced the inclined tramway system to the building located at left of center, where the author believes matte crushing and roasting were formerly conducted. These developments in directly reducing the matte eliminated the intermediate step of matte crushing and roasting and allowed blast furnace products to be transported directly to the reverberatory furnace in 1902. (Collamer Abbott Papers, University of Vermont.)

cial and legal problems caused the layoff of employees and shutdown of the mine, mill, and smelter by June of 1902.³⁰

After the Tysons

Several prominent mining engineers and consultants visited the Elizabeth Mine during the Tyson era. They conducted examinations of the mine and smelting facilities and interviewed the managers. They also collected samples of ore for assaying, measured the known workings and ore body, and prepared maps and reports to explain the geology and indicate the potential of the mine. In addition to Professor Howe in 1886, 1890, and again in 1894, these recognized experts included Lomax Littlejohn in 1888, H. C. Southworth in 1897, Messrs. Albert

R. Ledoux & Co. in 1899, and Reginald W. Petre in 1902. Russian Professor N. A. Bibikov visited the mine in 1896 while conducting studies at the nearby Ely Mine. Westinghouse representatives visited when the Elizabeth's purchase was being considered by that company. Other experts gave their opinions about the mine during the idle period following its 1902 shutdown and after work resumed in 1905. U. S. Geological Survey copper geologist Walter H. Weed visited in 1903. Both Philip S. Smith of Harvard and Otto Sussman of the American Metal Company wrote reports in 1904, followed by Ricketts & Banks in 1906, Frank L. Nason in 1904 and 1910, and N. O. Lawton in 1916.³¹

In 1905, John N. Judson and Lewis G. Rowand, former employees of the Wetherill Separating Com-

pany and involved with the development of magnetic separation equipment at the New Jersey Zinc Company, negotiated a lease and option on the mine from its receivers. Since the Wetherill Magnetic Separator patents did not cover pyrrhotite, Judson and Rowand did not have to pay license or use fees for their application of the technology to the Elizabeth's ores. They attempted to convince the American Metal Company (backed by the German conglomerate Metallurgische Gesellschaft, A.G.) to invest in the Elizabeth project. After those negotiations failed, they secured the financial backing of New Jersey Zinc magnate August Heckscher. But the magnetic separators which Judson and Rowand applied successfully in their New Jersey laboratory failed to work at the South Strafford site. The Elizabeth pyrrhotite does not respond to magnetic fields as well as other pyrrhotite ores, even though they improved their process by roasting the ore to make it

more magnetic. Although Judson and Rowand's magnetic separation process failed, in late 1906 Heckscher exercised his option to purchase the mine for only two hundred thousand dollars. He also purchased the Foster-Cleaveland (the former Vermont Copperas Company) property to the south. Heckscher then constructed an elaborate and expensive three-hundred-ton smelter plant in 1907, but that also failed.³²

Diamond drilling conducted subsequent to Heckscher's acquisition began to confirm the extent of the Elizabeth ore body. The massive ore deposit eventually proved to be more than two miles long. It lay at a depth of three hundred to six hundred feet, with a thickness of as much as sixty-four feet, though it more commonly ran twelve to thirty-five feet thick. The ore-dressing and smelting techniques applied by the Tysons and others could not economically treat such ore, which contained an aver-

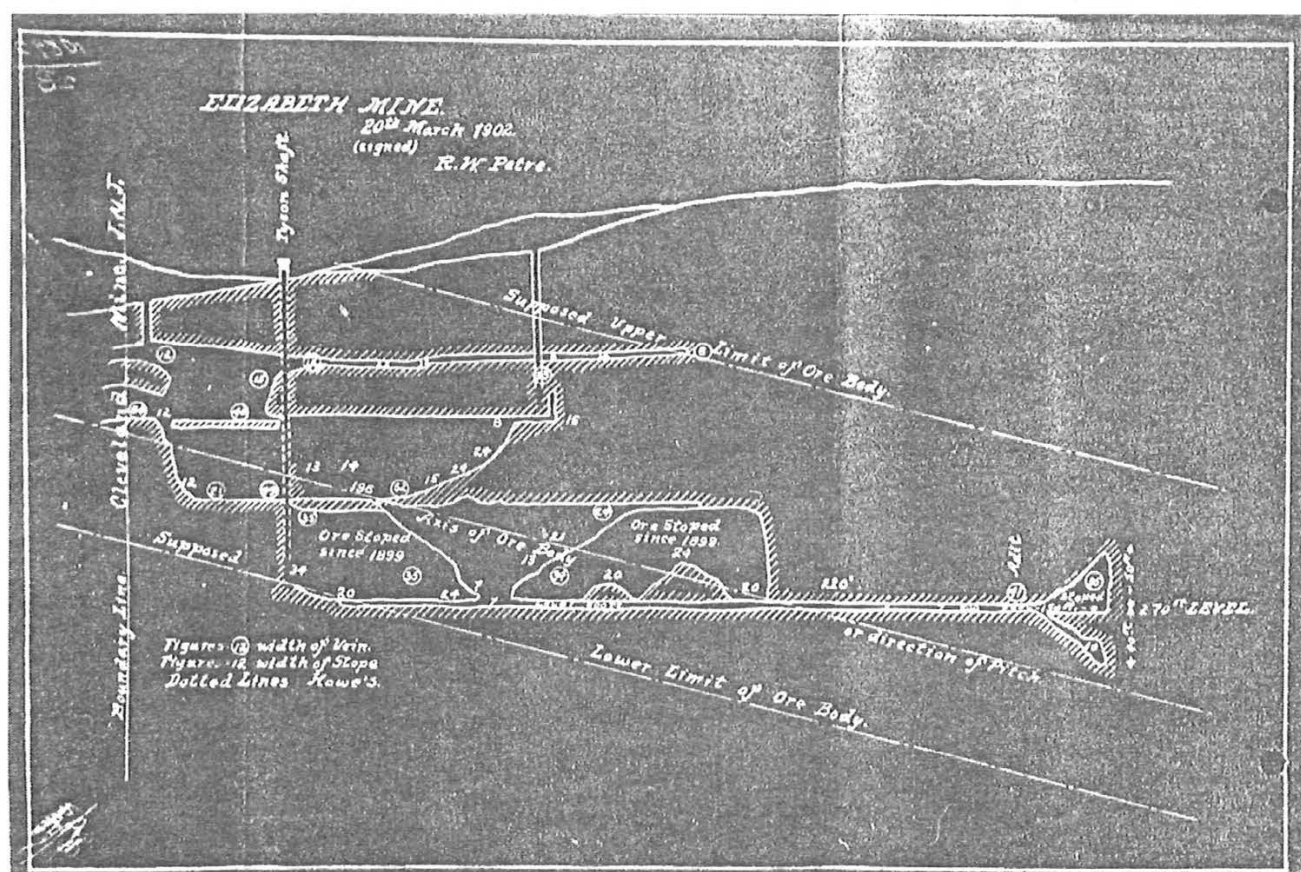


Figure 24: Longitudinal section map of the Elizabeth Mine looking from the east, prepared by Reginald W. Petre (with initials of John N. Judson added) in March 1902. The adit is located at the lower right. (Courtesy of Collamer M. Abbott.)



Figure 25: A winter view of the Elizabeth Mine's open cut on Copperas Hill looking north, c. 1962. This pit was mined on the old Foster–Cleaveland tract by the Vermont Copper Company during the 1940s and 1950s. It exposed old mine workings from the Tyson era where the large ore body dips below the surface adjacent to the historic Blaisdell property line (see the left side of Figure 24). The caved No. 2 Shaft is barely visible among the trees above the exposed upper stope. The mine and mill buildings of the 1880s, shown in Figure 6, were located on the right side of the dumps beyond the upper stope. (Courtesy of Collamer M. Abbott.)

age of less than two percent copper. The short-term successes experienced over the years had only been realized by mining high-grade ores during periods of elevated copper prices. The bulk of the Elizabeth's ores could not be worked economically until World War I, when fine-grinding and early froth flotation technology were successfully applied at the site.³³

American Metal conducted a short campaign at the Elizabeth in 1926, followed by another brief period of operations by National Copper from 1929 to 1930. During the early days of World War II, the U. S. Geological Survey and the Bureau of Mines, seeking to expand the copper-producing capacity of the nation, conducted studies of the site. Encouraged by the Vermont War Production Board, several influen-

tial individuals provided the large capital outlay required to reopen the mine. A new corporation, the Vermont Copper Company, equipped the mine with the modern mining facilities and five-hundred-ton-per-day flotation mill used during the mine's final fifteen-year run. The adit was enlarged to seven by nine feet to accommodate larger equipment and mine cars. A loan from the Metals Reserve Company, another federal agency, supplemented the significant private capital invested in the project. In 1943, because of critical wartime needs, the Vermont Copper Company received a premium price to supply copper under a guaranteed government contract. During this period of operations the Elizabeth Mine became one of the top twenty U.S. copper

mines, achieving eight hundred tons of production per day by 1953 and peaking at one thousand tons per day. The mine closed for the last time in 1958.³⁴

In recent years the work of the Elizabeth Mine Study Group, a local environmental effort to study acid mine drainage problems in the West Branch of the Ompompanoosuc River, has renewed interest in the Elizabeth Copper Mine. This volunteer group

understands the need to record and study this extensive historic site in order to gain local support for effective remediation and reclamation measures. The challenge is to clean up the mine's environmental problems without destroying its unique landscape and historical features, for the Elizabeth Mine represents some 150 years of Eastern U.S. copper mining history.

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- The Tysons clearly purchased their water jacket in 1899 per a \$2,375 contract with the Atlantic Works, which conducted other work on the furnace to the amount of \$927.94. Yet, the *Herald & News* (23 Nov. 1899) reported that the Elizabeth Mining Company was "putting in a new patent furnace for smelting purchased in Denver, Colorado," that they "commenced operations this week," and that an "expert from Denver was in charge." The author is unable to reconcile these differences, but thinks it is unlikely the company would have purchased equipment from distant Denver with many heavy equipment manufacturers available in the East.
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- This 550-page reference contains many of the details of a complicated legal case involving second and third generation members of the Isaac Tyson, Jr. family, including the ownership and finances of the Elizabeth Mining Company in relation to the other family-held businesses such as the Tyson Mining Company, the Mineral Hill Mining Company, and the Baltimore Chrome Works. Legal proceedings, which dragged on in the courts for some thirteen years, involved many attorneys, accountants, trustees, witnesses and family members. The author has intentionally left out these details to avoid distracting the reader from the subject addressed. Brief statements in this paper making mention of receivers, creditors, or the Tysons in relation to the management and operation of the Elizabeth Mine, are intended to simplify a complicated matter and should be understood in general terms.
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