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

Because of recent press coverage and community interest in the environmental effects of this abandoned mine site, it is timely to consider the Tyson era, as the mine's history continues to unfold to this day.

By Johnny Johnsson

The Elizabeth Copper Mine in South Strafford, Vermont, has an interesting history, from the initial discovery of its sulphide ore body in 1793 through its final closing in 1958.* The stories of early smelting in the 1830s, as well as more recent mining operations conducted since the 1940s, have been researched and published.[1] Nevertheless, the period of operations between 1880 and 1902, when members of the Tyson family and their associates attempted to develop the mine into a significant producer, is less well documented. This article briefly reviews the general history of the mine among the copper mines of Vermont, then examines some of the problems and successes the Tysons encountered during their tenure in developing the mine and smelting the difficult pyrrhotite ore.

The Orange County Copper District

The Elizabeth Mine, one of the primary producers of the Orange County Copper District, is located in the southern portion of the district in east-central Vermont. Geologically, the region is composed of highly folded metamorphic rocks (schists and amphibolites), and within these rocks are found several massive iron sulphide ore bodies containing varying amounts of copper of economic importance. Since these ore bodies are also folded within the rock strata, their origin predates the forces that folded the bedrock. These ores were deposited during sedi-

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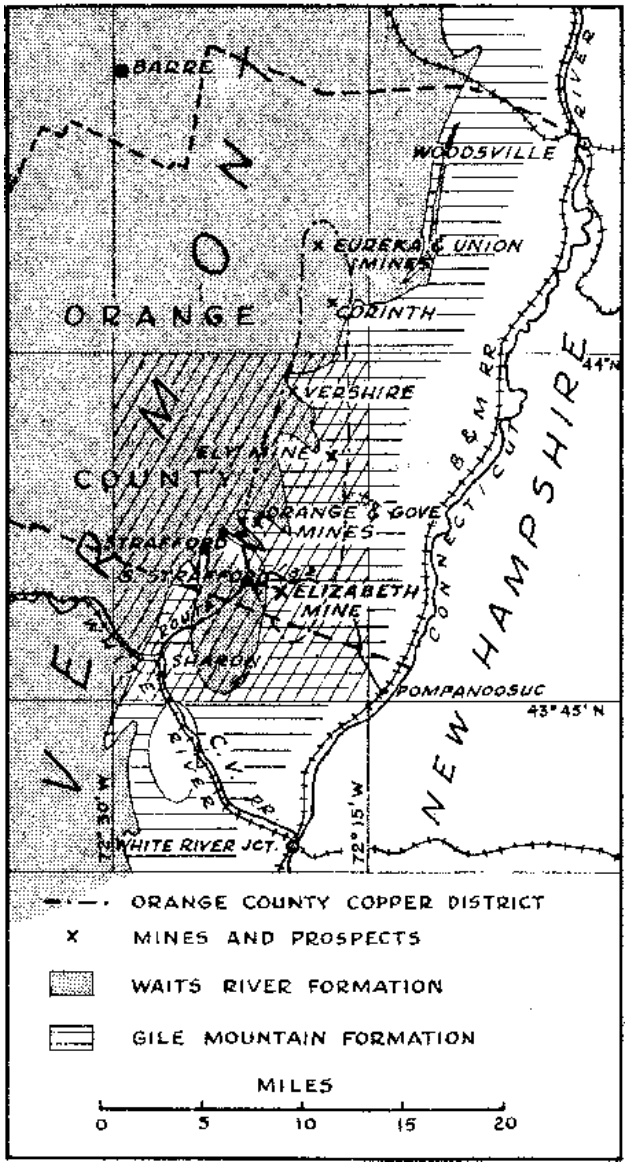

Figure 1. Location Map. The Elizabeth Mine is located in the southern part of the Orange County Copper District in east-central Vermont. W. S. White and J. H. Eric, "Preliminary report on the geology of the Orange County copper district, Vermont" (Washington: U.S. Geological Survey, 1944), figure 1.

mentation and volcanic activity on or near an ancient sea floor over 400 million years ago in geologic time. Then, tectonic forces associated with colliding plates of the Earth's crust folded the sedimentary layers with the enclosed ore bodies. Erosion and glaciation later exposed outcroppings of these ore bodies, which served as the points of discovery for local citizens.[2]

Other major mines include the Pike Hill mines, located near Corinth in the northern portion of the district, and the Ely or Copperfield Mine, located in South Vershire near the middle of the district. Situated in between these mines are several smaller mines and numerous prospect pits.

The history of the Ely Mine is probably the most exciting and romantic of the Vermont copper mines. The mine dates to the early 1800s and Isaac Tyson, Jr., patriarch of the Tyson mining family, and his associates had involvement there in the 1830s. Its primary period of operation was from 1854 to the mid-1880s. The Ely Mine became one of the largest copper mines in the country during the 1870s, competing with established mining districts in Michigan and Tennessee, and a village of nearly 1,000 inhabitants grew up around it. Copper smelting at Ely commenced in 1867 and became significant with the establishment of a major industrial complex. The decline of the mine by 1883 resulted in noteworthy labor strife known as the "Ely War." The mine subsequently faded into intermittent operations, last producing copper concentrates during World War I.[3]

The history of the mines on Pike Hill is somewhat subsidiary to that of the Ely Mine, because for much of their existence they were controlled by the Ely principals. Operated independently from the 1840s to the 1860s, Pike Hill copper ores were shipped to Boston and Baltimore for smelting. Later, teams hauled ore to Ely's numerous furnaces for smelting. The Eureka and Union mines experienced a brief revival during the early 1900s and World War I. In totality, the mines on Pike Hill contributed only about eight to nine million pounds of copper to Vermont's overall historic production. In contrast, the Ely Mine yielded some 30 to 40 million pounds of copper. Both Ely and Pike Hill featured higher grade copper ore than the Elizabeth Mine, but ultimately its vast quantity of low-grade ores and long life made Elizabeth the leading Vermont producer, topping out at 100 million pounds.[4]

Early Developments on Copperas Hill

The ore body on Copperas Hill, a few miles south of Strafford, Orange County, Vermont, was discovered in 1793, reportedly when the rusty mineral-bearing outcrop was noticed during maple-sugar sap

gathering. In 1809 out-of-state investors formed the Vermont Mineral Factory Company to manufacture iron sulphate, then known as copperas or green vitriol. Applications of copperas included the manufacture of inks and dyes, and it was also used as a mordant in the tanning industry.[5] The bronze-colored ore, composed mainly of the iron sulphide mineral pyrrhotite (much like more common iron pyrite or "fool's gold"), was mined from the earth, roasted with fire, and subsequently leached with water in a series of operations gradually moving down the steep hillside. The resulting copperas liquors were collected in wooden troughs and boiled and crystallized in lead-lined vats. The coarse green copperas crystals were then packed into barrels for shipment, mostly to Boston. At the urging of Colonel Amos Binney of Boston, President James Monroe, "an enthusiast in favor of American manufacturers," visited this early industrial works during his tour of New England in 1817.[6]

The company was able to recover some copper value from the leaching solutions by precipitating copper mud on scrap iron, because the ore contained irregular quantities of the copper-bearing mineral chalcopyrite.[7] By 1830, small furnaces for smelting roasted hand-cobbed copper ores were erected. Isaac Tyson, Jr., a Quaker chromium industrialist from Baltimore, became a partner with the Binney family, the major holder of the mineral rights. Taking his young family with him on the long journey to Vermont, he oversaw copper smelting in eight small furnaces there during 1833 and 1834, in an area now known as Furnace Flat.[8] As early as December 1833, Tyson conducted pioneering experiments using a hot-blast apparatus and anthracite coal to smelt copper, for which he was granted a patent in April 1834.[9] He was attempting more economical ways to win copper from the stubborn pyrrhotite ores, which are more difficult to smelt than the oxide ores found in many other districts. Unfortunately, the enterprise was not financially sustainable in the uncertain economy of the 1830s. It was shut down by 1839, but not before it had produced copper in sizable quantities for the time period.[10] Tyson retained a half-interest in the mineral rights to a portion of the significant Copperas Hill ore deposit, near the village now known as South Strafford.

Isaac Tyson, Jr., who died a wealthy man in 1861, groomed two of his sons, James Wood Tyson and Jesse Tyson, in the copper and chrome businesses. They knew how to conduct metallurgical assays and how to negotiate mineral leases and business deals, and they developed useful skills in applying technology. Being Quakers, both attended Haverford College near Philadelphia from 1841 to 1843.[11] They later served as trustees over the family's estate and as officers in the various companies created to continue their father's business enterprises. Although

Figure 2. James W. Tyson (1828–1900), founder and president of the Elizabeth Mining Company, astride a horse at Buena Vista Farm, c. 1890s. Photograph courtesy of Tyson archives.

Jesse, born in 1826, did participate in the copper business, his main focus was the Baltimore Chrome Works, where, as president and majority stockholder, he continued to dominate the chromium chemicals industry initiated by his father. James, younger by two years, became president of the Tyson and the Mineral Hill Mining companies, producers of chrome and copper, respectively. He had gained valuable experience as a youth while working in his father's hot-blast iron furnace in Tyson, Vermont, established in 1837 near Plymouth in Windsor County. Through the 1850s he also managed the Elba Furnace in Maryland, which his father had purchased for him, manufacturing car-wheel iron for the Baltimore & Ohio Railroad. In 1859 he served on the board of managers of the American Iron Association.[12] James has been described as being a very consistent person, compatible with his Quaker upbringing.[13]

The Elizabeth Mining Company

James W. Tyson surely recognized a valuable property when he saw one. Consequently, when most of the copper and chrome mining enterprises in Maryland declined, he turned his attention back to South Strafford, where he and Jesse as young children had observed their

father's involvement in the copper business in the 1830s. James purchased the other half-interest in the mineral rights to the Blaisdell Lot on Copperas Hill from the Binney heirs for $500, and began acquiring other nearby properties, partly with his own money but mostly with funds of the Tyson Mining Company. In 1881 James formed the Elizabeth Mining Company, naming it for his wife of thirty years, Elizabeth Dawson, the daughter of a Quaker family in Philadelphia. The stated purpose of this company, incorporated under the laws of the State of Vermont, was "the mining and smelting of copper ores." His brother Jesse and his sons Mordecai and Isaac were also officers and stockholders in the enterprise, the family trust holding a large interest in stock. Capitalized at $500,000, the company issued 100,000 shares at $5 par value, which were closely held.[14]

The Tysons often hired trustworthy agents to assist them in their business ventures. Thus, another incorporator of the Elizabeth Mining Company was William Glenn, a former Confederate military engineer and colonel, who served as the company's mining engineer and metallurgist. Glenn was a recognized expert in chrome mining and chromium chemicals and was quick to develop copper-smelting expertise.

Figure 3. Elizabeth D. Tyson (1828–1888), for whom the mine was named, c. 1887. Photograph courtesy of Webb L. Nimick.

Born in Norfolk, Virginia, in 1840, he had started his career at age fifteen as a chainman on the B & O Railroad. He proved himself working under John H. B. Latrobe, Isaac Tyson's attorney, close personal friend, and attorney for the B & O Railroad. Glenn rose rapidly in the railroad company and took on responsibilities such as overseeing the construction of a section of track in the mountains near Cumberland, Maryland. His study of mineralogy at this time led to his becoming a mining engineer. Shortly after his faithful wartime service, he accepted a position with the Tyson Mining Company, and he would serve Tyson interests for nearly forty years.[15]

In 1880, James Tyson entered into important negotiations with the owners of the neighboring Vermont Copperas Company property (also known as the Foster-Cleaveland tract) to prove title to his Copperas Hill property. He wanted to ensure that they did not have a valid adverse-possession claim on the Blaisdell Lot from any encroachment during the forty years it had lain idle. According to one newspaper account, Tyson had done "little more than enough work to protect his mineral rights here, for many years."[16] He and William Glenn traveled to Boston to meet with the principals, attorney John D. Bryant and businessman William H. Foster.[17] After some lengthy discussions, the parties settled the outstanding issues amicably. Tyson paid $1,000 to Bryant and Foster and they exchanged two small parcels of land. In addition, Tyson gave them $100 toward the construction of a new reservoir, guaranteed them access to water dammed up in their workings, and furnished an auxiliary supply from a well on one of his nearby farms.[18] Meanwhile, by sinking mine shafts from the top of Copperas Hill, Tyson began developing the pyrrhotite ore body as it dipped deeper underground. During the same period, the Strafford Mining Company worked the adjacent Foster-Cleaveland tract for copper ores under a lease, the property owners retaining the rights to the other ores for any copperas production. Tyson maintained friendly relations with his neighbors, and in early 1881 he charged some of his development expenses to an account with that unrelated company, until his own company was sufficiently organized.[19]

Like his father before him, James Tyson frequently utilized skilled Cornish miners to develop his mining properties. He now employed John Vial, one of his key Cornish mining captains from Maryland. Born in Camborne, Cornwall, in 1826, Vial had emigrated in 1844.[20] By 1850 he was working in Isaac Tyson's Mineral Hill Mine in Maryland, where he eventually held the position of superintendent, and where two shafts were even named after him.[21] At the Elizabeth Mine, Vial conducted the initial shaft-sinking. Several years later he encountered a "fine run

of ore" and skillfully kept the Tyson level away from copper ore containing too much silica.[22] He reportedly died of miners' consumption in 1895 and was buried not far from Mineral Hill in a Methodist churchyard in Carroll County, Maryland, where he had raised his family.[23]

Developing the Mine and Smelting Copper Ore

The Elizabeth Mining Company developed several initial levels in the mine, accessed via a ladderway and two shafts. The ore was hoisted to the surface for the process of separating by hand, or hand cobbing. One shaft, known as the Tyson Shaft, featured a steam engine for hoisting. The boiler and steam engine were transferred from the Tyson Mining Company's chromite mines in Maryland and Pennsylvania, shipped by rail to the station at Sharon, and then hauled to the crest of Copperas Hill by teams of up to seven horses each.[24] The hoisting equipment handled buckets each holding 300 pounds of ore, sometimes raising water as well because the mine had no pumps. At the second shaft, the company utilized a whim, or horse-operated hoist. After being crushed to pieces two inches or less in a secondhand ore breaker and hand cobbing, copper ore was trammed on rails in one-ton mine cars down the hill to the west.[25]

Pyrrhotite ore is difficult to smelt due to its high iron and sulphur content. The former element has a strong affinity for the silica found in many firebricks, and the latter has a strong affinity for the copper the smelting foreman is trying to produce. Therefore, successful smelting of pyritic copper ores requires an initial step of roasting to drive off a portion of the excess sulphur and partially oxidize the ore in preparation for smelting. Glenn and Tyson adopted their method of roasting from William H. Long at the nearby Ely Mine in Vershire, where an efficient system of 900-foot-long roast beds had been in operation for some years. Careful attention to details often meant the difference between success and failure in a smelting operation.

In a level area prepared for this purpose, the ore was heap-roasted for eleven weeks. In the roast beds, seven feet of broken ore was systematically placed in layers on top of nine inches of wood and the whole pile then covered with a few inches of fine ore particles. Workers ignited the wood beneath the pile and the fire spread first to the wood and then slowly through the ore pile. They controlled the combustion by adding shovelfuls of 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 combustion of the sulphur in the pile became self-sustaining, requiring little maintenance. Each 24-foot by 50-foot heap yielded approximately 350 tons of roasted ore suitable for smelter feed.

Figure 4. View of the deep Elizabeth Mine north open cut on Copperas Hill from the south. This pit was last mined on the old Foster-Cleaveland tract by the Vermont Copper Company during the 1940s and 1950s, obliterating remnant copperas mining excavations. This final phase exposed old mine openings from the Tyson era where the large ore body dips beneath the surface. The mine and mill buildings from the 1880s were located on the right side of the dumps. October 1998 photograph by the author.

Workers tended a number of heaps on the roast beds, working among heavy sulphur fumes. The sulphurous gases killed the vegetation in the surrounding environment, a fairly common occurrence in such mining districts until better methods were developed to capture the fumes or eliminate the need for roasting.[26]

The company also erected a 48-inch-diameter copper-smelting furnace near the roast beds by a small stream called Blaisdell (now Sargent Brook). Water circulated between the inner and outer steel shells to dissipate the heat, thereby extending the life of the furnace linings. During the summer seasons from 1882 to 1884, they smelted nearly forty tons per day of roasted ore in this small water-jacket furnace, producing a 20 percent copper matte.[27] Matte is an intermediate product of copper smelting, a double sulphide of iron and copper. This product was shipped to the Orford Copper & Sulfur Co. in Bergenport, New Jersey. The Tyson smelter also produced a small amount of pig copper, used to make high-quality brass pins in England. Connellsville coke from Pennsylvania and gas coke from Boston served as fuel in the smelting process.[28]

In 1882, James Tyson and William Glenn conducted experiments with the lining of their furnace. Finding that the lining of silica bricks in the hearth bottom was quickly eaten away by the molten material in the furnace, they replaced it with chromite sand. They hoped that chromite's refractory qualities could withstand heat and chemical attack from the smelting of pyritic ores, but the fine chromite they used had no physical bonding strength and was eroded away by the heavy molten matte. This trial failure, however, set the stage for later success.[29] William Glenn carefully documented the quantities of ore charged into the furnace, fuel consumption, and matte and slag assays, and discussed the cost-efficiency of water jackets in *The Engineering and Mining Journal.*[30] He also promoted the use of the so-called filter charge to charge a blast furnace, to prevent the roasted fines from smothering the combustion process. By carefully shoveling coarse, medium, and fine ore in regular succession on top of a layer of coke fuel, Glenn demonstrated a capacity improvement of twenty percent in the water-jacketed furnace.[31]

About this time, Boston copper metallurgist and professor Henry M. Howe served as a consultant to the Tysons. He recommended the development methods required to turn the Elizabeth Mine into a major producer. He suggested driving a long, deep horizontal passageway, or adit, from the east to open up and verify a large volume of ore reserves. Professor Howe also recommended stages of semi-pyritic smelting in a larger blast furnace, where the combustion of the sulphur in the ore would contribute heat to the smelting process. This method could produce black copper containing around 90 percent copper. Alternatively, Bessemerizing in a manner similar to the methods of the steel industry could produce high-grade matte.[32] However, the copper slump of the mid-1880s soon caused the suspension of mining operations in South Strafford.

Another Smelting Campaign

January 1888 brought some changes to the James W. Tyson family, commencing with the death of the mine's namesake, Elizabeth, in Baltimore, after a bout with pneumonia. This sad event caused the postponement of the wedding of the elderly bachelor Jesse Tyson to young Baltimore debutante, Edyth Johns. A scaled-down, intimate wedding among family members and close friends replaced the grand affair that had been planned, and Jesse had to rush from the ceremony to attend the funeral of his sister-in-law. James remarried in December 1890, uniting with Elizabeth Key Howard.[33]

Mining and smelting were again conducted from 1888 to 1890, because the price of copper was artificially elevated by the manipulations of the French Secretan Syndicate. First, ore-mining operations were resumed; then the Tysons began roasting the ores while preparing the smelter for operation, at times employing twenty to thirty men. Captain George W. Dow had charge of the underground workings, supervising the work of the miners.[34] The Elizabeth Mining Company issued six-percent mortgage bonds secured by the property to raise some $50,000 of needed working capital. The consensus of the board of directors was to operate the mine successfully so as to be able to sell it at a fair price.[35] During the summer and fall of 1890 smelting superintendent George A. Packard succeeded in manufacturing 40 percent copper matte from ore containing 5 to 6 percent copper.[36] The matte was shipped to the American Metal Company in New York for further smelting. The Tysons were eager to have a railroad built up the valley of the Ompompanoosuc River to South Strafford, as this would greatly reduce the costs of transporting ore, fuel, and supplies and make the marginal operation profitable.

A local newspaper article of the day proclaimed the high ethical standards of the operators of the Elizabeth Mine, describing them in these words: "Providence has placed it in the possession of some most excellent people of abundant means and a large amount of mining experience, but they are conscientious and humanity loving people as well."[37]

Further Mine Development Fosters Smelter Expansion

Another period of depressed copper prices kept the Elizabeth Mine mostly idle for about five years, and then development commenced along the lines recommended by Howe, with an adit driven some 1,400 feet through barren rock to the vein. Starting with hand drills, the company soon acquired an air compressor and drill to speed the pace of development. The miners finally reached the vein in June 1898, after

nearly three years of work. Put into service in early 1899, the new adit aided in the drainage, ventilation, and gravity mining of several hundred thousand tons of ore. With minor modifications it remained in use until 1958.[38] The Tysons soon built a mill equipped with a crusher able to handle 300 tons of ore per day. The mill featured revolving tables or picking belts to assist in efficient hand cobbing of the chalcopyrite-bearing ores.[39] The company also purchased a larger compressor capable of operating more drills at a greater distance inside the mine.

In 1899, copper prices once again boomed, this time because of market factors related to hungry acquisitions by the Rockefellers' Amalgamated Copper Company. The Elizabeth Mining Company continued to ship its richer copper ores to market to generate cash flow, by rail to tidal waters in Connecticut and then by barge to the Mountain Copper Company smelter in New Jersey. At the same time, it began constructing a larger smelting plant at South Strafford: a new 150-ton blast furnace for initial smelting and a new 10-ton reverberatory furnace for producing blister copper, 96 to 99 percent pure.[40] For maximum efficiency in handling materials, the roast beds were carefully laid out beneath a timber trestle and a parallel track. Each stage of processing was located along the descending hillside to utilize gravity in handling and

Figure 5. The Tyson Adit (1,340 feet long) was completed in 1898 and served as the mine's main entrance until 1958. June 1994 photograph by the author.

Figure 6. Heap-roasting near the Elizabeth Mill, c. 1902. Smoke from the roast beds near the left end of the railway trestle partially obscures the mill building. The wooden ore cars in the foreground were used to charge the copper blast furnace located near the photographer's vantage point. Collamer Abbott Papers, Special Collections, Bailey/Howe Library, University of Vermont, carton 13, folder 3.

transporting materials. An article in the *Boston Globe* reported favorably on the recent operations of the Elizabeth among the Orange County mines.[41]

By this time James W. Tyson, Jr., following in his father's footsteps, lived and worked full-time in Vermont, overseeing the operation. After receiving his formal education at Haverford, he had participated in some of the mining and smelting activities in South Strafford during the previous campaigns and later gained experience in Pittsburgh's steel industry. James Junior and his family resided in the large white brick house known as "Buena Vista Farm," a short distance down the road from the Elizabeth operations. The homestead still remains in the family today. James Senior had been suffering poor health for several years and could travel north only in seasonable weather, often directing company business from Baltimore. Bookkeeper H. Lee Hatch and Captain Dow regularly mailed reports to keep him informed of operations.[42]

The underground mining environment subjected both man and beast to various hazards. While the Elizabeth mine did not have the explosive

Figure 7. Young James W. Tyson, Jr. (1861–1946) in a reflective pose at Buena Vista, c. 1887. The youngest surviving son of James W. Tyson and the most active in copper mining and smelting, he worked at the Elizabeth Mine during the 1880s and managed the operations from 1897 to 1902. He superintended again under August Heckscher in 1907. An upstanding community member, he resided at Buena Vista Farm in South Strafford for nearly fifty years, and served as the town's representative in the legislature. Photograph courtesy of Webb L. Nimick.

gases and massive roof collapses typically associated with coal mining, its large underground openings offered the potential for falling rocks, and heavy equipment might crush someone in an instant. In the dim light of candles or oil lamps, dangers were not readily apparent. Miner Ed Carey was killed instantaneously by a falling rock in July 1900.[43] Injured miner Warren Flanders received a $40 collection from the other men while he lay at Mary Hitchcock hospital.[44] On one documented occasion in 1893, a blast nearly killed several miners when a rock struck only about two feet away from them.[45] Tragically, thirty-

three-year-old Arthur Kenison, son of an Ely miner, was killed instantly in July 1897 by a premature dynamite blast.[46]

The mine employed horses to draw the ore cars in the long adit. In February 1899, Buchanan Tyson's little horse Jack was severely burned when the oil lamp attached to its harness exploded. The frightened animal is reported to have lain down in the flaming fluid.[47] Later that year, a collision in the tunnel mortally injured another horse, but no miners were hurt.[48] In another instance, Willis Sharp was hurt while taking an ore car out of the mine.[49] Two buildings at the mouth of the adit burned in May 1899 and had to be rebuilt, and the workers' change house caught fire in 1900.[50] These and other such difficulties were part of the normal course of operations at the mine.

The elder James W. Tyson was well enough to travel to Vermont in June 1900 to attend to business, but by late July was so seriously ill that a physician and a nurse had to be called in from Hanover to care for him. Another doctor and a nurse accompanied him when he returned to Baltimore in the fall.[51] He died on December 3, 1900, the same day his granddaughter Rosa was born at Buena Vista. A memorial service was held on Copperas Hill while Tyson's funeral was conducted in Baltimore.[52] Like her father, Rosa Tyson would grow up to be a pillar of the South Strafford community.

James W. Tyson, Jr., carried on mining and smelting as best he could with little support and assistance from Baltimore, apart from faithful metallurgist William Glenn. The Elizabeth Mining Company was often short of working capital, with cash tied up in the thousands of tons of ore lying on the roast beds. The company had to take out small loans and seek cash advances on ore and matte shipments in order to meet monthly payrolls and pay its bills. For some time the principals had been trying to sell the operation for a good cash price, as the company was indebted to other family business concerns for several hundred thousand dollars. Potential buyers desired options with various contingencies, but their unsecured offers were declined. The Tysons even turned down a reported $600,000 offer from George Westinghouse.[53] Westinghouse instead purchased the mined-out Ely Mine in neighboring Vershire, spending a million dollars there over a five-year period conducting experiments in a failed smelting plant. Afterwards, not only were Westinghouse's plant and equipment removed, but the one-time boomtown of Copperfield was dismantled as well.

Innovations Amid Difficulties

The Tysons continued mine and smelter operations to try to prove the value of the property and its extensive ore reserves. The smelter

products were consigned to the Bridgeport Brass Company through its Oronoque Company affiliate in Vermont and shipped to the Nichols Chemical Company refinery on Long Island, New York, for refining.[54] Unfortunately, by 1901, as the price of copper once again fell, the asking price for the mine had to fall also. Because the company was now caught in a family legal squabble and encumbered by creditors, it received no serious offers to purchase the mine.[55]

Several factors combined to hinder smelting operations at the site. Gas coke shipments were either delayed, or contained excessive moisture or fines that made them unsuitable as smelter fuel. The local railroad proposals of the 1890s never came to fruition because of an unstable economy and poor prospects of financial success, so the Elizabeth Mine still faced high transportation costs. Securing fuels inexpensively and moving products economically to distant markets were critical to the success of any mine. Moving materials and goods to and from the remote Vermont location remained expensive and unreliable. Teams of

Figure 8. Tyson copper smelter operating, c. 1900 (possibly 1907) with smoke emanating from blower engine and blast furnace stacks. The reverberatory furnace was housed in the structure with the idle smokestack and the building to the far left was a miners' boarding house constructed c. 1900. Photograph courtesy of the Strafford Historical Society.

horses took cobbed ore or matte ten miles downhill to the Pompanoosuc Station of the Boston & Maine Railroad, returning with fuel and supplies. At times as many as seventy-five draught animals were hard at work. The company made frequent shipping arrangements with the station agent, Hersey E. Kendall.[56] During winter weather, sledding became the required mode of transportation. When "mud season" came in spring, haulers switched from runners to wheels.

During this period James Tyson, Jr. and William Glenn experimented successfully with several innovations. One was the use of chromite hearth linings in their 3-foot by 10-foot water-jacketed cupola furnace. Their knowledge of chromite through the chemical business in Baltimore gave them an advantage in applying the material as a furnace lining that might stand up to the smelting of pyrrhotite ore. Using both large and small pieces of interlocked Turkish chrome ore, hammered into place, they successfully built a furnace bottom that functioned well for more than twenty-six weeks. A typical silica-brick bottom deteriorated rapidly and had to be replaced weekly, as the excess iron in the molten pyritic ores consumed it. William Glenn shared this achievement at the 1901 American Institute of Mining Engineers meeting in Richmond, Virginia, and recommended it to all smelters. Tyson also used blocks of chromite ore in the bridge wall of the reverberatory furnace, where it stood up well, proving the effectiveness of the chromite.[57] Even today chromite is a preferred refractory material in reverberatory copper furnaces, in spite of the fact that it has been removed from many related uses because of hazardous waste concerns.

Another innovation concerned the process of copper converting. Tyson, assisted by Glenn and his smelterman, a Mr. Everett from Canada, devised a way to skip the expensive and laborious steps of crushing and roasting the heavy matte produced from pyrrhotite smelting, by directly reducing it in the small reverberatory furnace. They found they could successfully convert impure matte to blister copper by aiming a blast of superheated steam, air, and sand onto the surface of the molten charge.[58] The sand provided silica to draw away iron from the melt to form waste slag, leaving molten copper behind. They generated the steam by utilizing the waste heat from the smelter flue. In January 1902 they sought a patent, but to their disappointment the application was denied. Thomas Roberts of Baltimore and others already held patents covering a similar process, although they had not proven them practically as the metallurgical staff of the Elizabeth had done.[59] In his 1902 *Copper Handbook,* Horace J. Stevens referred to this method as the "reactor process."[60] The durability of the chromite refractory made the Tyson process effective, successfully producing blister copper in two steps in-

stead of three. Much of the slag from the smelting was handled using wheeled slag pots, or buggies, that could easily be maneuvered and dumped on a waste heap by one man. A trough with flowing water was also installed to granulate the molten slag and wash it away.

Continued financial and legal problems caused the shutdown of the mine, mill, and smelter by June 1902. The company owed Bridgeport Brass $55,000 on a chattel mortgage and had two $5,000 loans from the National Bank of White River Junction.[61] The Elizabeth Mining Company was effectively defunct.

After the Tysons

During its years of operation, a number of prominent mining engineers and consultants examined the Elizabeth Mine. They visited the mine and smelter complex to interview the management and collect ore samples for assaying. They measured the huge vein and prepared maps to accompany their reports, explaining the geology and indicating the potential of the mine. Recognized experts following Professor Howe included Lomax Littlejohn in 1888, H. C. Southworth in 1897, and Messrs. Albert R. Ledoux & Co. in 1899. In 1896 Professor N. A. Bibikov from Russia visited the mine while conducting studies on the Ely Mine, and Westinghouse representatives visited as well when a possible purchase was under consideration. Reginald W. Petre visited in 1902, and Walter H. Weed of the U.S. Geological Survey in 1903. Both Philip S. Smith of Harvard and German Otto Sussman of the American Metal Company authored reports in 1904, followed by others representing both the academic and business communities.[62]

In 1905, John Judson and Lewis Rowand, former employees of the Wetherill Separating Company and accomplished veterans of difficult ore-separation processes at the New Jersey Zinc Company, obtained a lease on the Elizabeth Mine from the court-appointed receivers. They conducted magnetic separation experiments in their laboratory in New Jersey, attempting to remove the valuable copper mineral chalcopyrite from the ubiquitous unwanted mineral pyrrhotite. Their process consisted of roasting the pyrrhotite ore to make it more magnetic, as the Elizabeth pyrrhotite is not as magnetic as other such ores. Since pyrrhotite was not covered in the Wetherill Magnetic Separator patents, they would not have to pay licensing fees to use the process.[63] Judson and Rowand tried to get American Metal (backed by the German conglomerate Metallurgische Gesellschaft, A.G.) to invest in their Elizabeth project. Failing in these negotiations, they convinced New Jersey Zinc magnate August Heckscher to be their financial backer. However, the process they had developed in the laboratory proved unsuccessful

at South Strafford. Heckscher exercised an option Judson had negotiated and purchased the mine for only $200,000 in late 1906, enabling the Tysons to settle with their creditors.[64] Under the direction of James Tyson, Jr., an inventory of roasted ores was smelted for a brief period in the existing Tyson blast furnace in early 1907. Heckscher then constructed an elaborate and expensive smelter plant rated at 300 tons per day, but it, too, failed after several attempts.

Exploration conducted with diamond drills in 1909 began to confirm the depth and lateral extent of the massive Copperas Hill ore deposit. The ore body eventually proved to be more than two miles long, some 300 to 600 feet deep, and usually 12 to 35 feet wide, with some sections reaching a width of 64 feet. On the whole containing less than 2 percent copper, the ore could not be treated economically by the milling and smelting techniques applied by the Tysons and others. Only the highest-grade ores were profitable, and then only during periods of elevated copper prices. It would take the successful application of early froth flotation technology during World War I to make the mine's future possible.[65] The flotation process involves grinding the ore to a powder, then using specific chemicals in an aerated water bath to cause only the copper-bearing minerals to adhere to the surface of the rising bubbles. The mineral-rich "froth" is skimmed off as a copper concentrate ready for shipment to a smelter.

After a short run by American Metal in 1926 and another by National Copper from 1929 to 1930, the Elizabeth Mine was outfitted during World War II by a new corporation, the Vermont Copper Company, with modern mining equipment and a 500-ton per day flotation mill for its final fifteen-year run. The support of the Vermont War Production Board and studies conducted by the U.S. Geological Survey and the Bureau of Mines helped to justify the large capital outlay required to reopen the mine. A loan from the Metals Reserve Company, a federal agency, supplemented the significant private investment. Because of wartime demands in 1943, the Vermont Copper Company received a premium price to supply copper under its guaranteed government contract. During this time, the Elizabeth Mine grew and became one of the top twenty U.S. copper mines, a noteworthy achievement to be named among the mammoth mines of the West found in Arizona, Montana, and Utah. It processed 800 tons per day of ore on average by 1953, with a peak production of 1,000 tons per day, finally closing in 1958.[66]

Recent Events

An unintended legacy of the Elizabeth Mine is acid mine drainage into the west branch of the Ompompanoosuc River. Acidic water con-

taining varying quantities of iron, aluminum, and other contaminants emanates from the former workings, exceeding established water quality standards. The regular decomposition of sulphide minerals in waste rock and tailings piles caused by the action of water and air also yields such drainage. As a result, federal agencies including the Army Corps of Engineers, the Environmental Protection Agency (EPA), and the U.S. Geological Survey, with the cooperation of the Vermont Agency of Natural Resources and Department of Environmental Conservation, have studied and continue to consider the Elizabeth site, which was listed on the National Priorities List of hazardous waste sites under Superfund laws in June 2001. In addition, the State of Vermont Historic Preservation Office is reviewing the continuing historical and archeological investigations, as the district has been determined to be eligible for the National Register of Historic Places. Counted among those conducting the historic and scientific studies are industrial archeologists, historians, environmental consultants, geochemists, and engineers. Nearly a dozen community groups have come together as stakeholders in an advisory capacity to help determine by consensus an acceptable solution from a series of options being provided by the government and consultants.

After many studies and community meetings, interested parties reviewed the EPA's Engineering Evaluation and Cost Analysis report and Proposed Plan of Action for a cleanup in Spring 2002 and gave feedback during a thirty-day public comment period. After considering these comments, EPA plans to conduct a Remedial Investigation and Feasibility Study based upon a cleanup direction selected. Archeological field work was conducted during Summer 2002. Further studies and meetings will take place before actual site cleanup commences, contingent upon adequate funding.[67]

The proposed cleanup solutions are controversial and the scale of the Elizabeth project is immense. It will be the first major mine cleanup project in New England, and soon will be followed by work at the other nearby abandoned copper mining sites. Interested parties have different priorities. Historians desire to study and preserve unique and historic elements of the site, environmental activists seek a thorough cleanup and restoration of the landscape, and many community members are concerned about the truck traffic required to transport dirt for capping the extensive tailings piles, as well as the loss of a familiar landmark. Still others, such as engineers and scientists, want decisions based upon sound scientific research and engineering principles. Government officials seek a cleanup that meets required environmental standards while addressing the related elements of concern, ever cognizant of the

considerable financial outlay from limited funds for the initial site cleanup and the requirements for ongoing maintenance costs in the future.

Notwithstanding the unfolding cleanup saga, the challenge remains to remediate the mine's environmental effects without destroying its unique historical and topographic features nor disrupting the community, for the Elizabeth Mine and its landscape represent some 150 years of eastern U.S. copper-mining history.

Notes

* With fond memories this article is dedicated to Frances Wilson of South Strafford, Vermont.

[1] Collamer M. Abbott, "Vermont's Pioneer Copper Plant," *The New England Galaxy* 6, no. 2 (Fall 1964): 33–41; Collamer M. Abbott, "Early Copper Smelting in Vermont," *Vermont History* 33, no. 1 (January 1965): 233–242. For a general history of Vermont's copper mines, the author recommends: Collamer M. Abbott, *Green Mountain Copper: The Story of Vermont's Red Metal* (Randolph: Herald Printery, 1973), 1–36. *Green Mountain Copper* was recently reprinted (2000) and copies may be obtained from the Thetford Historical Society. Another general reference is Katharine Blaisdell, *Over the River and Through the Years, Book Four: Mills and Mines* (1982), 46–84. The Strafford Historical Society has periodically (regularly in recent years) provided informative slide programs and articles concerning the history of Copperas Hill and the Elizabeth Mine.

[2] John F. Slack and Terry W. Offield, et al., "Besshi-type Massive Sulfide Deposits of the Vermont Copper Belt," in *SEG Guidebook* 17 (Society of Economic Geologists, 1993): 1–73.

[3] Abbott, *Green Mountain Copper,* 4–27; Susan Youngwood, "The Ely War," *Vermont Life* (Spring 1993), 44–47, 70.

[4] Abbott, *Green Mountain Copper,* 30, 35.

[5] Abbott, "Early Copper Smelting in Vermont," 233.

[6] Zadock Thompson, *Gazetteer of Vermont* (1842), 167; William Belmont Parker, *The Life and Public Services of Justin Smith Morrill* (Boston and New York: Houghton Mifflin Company, 1924), 22–23.

[7] Dr. John Locke, "Some account of the copperas mines and manufactory in Strafford, Vt.," *American Journal of Science and Arts* 3 (1821), 328.

[8] Isaac Tyson, Jr., "Old Memo & Journal 1833," Vermont Historical Society collection, 1–136; Isaac Tyson, Jr., "Memorandum Book 1835–1852," Tyson family archives (privately held), South Strafford, Vt., 17; Abbott, "Vermont's Pioneer Copper Plant," 33–41; Abbott, *Green Mountain Copper.*

[9] "Specification of a Patent for an improvement in the Mode of Heating and Applying Heated Air to Blast Furnaces. Granted to Isaac Tyson, Jr. city of Baltimore, 18 April 1834," *Journal of the Franklin Institute* 20 (1835): 407. Isaac Tyson, Jr. was inducted into the National Mining Hall of Fame and Museum in Leadville, Colorado in 1996, partly for his pioneering hot-blast copper smelting experiments at Furnace Flat, in addition to his noteworthy accomplishments in the chromium industry.

[10] Thompson, *Gazetteer of Vermont,* 168. Specific production figures are not given, but from this and other descriptions the copper enterprise in Strafford was significant for the era.

[11] *Biographical Catalog of the Matriculates of Haverford College, 1833–1922* (Philadelphia: Prepared by a committee of the Alumni Association, 1922), 36, 39; William Glenn, "Biographical Notice of James Wood Tyson," *Transactions of the American Institute of Mining Engineers* 31 (1902): 118–121.

[12] James P. Lesley, *The Iron Manufacturers Guide to the Furnaces, Forges and Rolling Mills of the United States* (New York: John Wiley, 1859), 25, 48, 50.

[13] Elizabeth Key Howard Tyson, "Memoirs" (n.d.), Tyson archives, 28.

[14] "Elizabeth Mine Act of Incorporation, etc.," 12 October 1881, Tyson archives, 1, 43–46.

[15] *The Baltimore Sun,* 12 February 1907, 7; *The Engineering and Mining Journal* 84, no. 3 (20 July 1907): 123. John H. B. Latrobe was the son of Benjamin H. Latrobe, an architect whose work included the U.S. Capitol.

[16] "Mineral Wealth!! That Lies Buried in Vermont Hills," *West Randolph Herald and News* (hereinafter *Herald*), 16 February 1893. The *Herald and News* published for Randolph, Vermont, and the *Chelsea Herald,* published for Chelsea, Vermont, were basically one and the same newspaper, and will both be cited as *Herald.*

[17] William Glenn to James W. Tyson, 1 February 1881, Tyson archives.

[18] Agreement and deed between Bryant and Foster and James W. Tyson, "Elizabeth Mine Act of Incorporation, etc.," 6 September 1881, Tyson archives, 58.

[19] Elizabeth Mining Company records, 1881, Tyson archives.

[20] Margaret Brauning, "Brauning Family Genealogy," containing 1895 John Vial obituary by Pastor S. W. Coe, 1997, 2.

[21] "Record of Proceedings, Mineral Hill Mining Co." (Eighth Annual Report of the President and Directors, 30 September 1871), 238.

[22] James W. Tyson, Jr., to James W. Tyson, 7 February 1900, 16 May 1900, James W. Tyson letterbook, Tyson archives, 183a, 263.

[23] Brauning, "Genealogy," 3.

[24] Patterson, Teele & Dennis, Certified Public Accountants, New York, Baltimore, Columbus, Ohio, "Reports and Schedules, Elizabeth Mining Company to December 31st, 1900, No. 3287," Mine Plant Account, 5 May 1882 to 31 July 1884, Strafford Historical Society collection; *Vermont Journal,* 22 July 1882.

[25] "A Vermont Mine," *Herald,* 24 January 1889; "Mineral Wealth!!," *Herald*; Elizabeth Smelter Records, 1882–1884, Tyson archives.

[26] William Glenn, "The Vermont Method of Heap-Roasting Copper Ores," *The Engineering and Mining Journal* 36, no. 23 (8 December 1883): 352–353.

[27] Elizabeth Smelter Records, 1882–1884; William Glenn, "Fuel in Cupola Smelting," letter to the editor, *The Engineering and Mining Journal* 38, no. 3 (19 July 1884): 34.

[28] William Glenn, "Water-Jackets versus Brick Furnaces in Copper Smelting," letter to the editor, *The Engineering and Mining Journal* 36, no. 18 (3 November 1883): 274.

[29] William Glenn, "Chromite as a Hearth-Lining for a Furnace Smelting Copper-Ore," *Transactions of A.I.M.E.* 31 (1902): 375.

[30] Elizabeth Mine & Furnace Statements, 1883 and 1884, Tyson archives; Glenn, "Water-Jackets versus Brick Furnaces," 274.

[31] Glenn, "Fuel in Cupola Smelting," 34.

[32] Henry M. Howe, "The Elizabeth Copper Mine, Vermont," *The Engineering and Mining Journal,* 42, no. 19 (6 November 1886): 327; Henry M. Howe, *Report on the Elizabeth Copper Mine of Strafford, Vermont, 1886* (Baltimore: Hoffman & Co., 1890), 10–11.

[33] "Death of Mrs. James W. Tyson," *Baltimore Sun,* Wednesday morning, 25 January 1888, 4; "The Tyson-Johns Wedding," *Baltimore Sun,* Friday, 27 January 1888, supplement, 2; Webb L. Nimick, "A Family History and Genealogy of James Wood Tyson and Elizabeth Dawson Tyson and Their Forebears and Descendants" (1994), Tyson archives, 66; Elizabeth Key Howard Tyson, "Memoirs," 28. The marriage of Jesse Tyson to Edyth Johns was almost scandalous, for he was sixty-six years old and she was only nineteen. The rest of the Tyson family had serious reservations about such a union. A similar situation arose when sixty-year old James W. Tyson remarried. Elizabeth Key Howard, a descendant of Francis Scott Key, author of the "Star-Spangled Banner," was thirty-three at the time. James's grown children at first objected to their father's marriage to someone younger than some of them, but they later came to accept and even befriend the second Elizabeth.

[34] "Vermont," *The Engineering and Mining Journal* 45, no. 13 (31 March 1888): 240; "Mineral Wealth!!," *Herald.*

[35] "Elizabeth Mine Act of Incorporation," board of directors meeting minutes of 9 April 1890, Tyson archives, 75–80.

[36] Elizabeth Mine, Furnace Operation & Furnace Records 1890, Tyson archives; George A. Packard, "Vermont," *The Engineering and Mining Journal* 85, no. 1 (4 January 1908): 47.

[37] "A Vermont Mine," *Herald,* 24 January 1889.

[38] Elizabeth Mine records, 1898, Tyson archives; James W. Tyson, Jr., letterbook, 15 June 1898, Strafford Historical Society collection, 273.

[39] Report of Albert Reid Ledoux in "Papers Descriptive of the Elizabeth Copper Mine, South Strafford, Vermont," from Ledoux & Co. to Lomax Littlejohn, New York (17 May 1899), Collamer Abbott Papers, Bailey-Howe Memorial Library Special Collections, University of Vermont, 6.

[40] George H. Perkins, "Metallic Products, Copper," in *Report of the State Geologist on the Mineral Industries of Vermont, 1899–1900* (Burlington: Free Press Association, 1900), 10; Elbridge C. Jacobs, "Copper Mining in Vermont," in *Report of the State Geologist on the Mineral Industries and Geology of Vermont, 1915–1916* (Burlington: Free Press Printing Co., 1916), 194; Horace J. Stevens, *The Copper Handbook,* vol. 2 for 1901 (Houghton, Michigan: Horace J. Stevens, 1902), 315; Glenn, "Chromite as a Hearth-Lining," 375.

[41] "Copper Mining Revived in Vermont," *The Boston Globe,* 8 December 1899. The same article was carried locally in the *Herald.*

[42] James W. Tyson letterbook, 1900, Tyson archives.

[43] *Herald,* 5 July 1900. Unless noted otherwise, transcriptions of untitled articles in Vermont newspapers were provided by Gwenda Smith, Strafford Historical Society.

[44] *Herald,* 21 June 1900.

[45] *Vermont Journal,* 11 March 1893.

[46] *Bradford United Opinion,* 16 July 1897 (transcription from Collamer Abbott, Notebook 51), 151.

[47] *Herald,* 9 February 1899. Buchanan Tyson, the oldest son of James W. Tyson, Jr., was about ten years old when this accident occurred.

[48] *Herald,* 9 November 1899.

[49] *Herald,* 2 November 1899.

[50] *Herald,* 4 May 1899; *Herald,* 27 December 1900.

[51] *Herald,* 21 June 1900; 26 July 1900; 30 August 1900, 11 October 1900.

[52] *Herald,* 12 December 1900; *Baltimore Sun,* 4 December 1900, 7; James W. Tyson, Jr., letterbook, 3 December 1900, Tyson archives, 156a.

[53] Record No. 15, *Edith [sic] Johns Cotten, Executrix of Jesse Tyson, Exceptant,* vs. *Julia McHenry Tyson et al.,* in the Court of Appeals of Maryland, Appeal from the Circuit Court of Baltimore City, filed 13 June 1913, "In the Matter of the Trust Estate of Richard W. Tyson, deceased," 87, Maryland Law Library, Annapolis. This 550-page reference contains many details concerning a complicated legal case involving second- and third-generation members of the Isaac Tyson, Jr., family, including the finances and ownership of the Elizabeth Mining Company in relation to the other family-held companies such as the Tyson Mining Company, the Mineral Hill Mining Company, and the Baltimore Chrome Works. Legal proceedings dragged on in the courts for thirteen years, involving many attorneys, accountants, trustees, witnesses, and family members. The author has not included these details to avoid distracting the reader from the main subject of the article. Therefore, 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 very complicated matter and should be understood in general terms.

[54] "Elizabeth Mine Act of Incorporation," Agreement between Elizabeth Mining Company and the Oronoque Co., 7 November 1900, recorded in minutes of board of directors meeting, 1 November 1900, Tyson archives, 104.

[55] Record No. 15, *Cotten* vs. *Tyson,* 38.

[56] James W. Tyson and James W. Tyson, Jr., letterbooks, 1899–1902, Tyson archives.

[57] Glenn, "Chromite as a Hearth-Lining," 375–379.

[58] William Glenn, "A New Method of Copper Matte Concentration," letter to the editor, *The Engineering and Mining Journal* 74, no. 25 (20 December 1902): 820–821; James W. Tyson, Jr., to William Glenn, 19 and 20 January 1902, Tyson archives, 754–756 and James W. Tyson, Jr., to Munn & Co., 25 January 1902, 783–784.

[59] Thomas Roberts, "Process of Reducing and Refining Copper," United States Patent Office, Letters Patent No. 568700, 29 September 1896; James W. Tyson, Jr., to William Glenn, 17 March 1902, Tyson archives, 883.

[60] Horace J. Stevens, *The Copper Handbook,* volume 3 for year 1902 (Houghton: Horace J. Stevens, 1903), 57.

[61] Record No. 15, *Cotten* vs. *Tyson,* 91.

[62] Transcriptions of the Howe, Littlejohn, Southworth, Ledoux, Petre, and Sussman reports (originally from the American Metal Company collection) are found in the Collamer Abbott Papers, Bailey/Howe Library Special Collections, University of Vermont; "Report of Prof. N. A. Bibikov on Elizabeth Copper Mine," 6 June 1896, Tyson archives, 1–6; Walter Harvey Weed, "Notes on the Copper Mines of Vermont," in *Contributions to Economic Geology,* U.S.G.S. Bulletin 225 (Washington: Government Printing Office, 1904), 190–201; Philip Sydney Smith, "The Copper Sulphide Deposits of Orange County, Vermont" (Ph.D. thesis, Harvard University, 1904), 1–177; Henry Lloyd Smyth and Philip S. Smith, "The Copper Deposits of Orange County, Vermont," *The Engineering and Mining Journal* 74, no. 17 (28 April 1904): 677–678.

[63] John Nichols Judson, *Elizabeth Mine, South Strafford, Vermont. Statement Respecting the Proposed Method of Working the Ore by Magnetic Separation* (New York: Evening Post Job Printing House, 1904), 1–28.

[64] Columbus O'Donnell Lee to James W. Tyson, Jr., 13 October 1906, Tyson archives.

[65] Elbridge C. Jacobs, "Reopening of the Vermont Copper Mines," in *Report of the State Geologist on the Mineral Industries and Geology of Vermont, 1941–1942* (Burlington: Free Press Printing Co., 1942), 12–16.

[66] Charles White Merrill and Helena M. Meyer, "Copper," in *U.S. Bureau of Mines Minerals Yearbook 1949* (Washington: Government Printing Office, 1951), 467; Jacobs, "Reopening of the Vermont Copper Mines," 1–6; Abbott, *Green Mountain Copper,* 30–36.

[67] Interested readers can find a wealth of information regarding the ongoing Elizabeth Mine remediation project from a number of sources. For starters, the author suggests reviewing the Elizabeth Mine Community Advisory Group website: http://www.dartmouth.edu/~cehs/CAGsite, or try contacting one of the EPA-appointed facilitators at 802-223-1330. Information found on the website leads in many diverse directions, further exemplifying the complexity and importance of this historic site.