BONANZAS & BORRASCAS – A COMSTOCK MINING HISTORY
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The Business of Mining:
The Sutro Tunnel, Ever-Expanding Technological Base

The "Feats of Labor", to steal a phrase from Eliot Lord, was no more evident on the Comstock than with the most controversial and colossal project ever undertaken – the Sutro Tunnel.[1] It was an underground passage, four miles long, that began on the surface in a place called Sutro, to the east of the Comstock, and reached a depth of 1,700 to 1,800 feet when it connected to the Lode under Virginia City. It was designed with several tasks in mind, although drainage was the principal one. As impressive as this "feat of labor" was, it highlighted another feat that helped to define the Comstock – the search for and the application of new technologies. In any comparative assessment of New World mining, one has to be struck by how much mechanization had entered the business of mining by the second half of the nineteenth century, especially underground. Spanish colonial mining had little mechanization below ground, and some above ground at the refineries. Spanish colonial mining was mainly labor intensive with little investment in capital goods. Comstock mining, however, had a heavy investment in capital goods, both above ground and below. Drills cut away the rock, pumps admitted air and drained water and elevators moved workers and ores in and out of the mine. Company correspondence referred to searches for better bits and bigger engines to accomplish the work. Machines did not replace humans, of course, but they in combination with human labor made it possible to be more productive at greater depths than ever before. There were limits, imposed by the physical environment, but not by the imagination of the entrepreneur. One of those projects of the imagination that almost became a fully achieved reality was the Sutro Tunnel.

The tunnel was the dream and the achievement of Adolph Sutro, whom Grant Smith described as "one of the most remarkable men that rose to power on the Comstock."[2] Because so many (including Sutro himself) have written about Sutro and his ambitions, I have chosen to confine my analysis to some specific matters dealing with finances and technologies within the context of the Comstock's economic development. As many contemporaries and later historians observed, the tunnel took a decade to build and therefore was opened only after the Lode's greatest bonanza had passed. As a result the tunnel, although aggressively and continually promoted, served as a postscript in the history of the Comstock. After numerous setbacks and threatened abandonment after abandonment the tunnel was completed, functioned as it was designed to do and was regarded as a success simply because it proved what could be accomplished in an age that combined the power of the machine and the capacity of labor. Indeed, one might postulate that the Sutro Tunnel was the final act in a drama that had raised the business of mining to unprecedented heights. As promoter, designer and entrepreneur did not Sutro embrace and embolden a spirit that many shared.

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[1] Lord, *Comstock Mining and Miners*, the title of Chapter 17.
[2] Smith, *The Comstock Lode*, 107.

The history of Sutro's tunnel began shortly after mining on the Comstock began. The idea for a tunnel was pitched to the Nevada Legislature [2nd Session] in 1865. The Legislature granted to Sutro an exclusive franchise to build a tunnel from the mouth of Webber Cañon in Lyon County to the Comstock at a point about 2,000 feet below the Gould & Curry croppings. A federal bill – The Sutro Tunnel Act – followed in 1866. It permitted him to buy public land for $1.25 per acre and private land for $5.00 per acre over the distance to the Lode. It also stipulated that anyone benefiting from the tunnel had to pay a fee to the company. What was not forthcoming in spite of many years of petitioning and imploring Congress was a federal loan. And the lack of capital would haunt Sutro to the very end of his participation in the tunnel project.[3]

The idea behind the tunnel actually made sense. The primary purpose of the tunnel was to drain water from a depth that was well below the levels that most of the underground operations had then reached. Sutro (and others) believed that mining companies would find richer ores the deeper they dug into the Lode. But a few hundred feet below the surface water had already become a problem and an expense for some mines, and the idea behind Sutro plan was to connect to the Lode at a depth sufficiently below the presumed location of the yet-to-be-discovered to let the water drain down and out. This idea was a variation on what Spanish miners had learned in Mexico and Peru. They would build an adit or tunnel below the vein of ore that they were working to remove the water. This was referred to in colonial documents as "dead work" because it had no other function except to drain water. These projects were expensive, time-consuming and often abandoned. They were more often built in Mexico than Peru because Mexican ores over time proved to be of higher grades and therefore of greater yields than Peruvian ores. Adits could in fact pay for themselves.[4] As efficient as Sutro's tunnel might have been for diverting water, Sutro had other plans for the tunnel. In addition to drainage he envisioned that it could be used to transport workers, supplies, ores and even visitors into the interior of the Lode. Since it was to be used for more than moving water the interior of the tunnel had to have a system of ventilation and illumination, had to be wide and high enough to accommodate rails, cars and passengers and had to keep the drainage ditch separate from the rail system. Further it was necessary to build the tunnel on a grade for the flow of the water as well as to intersect the Lode at an appropriately effective point. A quick, simple calculation reveals that the interior of that tunnel would be about 2 million cubic feet. Tens of thousands, perhaps hundreds of thousands of tons of soil, rock and clay (not to mention scalding water) would have to be removed to bring the tunnel into existence. This plan called for careful engineering as well as long-term financing, compliant laborers and drilling technology, some of which did not yet exist. As was his nature Sutro created an overly optimistic timetable of two and one half years for the completion of the tunnel. In a report to the 3rd Legislative Session the Surveyor-General thought the timetable was "impractical" and estimated that

[3] Lord, *Comstock Mining and Miners*, 233-235.
[4] For a comparative discussion of colonial Peruvian and Mexican mining, see Richard Garner, "Long-Term Silver Mining Trends in Spanish America: A Comparative Analysis of Peru and Mexico," *American Historical Review*, 93-4 (October, 1988), 929-934.

"with vigorous prosecution" five years would be needed.[5] It actually took 13 years to complete the tunnel, and not only did the companies discover the rich ores that Sutro had predicted when the tunnel was launched but they had already removed most of the profitable ores when the tunnel was finished. Among his supporters and enemies there was a consensus that such a tunnel, if it could be built, would serve the Comstock well, but like so many Comstock projects this one became bogged down in financial disputes, technical failures, political intrigues and a general dislike and distrust of Sutro within the mining community. The fact is the Comstock had its boom without the tunnel because miners found other ways to accomplish what the tunnel had proposed to do. Whether or not a functioning tunnel during the boom years would have made a significant difference in the Comstock's mining profits can hardly be tested. What attracts one's attention is how this project managed to stay alive as long as it did.

Part of the appeal of the project may have been its monumentality. Big projects and big dreams were standard fare on the Comstock. There is no doubt that Sutro like many of his contemporaries overstated the prospects and in particular the financial prospects of the tunnel. In fact, though, it was completed much in the way that his original plan had envisioned.[6] His franchise gave him a claim of land about one mile in width. From Webber Cañon the tunnel would be dug through the middle of the claim to connect with the Comstock (actually at the Savage Mine to the south of Gould & Curry) at between 1,600 and 1,700 feet. The depth of the tunnel would increase, of course, as the tunnel made its way under rising surface elevations until it reached the Comstock, a distance of 20,000 feet. Given the dual purpose of the tunnel – drainage and transportation - it was designed to be 7 feet high, 8 feet wide at the top and slightly wider (between 9 and 9.5 feet) at the bottom of the tunnel. Tracks for two railways would be laid on the floor of the tunnel along with a properly covered conduit for water removal. At the Comstock end a connection would be made at no less than 1,800 feet. The grade was to be not less than one inch per 100 feet. Sutro understood that time was of the essence so he planned to excavate from both directions. To accomplish this he proposed the construction of four shafts along the route at 4,000 to 5,000-foot intervals. Once these shafts reached their appropriate levels work digging the tunnel could be sped up. The shafts could also improve ventilation and facilitate maintenance of the tunnel. This part of the project ran into numerous delays and difficulties. The first two shafts were completed, and the third and the fourth, the deepest shafts, were abandoned. Although in the mid-1860s when Sutro devised his plan to he (and others) believed rich ores lay below the 1,000-foot level, which some companies had already begun to explore. It turned out, of course, that the richest ores lay between the 1,200- and 1,700-foot levels, and had Sutro been able to complete the tunnel as scheduled by the late 1860s or early 1870s these levels could have been connected to the tunnel and drained accordingly. With ores discovered below the 1,700-foot level the tunnel would have been less effective. It would

[5] "Annual Report of the Surveyor-General…1865" in *Senate Journal and Appendix*, 3rd Legislative Session (1867), 24-25.

[6] "Annual Report of the Surveyor-General…1865" in *Senate Journal and Appendix*, 3rd Legislative Session (1867), 24-25; Summary of Articles of Agreement between Gould & Curry and Sutro Tunnel Company (26 Mar 1866) in Folder from Virginia Consolidated Mining Company (29 Mar 1879), NC7/1/6, Special Collections, Library, University of Nevada, Reno.

have been necessary to pump water up to the tunnel. But unbeknownst to Sutro and anyone else who speculated about how deep the Lode's riches lay his tunnel intersected the Lode at about the point where the ores petered out. By the time that the connection with the Lode was made the tunnel project itself had become an anachronism, a victim of time, as was true of other monumental projects. By 1878 while some water-logged, non-producing mines could be benefit from the tunnel, they remained barren. Other mining companies were exploring depths well below the point where the tunnel connected to the Lode, and given the absence of ore and the cost of capital no effort would be made to adapt the tunnel to the new realities.

In addition to draining the mines Sutro's tunnel would also serve as a conduit for moving supplies, workers ores to and from the Lode. Being both a visionary and a businessman Sutro had concluded that if such a link were opened he would not only earn income from drainage and transport but he could also reap greater wealth by owning or controlling the mills that could be built at the end of his tunnel. It proved to be, of course, unrealistic and unrealizable. Even if the tunnel had been completed according to initial and overly optimistic predictable, the flow of material and personnel through a single artery could not accommodate the complexity that came to characterize Comstock mining. Moving hundreds and at times thousands of workers along with tens of thousands of tons of ore, residue and supplies on dual tracks over four miles was an invitation to disaster. Already by the mid-1860s the pattern of the infrastructure of the Comstock was in place. Mining companies were making larger and larger investments as the tunnel project failed to keep to its original timetable. That plus a general distaste for the bravado and arrogance that Sutro constantly displayed landed him far fewer clients than he needed to make the project financially sound. Some leases were signed, and once the tunnel was operating some lessees benefited from a connection to the tunnel. Nonetheless Sutro never lost faith (at least publicly) that he could make the project work to the benefit of himself and his investors even as the Comstock community virtually ignored Sutro and the on-again, off-again tunnel project. As evidence of his confidence, he was alleged to have said that after Virginia City was abandoned, "the owls would roost" in the tunnel.[7]

In his 1879 (and last) legislative report the Mineralogist summarized various statistics for the long history of the tunnel and its final connection to the Lode. The distance of the Sutro Tunnel to a tunnel of the Savage Mine (rather than Gould & Curry) was 20,018 feet and to the mine's shaft was 20,489 feet. The first was reached at 11 PM on 8 July 1878 when workers from Savage made a 5-foot hole that connected the mine with the tunnel. The shaft was reached two months later. The initial connection was made at a depth of 1,640 feet. Only two of the vertical shafts (1 and 2) had been sunk to their desired depths. Shafts 3 and 4 were abandoned at 456 feet and 674 feet respectively, about half the distance anticipated because of flooding. Interior dimensions were close to what the original plan called for. The easiest digging was the first 2,000 feet; after that it

[7] "Annual Report of the Surveyor-General…1865" in *Senate Journal and Appendix*, 3rd Legislative Session (1867), 24-25; Smith, *The Comstock Lode*, 110.

was hard rock. Since digging on the tunnel did not begin until 1870, the tunnel took 8 years, 8 months and 19 days.[8]

Sutro hoped, of course, to discover rich ore deposits on the way to the Comstock. He found some ore but never enough to help to pay the bills in the course of digging the tunnel. If the tunnel had been finished within two or three years after it was launched, it might have generated significant income, at least from drainage contracts, as the mining companies discovered both rich ore and voluminous water between 1,000 and 1,500 feet. But a four-mile tunnel at depths as great as 1,600 feet was not a feat to be easily and quickly accomplished, especially when capital to finance the project was in short supply. His first plan was to ask Comstock miners to sign leases that provided for a subscription of $3 million and a schedule of fees for the use of the tunnel. In the spring of 1866 23 local owners agreed to the subscription and to pay the fees for drainage and other services, if they chose to use them.[9] The leases committed mining companies to pay $2 per ton of ore extracted from mines drained by the tunnel. If companies used the tunnel to remove rock and other debris they would pay 25 cents per ton-mile and if they used it to transport workers they would pay 25 cents per worker. All such payments were to be made in gold coin and "not otherwise". The $3-million subscription was to be spread over a ten year period with annual payments of $300,000, of which not less than $200,000 was in cash. The first payment was due 1 August 1867.[10] The leases provided that the subscriptions would only be paid if the tunnel (not yet even started) could serve the companies advantageously. That phrase had an opened-ended quality. It is not clear exactly how much if any capital was raised locally in 1867 and 1868. If Sutro had raised $200,000 or $300,000, as stipulated, he could certainly have begun the tunnel. But the tunnel was not started. The leases did not yield what Sutro needed at once – money up front. As Comstock interest in Sutro's tunnel waned, Sutro extended his search for investors to San Francisco and the East Coast. Opposed fiercely by William Sharon, the titan of the Lode at the time, and caught unexpectedly in a downdraft in Comstock production, Sutro lost nearly half of his leases by the spring of 1869. The remainder renewed their contracts for a year and apparently agreed to subscribe $600,000, although it is no clear how much if any of that was ever received by Sutro. On 29 November 1869 the certificate of incorporation for the Sutro Tunnel Company authorized the issuance of 1.2 million shares of stock at $10 per share for a total of $12 million. Sutro's name was not among those listed in the incorporation, but his name was among those who transferred the ownership of the Sutro Tunnel to the new corporation. Some capital was also raised from the Miners Union.Having raised enough money to launch the project the company excavated about 1,800 feet in the first year. This was the easiest section of the tunnel to build, and yet the work had barely covered a tenth of the distance. At this point

[8] "Biennial Report of the State Mineralogist…1877 and 1878," in *Appendix to Journals of Senate and Assembly*, 9th Legislative Session (1879), 84-85; Statement of the Condition of the Sutro Tunnel by Pelham W. Ames, Sec., Sutro Tunnel Company, 1878, MS-NC3, Bx 1, Nevada Historical Society; Smith, *The Comstock Lode*, 112.

[9] Smith, *The Comstock Lode*, 108. Not reported how many paid.

[10] Summary of Articles of Agreement between Gould & Curry and Sutro Tunnel Company (26 Mar 1866) in Folder from Virginia Consolidated Mining Company (29 Mar 1879), NC7/1/6, Special Collections, Library, University of Nevada, Reno. It is presumed that the agreement between Gould & Curry and Sutro Tunnel Company was more or less generic, typical of what other companies agreed to.

the lack of money and formidable technical problems caused Sutro to abandon the project, the first of several abandonments.[11]

In the early 1870s the task of raising capital shifted from Nevada and the West to Europe. In the absence of local subscriptions, Wall Street investments or federal assistance Sutro took his dog-and-pony show abroad. His position was strengthened when rich ore deposits were discovered at 1,000 to 1,200 feet, first at Crown Point and then at Belcher and other mines. He was quick to remind everyone that he had long said that rich ore bodies lay above the tunnel's proposed depth, and these discoveries proved him right. In spite of his clairvoyance or luck further boasting did not win him any new friends or subscriptions locally. Sharon's implacable opposition continued and intensified. Sutro's salvation came by way of a London banking firm, McCalmont Brothers with offices at 15 Philpot Lane. Their partners were other European investors, Abraham and Isaac Seligman. Their association with Sutro over more than a decade was a rocky relationship at best. To the bankers Sutro appeared cocky, impulsive and flamboyant, too often a loose cannon instead of a serious businessman, and, not surprisingly, Sutro found the bankers be staid, rigid and uninformed. Hundreds of letters and telegrams flew back and forth across the Atlantic. Sutro made at least one trip to London, and in 1878 because the relationship had grown so acrimonious, he was told in no uncertain terms not to make another trip. Sutro was not reluctant to speak his mind, and in one letter he disparaged the brothers for their inability to understand the business of mining. In their reply the brothers wrote: "We prefer to pass over your remarks as to our 'shortsightedness and blindness'."[12]

In combing through numerous documents from several archives, one cannot always be certain which agreements were signed or scrapped and which revisions were accepted or rejected by all parties. One uncontested point is that although the initial McCalmont investment of several hundred thousands dollars was small, it soon grew through various refinancing schemes to millions of dollars. The pivotal years were 1873 and 1874. In 1873 the McCalmont Brothers and the Seligmans were designated the "Mortgage Trustees" for the issuance of bonds worth 1.6 million pounds sterling or nearly $8 million. As such they held a lien on the tunnel and other (unspecified) properties. Although the documentation of the Sutro tunnel is extensive, it is proven difficult to pin down exactly how many bonds were sold and how much money if any was raised beyond what the bankers and their partners had subscribed by 1873. The documentary evidence is not very helpful relative to the early financing of the Sutro Tunnel. But since the digging had resumed in 1871 certain costs had to be met for the tunnel to have added the several thousand feet that it did. These may have been covered by money borrowed from the European bankers and investors. There is no indication, however, that the banking house had raised or advanced $8 million. In a draft of a Memorandum of an Agreement between Sutro and McCalmont Brothers & Co, revised over a period of several months in late 1873 and early 1874, a bond-backed mortgage

[11] Bound Volume of Abstract of Titles, 1877, pp. 6, 7, 32, Sutro Tunnel Company, MS-NC3, Bx 4, Nevada Historical Society.
[12] Letter from McCalmont Brothers to Adolph Sutro, 3 December 1878, Sutro Tunnel Company, MS-NC3, Bx 1, Nevada Historical Society.

worth 600,000 pounds or $2.9 million was canceled (without explanation) and a second bond-backed mortgage held by McCalmont Brothers worth 133,000 pounds or $648,000 was rescheduled from 133,000 pounds to 100,000 pounds. At the same time McCalmont was permitted to purchase 300,000 shares of company stock at a price of $10 (2.05 pounds) per share. Not all the money raised from the sale of stock to the brothers would become available to the company. The bankers would retain ten shillings or about $2 per share to retire liabilities arising from the 133,000 pounds in mortgage bonds reduced to 100,000 pounds under the control of the McCalmont Brothers. The Sutro Tunnel Company would be charged interest of 4 percent on all the money (even that which was retained) used to purchase the 300,000 shares of stock (since Sutro had no income with which to pay dividends). The company would pay $6,000 a month from December 1873 to October 1874 on half of the 300,000 shares for a total of $60,000. And it would pay $3,000 a month from October 1874 until April 1876 on the other half. It was presumed that the tunnel would be open and generating revenue by 1876. At this point, it would appear, that the Europeans were on the hook for $2 to 3 million in a company that had no earnings. Quite possibly what the Europeans did was to assume any and all outstanding debts from previous years. The extent to which the company had accumulated debts since the project was launched and then suspended is not known precisely, but the work that had been done could hardly have been paid for with lease payments or company revenues. That the company had debts was intimated in Sutro's own statement that with this new arrangement the company was not only debt-free but also had funds on hand to proceed.[13]

Work on the tunnel did proceed with only a few interruptions for the next half-dozen years but with continual wrangling between the company and its financiers. Extant financial documents are not prevalent and useful after 1873. As promised, the tunnel did not open in 1876, and the company repeatedly made demands on the banks to advance more money and to modify the terms of the agreements. It appears that the London firm fully expected the tunnel to become a paying proposition even as the Comstock entered a post-bonanza cycle. When completed in 1878 the tunnel had missed the opportunity to serve the Comstock in the way envisioned by Sutro. He quietly sold out and the London bankers were left as the principal owners of a project that would not ever generate any significant revenue. The new owners could not turn around the company, and finally in 1889, when McCalmont foreclosed on the tunnel, it was reorganized as The Comstock Tunnel Company and continued in existence until the 1930s. Up to 1885 the tunnel never had enough business to pay its bills or satisfy its creditors. It may have cost McCalmont Brothers and its other stockholders and investors between $5 and 6 million to complete the tunnel and another $1 to $2 million to manage it. In the 1880s its stock was nearly worthless, although it continued to trade. Shrewd to the very end Sutro managed to sell his shares for several million dollars in 1879 and took his fortune to San Francisco where

[13] Drawn from various copies of correspondence between Sutro Tunnel Company and McCalmont Brothers, November and December, 1873, Letterpress Book, Sutro Tunnel Company, MS-NC3, Bx 2, Nevada Historical Society. See also a working draft of a "Memorandum of Agreement made this [blank] 1874 Between The Sutro Tunnel Company…and Messrs McCalmont Brothers & Co…," MS-NC7/1/5, Nevada Historical Society. This was not the final agreement since it was not signed and some text was crossed out and new text was penciled in.

he became a controversial and colorful real estate developer. While Sutro can be faulted for his promotional antics, he did in fact complete a functioning tunnel. Whether or not the McCalmont firm were victims of Sutro's endless sales pitches, they were certainly guilty of the lack of due diligence, to use today's jargon. They had little first-hand knowledge of the risks associated with the Comstock. That they continued to support the tunnel under Sutro and then after his tenure to manage the tunnel seemed to have but one rationale – to try to save what was a less than "quality-grade" investment in the first instance.[14]

The story of the Sutro Tunnel has another side. As intriguing as the financial wheeling and dealing was, the fact that the tunnel was completed for the length and at the depth in accordance with the basic plan represented a major achievement. It was a prime example of the convergence of entrepreneurship and technology in the new industrial culture of late nineteenth-century America. The technical hurdles were numerous, and modifications of and refinements to the plan had to be accommodated. Without a new generation of "tools and machines", however, the project would surely have remained a fantasy. Various maps from the Becker Atlas shows that for the first 3.5 miles the tunnel passed through various types of andesite rocks, mainly what the surveys described as "later hornblende andesite" for the first half of the distance and then "augite andesite" for the latter half. Along the way it passed through several other lodes before it reached the Comstock Lode. They include the "Great Flowery Lode" near Shaft 1 or about 2,200 feet from the mouth; the "Coryell Lode" between Shafts 2 and 3 or between 10,000 and 10,600 feet; the "Occidental Lode" just beyond Coryell or between 11,600 and 11,700 feet; and "Solferino Lode" between Shafts 3 and 4 or between 14,000 and 15,500 feet. Some of these Lodes contained vein matter and quartz. Once the tunnel reached 17,000 feet it was in the vicinity of the Comstock Lode. The rock type changed to various forms of diorite. When Sutro began the project, the geology had not been mapped yet. He did not know what he would encounter, and perhaps he had convinced himself that despite the lack of specifics he knew enough about the geology and the technology to press ahead. In the first few years before the project was shut down for lack of money and support, it had reached about 2,000. Once the project was revived in the early 1870s the pace picked up. It is important to stress the figures for how many feet were dug in any given year included explorations for gold and silver on either side of the tunnel itself. It had been Sutro's hope that he could pay for the pay through the discovery of profitable ores in the vicinity of the tunnel. While the tunnel's path crossed several quartz formations before reaching the Comstock Lode, these minor lodes were mainly vein matter with little or no profitability. From 1871 when construction resumed some of the excavation data include those additional excursions. In 1871 and 1872 3,480 feet were dug or about 72 feet per month. The next year (1873) the number jumped to 1,919 feet or

[14] Lord, writing in the early 1880s after Sutro had sold his stake, put the cost of construction at more than $2 million. His figures were based on data from the company's annual reports and other correspondence. Other sources indicate that the total cost (construction, management, loans, etc.) probably reached $5 to $6 million. It is worth noting that when Lord wrote his Comstock study he was undecided as to whether the Sutro Tunnel was worth the investment. It was not yet clear even to someone as perspicacious as Lord that the Comstock had run its course and without new rich deposits the Sutro Tunnel could not repay its investors or revitalize the Lode. *Comstock Mining and Miners*, 342-343, 346-347. See also Smith, *The Comstock Lode*, 115.

105 per month. The length had reached 5,394 feet. In 1874 2,682 feet (223 feet per month) was added for a total length of 8,079 feet. These advances were largely possible because of the installation of six Burleigh drills. Burleighs were among the most advanced (and most expensive) drills available. But the drills constituted only part of the mechanization of the operation. Air compressors were needed to drive the drills. Along with the purchase of new Burleighs the tunnel company bought a new air compressor from the Humboldt Company of Germany for installation in Shaft 2 to complement the air compressor built by Société Cockerill of Belgium in Shaft 1. In 1875 the monthly gain of 312 feet a month or 3,728 feet for the year was the best yet. In 1876, however, progress slowed to 261 feet per month or 3,130 feet for the year. By the end of 1876 the tunnel had reached almost 15,000 feet, and because it was passing through a quartz formation known as the Solferina Lode progress had slowed. The company reported that exceptionally hard rock had stymied even the Burleigh drills. In 1877 two Burleighs were taken off the compressors in order to improve the efficiency of the remaining drills. In the next year and a half (January 1877-July, 1878) the remaining 5,400 feet to access the west wall of the Comstock Lode was cut through at depths between 1,600 and 1,700 feet. Since the vertical shafts # 3 and #4 had never been completed all the tools and supplies had to be conveyed through more than 10,000 feet of the tunnel. Plans were to extend the tunnel into Mt Davidson proper at a depth of perhaps 3,600 feet. That, of course, did not ever become a reality.[15]

A single connection to the Comstock would have had only minor consequences for draining the Lode. The lateral tunnel along the Comstock had to be built to connect other mines. Such a tunnel was planned to the same specifications as the main tunnel. The southern branch of the lateral tunnel began at 19,715 feet, 400 to 500 feet before the tunnel actually broke through to the Savage mine, and was to connect with the Julia Mine, a distance of about 1,400 feet. In October and November 1878, nearly 900 feet of the southern lateral tunnel had been cut. Julia Mine was under contract to pay $100,000 of which it had already advanced $40,000. The lateral did reach Julia, but the balance if paid was not recorded. Julia may have been drained but still remained unproductive. The southern lateral was originally planned to run about 8,500 feet to Alta Mine and the northern lateral about 4,500 feet to Union Mine. Much of the equipment for the lateral work was contained in Shaft 2, a distance of about 10,000 feet. It was noted that the aforementioned compressor to power both Burleigh and Ingersoll drills as well as the blower for ventilation and the hoist for moving workers and supplies were all located in that shaft. Indeed some of the equipment was located in Shaft 1, which was even farther from the site of the work.[16] Although Sutro Tunnel abandoned plans to extend the main tunnel into Mt Davidson, it continued sporadically to work on the lateral tunnels until it

[15] "Biennial Report of the State Mineralogist…1877 and 1878," in *Appendix to Journals of Senate and Assembly*, 9th Legislative Session (1879), 81-85. Also information on the progress of the tunnel including workers employed, temperatures of air and water, nature of the ground and rock, etc. can be found in various correspondence folders with dates of 1867, 1871, 1874-1879 (most prolific for 1878) in Sutro Tunnel Company, MS-NC3, Bxs 1-3, Nevada Historical Society. The Mineralogist's data were collected from company reports and interviews, and while they could not be absolutely verified from other documentation, they appear to be generally in line with the actual results.

[16] Statement of condition by P. W. Ames, Sec., of the Sutro Tunnel Company, 1878, MS-NC3, Bx 1, Nevada Historical Society. Also see Smith, *The Comstock Lode*, 113.

had traversed a substantial part of the length of the Lode. Like the main tunnel the lateral tunnels assisted in the drainage of a Lode that had exhausted its wealth.

As monumental as the Sutro tunnel was, it was not the nation's only large-scale engineering accomplishment. The nation's longest tunnel was The Hoosac Tunnel, built under the Berkshire Mountains in western Massachusetts. The project was launched in 1851 and after several delays it was completed two decades later in 1875. It was longer than Sutro by almost 5,000 feet and bigger with an interior height of 20 feet and a width of 24. It cost twice as much to build, not only because of its size but also in part because the interior was bricked. At the eastern entrance the summit of the Hoosac Mountain was 1,429 feet high and on the western entrance it was more than 1,718 high. Sutro was somewhat deeper. The Hoosac had three shafts for ventilation and light while Sutro had four planned but only two finished. The grade in Hoosac was much greater than in Sutro. There were essential differences. The most obvious was that Hoosac was a tunnel with light on both ends, whereas Sutro, being a underground tunnel, ended in darkness. Hoosac rocks consisted of mica slate, mica shist and milky quartz instead of andesites and diorites. There was no indication that Hoosac workers had to contend with scalding water and high temperatures to the same degree that Sutro workers did. Both structure epitomized bold thinking about overcoming environmental and geological barriers with the help of course of new technologies.[17]

Key to the construction of both tunnels (as well as very deep underground mining) was drilling equipment in particular the Burleigh drill, eventually found their way to the Comstock. For centuries "tunneling, mining and quarrying" required intensive human labor. Pounding and cracking the rock and then inserting a wedge to break the rock apart were the accepted techniques. In some cases heating the rock and splashing it with cold water could create fissures that wedges could be driven into. The use of gunpowder as an explosive in the seventeenth century added another tool, but underground explosives had posed problems. First was cutting the hole for the powder, not always an easy task. Additional controlling the area of the blast and venting the area of noxious chemicals was not easily accomplished. It has been generally argued, however, that the introduction of powder in Spanish American silver mining helped to raise output in many older mines. By the nineteenth century the application of explosives underground was better understood and more widely practiced, although cutting and extracting the rock with hammers and chisels remained the miners' primary tools. Toward the middle of the nineteenth century a Massachusetts inventor, Joseph Crouch, fashioned a steam-powered drill that repeatedly slammed into the rock until it broke it apart, and while it could be used in quarrying, it was too bulky to be used in underground tunneling or mining. Steam was fast becoming a source of power for many machines, but the residue of steam posed breathing problems for workers in confined spaces like tunnels and mines that could be avoided in open areas. During the construction of Mt Cenis Tunnel between Italy and France in the early 1860s the chief engineer, Germaine

[17] See www.boudillion.com/hoosac for data on the tunnel. Also data on the Hoosac, Sutro and other long American and European tunnels was compiled for the 1880 Census available On-Line at www.census.gov/prod/www/abs/decennial/1880.htm, United States Census Bureau. *Statistics and Technology of the Precious Metals*, vol. 13, 125, Table XVII.

Sommeiler, and his associates replaced steam with compressed air, and rather than steam contaminating the work area the air cooled it. But the drill itself, even when driven by air, remained unreliable and cumbersome. Thus, in the middle 1860s during the construction of the Hoosac Tunnel Charles Burleigh introduced the first pneumatic drill that was easier to use, although it could not be quickly set up or moved about. The Burleighs not only inserted and retracted the drill, but they also turned the drill slightly for each new contact with the rock. Further improvements of the pneumatic drills made them lighter and simpler and above all easier to assemble and move.[18]

The advance in drilling had to be accompanied by an advance in the bits that the drills use to break up the rock. Diamonds, of course, being the hardest known mineral, would cut any rock such as quartz, which was three levels below diamonds in hardness. Egyptians apparently used diamond-pointed drills in their stone quarries. But the first "diamond core" drill were invented in France by a French engineer, Rodolphe Leschot, in 1863 in connection with the Mt Cenis tunnel project. The diamond bit on the end of the drill was a "tube or cylinder" with six stones or more distributed between the outside and inside circumference of the bit. Later models apparently had more than twice that number. Some diamonds were superior to others, although Leschot, since he had been a watchmaker, may have used jewel-grade diamonds that were less effective than other grades. Leschot device was patented in the United States about the same time that Burleigh had invented his device.[19] Diamond bits combined with pneumatic drills came along at an opportune time for the Sutro Tunnel in particular and for the deeper and deeper probes along the Comstock Lode. Although Sutro, starting in 1874, could have acquired more than a half-dozen Burleighs, the Yellow Jacket Mining may have been the first company to acquire a Burleigh in 1872.[20] Company accounts (to be discussed later) document that some companies purchased diamond bits to be used on their pneumatic drills. Within a few years of Yellow Jacket's purchase diamond bits and pneumatic drills had become a part of the basic underground equipment for building the tunnels and extracting the ores.

Once the main tunnel had reached the Lode at Savage and the lateral tunnel branched off to serve other mines, the drainage of the Comstock, as Sutro had envisioned it, began in earnest. Water at the level of the tunnel or above it could be easily channeled into the Sutro through drainage ditches or pipes. Water below the 1,600-foot level had to be pumped up to the tunnel, a more expensive and less convenient operation. Removing or controlling water within the mines had long been an inconvenience and expense. The Mineralogist estimated that the mining companies spent about $3 million per year to drain their mines. He assumed that the Sutro Tunnel could greatly reduce that cost. The figure cannot be verified, but according to the Sutro pumping records the volume of water carried by tunnel once it had reached the Lode averaged about a million and a quarter gallons a day. In a progress report from 1878 the figure of 1,285,000 was cited as

[18] See www.fofweb.com for article by Rudi Volti, "Pneumatic Drills," *The Facts on File, Encyclopedia of Science, Technology, and Society* (New York: Facts on File, Inc, 1999, 2003).
[19] See www.oilhistory.com for discussion of drills and bits by Samuel Pees.
[20] Lord, *Comstock Mining and Miners*, illustration between 336 and 337.

the daily flow.[21] An immediate beneficiary was the Combination Shaft and the consortium of three companies, Chollar Potosi, Savage and Hale & Norcross, which was building the shaft. It had reached 2,200 feet only to encounter hot water that quickly flooded Savage and Hale & Norcross up to the 1,800-foot level. Pumping by the companies had little effect in reducing flood levels and was very costly. When the connection was made with the Combination Shaft on 30 June 1879, Sutro wrote to Ames that the pumping had begun at 6 AM and the water reached the mouth of tunnel at 7:20 AM. The water temperature at the mouth was initially 90 degrees and gradually increased to 114 degrees. "Everything works like a charm," wrote Sutro. The heat of the water did not "discommode" any of the tunnel operations. The water flowed through the connection with the Carson River as if "it had been going there for years". The operations were soon made dry enough to be worked. To honor the occasion Sutro gave his men the day off and that fires would be lit on the ranges around the Comstock that evening to celebrate. Unfortunately celebratory fires on the ranges of the Comstock would not turn water into gold or silver. As he praised the performance of his creation, however, he already had an eye on the exit from the Comstock.[22]

Since the opening of the tunnel in 1878 Sutro had expressed disappointment at the volume of water draining from the Comstock. Since the tunnel's only business appeared to be drainage of water, volume was an indicator of how many mining operations had been signed up to use the services of the tunnel. Many of the mines on the Lode's southern branch had pipes connecting to the lateral tunnel, and his next effort was accomplish the same on the northern branch. This would double the flow of water, he said, and twice the flow meant more mines paying fees to keep the operations dry so that the ores could be hoisted.[23] Moreover mining companies could continue their search for new ore bodies at even greater depths. And his plans for expansion and improvement did not end there. Surely, though, at the same time Sutro knew what the most seasoned observers knew – the boom was over, and the Lode was running out of ore. His European backers were certainly beginning to show more skepticism. After the initial connection was made in July of 1878 McCalmont Brothers warned Sutro to concentrate on signing up mining companies to use the tunnel as it currently existed in order to generate some income and to abandon any plans for expansion and improvement. Writing on 2 July 1878 McCalmont urged Sutro "…[to] make the best bargains you can with the Comstock mines…," although the Brothers did agree to some minor improvements for roads and cultivation of alfalfa and barley for the animals. "We adhere to existing terms of mortgage due 1891."[24] A few weeks later the Brothers issued a further rebuke. Since the goal had been reached, London will provide no further outlays. "We are aware of Mr.

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[21] Reports of Progress of Work, 1878, Sutro Pumping Company, MS-NC3, Bx 1, Nevada Historical Society.

[22] "Biennial Report of the State Mineralogist…1877 and 1878," in *Appendix to Journals of Senate and Assembly*, 9th Legislative Session (1879), 85; Letter from A. Sutro, Supt., to P. W. Ames, Sec., Sutro Tunnel Company, 30 Jun 1879, MS-NC3, Bx 4, Nevada Historical Society. It is not reported in Sutro's letter how much of the daily flow was from the Combination Shaft.

[23] Letter from A. Sutro, Supt., to P. W. Ames, Sec., Sutro Tunnel Company, 30 Jun 1879, MS-NC3, Bx 4, Nevada Historical Society.

[24] Copy of Letter from McCalmont Brothers, London, to A. Sutro, 2 Jul 1878, Sutro Tunnel Company,, MS-NC3, Bx 1, Miscellaneous Letters, Nevada Historical Society.

Sutro's ambitious views, necessitating enormous expenditures in the future, such as draining the tunnel, leveling the floor, new lines of rails, smoothing sides of the tunnel, extensive drifts, prospecting, locomotive power, or wire ropes, etc. etc., all of which, however necessary they may be, we can no longer provide." They intimated that they might not pay the next installment due Sutro under the terms of the mortgage on 1 August.[25] A week later they wrote: "We can but repeat what we said in our last that if you are unable to make arrangements to procure funds from other sources, we see nothing for it but to suspend work, and close up pending operations with as little prejudice to all concerned as possible."[26] Such was the nature of the correspondence between Sutro and his backers for a year. The tunnel was losing money, and Sutro's response was for the company to grow its way into prosperity while the London firm was set on curtailing expansion, generating revenue and reducing indebtedness. In 1879 after 15 years of almost endless warfare Sutro quit. He dissolved his association with the company for several million dollars, and a new group took control under the direction of the trustee, C. W. Brush. It did not matter who owned the tunnel. Its business, so intimately linked to the health of the Lode mining entrepreneurs would, like them, end up in bankruptcy. Fewer enterprises meant fewer leases, and fewer leases meant fewer receipts despite the tunnel's success. That anyone would pay as much as Sutro was paid remains a mystery.

For the new owners making the tunnel profitable under worsening economic environment was daunting to say the least. In letters and reports from George Sprecht, the chief administrator of the Sutro Tunnel Company, to C. W. Brush, a trustee, during 1881 – the worse year for production in Comstock mining – discussed some strategies for doing that. The detailed calculations would have warmed the cockles of every cost accountant's heart. But unfortunately some of the figures are not fully explained and the totals cannot always be duplicated. Accountancy had assumed a new importance in corporate American, and the Comstock mining industry was no exception, but detailed cost statements did not necessarily provide accurate information. Part of the problem in regard to the Sutro Tunnel Company was that the information was contained in several different reports, each of which had a slightly different objective. Sprecht reiterated that the purchase plan called for paying $500,000 per year over 10 years to retire the $5 million mortgage and assumed surpluses from the following revenue sources: 40 percent from drainage royalties, 30 percent from transportation contracts, 15 percent from reduction of ores and 15 percent from opening new mines within the tunnel's own right-a-way. If transportation contracts were to yield $200,000 in surpluses to cover their share of the annual mortgage payment, two or three times that amount would have to be generated in income to pay expenses before any surpluses could be realized. In some of the agreements between the tunnel company and the mining companies they included provisions that the transport of ore was $2 per ton, rock and waste 25 cents per ton-mile

[25] Copies of Letters from McCalmont Brothers, London, to A. Sutro and C. W. Brush, 25 Jul 1878, Sutro Tunnel Company,, MS-NC3, Bx 1, Miscellaneous Letters, Nevada Historical Society.
[26] Copy of Letter from McCalmont Brothers, London, to A. Sutro, 30 Jul 1878 Sutro Tunnel Company, MS-NC3, Bx 1, Miscellaneous Letters, Nevada Historical Society.

and workers 25 cents per person each way.[27] How much haulage business had Sutro rounded up since the opening of the tunnel? No direct documentation has been found thus far, but based on some indirect evidence the answer appears to almost none. The company did report that between September 1878 and December 1880 the tunnel was used to haul on average 116 tons (58 carloads) of rock per day. What is not clear is where rock came from - Sutro's own excavations or mining company excavation? If one assumed that all the rock came from paying customers at the stipulated rate of 25 cents per ton-mile, the total income would be a measly $10,000 to $11,000 dollars, a long way from the hundreds of thousands needed to reach the company's financial goals.[28]

The flurry of activity in 1881 by Sprecht to find new strategies for improving revenues appeared to focus mainly on how to make the tunnel more of a transport conduit than it had been. The immediate question was whether the mode of transport – mule-driven trams – should be replaced. To remove the aforementioned 116 tons on average per day the company employed six daily trains of 10 cars with three mules and one mule driver per train. Without accounting for the cost of the equipment or the wage of the driver the report stated that to move a ton of rock cost 5.73 cents per ton-mile (round-trip calculated at 10 miles). Mule power was then compared to steam and air (compressed) power. At Bald Mountain Mining Company steam cost about 6.1 cents per ton-mile without any other specific being offered. Compressed air was estimated at 5.29 cents per ton-mile, although that figure was suspect since compressed air could only be used in part of the main tunnel and would have to be combined with some other mode in the rest of the main tunnel and the lateral tunnels. Sutro had a stable of 72 mules, which had to be fed, shoed and generally cared for, and while the figures are fuzzy and not always reconcilable, the cost of maintaining the mules accounted for perhaps half of the total cost of 5.7 cents per ton-mile. The other expenses included lubricating and illuminating oils (each train carried seven torches) and repairs of tracks and cars[29]. To replace mules with a locomotive powered by steam or air a source of power had to be tapped. The preferred source was water. The Lode and the tunnel, of course, had ample water but the flow was apparently inadequate to generate the needed power. At the mouth of the tunnel was the Carson River, which could be harnessed to power the steam locomotive system that Sprecht leaned toward. In comparing hoisting and hauling costs for Comstock mines Sprecht concluded that the average was $2.90 per ton with existing facilities but could be reduced to $1.55 per ton with upgraded Sutro operations. Sprecht's figures included some hoisting charges inside the mines since the mines were lifting ore and waste from depths

[27] Articles of Agreement between Sutro Tunnel Company and Consolidated Virginia Mining and California Mining Companies, 29 March 1879, Article 12 (p. 27), NC7/1/6, Special Collections, Library, University of Nevada, Reno; Articles of Articles of Agreement between Sutro Tunnel Company and Segregate Belcher Mining Company, 29 March 1879, Article 12, MS-NC3, Bx 1 Sutro Tunnel Company, Nevada Historical Society. With respect to ore if the gold yielded coin less than $40 the rate dropped to $1 per ton.

[28] Letters from George Sprecht to C. W. Brush, Trustee, Sutro Tunnel Company, 5 May 1881 and 5 June 1881, MS-NC3, Bx 1, Miscellaneous Letters from April 1881, Nevada Historical Society.

[29] Duplicating the calculations as given in the document proved to be difficult. I have accepted the report's figure of 5.7 cents per ton-mile without being able to verify its accuracy. The aim here is to provide a comparative benchmark, and no more. See Letter from George Sprecht to C. W. Brush, Trustee, Sutro Tunnel Company, 5 May 1881, MS-NC3, Bx 1, Miscellaneous Letters from April 1881, Nevada Historical Society.

below the level of the tunnel itself. His haulage figures also included the costs for installing the locomotive system, servicing the mortgage (nearly half the total) and operating the tram. Calculated on strictly a per-ton basis, since this was how mining companies calculated their hoisting and hauling costs rather than per ton-mile, Sutro could save the mining companies on average $1.35 per ton.[30]

Even as large as the savings might have been (under ideal circumstances), they offered little or no incentive for mining companies in 1881. Not only did Sutro lack the capital to rehabilitate the tunnel – mule-driven trams remained for decades – but the mining companies also lacked the financial means to abandon an old system and embrace a new one. Efficiencies in hoisting and hauling could be realized as long as the quantity and the quality of the ore continued to decline as rapidly as it had since 1878. By Sutro's own calculation the company would have had to contract to move hundreds of thousands of tons to generate the level of income needed to meet various obligations, in particular the repayment of the debt, at a time when tonnage had reached the lowest levels in the history of the Comstock. Despite a valiant effort, at least on paper, to rejuvenate the tunnel business, the company could not rejuvenate the Lode.

Underground mining was a constant war with the natural forces almost on a daily basis. With the Sutro Tunnel one could observe the beneficial impact of new technologies in taming those natural forces. The fact was that while Sutro "stumbled" toward completion mining companies had sunk some of the world's deepest shafts and built some of the longest tunnels in the world with a combination of old and new technologies. Adaptability appeared to be the key to success. Although hard to quantify it comes through in the hundreds of pages of daily or weekly reports written by foremen and superintendents. References to new machines and techniques were frequent, but much of the content of these reports concerned low-tech matters of digging and re-digging, building and rebuilding, timbering and re-timbering the interior spaces that the workers and the machines needed. Logistical questions always loomed large because the means had to be found to move workers, ores, supplies and even machines from the surface to the bottom and back to the top or from one part of the mine to another part. Bigger engines, stronger cables, larger cages and other technological innovation let shafts operate faster and even more safely, but even after the better technology had been put to work, the shafts themselves, mostly constructed from wooden timbers, had to be secured constantly against bulging and snapping because of the movement of the earth around them. Mining companies were as much in the business of reconstruction as construction. Once a facility had been built it had to be serviced, upgraded and at some point replaced.

By the time the Sutro Tunnel began to drain mines on the northern end of the Comstock Lode in 1878, the search for ore had already moved well below the 1,600- to

[30] These conclusions require a "certain faith" in the way Sprecht or his associates computed their costs. Theoretically it was possible that under the appropriate reconfiguration of the tunnel it would be cheaper to move people and things through the tunnel to the Lode. That ignored, of course, the fact that large sums had been invested in other ways of servicing the mines. See Letter plus accompaniments to C. W. Brush, Trustee, The Sutro Tunnel Company, 5 June 1881, MS-NC3, Bx 1, Miscellaneous Letter from April 1881, Nevada Historical Society.

1,700-foot level where the linkage occurred. There was the hope, of course, that by draining old works above the level of the tunnel new ore deposits would be located and that given the network in place they would be easily and profitably accessible. But while such discoveries were a possibility, for which some precedent existed, the main focus of the remaining mining companies appeared to be deeper rather than shallower probes. By the 1880s mining companies were opening up new work areas 2,000 to 3,000 feet (and more) below the surface. Numerous examples from company records could be cited. Since the Sutro Tunnel served primarily the northern branch it might be useful to examine explorations by a mining company on the southern branch. Yellow Jacket, still a William Sharon property, had fallen from among the ranking producers after the 1868 fire. It had a claim nearly 1,200 feet long, and in November 1876 it began the construction of a new shaft between two existing shafts. The shaft to the north had served for the exploitation of relatively shallow ores, 100 to 400 feet below the surface, which it shared with its northern neighbors Confidence and Challenge. The southern shaft, however, built to extract ores shared with Kentuck and Crown Point on its southern boundary had reached the 2,400-foot level. The new shaft had reached 2,636 feet (almost the 3,000-foot level) by June 1879, and another 400 to 500 feet would be added during the next several years before the project was halted.[31] To reach 2,600 feet the company averaged about 80 feet a month. Divided into fiscal years from July to July progress on the shaft was reported as 768 feet in 1877, 780 feet in 1878 and 1,088 feet in 1879. The range was from a high of 155 feet in December 1876 to a low of 33 feet in July 1877. During the fiscal year ending July 1 1879 in addition to sinking and timbering the shaft almost 1,100 feet other work was underway. Water tanks were constructed at the 1,550- and 2,300-foot levels to hold 31.5 tons (7,554 gallons) and 21.5 tons (5,096 gallons) respectively. Pipes for compressed air were installed from the surface to 2,300 feet. At 2,500 feet more than 1,400 feet of drifts were cut during the year. Air circulation was always a concern, and with the extended shaft and repairs to some of the winzes, ventilation had been improved vastly, all the way to the 2,500-foot level. Moreover the creation of two stations adjacent to and connected with the new shaft at 2,300 feet and 2,500 feet improved the airflow and lowered the temperature. The total volume of air that passed down the new shaft through the repaired passages was measured at 34,200 cubic feet per minute. Temperatures now ranged from 66 degree to 96 degrees Fahrenheit. Perhaps more importantly Yellow Jacket no longer had to depend on adjoining mines for ventilation. Two air compressors, a Burleigh and a Warring, supported excavating for the shaft and mining of the ore. Both had been used previously in the older shaft. Because of the depths new hoisting equipment had to be purchased. An order had been placed with Risdon Iron Works for the construction of “a pair of horizontal, direct-acting hoisting engines, eight feet stroke by twenty-eight inches diameter of cylinder, with complete appurtenances for a first-class hoisting apparatus” The contract called for completion and transport of the machines in 125 days at a cost of $142,500, one-third to be paid when work half done, one-third when machines is shipped and the final third when the engines were in operation. New cables had been ordered from England. They were 3,700 feet long, eight inches wide and three-eights of an inch thick, and they were scheduled for

[31] Grant Smith wrote that the shaft reached 3,080 feet or just below the 3,400-foot level. Smith, *The Comstock Lode*, 280. See also Becker, “Longitudinal Vertical Projection of the Comstock Lode…,”in the *Atlas*, Sheet X.

delivery in December 1879. In the meantime, until the new equipment was installed, the current hoisting machinery was being supplemented with a "donkey engine" at 2,300 feet. Rock excavated from below this point was lifted by the donkey engine and then was then stored at 2,300 feet. To try to hoist from the new depths to the surface with the existing "geared hoisting machinery" would be unsafe under the strain necessarily imposed upon it…." The final matter to be considered was water. About 1,000 tons a month appear in the shaft at the 1,550-foot level where it is stored in a tank and another 300 tons below that level. Water raised through the shaft amounted to about 300,000 gallons per month. The biggest problem, however, was that even though a vein of about 700 feet was found at the 2,500 feet, it was filled with porphyry and not worth much. All the work for the year had failed to produce much profitable ore. The mills, owned by Sharon and associates, refined the low-grade ores at a profit, but the mine did not yield a profit.[32]

The Superintendent's Annual Report for 1878-1879 included some figures on Yellow Jacket's finances. The balance sheet showed that the company had receipts and disbursements of $446,000. Receipts included no money from mining of ore, the company's principal business. Rather 80 percent or $360,000 of the receipts came from assessments against the stockholders. Another 20 percent was a balance carried over from the previous fiscal year (1877-1878). On the disbursement side 70 percent or $313,000 of the total outlays ($446,000) was for the construction of the new shaft. Another 22 percent was cash on hand ($41,000), labor in the old works ($31,000) and purchases of mining supplies ($28,000). The breakdown for the construction of the new shaft was fairly precise. The list below gives the total cost for each category and the percentage, as calculated by the company (dollars rounded up or down):

Labor-Miners' Wages	$134,319	42.84%
Machinery-All Foundry Work & Machinery	$89,533	28.83%
Timber-All Wood Work	$24,029	7.68%
Wood-Coal & Fuel	$22,083	7.06%
Iron & Steel-All Hardware	$12,842	4.10%
Powder & Fuse	$8,845	2.83%
Freights-Virginia & Truckee RR-Machinery, supplies	$5,260	1.68%
Water & Ice	$4,188	1.34%
Candles & Oil	$3,623	1.15%
Taxes-State, County, Town	$2,694	0.86%
Construction Engineer-W. H. Patton	$2,500	0.79%
Sundries-Not Specified	$1,820	0.58%
Masonry-Sand, Stone, etc.	$843	0.26%

[32] "Annual Report of the Yellow Jacket Silver Mining Co. for the Year Ending June 30th, 1879," with accompanying sketches and plans, NC61 and NC61/2, pp. 5-7, Special Collections, Library, University of Nevada, Reno. See also Smith, *The Comstock Lode*, 280-281. Smith had some interesting observations about the size of the pumps, the fly-wheels and rod-catchers on he pumps and the breakdown of the pumps in 1880, based on the diary of Superintendent Thomas G. Taylor. None of this changed the fact that making money from Yellow Jacket's ore was almost impossible. Lord briefly described the size and horsepower of the engines that drove the hoists in Yellow Jacket's shaft in *Comstock Mining and Miners*, 347.

Total	$312,579	100.00%

The two major expenditures were labor (43 percent) and machinery (29 percent). They combined for 72 percent of the total. Two other items of interest were costs for timber (7.68 percent) and wood (7.06 percent) – the former for framing a shaft that had grown by 1,088 feet ($20 to $25 per foot) and the latter for fuel (plus coal) to power the equipment. It is worth noting that W. H. Patton, who had a long career in Comstock mining, was the consulting engineer at an annual salary of $2,500. The company computed the average cost of the shaft per foot between November 1876 and June 1879 at $374 to reach 2,636 feet. The most impressive gains were in the first three months (November 1876-January 1877) when the shaft had reached nearly 440 feet (one sixth of the total distance and just under 150 per month) before the advance fell off to more modest monthly averages of 80 feet per month. The cost per foot for the fiscal year 1876-1877 (only eight months) was $166 per foot to excavate 768 feet. In the next fiscal year (1877-1878) outlays rose sharply to nearly $700 per foot or a total of $545,714 to add 780 feet. Finally in the fiscal year July 1878-June 1879 when 1,088 feet were added the cost per foot was $287, a decline of more than 60 percent from the previous year. By any measure, at a time of a deepening depression, the expenditure of a million dollars to build a new shaft to explore a region one thousand feet below the last profitable ore findings was risky if not wasteful. But it was that kind of ambition that had served the Comstock well for two decades. It would eventually become clear to speculators and investors alike that the richness of the Lode did in fact have a limit.[33] Yellow Jacket did begin to produce refinable ores in 1883 and continued to do so through 1885, the end of the period under review here. In one of two quarters yields exceeded costs, but in most quarter the ore was not valuable enough to cover operating expenses. Yields per tons ran in the range of $10 to $25 with the lower yields predominating. It is doubtful hat the new shaft was ever paid for with ore from the mine.

Shafts allowed miners to reach new depths, but once there the work of tunneling had to begin. Underground tunneling had many different aspects and components. The *Atlas* assembled by George Becker and his team as a part of the 1882 publication *Geology of the Comstock Lode and the Washoe District* was a *tour de force*. Ophir was one of the earliest quartz mines, and twenty years later after years of little or no production of profitable ores it consisted of a vast underground network that was still under construction. Ophir ended up with a claim about 700 feet long. Its main deposits were relatively shallow. They were located between the surface and about 500 feet on the claim's southern half. Four or five different shafts had been constructed to intersect the Lode, which as noted earlier, angled toward the east before it was squeezed out completely. Below 500 feet in the underground area served by these shafts there was virtually no further tunneling. Hard rock had replaced vein matter. To the east toward the hanging wall the company dropped the Ophir Shaft, which would eventually reach 2,500

[33] Annual Report of the Yellow Jacket Silver Mining Co. for the Year Ending June 30th, 1879," with accompanying sketches and plans, NC61 and NC61/2, pp. 8-9, Special Collections, Library, University of Nevada, Reno. No taxable bullion was recorded for Yellow Jacket in 1880, but some appeared in later years. See assessments in The County Records Microfilm Project, ST 67 Story County, Special Collections, Library, University of Nevada, Reno.

feet. A small deposit of rich ores was found between 1,500 and 1,600 feet at approximately the same depth as the Consolidated Virginia-California finds of the mid-1870s. It had a limited duration. But it spawned new underground projects. Tunneling moved in both directions from the Ophir Shaft, which more or less bisected the claim, toward the Mexican Mine on the northern boundary and the California Mine on the southern boundary. In the 1879 Annual report the Ophir's President, C. W. Weller, acknowledged that the mine "even in periods of great depression …never ceased to be a favorite with the public." In the current year people "felt" confident about the mine's future even though most of the construction could be appropriately classed as "dead work" that was necessary to find and extract the ore. The feeling that the mine had a bright future resulted from the discovery of the so-called Hardy Vein about 2,000 feet below the surface. In 1879 it produced about $1.3 million in bullion on 20,000 tons at an average yield of $64 per ton. Because the vein was irregular it was costly to exploit. Even though the company had paid a small dividend the cost came in at about $56 per ton. Nonetheless the President concluded his report with conviction that the future prospects were bright and the flow of dividends would continue.[34]

To reach these depths the main shaft had to be extended. During the previous year the Ophir Shaft had reached 2,200 feet. In 1879 it had been extended 498 feet to a point 30 feet below the station at 2,500 feet. That would appear to be less than the actual distance should be, and the reason was that the shaft was being extended on an incline rather than strictly vertically. The tunnel was said to have "passed through" alternating "stratas of vein porphyry, birdseye porphyry and quartz, dipping to the west passed through near the 2300 level showing about three feet think and giving good assays." At 2,500 feet the quartz dipped eastwardly, and it may be richer than the quartz noted above. Large rooms were excavated and timbered at 2,200 and 2,300 feet. Several "bobs" had to be replaced, and new tanks and chutes had to be installed. Drainpipes had to be constructed through adjoining mines to Savage where a connection with the Sutro Tunnel was made. A new air compressor was attached to the hoisting engine so that in an interesting configuration that saved some money the compressor was driven "by the weight of the descending cable and giraffe (?)" and then stood "without motion" when the hoist operated. "The practical result of this…will be to give us over 3000 cubic feet of air per hour, at a pressure of 80 pounds to the square inch, at no additional expense" while simultaneously saving "the wear of the brake machinery heretofore used to control the descent of the cable and giraffe." Finally and perhaps most demanding work was to keep the shaft properly timbered. Between 700 and 1,400 feet the ground was so unstable that a crew of at least 40 men was required daily to keep it in proper condition.[35]

Extensive tunneling was also described in Superintendent W. H. Patton's 1879 Report. At 1,600 feet drifts had been constructed both north to the Mexican and Union

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[3434] *Annual Report of the Ophir Silver Mining Company, December 1879* (San Francisco: Bunker and Hiester Printers, 1879), 5-7, NC56, Special Collections, Library, University of Nevada, Reno. See assessments in The County Records Microfilm Project, ST 67 Story County, Special Collections, Library, University of Nevada, Reno.

[35] *Annual Report Ophir Mining, 1879*, 15-17, NC56, Special Collections, Library, University of Nevada, Reno.

mines (approximately 600 to 700 feet) and south to the California Mine (approximately 400 to 500 feet) for purposes of ventilation and drainage. Repairing and maintaining drifts (of similar length) with same mines at 1,700 was also necessary to protect the air and remove the water. Work at 1,900 feet was primarily ore extraction in drifts that covered hundreds of feet. According to Becker's illustration the drift at 1,900 was (by 1882) a five-sided loop that measured about 1,500 feet. It was located between the Ophir Shaft and the California border on the south. In fact it crossed over the border into California ground. Both Ophir and California had the same owners. On the north side of the main shaft a V-shaped drift from 500 to 600 feet in length was constructed. At the Mexican border it turned west (creating the V) and eventually connected with a winze from the 1,700. The main drift at 2,000 feet measured nearly 1,500 from the main shaft to California on the south and Mexican on the north. Much of the work had been comp0leted prior to 1879. The Mexican and Union consolidated Mines pushed the drift further northward to connect with the Union Shaft. On the south the drift continued through California, Consolidated Virginia and Best & Belcher to Gould & Curry where it connected to the main shaft. This drift across seven different properties greatly improved the ventilation in all the connecting galleries. On the Mexican boundary a winze was dropped to the drift at 2,300 feet (a distance of 300 feet) through a drift at 2,100 feet. A joint (with Mexican) crosscut was run about 300 feet in a western direction. Both the winze and the crosscut "passed through alternate streaks of hard porphyry and vein matter having a westerly dip, showing some quartz, giving low assays" but also improving with depth (thus the apparent reason behind the winze). Because of the appearance of water in the crosscut work was suspended as of August 1879 until new pumps could be installed. The northeastern drift at 2,100 feet was extended to Mexican and connected to the joint Ophir-Mexican winze from 2,000 feet. To the south of the main shaft the drift consisted of two parts. A southwesterly drift, beginning in April 1879, was extended about 150 feet. It ran through the so-called Hardy Vein, and for about 100 feet good quality ore was found, after which the assays fell sharply. Half way along this drift an upraise was constructed to reach the ore above the drift. The other part, moving in a northeasterly direction was started in May 1879 and had reached more than 400 feet. After almost 200 feet of vein matter the drift entered "good milling ore with a width of about 3 feet." This was continued for about 100 feet and then gave way to low-grade ore. The face of the stope at the current terminus of the northeasterly drift the face of the stope looked promising again. An upraise was constructed in order to connect to the drift at 2,000 feet and an east-west crosscut was also under construction. The upraise passed through some good ores, but the crosscut found mainly hard rock and vein matter. At 2,300, 2,400 and 2,500 feet, in addition to completing or enlarging the stations at each level on the main incline some drifts were being started or extended to the north and to the south. A fairly long drift at 370 feet was finished from the shaft to the northern boundary for a connection with the adjoining Mexican mine. All of this work on the main incline shaft and on hundreds if not thousands of feet of drifts, upraises and winzes pockets of good-quality ore had been found but, as Superintendent Patton himself concluded the main ore vein remained elusive. This was an extraordinarily active year in pursuit of the Hardy Vein. Expensive as it was Patton was happy to report that enough millable ore had been lifted to cover the costs, to pay a dividend of $1 per share ($10,800) and even to retain a surplus ($134,892). And the future was bright because

with more of the Hardy Vein above 2,100 feet remaining to be exploited funds would be available to push ahead with prospecting in all directions and on all levels.[36]

In the Inventory of Property attached to the 1879 Annual Report Patton listed the value of buildings, equipment, supplies and merchandise as of 1 December 1879. The total value of the property was nearly $350,000. The inventory did not explain how the valuations were arrived at, and more than likely they involved a formula based on replacement costs. Two items – real estate and buildings – totaled $72,000. The buildings included hoisting works, incline and pumping engines, ore dumps, administrative offices, work and worker areas and furnishing. Perhaps the most relevant category, given the discussion above, was machinery. The list with the valuations is shown below:

2 hoisting engines, reel & gear, complete	$29,000
1 double incline engine, 2 hydraulic engines attached	75,000
1 Burleigh air compressor	5,500
1 Booth air compressor	4,000
2 double engines, underground, on winzes	2,800
7 large Ingersoll drills	2,450
6 small Ingersoll drills	2,000
5 Burleigh drills	2,000
1 Baker blower, 2 giraffes, 4 tanks, 6 cages, 38 ore cars	3,600
1 engine to drive saws	900
1 large pumping engine	34,500
Plunger and Cornish pumps, iron bobs, various pipes	17,500
2 boiler pumps	1,000
11,262 feet round steel wire cable	18,000
10,900 feet flat steel cable	12,900
2,000 feet water pipes, hydrants & hoses	9,500
10 boilers	18,000
Blacksmith & machinist tools – lathe, punch, press	6,500
Total	$241,750

The inventory contained at least 18 drills, with a stated total worth of $6,500 Within the group the Burleighs appear to have a somewhat higher valuation at $400 apiece compared to the 7 large and 6 small Ingersolls at $325 to $350 each. Two air compressors totaled $9,500 with the Burleigh being a third more than the Booth. Two sets of cables with a total length of more than 22,000 feet were said to be worth $30,000. These three categories added up to $47,000. The largest category consisted of engines, pumps and boilers and their attachments such as pipes, tanks, etc with a total valuation of about $195,000. The hoisting engine and the double engine for the incline shaft (described above) and their accoutrements were set at $104,000 while several pumps with their attachments was set at $52,000. The double engine for the incline shaft had the highest valuation at $75,000. In addition to buildings and machines the inventory included

[36] *Annual Report Ophir Mining, 1879*, 10-17. NC56, Special Collections, Library, University of Nevada, Reno.

supplies that totaled about $15,000. These included almost 500 cords of wood ($4,828), 326,303 feet of timber ($5,547), more than 100 gallons of coal, lard and machine oil, 24,500 tons of Cumberland coal, hundreds of pick and sledge handles and shovels and axes and many sundries such a powder, fuses and rails. In the course of the year (1879) Ophir extracted 20,000 tons of ore and removed 61,000 tons of rock. The ore yielded about $1.2 million in bullion. Ophir's inventory at year's end was comparable to inventories compiled by other mining companies. For example at the end of 1875 in the midst of a real bonanza Consolidated Virginia declared its inventory to be worth about $400,000, and a year later sharing in the same bonanza California also declared an inventory of about $400,000. What is more important than the valuations is the degree to which one can judge how important machinery and technology was for these operations. Much of mining was still the result of manual labor but greatly aided by pneumatic drills, heavy-duty cables and powerful engines.[37]

Ophir's Balance Sheet for the year revealed more details about financing these operations. Most but not all of Ophir's total income was derived from bullion, about $1.3 million of $1.6 million. The three neighboring mines, Union Consolidated, Mexican and California, paid Ophir over $200,000 for material, labor, power and pumping with Mexican its northern neighbor accounting for more than $100,000 of the amount. As noted above Ophir and Mexican engaged in several joint projects to extend and connect their drifts. On the expense side the largest item, not surprisingly given the extent of tunneling already discussed a third - $535,000 – was paid in salaries and wages. These figures suggest the possibility that over the course of the year Ophir employed several hundred workers. Such a number does not seem unrealistic when the range of underground construction is considered. More than $400,000 was spent on supplies including equipment, although the actual items purchased during 1879 unfortunately were not specified. These purchases, however, were reflected in the inventory totals cited above. Reducing the ore cost $173,000 or $8 to $9 per ton. More than $300,000 was tied up in stockholder dividends, ore and cash on hand and bullion discounts. The latter was necessary because the bookkeeping value ascribed to silver was higher than the market value of silver. In almost all companies during the 1870s the value of silver per ounce was pegged at a certain amount even though the sale of an ounce of silver on the open market would yield 10 to 20 percent less than what was entered. Eventually that had to be accounted for in the companies' yearend statements. The remaining $100,000 or so was allocated to office expenses, freight, assays, insurance, etc. According o its declaration before Story County's assessor the company had direct expenses of $1.1 million with almost a million of that devoted to extraction to generate $1.3 million in bullion. That meant that the yield per ton of ore was about $64 and the cost per ton was $58. This did not make for a highly profitable operation and did explain the relatively low dividend of about $5 per ton.[38] The underground work described in the Superintendent's report and

[37] *Annual Report Ophir Mining, 1879*, 18-20, NC56, Special Collections, Library, University of Nevada, Reno; Annual Report, Consolidated Virginia Mining Company, 1875, NC99/1/5/1, 13, and Annual Report, California Mining Company, 1876, NC99/1/5/6, 14-15, Special Collections, Library, University of Nevada, Reno.

[38] *Annual Report, Ophir Mining, 1879*, 22-23, NC56, Special Collections, Library, University of Nevada, Reno.

summarize above were costly, and they were justified on grounds that the Hardy Vein located at 1,900 feet would lead to a substantial deposit and hopefully a new bonanza. The Hardy Vein petered out, and by the end of 1880 the mining costs per ton were twice the yields per ton. The Ophir, which more or less inaugurated quartz mining on the Comstock, would also serve as the last hurrah. The Hardy Vein was rich enough to animate the long-held hope that new bonanzas lay at greater depths and given the technology could be successfully and profitably exploited. In fact the dissolution of the Hardy Vein sealed once and for all the end of the Comstock. Returns on investments in Comstock mines between 1880 and 1885, the silver anniversary of the discovery of ore, ceased to exist. And with that came the end of a remarkable saga that witnessed the conjuncture of ambitious and at times reckless entrepreneurs and of widespread application of a changing technology.

Links: