# ESSAY THIRTEEN
# SUTRO TUNNEL & UNDERGROUND TECHNOLOGY

The "Feats of Labor", to steal a phrase from Eliot Lord, was no more manifest 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 only some above ground at the refineries. The nineteenth century had a much stronger industrial base than previous centuries, and the application of that base was evident almost from the beginning at the Comstock, 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 specific matters dealing with finances and technologies relating to the Sutro Tunnel rather than the career of Sutro. It is widely observed because the Tunnel took a decade to build and, therefore, opened only after the Lode's greatest bonanza had passed, it served as a postscript in the history of the Comstock. Even so, after numerous setbacks and threatened abandonments the Tunnel was completed, functioned as it was designed to function 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 conclude 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, Sutro embraced the dreams of many of his compatriots except his dreams were grander and bolder. He has

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[1] Lord, *Comstock Mining and Miners* (San Diego, CA: Howell-North Books, 1980), Chapter 17.

[2] Smith, *The History of the Comstock Lode* (Reno/Las Vegas: University of Nevada Press, 1998, 107.

been caricatured as essentially a promoter – to the extent that he continually repackaged the venture to attract investors – but in promoting he was also advancing the power of technology. No doubt in the end Comstock companies found other ways to drain the Lode, but Sutro still left his mark, much to the chagrin of his many foes.

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 during the 2nd Session in 1865, and an agreement was signed 4 February 1865.[3] 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. He was not uniformly admired in the Halls of Congress after the 1866 Legislation was enacted. When the House of Representative debated [21 February 1873] a $2-million-loan request because the project had stalled for the lack of money at an evening session, Representatives were not kind in their descriptions of him as nothing more than a selfless promoter and worse. The project will eventually be completed with funding from a Scottish/English investment house.[4]

The idea behind the Tunnel was not irrational. Interconnecting adits and tunnels for drainage were being built by the companies themselves to deal with water as their probes had reached 500 feet. Sutro's plan was far more ambitious. It was to construct a Tunnel that began at the Carson River, five miles east of the Lode, and connect with the Lode 1,600 and 1,700 feet and from there to build horizontal tunnels along the Lode to drain all the mines of all the water above that level. If the mines pierced that level [no where near in the early 1860s] and found water, pumps would be used to lift the water to the main drainage Tunnel. That ore would be found before 500 feet was not a pipe dream, made up by Sutro and his advocates to bamboozle locals into building a Tunnel. Sutro hired a distinguished German mineralogist/engineer, Baron von Richthofen, then working in California, to prepare an assessment for the discovery of deeper and possibly richer ore bodies. By the time the von Richthofen had arrived n the Comstock, the geology of the Lode was better understand — that it was a fissure angling away eastwardly from Mt Davidson, basically.the footwall. How steep the angle and deep the fissure remained to be

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[3] Copy available Sutro Tunnel Records, NC07, Special Collections, Library, University of Nevada, Reno [hereafter SC-L/UNR].

[4] Lord, *Comstock Mining and Miners*, 233-235; A copy of the Agreement with the Nevada Legislature may be found in Sutro Tunnel Company Records, NC07, SC-L/UNR; Congressional Globe, 21 February 1873, pp. 1595-1601, online as Google Book at https://books.google.com/books?id=ZXu4fUerQwQC, It may also be noted that Post-Civil-War Congresses were stingy with money for such projects *laissez-faire* was a dominate economic idea.

determined. The Baron was to try to shed some light on those unknowns, inasmuch as the Sutro Tunnel was to enter the Lode at two to three times the depth of the current operations.[5] Spanish colonial miners had learned to build adits and tunnels to drain water from the interior to the outside in Mexico and Peru, and some Mexican miners had staked claims on the Lode and were applying Mexican methodology, more akin to drift mining than deep mining, on their properties. Maps from the early years and surveys from the later years identified some of those drainage operations, but the Sutro Tunnel was not only a grander project — cutting a workable tunnel five miles into the Lode itself but also a hugely expensive one. The Spanish called these undertakings "dead work" [*faenas muertas* or dead tasks] because they seldom yielded any ores or profits. The simple truth was that without them ores beds were inaccessible. Mexican mining laws [derived from Spanish mining laws] recognized their importance. Section IX of the Mexican Mining Laws , published shortly after Independence, illustrates that any partner who failed to pay his share of "dead works" could lose his share of millable ores.[6]

Sutro's Tunnel was *faenas muertas* on a massive scale. It was to be paid for by mining companies agreeing to pay Sutro an annual fee. The Baron's report on how he envisioned the structure of the fissure and its potential for near-limitless ore production helped the Tunnel project, at the very least, to get off the ground. It was mainly geological in content. He was trained as an East European mining

**FIGURE 1: SECTION IX, SUTRO TUNNEL AGREEMENT**

SECTION IX.

If, while any mine is in a course of profitable working, any partner should refuse to concur in the expenses of the dead works (*faenas muertas*) established according to the forms before prescribed), upon the ground that such dead works would consume a part or the whole of the produce of the mine, the rest of the partners may retain and devote to this purpose a part or the whole of the produce which falls to his share.

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[5] Ferdinand Freiherr von Richthofen, *The Comstock Lode: Its Character, and the Probable Mode of its Continuance in Depth* (San Francisco: Turner & Bacon, printers, 1866). Available online at https://babel.hathitrust.org/cgi/pt?id=mdp.39015068458887;view=1up;seq=5. Freiherr, translated as Baron, was formerly a title but become part of the family name. He was known as the Baron.

[6] They were more often built in Mexico than Peru because Mexican ores over time proved to be of higher grades & therefore of greater yields. 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, online at https://www.insidemydesk.com/lapubs/CompSil.pdf. Photograph of Section IX in Sutro Tunnel Agreement from Charles Thomson, trans., *The Ordinances of the Mines of New Spain…*, (London:John Booth, 1825), 103, online at https://books.google.com/books?id=I_hYAAAAYAAJ&pg=PA103&lpg=PA103&dq=dead+works+in+spanish+mining&source=bl&ots=hSdk2ugJZY&sig=JThPxG53GDiqsGwYljmoGkjeUZE&hl=en&sa=X&ved=2ahUKEwjMxtfytJ_cAhVKWq0KHeJQCr4Q6AEwBHoECAQQAQ#v=onepage&q=dead%20works%20in%20spanish%20mining&f=false

engineer with some experience in Mexico and Bolivian mining. Nevada geology was new to him, as it was to most everyone — investor, miner, scientist — on the Comstock in the early 1860s but that did not necessarily disqualify him. His report was written in fairly technical language: some of his findings (below) in layman's language with my comments in parentheses were as follows:

1. Rocks were broadly classified as *ancient series* [early to middle Tertiary…60 to 20 mya (millions of years ago(] and *recent series* [late to post Tertiary…after 20 mya]. (pp. 14-15).

2. Vein [outer layer] was enclosed in propylite rock of different varieties along its [the fissure's] distance. In some places as large crystals and in others minute. Predominately green but not uniform. Either "compact and homogeneous" or brecciated (broken). [On the hardness scale it can measure 5-6, highest 10.] (p. 22)

3. Outcroppings were not a "continuous line, but consisted of small and detached ranges of quartz [slightly harder than propylite and the next layer], ordinarily protruding from surrounding ground…." Horizontal outcropping measurement can be as much as 600 feet. Country rock [such as granite] can be embedded in quartz. Outcroppings did not indicate location of underground wealth. [p. 24]

4. Vein matter, if "we consider every substance which enters into the composition of the body of the vein, between its two walls…" consisted of "fragments of country-rock, clay and clayey matter, quartz, and ores." [He then described each aforementioned substance in greater detail.] As depth increased, the quartz grew whiter [away from the surface where it was mixed with reddish clay]. The quartz along the eastern wall [hanging wall] can be more "finely-disseminated" than along the western wall [footwall]. Comstock quartz was "rarely solid, and blasting [was] not applied for its removal except in a few instances." It could be fractured to such an extent that it had the "appearance of crushed sugar." The bodies of crushed quartz could be large or small and was usually rich. [pp. 26-28]

5. Within an ore zone the ores tended to be richer toward the center and was also softer and easily extracted, while the outer parts tended to be hard with "second-class and low-grade ores." Describing the ore body shared by Ophir and Mexican mines, he said: "it commenced on the surface, where it was only two feet wide, and descended to the depth of" 330 feet. Gradually increasing in width it finally reached 45 to 50 feet before narrowing and terminating. It was mainly against the eastern wall, and at the surface it angled toward the western wall, "straightened out" in the middler where it was the richest and angled east before disappearing. [pp. 30-31]

6. Was the Comstock a "true fissure vein" or some variation of such. By definition true fissure veins extended "indiscriminately" through varying rock, was of indefinite depth,

evidenced "dynamic action" beyond opening of the fissure, contained erupted rock and was filled from below by "chemical action." [pp. 40-41]

He then raised the issue of negative evidence in opposition what he had just described. Since the crucial question was depth, he discussed the connection between a true fissure vein and unlimited depth. He could not prove that the Comstock fit the model that he argued for, but to buttress his case he reviewed the character of fissures in other major [principally silver] mining centers such as Guanajuato and Zacatecas in Mexico and mines in Saxony and Hungary. One point in particular, which he stressed, was that while barren zones should be anticipated, they would be episodic or incidental: "It is a well-known fact that the enclosing rocks have usually great influence on the quantity and quality of the ores of certain metals in mineral veins, and that a rich lode passing into a different formation frequently becomes barren or poor." [Such occurred at both Guanajuato and Zacatecas.] So long as the enclosing rock maintained its character -- and that was "anticipated" — the depths of the ore zones were limitless.[7]

It should be underscored that miners had a work-a-day command of the information contained in Richthofen's Report by the mid-1860s. Nonetheless, having an evaluation written by a world-class scientist with knowledge of other mining camps with similar structures [Comstock, Zacatecas and Guanajuato all belonged to the geological region known as the North American Cordillera], despite the occasional technical lingo, was welcome at a time that uncertainty had gripped the Lode community. His Report was widely-distributed and -quoted. In a compelling way it offered reassurance that investing in deeper exploration would pay off, at least by his estimate the probability was high that it would. Aside from the perplexing question of depth, Richthofen helped to explain in a more positive fashion what was to be expected, based upon rock formations and fissure structures.

Diverting water was not Sutro only plan 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 to permit the natural flow of water and to intersect the Lode at an appropriately effective point. Under these conditions it was calculated 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

[7] Richthofen, *Comstock Lode*, 73-74. The Section entitle "Mode of Continuance in Depth" begins on p. 56 and continues to p. 74, & treats many geological issues in order to strengthen his argument. Online at https://babel.hathitrust.org/cgi/pt?id=mdp.39015068458887;view=1up;seq=78.

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 Legislature the Surveyor-General disagreed with Sutro's timetable; he wrote that it was "impractical" and estimated that "with vigorous prosecution" five years would be needed.[8] It actually took 13 years to complete the Tunnel, and not only did the mining companies discover the rich ores that Sutro had predicted when the Tunnel was launched but unfortunately they had removed most of the profitable ores before 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. Whether or not a functioning Tunnel during the boom years would have made a significant difference to the bottom line for the Comstock mining companies can hardly be tested. The historical interest in the Sutro Tunnel is that it got built at all.

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.[9] 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 drainage of water. 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. In the

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[8] Surveyor-General, "Annual Report of the Surveyor-General of the State of Nevada for the Year 1865" in *Senate Journal and Appendix*, 3rd Legislative Session (1867), 24-25. Not available online.

[9] Survey-General, "Annual Report…1865" in *Senate Journal and Appendix*, 3rd Legislative Session (1867), 24-25. Not available online. 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, SC-L/UNR.

mid-1860s, when Sutro devised his plan, he was among those investors who believed that the Lode's richest ores yet 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. If ores had discovered below the 1,700-foot level, the Tunnel would have been less effective. Rich ores at greater depths would have required water to be pumped up where the Tunnel intersected the Lode. But, unbeknownst to Sutro and everyone else who speculated about the configuration of the Lode, the richest seams lay slightly above where his Tunnel and Lode joined and below this level the ores petered out. When the Tunnel and the Lode were joined, the Tunnel project itself had become an anachronism, a victim of time, as was true of other monumental projects. By 1878, while a few water-logged, non-producing mines could have benefited from the Tunnel, they remained barren of ore. Other mining companies were exploring depths below the connecting point, and even though management drew up plans to adapt the Tunnel to the new underground reality, they were abandoned because in the face of continued barrenness costs were prohibitive.

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 on their own to hoist ore, accommodate personal and process ore and had little financial incentive to turn such tasks over to a Tunnel promoter who failed to keep to his 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 drainage leases were signed early on but given the delays were soon abandoned. The anticipated revenue stream of companies signing such leases dried up, and increasingly, to keep the project afloat, Sutro, who never lost faith (at least publicly), had to entice investors outside the Comstock to put up the needed capital. That he succeeded over the years is itself another oddity in this long saga. The local community virtually ignored Sutro and the on-again, off-again Tunnel project. As evidence of his undiminished, at

least publicly, confidence, he was alleged to have said that after Virginia City was abandoned, "the owls would roost" in the Tunnel.[10]

In his 1879 (and last) legislative report the Mineralogist summarized various statistics from the long history of the Tunnel and its final connection to the Lode. The distance of the Sutro Tunnel to a floor 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 punched a 5-foot hole that joined 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 Tunnel's 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 was hard rock. Since digging on the Tunnel did not begin until 1870, the Tunnel took 8 years, 8 months and 19 days.[11]

Sutro hoped, of course, to discover rich ore deposits on the way to the Comstock Lode. He found some but never enough to help to pay the bill for 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. Sutro's initial financing 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 mine owners agreed to the subscription and to pay the fees for drainage and other services, if they chose to use them.[12] 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

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[10] Surveyor-General, "Annual Report of the…1865" in *Senate Journal and Appendix*, 3rd Legislative Session (1867), 24-25. Not available online. Smith, *Comstock Lode*, 110.

[11] Mineralogist, "Biennial Report of the State Mineralogist of the State of Nevada for the Years 1877 and 1878," in *Appendix to Journals of Senate and Assembly*, 9th Legislative Session (1879), 84-85/86-87, online at https://babel.hathitrust.org/cgi/pt?id=mdp.39015074976476&view=1up&seq=86; Statement of the Condition of the Sutro Tunnel by Pelham W. Ames, Secretary, Sutro Tunnel Company, 1878, MS-NC3, Bx 1, Nevada Historical Society [hereafter NHS]; Smith, *Comstock Lode*, 112.

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

$200,000 was to be in cash. The first payment was due 1 August 1867.[13] 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 capital, if any, 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, construction on the Tunnel did not start. 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 and agreed to up their annual subscription to $600,000 for the coming year. Again, it is no evidence that Sutro received what he was due. At the end of the year, 29 November 1869, Sutro Tunnel Company re-incorporated. Under the certificate of incorporation Sutro was authorized to issue 1.2 million shares of stock at $10 per share for a total of $12 million. Adolph Sutro 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 [1869-1870]. This first section barely covered a tenth of the distance and was a sign of the task ahead. Once again, the lack of money and formidable technical problems caused Sutro to abandon the project, the first of several abandonments.[14]

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 to be staid, rigid and uninformed. Hundreds of letters and telegrams flew back and forth across the Atlantic. Sutro made at least one trip

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[13] Summary of Articles of Agreement between Gould & Curry & Sutro Tunnel Company (26 Mar 1866) in Folder from Virginia Consolidated Mining Company (29 Mar 1879), NC7/1/6, SC-L/UNR. 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.

[14] Bound Volume of Abstract of Titles, 1877, pp. 6, 7, 32, Sutro Tunnel Company, MS-NC3, Bx 4, NHS.

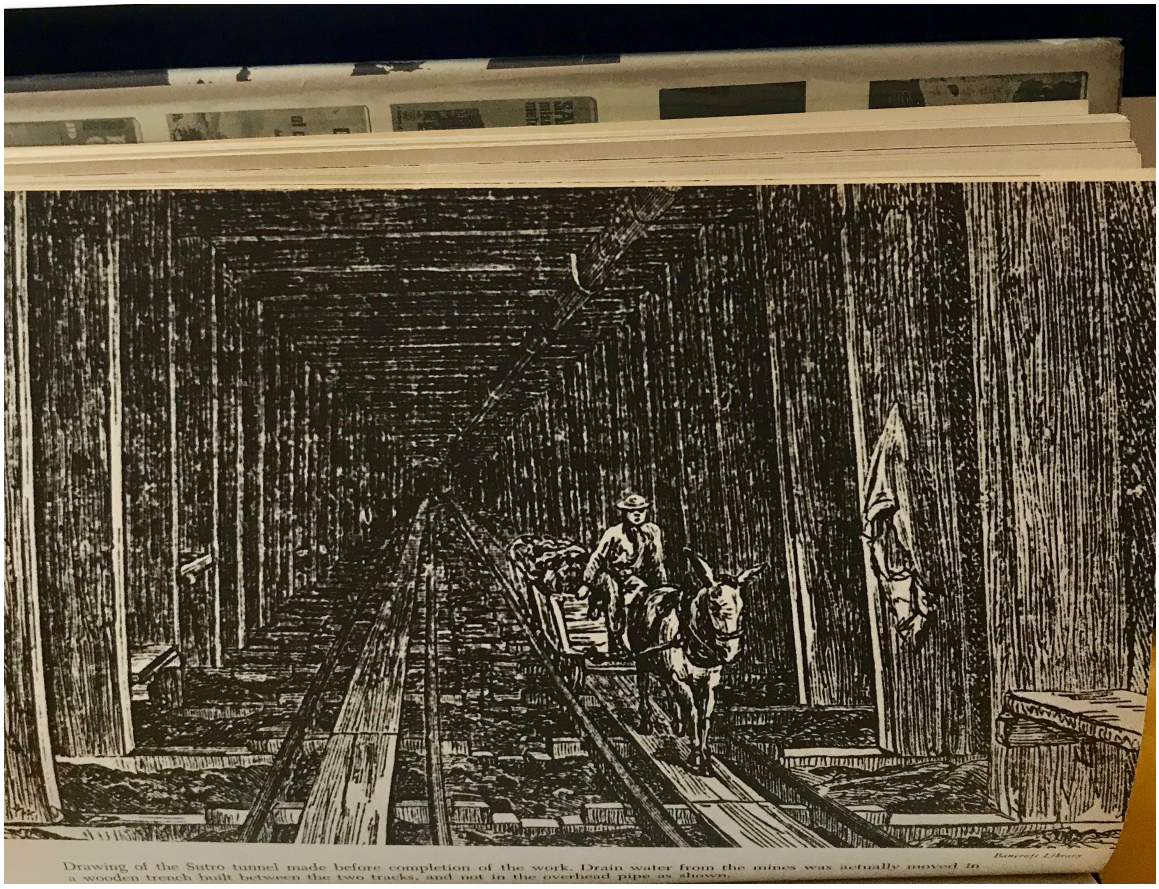
to London, and in 1878 because the relationship had grown so acrimonious, he was told in no uncertain terms not to make another trip. Sutro was not reluctant to speak his mind, and in one letter he disparaged the brothers for their inability to understand the business of mining. In their reply the brothers wrote: "We prefer to pass over your remarks as to our 'shortsightedness and blindness'."[15]

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 the 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 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 has proven difficult to pin down exactly how many bonds were sold and how much money was raised beyond what the bankers and their partners had subscribed by 1873. Moreover, the documentary evidence is not very helpful relative to the early financing of the Sutro Tunnel. 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 part or all of $8 millions. 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 worth £600,000 or $2.9 million was canceled (without explanation) and a second bond-backed mortgage held by McCalmont Brothers worth £133,000 or $648,000 was rescheduled from £133,000 to £100,000. At the same time McCalmont was permitted to purchase 300,000 shares of Company stock at a price of $10 (£2.05) 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 in mortgage bonds, reduced to £100,000, under the control of the McCalmont Brothers. The 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 would appear that the Europeans assumed any and all outstanding debts, which had been mounting since the project was launched. Sutro intimated as much without giving any detailed figures; when commenting on the new arrangement, he averred that the Company was not only debt-free but also had funds on hand to proceed. The work up to this point could hardly have been paid for with lease payments or

[15] McCalmont Brothers to Adolph Sutro, 3 December 1878, Sutro Tunnel Company, MS-NC3, Bx 1, NHS.

Company revenues. Despite a pile of debt, technological challenges ahead and waning support on the Comstock itself, the new financial team presumed that the Tunnel would be open and generating revenue by 1876, i.e., in three years after nearly six years of starts and stops. At this point the Europeans were probably on the hook for $2 to $3 million in an enterprise without any past earnings and no assurance of future earnings.[16]

**FIGURE 2: DRAWING OF SUTRO TUNNEL INTERIOR**




**[SOURCES & NOTES**: Photograph from Bancroft Library Collection, published in Lord, *Comstock Mining and Miners*, between pp. 332 & 333.**]**

Work on the Tunnel did proceed with only a few interruptions, but it took nearly twice as long to complete as predicted. And, the wrangling between the Company and its financiers never abated. Extant financial documents are sparser than necessary to reconstruct a full financial profile of Sutro operations after 1873. The Tunnel did not open in 1876, as promised, and the Company repeatedly made demands on the bankers to

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[16] From various communiqués between Tunnel Company & McCalmont, Letterpress Book, Sutro Tunnel Company, November-December, 1873, MS-NC3, Bx 2, NHS. 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, NHS. This was not the final agreement, since it was not signed & some text was crossed out & new text was penciled in.

advance more money and to modify the terms of the agreements. It appears that the Londoners fully expected the Tunnel to become a paying proposition and did not understand or were not informed that Comstock had entered a post-Bonanza cycle. By1878, Sutro had missed the opportunity to serve the Comstock in the way he envisioned. 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 as such 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, their allies and other 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 he became a controversial but 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 showed little first-hand knowledge of Comstock risks or prospects. Once in they had no exit strategy.[17]

The story of the Sutro Tunnel has another side. As intriguing as the financial wheeling and dealing were, the fact that the Tunnel was completed for the length and at the depth in accordance with the basic plan represented a major technical 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 minor offshoot lodes before it reached the main 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

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[17] Lord, writing in 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 & other correspondences. Other sources indicate a total bill (construction, management, loans, etc.) of $5 to $6 million. Lord was ambivalent as to whether the Sutro Tunnel was worth the investment. *Comstock Mining and Miners*, 342-343, 346-347. See also Smith, *Comstock Lode*, 115.

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. While the Tunnel's path crossed several quartz formations before reaching the Comstock Lode, these minor lodes were mainly vein matter with few or no profitable ores. From 1871, when construction resumed, some of the excavation data include those additional excursions. In 1871 and 1872 3,480 [1,740 per year] feet were dug or about 145 feet per month. The next year (1873) the number jumped to 1,919 feet or 151 per month. The length had reached 5,394 feet. In 1874 2,682 feet (224 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 Germany's Humboldt Company 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 east 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 occur.[18]

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-foot point from the mouth and

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[18] Mineralogist, "Biennial Report…1877 and 1878," 81-85/83-87, online at https://babel.hathitrust.org/cgi/pt?id=mdp.39015074976476&view=1up&seq=83; Also information on the progress of the Tunnel including workers employed, temperatures of air & water, nature of the ground & 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, NHS. The Mineralogist's data were collected from Company reports and interviews, & while they could not be absolutely verified from other documentation, they appear to be generally in line with actual results.

still technically 400 to 500 feet from intersecting the main fissure at the Savage mine. The Julia Mine, under contract to pay $100,000 of which it had already advanced $40,000, was about 1,400 feet from where the lateral Tunnel was started. In October and November 1878, nearly 900 feet of the southern lateral Tunnel had been cut, and in the following months it was extended through the remaining 500 feet. If Julia paid the balance, it is not recorded. Even if Julia was drained, it listed no millable ores. 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.[19] Although Sutro Tunnel abandoned plans to extend the main Tunnel into Mt Davidson, it continued sporadically to work on the lateral Tunnels until it 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 185, 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 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 steeper than in Sutro. There were essential functional 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 structures epitomized bold thinking about overcoming environmental and geological barriers with the help, of course, of new technologies.[20]

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

[20] See http://www.hoosactunnel.net/vital.php for data on the Tunnel. Also data on Hoosac, Sutro & other long American & European tunnels were compiled for the 1880 Census & published in C King, S F Emmons & G F Becker, eds., *Statistics and Technology of the Precious Metals* (Washington DC: GPO, 1885), 13:125, Table XVII. https://books.google.com/books?id=1A1kzgEACAAJ&printsec=frontcover&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false.

Key to the construction of both tunnels (as well as very deep underground mining) was drilling equipment, in particular the Burleigh drill, which eventually found its 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 into which wedges could be driven. The use of gunpowder as an explosive in the seventeenth century added another tool, but underground explosives from the outset had posed physical challenges: first was cutting the hole for the powder, not always an easy task; additionally, controlling the reaction within the area of the blast and then venting it of noxious chemicals were 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 continued to be the workers' 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 the rock 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 further breathing problems for workers already suffering from bad air in confined underground spaces 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 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 Burleigh design 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.[21]

The advance in drilling had to be accompanied by an advance in the bits that the drills uses 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 was 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

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[21] Rudi Volti, "Pneumatic Drills," *The Facts on File, Encyclopedia of Science, Technology, and Society* (New York: Facts on File, Inc, 1999, 2003).

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. 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. 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 of diamond bits and pneumatic drills had become a part of the basic underground equipment for building tunnels and extracting 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. In removing or controlling water within the mines, according to the State Mineralogist, cost mining companies about $3 million per year. 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 the daily flow.[22] 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 pools of scalding water that quickly flooded Savage and Hale & Norcross up to the 1,800-foot level. Pumping by the companies had little immediate effect in reducing flood levels, besides which. was very costly. When the connection was made with the Combination Shaft on 30 June 1879, Sutro wrote to Ames, the Secretary of the Board, that 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 90 degrees and gradually increased back through the Tunnel to 114 degrees. "Everything work[ed] like a charm," wrote Sutro. The heat of the water did not "discommode" any of the Tunnel machinery or equipment. The water flowed through the Tunnel to the Carson River as if "it had been going there for years". The interiors of the shaft and mines were soon made dry enough to be worked. To honor the occasion Sutro gave his men the day off and ordered 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

[22] Reports of Progress of Work, 1878, Sutro Pumping Company, MS-NC3, Bx 1, NHS.

performance of his creation, however, he already had an eye on his exit from the Comstock.[23]

After the successful opening of the Tunnel in 1878, Sutro expressed disappointment that the Tunnel was not draining more water. Since the Tunnel's only income-producing business appeared to be drainage of water [visitors could pay to ride the train through the Tunnel], volume was an indicator of how many mining operations had been signed up to use Sutro's drainage services. Many of the mines on the Lode's southern branch had pipes connecting to the lateral Tunnel, and Sutro could deduce that more connections should be contracted on the northern lateral Tunnel where much of the mining activity was taking place. This would double the flow of water, he said, and twice the flow meant more mines paying fees to keep their operations dry.[24] In the meantime, 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."[25] 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. 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.[26] 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

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[23] Mineralogist, "Biennial Report…1877 and 1878," 85/87, online at https://babel.hathitrust.org/cgi/pt?id=mdp.39015074976476&view=1up&seq=87; Letter from A. Sutro, Supt., to P. W. Ames, Secretary., Sutro Tunnel Company, 30 Jun 1879, MS-NC3, Bx 4, NHS. It was not reported in Sutro's letter how much of the daily flow was strictly from the Combination Shaft.

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

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

[26] 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, NHS.

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."[27] 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 from what remained 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 to exit, given the diminishing value of the Lode, remains a mystery (at least to me).

For the new owners making the Tunnel profitable under a 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 – they discussed some strategies for doing that. The detailed calculations would have warmed the cockles of every cost accountant's heart. Unfortunately, some of their calculations are not fully explained, and their totals cannot always be duplicated. Accountancy had assumed a new importance in corporate American, and the Comstock mining industry was no exception, but detailed statements did not necessarily provide accurate cost 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 his amortization plan called for paying $500,000 per year over 10 years to retire the $5 million mortgage and, to accomplish this, he 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. Given the state of mining on there Lode, all these projections were suspect. If transportation contracts were to yield $150,000 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 and workers 25 cents per person each way, all of which assumed the Company could round haulage business to the tune of several hundred thousand dollars at time when yield of bullion in dollars per ton of ore were falling below

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[27] Copy of Letter from McCalmont Brothers, London, to A. Sutro, 30 Jul 1878 Sutro Tunnel Company, MS-NC3, Bx 1, Miscellaneous Letters, NHS.

$20.[28] How much haulage business had Sutro rounded up since the opening of the Tunnel? No direct documentation has been found, 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 excavations? 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 what the Company needed to reach its financial goals.[29]

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.[30] 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

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[28] 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, SC-L/UNR; Articles of Agreement between Sutro Tunnel Company and Segregate Belcher Mining Company, 29 March 1879, MS-NC3, Bx 1 Sutro Tunnel Company, NHS. With respect to ore, if the gold yielded a coin at less than $40, the rate dropped to $1 per ton.

[29] Letters from George Sprecht to C. W. Brush, Trustee, Sutro Tunnel Company, 5 May 1881 & 5 June 1881, MS-NC3, Bx 1, Miscellaneous Letters from April 1881, NHS.

[30] 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, & 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, NHS.

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 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 (on paper).[31]

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 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 to rejuvenate the Tunnel business, the Company could not rejuvenate the Lode and, therefore, could not rejuvenate itself.

Underground mining was a constant war with the natural forces 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 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 more safely, but even after better technology had been put to work, the shafts themselves, mostly constructed from wooden timbers, had to be secured constantly against bulging

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[31] 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 & things through the Tunnel to the Lode. That ignored, of course, the fact that large sums had been invested over the years in other strategies for 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, NHS.

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 1,700-foot level where the lateral connection was made. There was 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 could 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 operations 2,000 to 3,000 feet (and more) below the surface. Numerous examples from company records could be cited. 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 was pushed to 2,636 feet by June 1879, and another 400 to 500 feet would be added during the next several years before the project was halted. The exact point of cessation is hard to determine.[32]

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 1 July,1879, in addition to sinking and timbering the shaft, almost 1,100 feet of other work was underway. Water tanks were constructed at 1,550- and 2,300-feet to hold 31.5 tons (7,554 gallons) and 21.5 tons (5,096 gallons) respectively. [See Footnote below re: depths and their measurements.] 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 of the

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[32] Grant Smith wrote that the shaft reached 3,080 feet or near the 3,400-foot level, a measurement made from the Surveyor's Point at Gould & Curry. Smith, *Comstock Lode*, 280.

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 [sic]." The contract called for fabrication and transport of the machines in 125 days at a cost of $142,500, one-third to be paid when the work was half done, one-third when the machines were shipped and the final third after the engines were in operation. New cables also had been ordered from England. They were 3,700 feet long, 8 inches wide and 3/8 of an inch thick, and they were scheduled for delivery in December, 1879. In the meantime, until the new equipment were 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 to 2,300 feet where it was then stored. 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…," said the Company. The final matter to be considered was water. About 1,000 tons a month appeared 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 averaged 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 ore that would cover the costs of repairing and expanding the mine. The mills, owned by Sharon and associates, refined the low-grade ores at a small profit, but that did not pay for mine renovations.[33]

The Superintendent's Annual Report (1878-1879) included 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. Eighty percent or $360,000 of the receipts came from assessments against stockholders. Another 20 percent was the 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 and 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

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[33] Care was not always taken in describing depths…whether they referred to a measurement from the surface or from the Surveyor's Point at Gould & Curry. Yellow Jacket & the Surveyor's Point were about 1.1 miles apart, & the difference in elevation was about 340 feet, a figure that would be subtracted from the Surveyor-Point depths. Thus, if the water tanks were at the Surveyor-Point level, they would be at 1,200 & 2,00 feet, respectively, from the surface. The depths cited in the forgoing paragraph are relative, since the exact point of measurement was ambiguous, but still useful as approximations. "Annual Report of the Yellow Jacket Silver Mining Co. for the Year Ending June 30th, 1879," with accompanying sketches & plans, NC61 & NC61/2, pp. 5-7, SC-L/UNR See also Smith, *Comstock Lode*, 280-281. Interesting observations by Smith on size of pumps, fly-wheels & rod-catchers on pumps & breakdown of the pumps in 1880 from diary of Superintendent Thomas G. Taylor. Lord briefly described size & horsepower of engines that drove hoists in *Comstock Mining and Miners*, 347.

for construction of the new shaft was fairly precise. The list below shows total cost for each category and the percentage, as calculated by the Company (dollars rounded):

| | | |
|---|---|---|
| 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% |
| **Total** | **$312,579** | **100 %** |

The two major expenditures were labor (43 percent) and machinery (29 percent). They combined for 72 percent of the total. These were labor-intensive renovations, and without any bullion return, which would measure a wage against a value, they would top the list. That was not the case in ore-producing mines. 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 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 level 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. 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 or two quarters yields exceeded costs, but in most quarters 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 that the new shaft was ever paid for with ore from the mine.[34]

Shafts allowed miners to reach new depths, but once there the work of tunneling or drifting 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* in regard to how the underground network developed. Ophir was one of the earliest quartz mines, and, twenty years later (having been own by William Sharon and now by John Mackey) after a checkered career, it produced some ore but mainly consisted of a vast unproductive underground network that was still under construction. Ophir ended up with a claim about 700 feet long [north to south]. Its main deposits had been located in relatively shallow ground across 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 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 launched the Big Bonanza in the mid-1870s. It was connected to California's ore body but was narrower and smaller, although it made money for its former owners. That helped to spawn new underground projects in Ophir and among its northern neighbors. 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. 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

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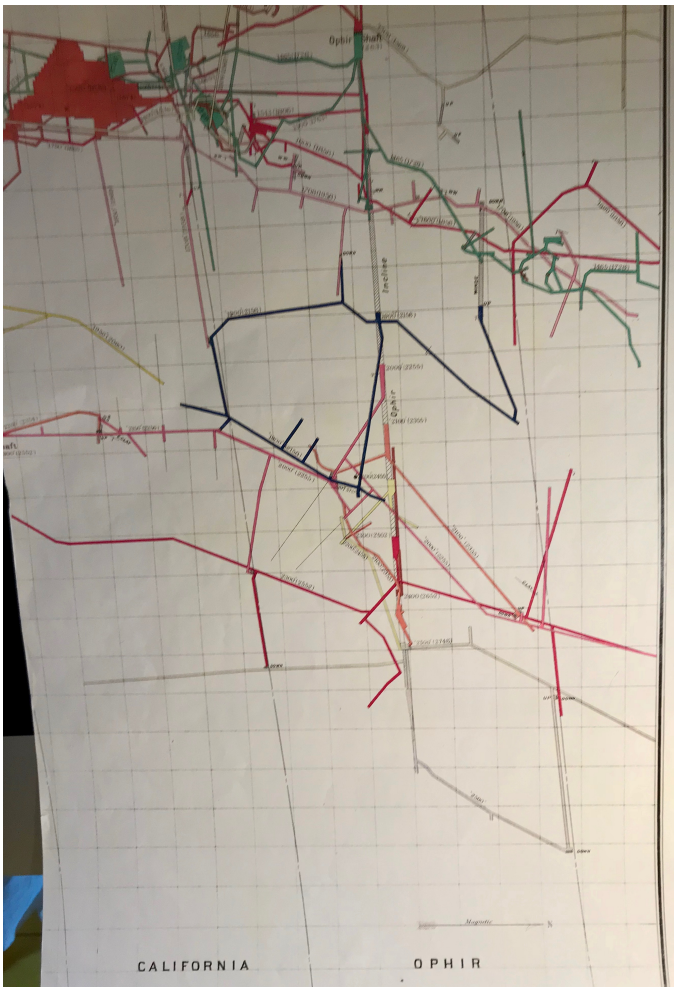
[34] Annual Report of the Yellow Jacket Silver Mining Co. for the Year Ending June 30th, 1879," with accompanying sketches & plans, NC61 and NC61/2, pp. 8-9, SC-L/UNR.

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.[35]

**FIGURE 3: DEPTH, OPHIR MINE**
**[Expandable]**




To reach these depths the main shaft had to be extended. During the previous year the Ophir Shaft had reached 2,200 feet or 2,450 from Surveyor's Point, Gould & Curry, as shown in the color of salmon in Figure 3.[36] 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 thick and giving good assays." At 2,500 feet — very bottom of photograph in gray color — the quartz dipped eastwardly, and it may have been 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 were constructed southward through adjoining mines to Savage [third property south of Consolidated Virginia] where a connection with the Sutro Tunnel was made. A new air compressor was attached to the hoisting engine in a configuration that saved some money because the compressor could be driven "by the weight of the descending cable and giraffe" and then allowed to stand "without motion" when the hoist was actually in operation. "The practical result of this…will be to give us over 3000 cubic feet of air per

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[35] Annual Report of the Ophir Silver Mining Company, December 1879, 5-7, NC56, SC-L/UNR.

[36] Comstock Map, Sheet 16, George Becker, *Atlas To Accompany….Geology of the Comstock* (Washington, DC, 1882), online at https://exhibits.stanford.edu/mining/catalog/qq365xm3376 .

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, perhaps the most demanding, was work 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.[37]

The depiction of Ophir's underground in Becker's *Atlas*, Plate XV [above photograph] shows the Ophir Shaft at a depth of 2,500 feet [2,745-foot level from Surveyor's Point, Gould & Curry] in a grayish color [more yellow in the original. The diagonal criss-crosses represented the inclines built where the shaft had to be modified. At the top of the photograph on Ophir's southern border with California, rust and green in color, are ore bodies worked at some profitability during the Big Bonanza. Even though the Annual Report in 1879 extolled the discovery of the Hardy Vein at 2,000 feet, It was not depicted.

The colored lines, indicating depth, spread across the Ophir space, were tunnels ands drifts, some built in earlier years and others being constructed in connection with the deepening of the new Ophir Shaft. Superintendent W. H. Patton's 1879 Report, a part of the Annual Report, described them in some detail. At 1,600 feet drifts had been constructed both north to the Mexican and Union 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 feet was also necessary to protect the air and remove the water. Work at 1,900 feet was primarily ore extraction in drifts that traversed 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, but that mattered little since both Ophir and California by then had the same owner. 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 a 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 completed 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

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[37] Annual Report…Ophir Mining, 1879, 15-17, NC56, SC-L/UNR.

improving with depth (thus the apparent reason behind the construction of 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 [not shown], 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 continued for about 100 feet and then gave way to low-grade ore. The face of the stope at the terminus of the northeasterly drift looked promising again (at the time the report was written). 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 2,370 feet [just above 2,400 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 shaft/incline and on hundreds if not thousands of feet of drifts, upraises and winzes found pockets of good-quality ore, but, as Superintendent Patton himself concluded, the main ore vein remained elusive. This was an extraordinarily active year (typical of a Mackay venture) in pursuit of the Hardy Vein. The accounts attached to the Annual Report showed ore worth $1.3 million, although the Assayer Office declared $1.2 million. A third of the revenue belonged to Q1, 1879; it stood at about $250,000 per quarter thereafter. Fore the year Ophir had a profit of nearly #7 per ton. What was more telling, however, was the decline in net yield per ton from $26 in Q1 to a minus $13 in Q4. Expensive as it was — Patton acknowledged that — Ophir did not end the year in the red. 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). (Typical outcome for Mackay ventures, although of late his luck had been running in reverse.) And the future appeared bright because with more of the Hardy Vein above 2,100 feet to be exploited funds would be available to push ahead with prospecting in all directions and on all levels.[38]

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 set at nearly $350,000. The inventory did not explain how the valuations were arrived at; 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,

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[38] Annual Report Ophir Mining, 1879, 10-17. NC56, SC-L/UNR.

work and worker areas and furnishing. Perhaps the most relevant category, given the discussion above, was machinery.

| | |
|---|---|
| 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 group 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 were 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 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. Wear and tear had to be a factor, although depreciation, as a cost, was not recorded. 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 Big 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 had become for these deep operations. Much of mining was still the result of manual labor but greatly aided by pneumatic drills, heavy-duty cables and powerful engines.[39]

Ophir's Balance Sheet for the year revealed more details about financing these operations. Most of Ophir's income (unlike the previously discussed Yellow Jacket) was derived from bullion, about $1.3 million of $1.6 million total. Other revenues derived from the three neighboring mines [also under the control of Mackey]; Union Consolidated, Mexican and California, paying Ophir over $200,000 for material, labor, power and pumping with a single mine, Mexican, owing more than $100,000 of the amount. As noted above, Ophir and Mexican engaged in several joint projects to extend and connect their drifts, and that would account for Mexican's share. On the expense side the largest item, not surprisingly given the extent of tunneling already discussed was labor at a third - $535,000. These figures suggest the possibility that over the course of the year Ophir employed several hundred workers. Indeed, on 1 Oct 1879, Ophir's payroll was 378 workers including 277 miners, 28 laborers, 19 carpenters, 13 engineers and from 2 to 10, surface men, pumpmen, blacksmiths, firemen, machinists, ropemen and watchmen. In terms of its workforce, this was a going concern. Six months later [March, 1880] it still employed 366 workers.Six months after that the payroll had plummeted to 18. No further payrolls have been found. Ophir continued to hoist ores — several thousand tons per year — through 1884. Net yields ranged from several dollars per ton in gains to several dollars per ton in losses. Costs were high earlier when the discovery of the Hardy Vein encouraged more investment and expansion. The Hardy Vein petered out, and by the end of 1880 the cost of mining ramped up. The Ophir, which more or less inaugurated quartz mining on the Comstock, remained in business until 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

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[39] Annual Report Ophir Mining, 1879, 18-20, NC56; Annual Report, Consolidated Virginia Mining Company, 1875, 13, NC99/1/5/1; Annual Report, California Mining Company, 1876, 14-15, NC99/1/5/6, SC-L/UNR.

fact the dissolution of the Hardy Vein sealed once and for all the northern Comstock's fate. Returns on investments 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.