The CENTRAL PACIFIC RAILROAD'S SUMMIT TUNNEL

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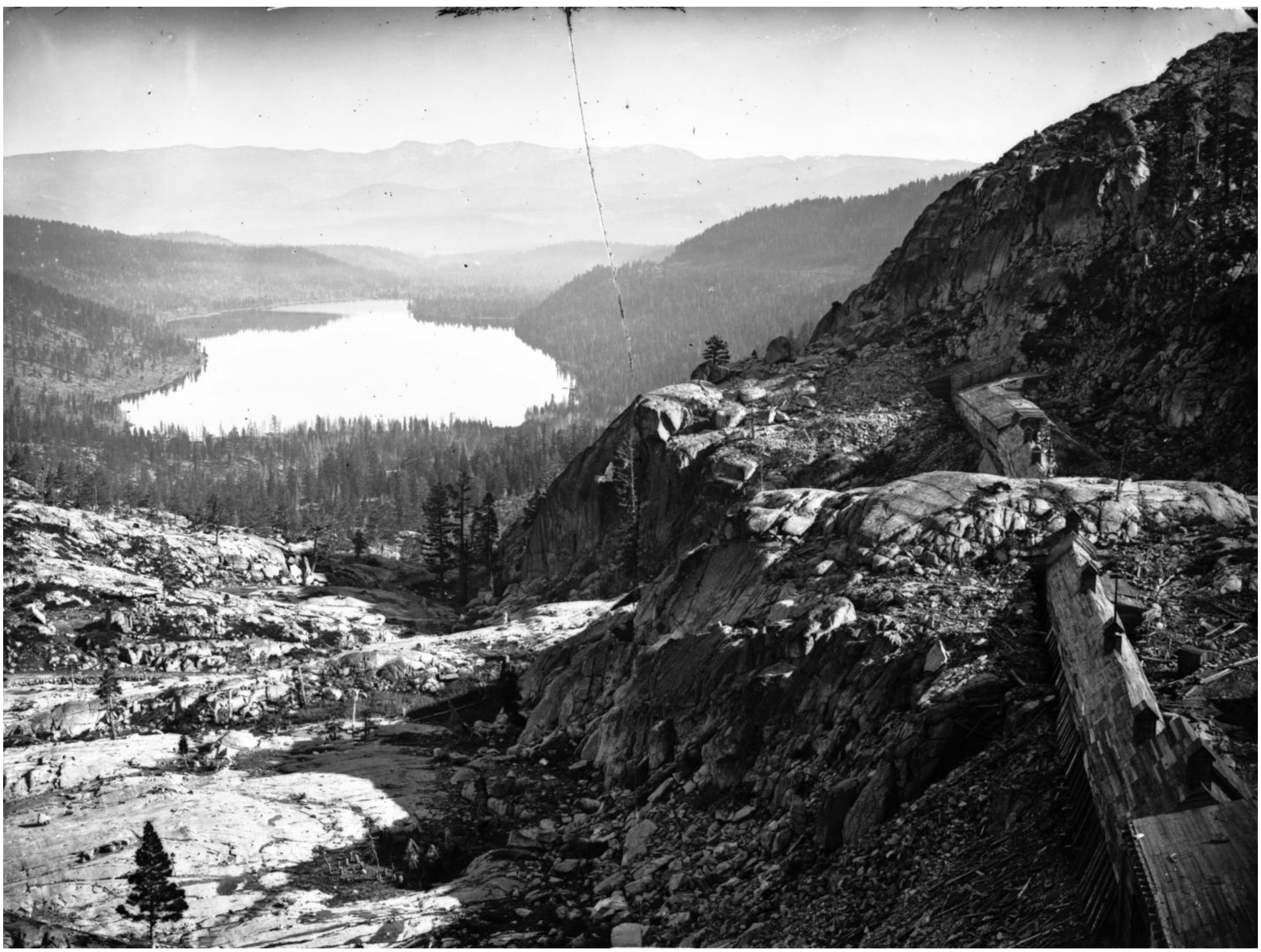
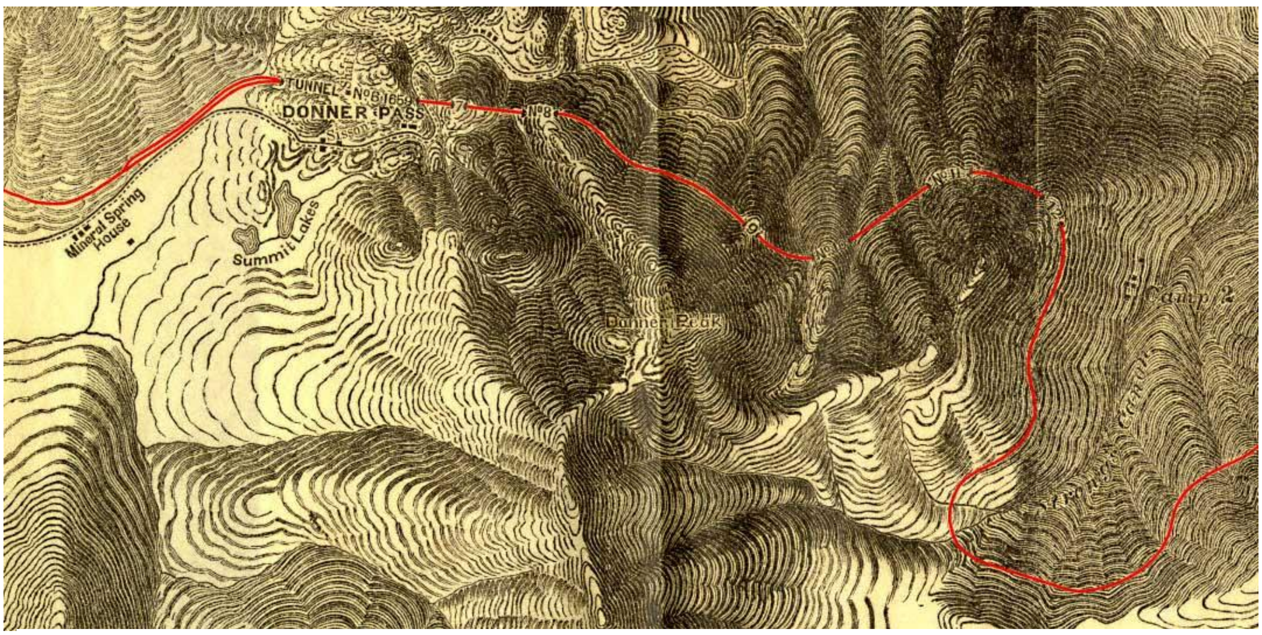


Andrew Russell, No. 228,"Donner Lake and Snow Sheds." Large Format Glass Plate, OMC.

Tunnel No. 6, the Summit Tunnel

As the Central Pacific rushed to build the line over the Sierra Nevada, they knew that the critical items for keeping the construction on schedule were the tunnels at the summit. The Chinese crews were released to work on the tunnels at the summit as the crews completed the track into Cisco. In a two mile reach from the summit, the CPRR constructed 7 tunnels, the longest at 1,659 feet was the Summit Tunnel, #6. In 1865, Chinese gangs were sent to the summit to start on Tunnel #6, but by the time winter hit the Sierra, they had only excavated the cuts at each end without starting the tunnels, so work stopped for the winter. Donner Pass receives some of the highest snowfall in the west with an average of about 34 feet. Civil engineer John Gilliss, in his 1870 ASCE paper, stated "*During the fall of that year [1866] the track reached Cisco, and as fast as the gangs of Chinamen were released, they were hurried to the summit to be distributed among the tunnels...".* (1) For the next 2 years, all cargo and passengers were offloaded at Cisco and used the Dutch Flat and Donner Lake Wagon Road to reach their destinations.

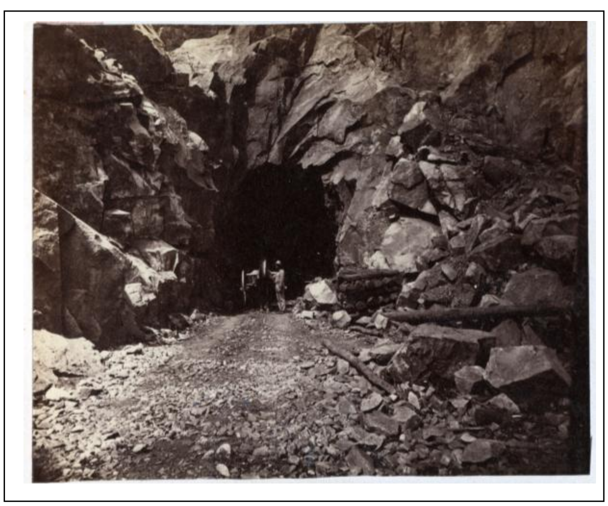


Detail from "Central Pacific Railroad Map from Summit Valley to Truckee River", signed by Sam Montague and Lewis Clement, 1868. Tunnels 6 through 12 shown.

Surveying the Tunnels

John Gilliss was the resident engineer at the 7 summit tunnels, and led the civil engineers surveying the tunnels and overseeing the construction. The civil engineers were housed in one of a group of about dozen buildings constructed at the pass to house the work crews and store supplies. As Gilliss described it: "*Our quarters were at the east end of Donner Pass, but still in the narrow part."* (2)

Approximate location of structures at Summit Camp from Alfred Hart photos. Shaft-house at upper left. Dutch Flat & Donner Lake Wagon Road in red. Locations were approximated by overlaying over the Hart photos new photos by drone from same spot as the Hart photo.



Alfred Hart #198. "*East Portal of Summit Tunnel, Western Summit. Length 1,660 feet.*"

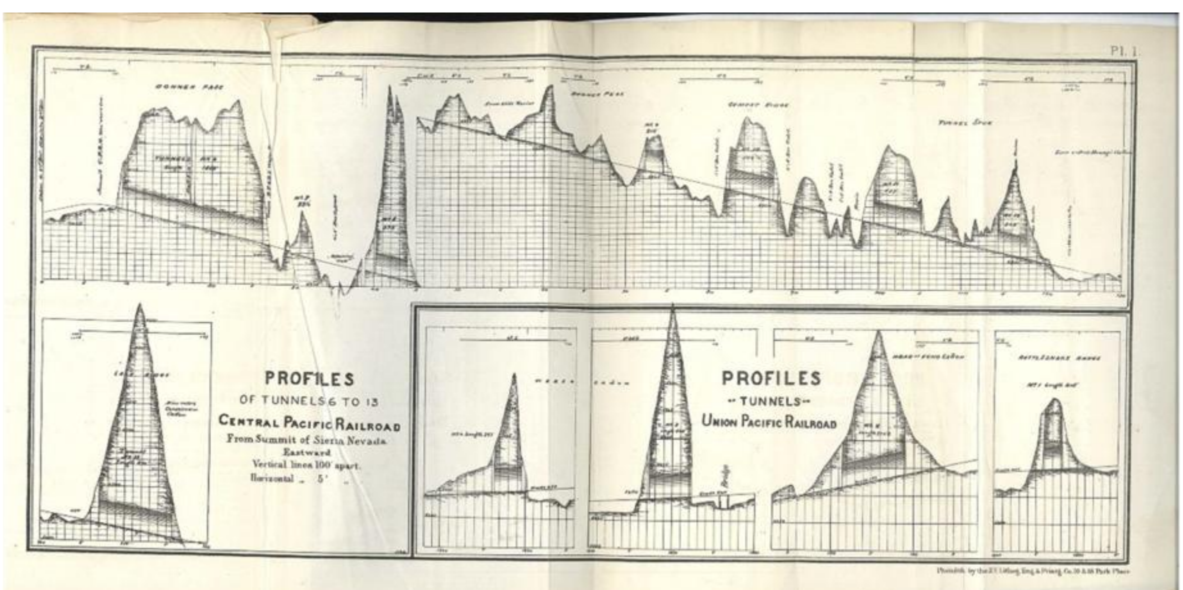
Alfred Hart #116. "*Camp Near Summit, Mt. King in Distance*"

Gilliss continues with his description of surveying in the tunnels: *"...the centre line was secured generally by small holes drilled in the roof, with wooden pegs and tacks. These points were placed as far apart as length excavated would permit..*.". The civil engineers worked day and night to keep the line accurately, and Gilliss mentions *"...walking two miles over the hills after dark, and staking out the east end of No. 12 by the light of a bonfire; at nine 0'clock the men were at work."* (3) All of the survey points in the tunnels are located overhead, with a plumb bob lowered from the overhead tack to the center of the transit to shoot the next point. The survey line was carried around the granite spurs or ridges where the tunnels were constructed by chain-men suspended with ropes. (4)

Surveying in winter added to the difficulties: *"In running lines outside during the winter, it was generally necessary to make deep cuts in the snow, and sometimes tunnels, through the snow, to get to the original transit points."* Even with all of these difficulties, the tunnel construction was amazingly accurate. Tunnels on curves were more difficult, and in discussing Tunnel #11, which was curved, and part was through decomposed granite, Gilliss says "*the usual difficulties of working with instruments by candle-light were much increased by the numerous temporary timbers in the headings* [*. The lines met in the centre of the tunnel* [#11], *parallel to each other, but two inches apart. In the other cases [the other 6 tunnels] the discrepancies were too slight to notice."* (5)

<u>Construction</u>

All seven of the tunnels at the summit were worked on simultaneously, but Tunnel #6, the Summit Tunnel, was the longest and became the critical construction impacting the schedule. The remaining discussion will concentrate on Tunnel #6, although all of the tunnels at the summit used the same construction methods, except in most cases without nitroglycerine.

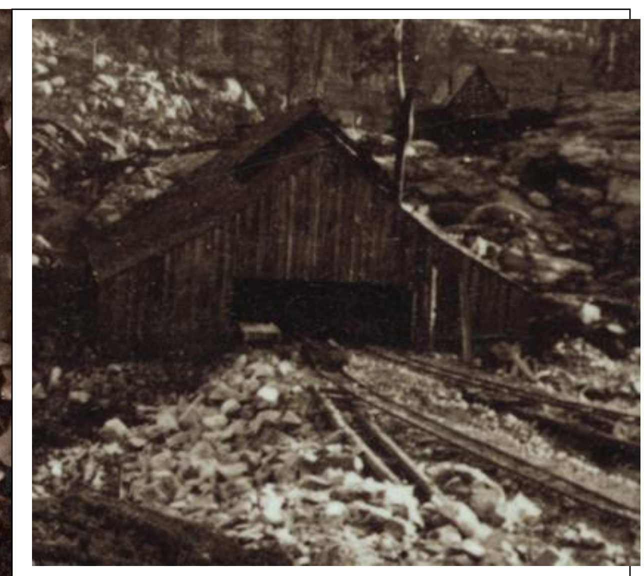


"Profiles of Tunnels 6 to 13 Central Pacific Railroad", From "Tunnels of the Pacific Railroad", John R. Gilliss, ASCE, January 5, 1870.
The notes on the profile between tunnels 7 and 8 at the China Wall are "4' X 5' Box Culvert" and "Retaining Wall."

Tunnel #6 was excavated through hard fractured granite which did not require timber supports. Gilliss describes "*The material is granite of a medium quality, crossed by seams in every direction.*" (6) The tunnel dimensions were 16 ft. wide by 11 ft. high to the spring line for the arched soffit, which was 16 ft. in diameter. The tunnels were constructed by first excavating the "heading" which is the arched portion at the top of the tunnel. The excavation of the "bottoms" followed. The work crew of about 30 Chinese was split into 2 gangs, one for the headings and one for the bottoms. It was important to keep the more difficult headings going, so they were pushed hard until they were through. The bottoms were easier and followed later. The average progress using nitroglycerine at Tunnel #6 was 1.82 ft. per day for the headings and 4.38 ft. per day for the bottoms. (7)

To speed construction of Tunnel #6, a central shaft was excavated to allow for the working of four headings simultaneously. Hoisting works were constructed over the shaft. The hoisting engine was the old locomotive *Sacramento*, the first locomotive to run on the Sacramento Valley Railroad. The shaft was 8 ft. by 12 ft. and 72.9 ft. deep. Two 5'X 5' compartments were constructed in the shaft for the buckets, one for loaded buckets up and one for lowering empty buckets. The buckets were 4'9" square and 2'6" deep. They sat on "trucks" in the tunnel which ran on rails. At the top of the hoist, they were again placed on "trucks" to run on rails to the "waste bank." (8)

Detail from Hart #197. "*Summit Tunnel, before completion-Western Summit -Altitude 7,042 feet.*"
Note end of tunnel where the "heading" is clear above the "bottoms."



Detail of Hart #96. "*Shaft House over Summit Tunnel, American Peak in Distance.*"

Nitroglycerine

On February 9, 1867 the use of nitroglycerine was initiated at the Summit tunnel. Nitroglycerine was invented in 1847 by Italian chemist Ascanio Sobrero and was never patented, so its manufacture and use was public domain. Alfred Nobel was given a patent (No. 50,617) in October 1865 for the use of nitroglycerine as a blasting agent. (9) Since he couldn't patent nitro itself, he patented the methods for igniting the nitro using black powder, using either a fuse or electric spark to ignite the black powder. Nitroglycerine could not be fired with just the heat of a flame or electric spark; it need a rapid compression to detonate it.

In California, Nobel's rights to "Nobel's Patent Blasting Oil" were held by Julius Bandmann of Bandmann, Nielsen & Co. (10) Collis Huntington was scammed in late 1867 by Taliaferro Shaffner into paying $500 for the rights to use nitroglycerine in California, rights that Shaffner did not possess. (11) On April 12, 1866 Julius Bandmann gave a demonstration on the use of nitro to the engineering staff and others with the Central Pacific Railroad at Camp 21 near Dutch Flat. It apparently impressed them enough to decide to use it the following year at Tunnel #6. (12)

To reduce the danger of transporting the nitro, it was manufactured on site by James Howden. The use of nitro increased the rate of excavation for the headings from an average of 1.18 ft. for black powder to 1.82 ft. per day. For the bottoms the increase was from 2.51 ft. per day to 4.38 ft. per day, an increase of 74%. (13) There were several reasons for the increased rate besides the greater explosive energy of nitro:

- The nitro required only 1.25 inch holes instead of the 2.5 inch holes for black powder.
- Fewer holes were required, 2 smaller holes for every 3 black powder holes.
- The granite was broken into smaller pieces easing removal of excavated material.
- Less time was required to clear the tunnels of smoke.

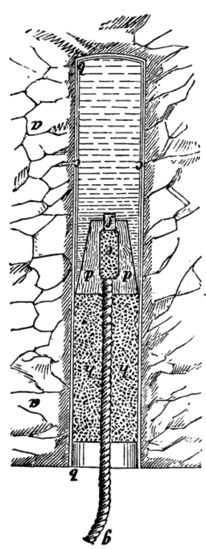
Nitroglycerine was used in the tunnel by pouring it into metal tubes or cartridges. A reporter with the Sacramento Daily Union described "Nitro Glycerine and its Use" in a visit to the site on April 17, 1867. (14)

> "*A hole two and a half feet deep, and of one and a quarter inches in diameter, is drilled in the rock that is blasted, and three and a half ounces of the nitro glycerin are placed in an appropriately shaped tin box or cartridge. On the top of the compound is placed a small copper cap containing a few grains of powder. A hole is left in the cartridge to admit the fuse, connecting with the surface. The apparatus is then lowered to the bottom of the hole, and upon it a plugging of paper is first pressed down, and over that damp sand or earth is tightly rammed down until the cavity is entirely filled. The operators light the fuse and retire, and in about a minute a terrific explosion occurs."*

The Nitro holes were 2.5 ft. deep. A plug, probably wood, was installed to keep the nitro in the tube. Black powder was inserted in the tube above the wood plug. The powder was ignited with a lit fuse, although, at the recommendation of Edwin Crocker, the Central Pacific did experiment with electric spark ignition using batteries. But it was too complicated for the work crews, so they returned to fuses. (15) The major advantage of using electricity to fire a charge is that a number of simultaneous charges can be ignited...with fuses only one charge at a time can be ignited.

Using metal tubes was a common practice in mining and tunnel excavation when using liquid nitroglycerine as a blasting agent. Unless the drilled hole was through solid rock without cracks or seams, the nitro would leak out of the hole. Also, the fumes from liquid nitro were dangerous and the metal cartridge kept them contained. (16) From an article in the November 30, 1867 Sacramento Daily Union (17), an accident occurred at the summit. A blacksmith was repairing one of the iron tubes he thought he had washed clean of nitro when it exploded in his hands. Another advantage of the cartridges is that the drill holes can be horizontal or even upward slopping.

BLASTING OIL. 11



Directions for Charging Horizontal or upward bores when Cartridges are required.

a Shows the rock.
b A bore.
c A cartridge.
d A conical wooden igniter, which is slightly pressed into the cartridge to keep tight.
e Charge of gunpowder in the igniter. *d.*
f A cork.
g A fuse.
h A tamping of loose sand or clay. The cartridge should be filled with oil till the igniter is sure to dip in it. In mines it is always safer to make use of cartridges, as if any oil should escape unexploded, it is diffused by the explosion in the atmosphere, which renders it deleterious.

Bores of 20 to 30-in. of depth and ⅝ to ¾-in. diameter, with cartridges 4 to 8-in. in length and ⅝ to ¾ in. diameter appear to be the best adapted for mines.

Nobel's Patent Blasting Oil.
(Nitro-Glycerine)
Bandmann, Nielsen & Co., 210 Front Street, San Francisco, Sole Agents for California, etc., etc.

Using a metal cartridge for vertical bore holes.

Why was Nitro's use not continued after Tunnel #6? Several reasons.

1. The other 6 tunnels at the summit were completed quick enough without its use, other than some nitro use at tunnel #8.
2. Logistics may have also been an issue. Tunnel #6 is at the top of the summit and near to where Howden was manufacturing the nitro. To carry the iron tubes full of nitro to the other tunnels increased the risks, and moving the manufacturing to each tunnel was not practical.
3. For uses other than the tunnels, nitro was not as practical as black powder. Nitro did not work as well for the seam blasting which was used for rock where large seams were filled with barrels of powder.
4. For the blasting of softer rock and material, the blasted material was frequently used for fill. The nitro would blow the material down the mountain, preventing its use as fill.

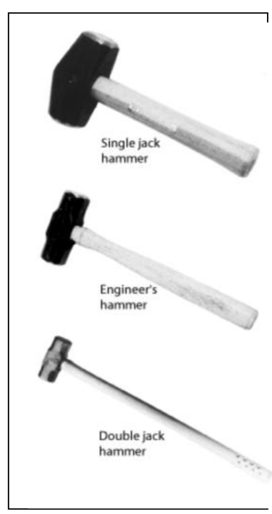
Noble patented Dynamite in the U.S. in 1868, and it started replacing the use of liquid nitroglycerine. Julius Bandmann of Bandmann, Nielsen & Co. was given the rights for the Noble patents in the U.S. west coast in late 1865, and on May 26, 1868 Noble assigned his patent for Dynamite to Bandmann. (18) Bandmann opened the first "Dynamite" (called Giant Powder by Bandmann) manufacturing plant in the U.S. near San Francisco.

Labor

The tunnels at the summit were constructed by Chinese labor with European foremen. The Chinese worked 8 hour shifts with the work continuing night and day. The Foremen worked 12 hour shifts. Each shift was about 30 Chinese, with three shifts per day at each of the four tunnel headings giving a total of about 360 Chinese working on the tunnel itself. There were others supporting the tunnel workers , including black smiths fabricating the iron tubes and sharpening the drill steel, Howden's assistants with the nitroglycerine, etc.

The Chinese became experts at double jacking the holes for the nitroglycerine. It normally took three workers, two with 8 lb double jacks, which were what we would today call sledgehammers, and one holding and turning the steel. A double jack is a hammer held with two hands with heads between 6 and 8 lbs., while a single jack was held with one hand, and had a head of between 3 and 4 lbs. Below are descriptions of single jacks and double jacks from *Hand Drilling and Breaking Rock for Wilderness Trail Maintenance*, U.S. Forest Service.(19)

Single jack	These are also called 'club' or hand drilling hammers. Handles are commonly 10 inches long, and heads weigh either 3 or 4 pounds. The short handle is uniquely suited to hand drilling because it resists breaking better than longer ones, and it facilitates accuracy by requiring the hand to be close to the head.
Double jack	These large driving sledges have 36-inch handles and 6- or 8-pound heads. Because their use requires considerable expertise from both the driller and holder, we recommend that you use single jacking or modified double jacking until safety and proficiency with the double jack can be assured.



In the 1877 "*Report of the Joint Special Committee to Investigate Chinese Immigration*", Charles Crocker was asked about the endurance of the Chinese workers, and told the following story: (20)

> *They are equal to the best white men. We tested that in the Summit tunnel, which is in the very hardest granite. We had a shaft down in the center. We were cutting both ways from the bottom of that shaft. The company were in a very great hurry for that tunnel, as it was the key to the position across the mountains, and they urged me to get the very best Cornish miners and put them into the tunnel so as to hurry it, and we did so. We went to Virginia City and got some Cornish Miners out of those mines and paid them extra wages. We put them into one side of the shaft, the heading leading from one side, and we had Chinamen on the other side. We measured the work every Sunday morning; and the Chinamen without fail always outmeasured the Cornish miners; that is to say, they would cut more rock in a week than the Cornish miners did, and there it was hard work, steady pounding on the rock, bone-labor. The Chinese were skilled in using the hammer and the drill; and they proved themselves equal to the very best Cornish miners in that work. They are very trusty, they are very intelligent, and they live up to their contracts.*

The China Wall

Between Tunnels 7 and 8 was a deep ravine that needed to be filled. The downhill side was very steep, so using fill with a fill slope was not practical. The wall, constructed by the skilled Chinese workers of hand-placed stone without mortar, was 75 feet high at its highest point. The foundation and 4'X5' box culvert were started in the fall of 1866, but not completed when winter hit, and the ravine filled with snow. They needed to have the foundation and culvert completed by the start of the spring runoff, so a tunnel was built through the deep snow with a cave at the end so the Chinese workers could complete the lower wall and culvert. (21) As the snow melted in the spring of 1867, the remainder of the wall was constructed.

Alfred Hart #202, "East portals of Tunnels Nos. 6 and 7, From Tunnel No. 8". China Wall under construction in foreground with crane to handle rock.

Detail of China Wall with hand laid stone without mortar. The track above operated from1868 until 1993, carrying heavy modern trains without movement or damage to the wall.

<u>Conclusion</u>

The last heading for the summit tunnel was holed through by September 26, 1867. Removal of the bottoms was completed by November 7, 1867, and track was laid through the tunnel on November 29, 1867. The first locomotive went through on December 1, 1867. In the 4 months until the line down to Truckee was completed, passenger trains stopped at the east end of the summit tunnel on the Dutch Flat and Donner Lake Wagon Road and caught a stage into Truckee. The final connection to Truckee was made at Strong's Canyon on April 2, 1868. By this time the line below Truckee had been completed to Truckee Meadows in Nevada.

Telegrams between Thomas Durant and Leland Stanford
Sacramento Daily Union, April 22, 1868.

SHERMAN'S SUMMIT, April 16, 1868
LARAMIE MOUNTAINS via CHEYENNE, April 17.
Leland Stanford, President, Central Pacific Railroad:
We send you greetings from the highest summit our line crosses between the Atlantic and Pacific oceans, eight thousand two hundred feet above the tide water. Have commenced laying the Irion on the down grade westward.
T.C. DURANT
Vice President, Union Pacific Railroad

OFFICE CENTRTAL PACIFIC RAILROAD COMPANY,
SACRAMENTO, APRIL 17, 1868.
To T.C. Durant, Vice President, Union Pacific Railroad, Sherman's Summit, Laramie Mountains via Cheyenne:
We receive your greeting with pleasure. Though you may approach the union of the two roads faster than ourselves, you cannot exceed us in earnestness of desire for that great event. We cheerfully yield you the palm of superior elevation. Seven Thousand and forty-two feet has been quite sufficient to satisfy our highest ambition. May your descent be easy and rapid.
LELAND STANFORD
President, Central Pacific Railroad Company

References

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2. Gilliss, p. 156

3. Gilliss. P. 159

4. Robert L. Harris, CE, *The Pacific Railroad-Unopen*, The Overland Monthly, Vol. 3, September 1869

5. Gilliss, p. 159

6. Gilliss, p. 161

7. Gilliss, p. 167

8. Gilliss, p. 162

9. *United States Patent Office, Patent No. 50,617, dated October 24, 1865, Alfred Nobel, of Hamburg. Improved Substitute for Gunpowder*

10. *Nobel's Patent Blasting Oil. (Nitro-Glycerine). Bandmann, Nielsen & Co., 210 Front Street, San Francisco, Sole Agents for California, etc., etc*., Mining and Scientific Press Book and Job Printing, 1865.

11. *Mining and Scientific Press, The New Blasting Agency. Nobel's Patent Blasting Oil (Nitro-Glycerin*e.), San Francisco, Saturday, December 23, 1865.

12. Nobel's Patent Blasting Oil, Dutch Flat, April 12, 1866.*Daily Alta California*, April 18, 1866.

13. Gilliss, p. 168

14. Nitroglycerine and its Use, Donner Pass, Nevada County, April 17, 1867, *Sacramento Daily Union*, April 19, 1867.

15. Letter from Edwin Crocker to Collis Huntington dated August 15, 1867. From Huntington Papers 1856-1901, Microfilm at Sacramento State University Library.

16. Henry S Drinker, E.M., *A Treatise on Explosive Compounds, Machine Rock Drills, and Blasting*, 1883, p. 70.

17. Death From Explosion of Nitro Glycerine*, Sacramento Daily Union*, May 29, 1867.

18. Henry S. Drinker, E.M., *Tunneling, Explosive Compounds, and Rock Drills, A Review of Tunneling from the Reign of Rameses II to the Present Time*, 1882. p. 100

19. *Hand Drilling and Breaking Rock for Wilderness Trail Maintenance*, U.S .Forest Service. 1984.

20. *Report of the Joint Special Committee to Investigate Chinese Immigration*, 1877. Testimony by Charles Crocker, p. 667.

21. Gilliss, p.159

<u>Other Resources</u>

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<u>Alfred Hart photos</u>

Library of Congress
Official Alfred Hart Photographs of the Central Pacific Railroad Construction
Between 1862 – 1869
Albumen prints. Only 189 of the 364 photos are available.
Can be downloaded in GIF, JPEG, or TIFF. TIFF downloads are about 32 MB.
https://www.loc.gov/search/?fa=partof:lot+11477

Online Archive of California
Stanford University Libraries
Stanford Digital Repository
Alfred A. Hart photograph collection 1862 – 1869
Albumen prints. All 364 Hart Central Pacific photographs are available.
Downloaded as JPEG between 3 and 4 MB.
https://purl.stanford.edu/nj339gb1246#