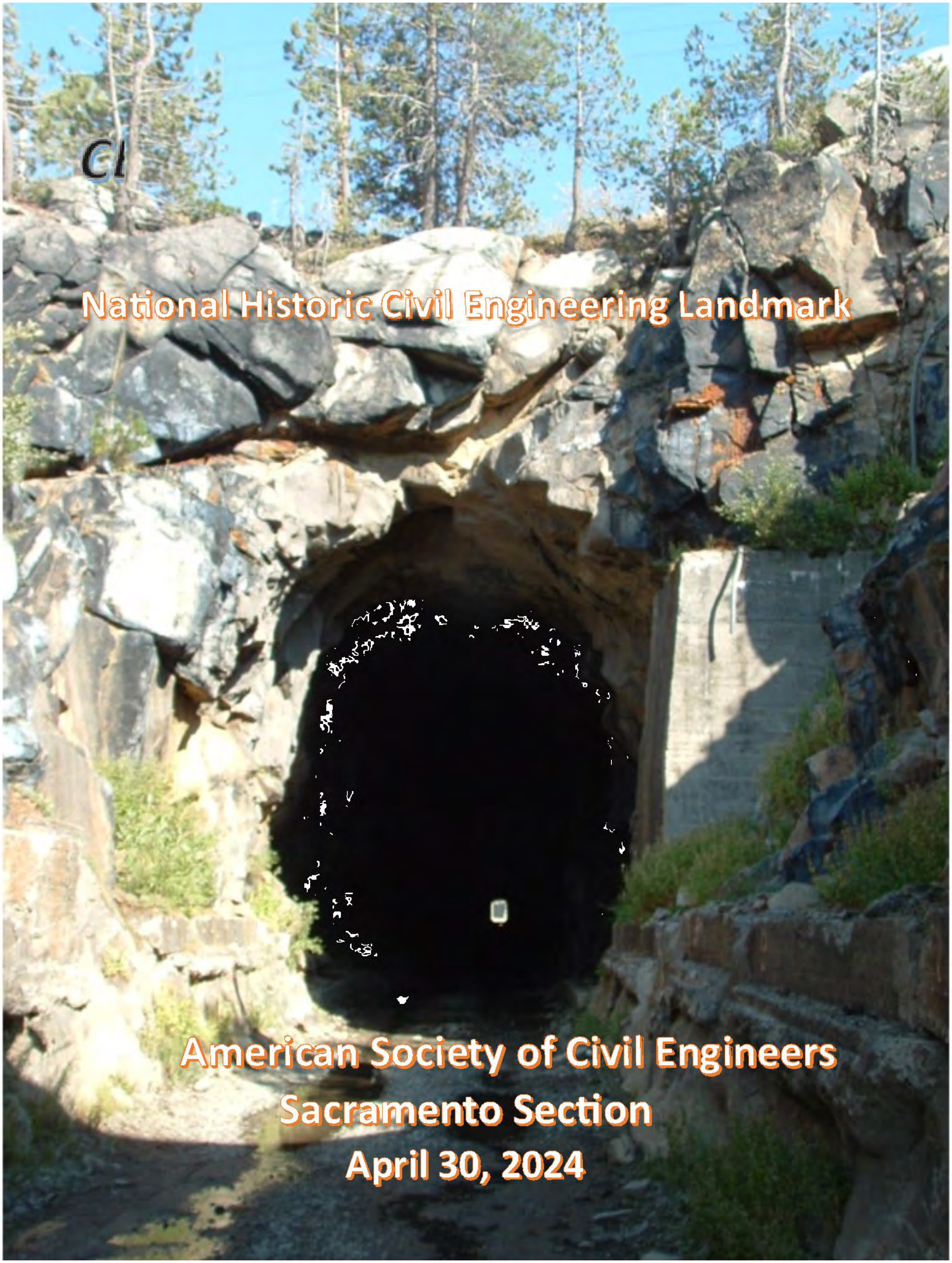


National Historic Civil Engineering Landmark

American Society of Civil Engineers
Sacramento Section
April 30, 2024


NATIONAL HISTORIC
CIVIL ENGINEERING LANDMARK
AMERICAN SOCIETY OF CIVIL ENGINEERS
1852
SUMMIT TUNNEL
THE LONGEST AND MOST DIFFICULT TO CONSTRUCT OF THE CENTRAL PACIFIC RAILROAD'S 15 TUNNELS ACROSS THE SIERRA NEVADA WAS THE 1,659-FOOT LONG TUNNEL 6, THE SUMMIT TUNNEL. IN FEBRUARY 1867, THE CHINESE WORKERS STARTED USING NITROGLYCERINE, IN ADDITION TO BLACK POWDER, TO BLAST THROUGH THE HARD SIERRA GRANITE. THIS WAS THE FIRST USE OF HIGH EXPLOSIVE NITROGLYCERINE FOR RAILROAD CONSTRUCTION IN THE U.S. WHEN COMPLETED, THE TUNNEL WAS THE HIGHEST IN THE WORLD AT OVER 7,000 FEET. HEAVY SNOWFALL AT THIS ELEVATION FORCED CHINESE WORKERS TO DIG SNOW TUNNELS TO PROVIDE ACCESS TO TUNNEL PORTALS AND REMOVE WASTE ROCK.
COMPLETED 1867
DESIGNATED 2024

Table of Contents

National Historic Civil Engineering Landmark Nomination

Submitted by the Sacramento Section, April 30, 2024

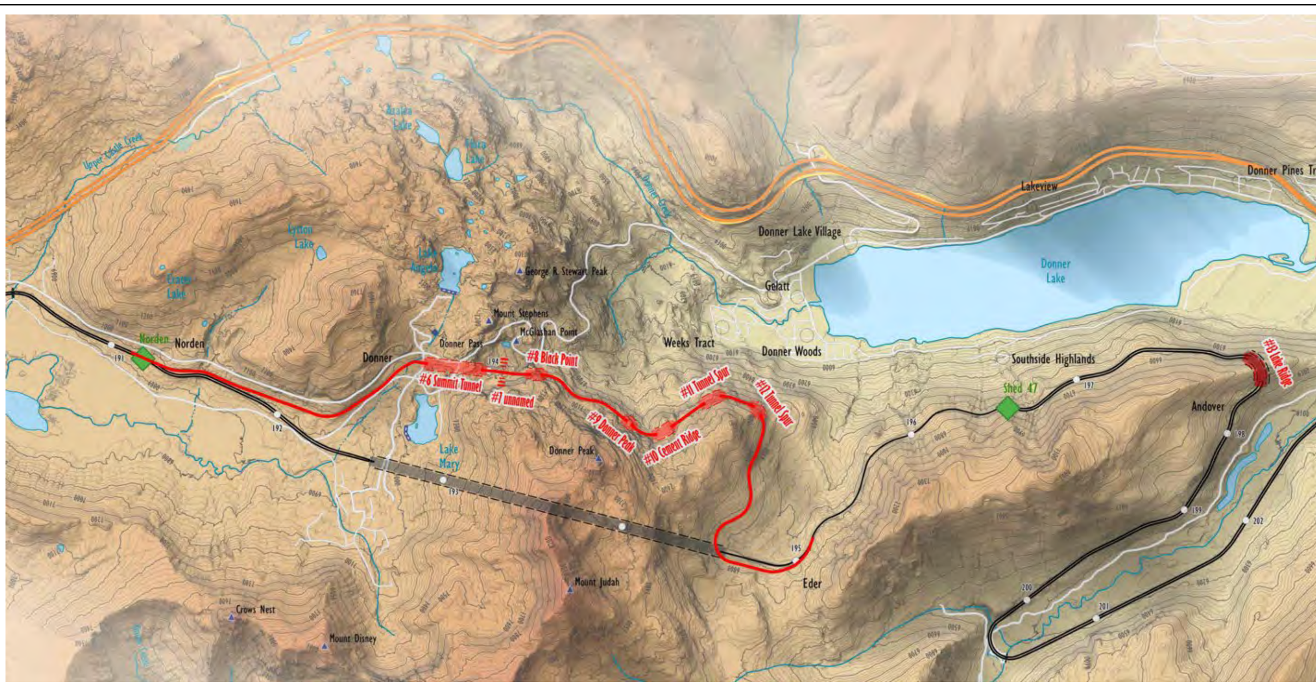
Summit Tunnel of the Central Pacific Railroad

Placer and Nevada Counties, California
92 miles east of Sacramento, CA.
9 miles west of Truckee, CA.

West portal in Nevada County: **39°18'60.0"N 120°19'46.4"W**
East Portal in Placer County: **39°18'57.6"N 120°19'25.4"W**

Although the tracks have been removed from the tunnel and section in red on the map, the 500' ROW including land above the tunnels is owned by the Union Pacific Railroad.

The property is leased by the Sugar Bowl Company, which controls the land use on the property.



Map prepared by Michael Chong, a descendent of a CPRR railroad worker.

1. Date of Original Construction

October 14, 1865 – December 1, 1867

Initial construction of the Summit Tunnel, Tunnel No. 6, began on **October 14, 1865**, but severe winter storms quickly shut down construction. The goal was to get the east and west tunnel headings deep enough into the mountain to allow work to continue protected from the weather during the winter. The deep snow stopped the work before the headings were completed.

The construction continued in **April of 1866** with the Chinese working three 8 hour shifts 6 days a week. The Irish foremen worked 12 hour shifts. By **September of 1866**, the tunnel work was all inside the headings, so work continued during the winter of **1866-1867**. On **August 29, 1867**, the headings were broken through the length of the tunnel. This was a huge benefit for the Chinese workers in the tunnel allowing fresh air to blow through the tunnel. The tunnel was completed and tracks installed on **November 30, 1867**, and, according to Gilliss, with the tunnels at the two headings meeting with offsets too small to measure. The first locomotive traveled through the tunnel on **December 1, 1867**.

In summer of **1967** the Summit Tunnel floor was lowered 3.5 feet so that double-stack freight trains could use the tunnel. The tunnel remained in continuous use until **1993**, when the tracks were removed. All trains now use the 3 mile long Tunnel 41, which was completed in 1925.

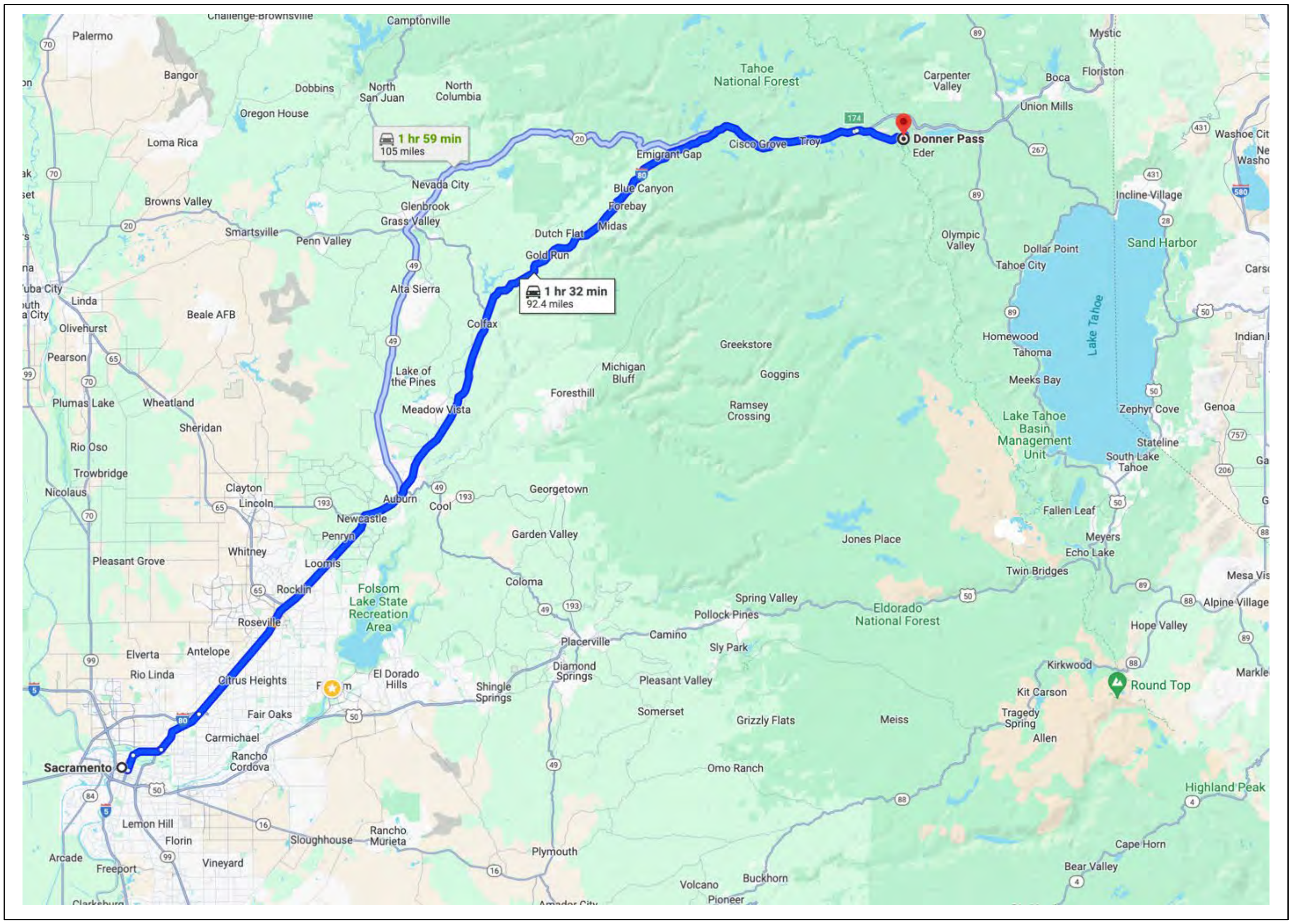
Summit Tunnel Timeline

1865, October 14	Work starts on tunnel facings at Summit.
1865, Winter	Deep snow stops work before facings completed.
1866, Spring	Push to get headings into tunnels so could work during following winter.
1866, April 12	Bandmann, Nielsen & Co., Nobel's patent holders in California, conduct tests of nitroglycerine for CPRR civil engineers at Camp 21 near Dutch Flat.
1866, August	Civil engineer John Gilliss hired to lead engineering of summit tunnels.
1866, August 27	Central Shaft at Summit Tunnel started. 8' X 12', 90' to bottom of tunnel.
1866, September 16	Tunnel work finally all inside of headings.
1866, November 28	Union Pacific RR civil engineers Thomas Bates and Fred Hodges, after completing UPRR survey from Salt Lake City to California state line, visit CPRR construction at summit. (12/01/1866 SDU)
1866, December 19	Work begins on 2 headings in central shaft.
1866, Winter	Most Chinese workers sent to work in Truckee Canyon. Over 1,000 Tunnel workers remain at summit to work during winter.
1867, January 7	Working on bottoms, 1' per day, preparing to use nitro. (EBC)
1867, Winter	Work continues using snow tunnels.
1867, February 2	Chinese strike above Colfax.
1867, February 9	James Howden manufactures first nitroglycerine at Summit.
1867, February 15	Tried using batteries to fire explosives. Too complicated for foremen. (EBC)
1867 February 17	Cornish miners from Comstock working one end of central tunnel competing with Chinese at other end…Chinese win.
1867, April 22	After 7.5 months work on Summit Tunnel, 910 ft. drilled, 750 ft. remaining.
1867, May (?)	Chinese worker pay increased from $31 to $35 per month (EBC, June 4).
1867, May 9	Foreman Henry McCarty killed in Summit Tunnel by hitting unexploded nitroglycerine with his hammer.

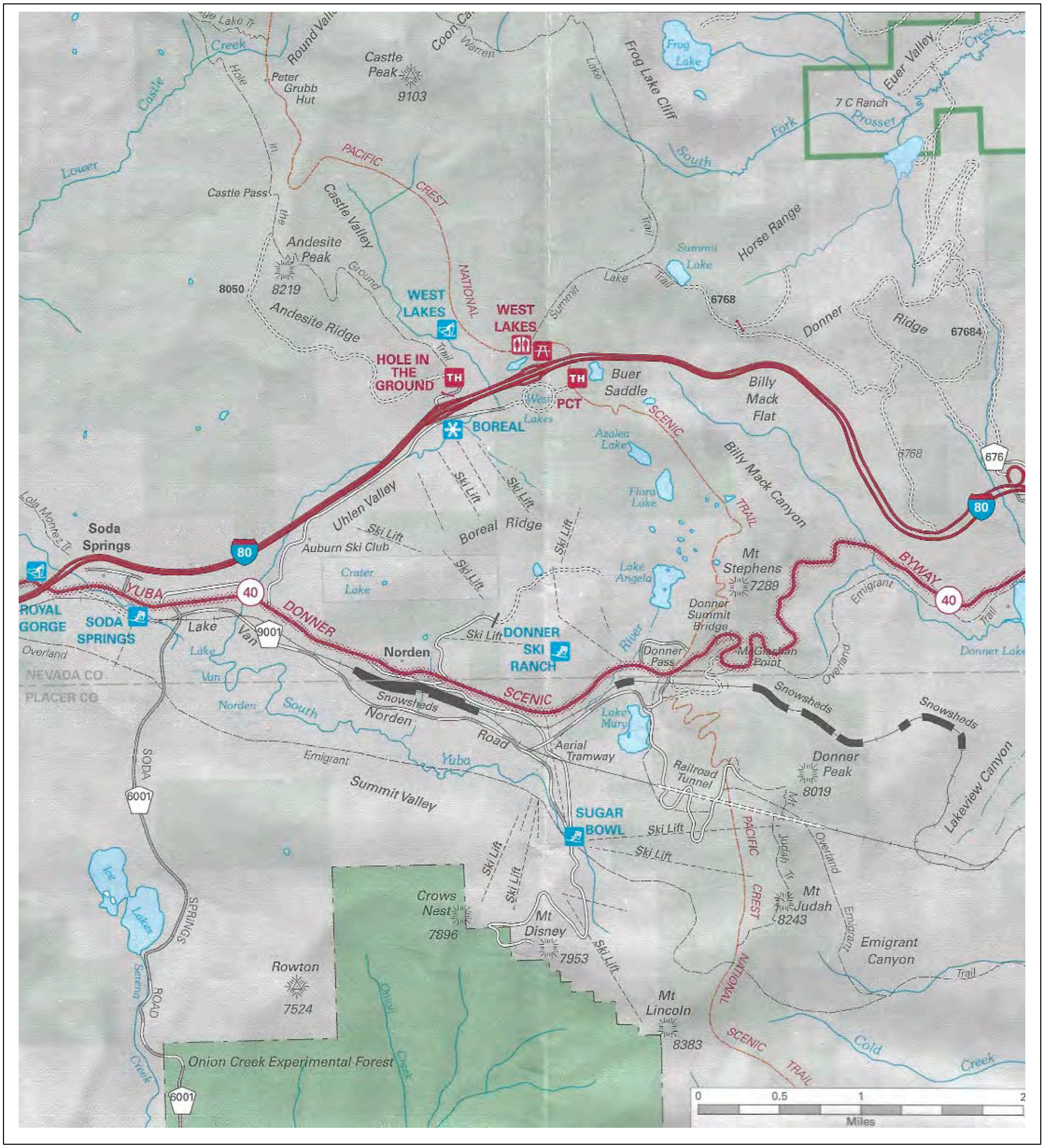
1867, June 4	Letter E.B. Crocker to C.P. Huntington, raised Chinese pay from $31 to $35 per month.
1867, June 26	Chinese workers strike between Cisco and Strong's Cañon, the area of heavy rock work. Demand 10 hour day and $40 per month.
1867, July 1	Chinese worker strike ends in 6 days; no change to pay or hours.
1867, July 2	Most Chinese removed from tunnels except headings to work on open cuts and retaining walls; will work on bottoms when snow falls.
1867, August 21	Old nitro plant at summit burns, no explosion, nitro moved to new building.
1867, August 29	Headings at Summit Tunnel broken through.
1867, October 8	8" snow; fear tunnels may not be completed before winter.
1867, November 24	Blacksmith heating nitro cartridge to repair it; lost both hands in blast.
1867, November 30	Tunnel construction completed.
1867, December 1	Track finished through Summit Tunnel. Locomotive passes through to Tunnel 12 at Strongs Cañon.
1868, Spring	Regular train scheduled stop at east end of Summit Tunnel. Passengers transfer to stages on Dutch Flat and Donner Lake Wagon Road.
1868, June 17	Last rail laid to connect California to Nevada at ceremony at Strong's Cañon.
1868, June 18	First train from Sacramento to Reno.
1868, June 19	First train from Reno to Sacramento.

2. Local and Vicinity Maps

Google view of Donner Pass. The Summit Tunnel is shown with the white line. The red & white dashed line indicates the County Line between Nevada County to the north and Placer County to the south. The closest incorporated town is Truckee, 9 miles east of the pass. The community of Soda Springs is 3 miles to the west.



Donner Pass is 92 miles east of Sacramento and about 3 miles south of Interstate 80. Interstate 80 over the summit is usually open all year, but with frequent short term closures during winter storms.



U.S. Forest Service map of Summit area. The area is a mixture of private ownership and USFS ownership. The strip above the tunnel is owned by the Union Pacific but leased by Sugar Bowl Corp.

3. Names of Key Engineers

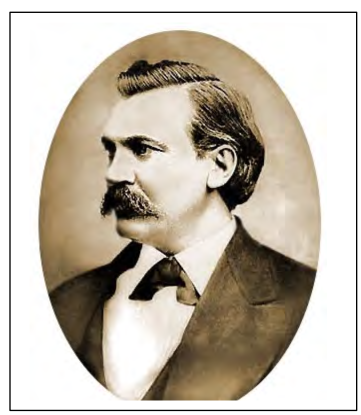
John Roberts Gilliss, M. ASCE

John Gilliss was born in D.C. on January 4, 1842 and graduated from Georgetown University in 1857 at age 15. During the Civil War he worked as a civilian for the Army Corps of Engineers. In August, 1866 he was hired by the Central Pacific Railroad as the Resident Engineer in charge of the construction of the 7 tunnels at Donner Summit. After the completion of the tunnels at the Summit in 1867, Gilliss was hired by the Union Pacific Railroad to oversee the construction of their tunnels in Weber Canyon , Utah. Several of the UPRR tunnels also used nitroglycerine. After the 1869 completion of the Transcontinental Railroad, Gilliss moved back to New York City where he worked on the Beach Pneumatic Transit Tunnel. He died of a brain aneurism on July 15, 1870, age 28.

On January 5, 1870 Gilliss read a paper before the Society called **"Tunnels of the Pacific Railroad."** It was published in Volume I of the ASCE Transactions in 1872. It is one of the best descriptions of early tunnel construction in the mountains, and is probably the most referenced ASCE Transaction from the 19th century. It is included in the Appendix.

Other civil engineers that worked for Gilliss include **A.R. Guppy, Henry Root,** and **Robert Harris**. Root wrote a paper published in 1921 that presented his experiences working for the Central pacific and later the Southern Pacific. Harris published an article on his experiences at the Summit in an 1869 issue of *The Overland Monthly* magazine.

Lewis Metzler Clement



Lewis Clement was Gilliss' immediate boss and was the Assistant Chief Engineer for the Central Pacific Railroad. During construction of the railroad he was based at the Summit with Gilliss and was in charge of the 50 miles from Alta to Truckee.

4. Historic Significance

- First use in the U.S. of Nitroglycerine high explosive for railroad construction in February 1867.
- First on-site manufacture in the U.S. of Nitroglycerine for construction, February 1867.
- Highest elevation tunnel in the world when completed in November, 1867 at approximately 7,030 feet.

For centuries, low-explosive **black powder** was used as a blasting agent in construction to ease the burden on manual labor. It was used extensively in construction of early railroads, including in tunnels. It worked fine for most blasting needs, but was not very effective in blasting hard rock like granite, and was difficult to use in wet environments.

Although nitroglycerine, was invented in 1846, it was considered too dangerous for use in blasting. **Alfred Nobel** developed methods for construction blasting with nitroglycerine in **1865** that initiated its use in construction and mining in Europe. Nitroglycerine was approximately 6 times more powerful than black powder and was the beginning of the development of high explosives for construction. Nitroglycerine has a very high blast velocity and is much more effective against hard rock than the slow velocity black powder. Nobel invented nitroglycerine-based **dynamite** in **1867**, but it was not widely used until the **1870s**. Many mining and construction operations continued to use liquid nitroglycerine because it was more powerful by volume than dynamite and was less expensive. The manufacture and use of nitroglycerine was never patented so it was in the public domain.

The nitroglycerine used on the Summit Tunnel was manufactured on-site by chemist **James Howden**. Howden's **Chinese** assistants would pour the nitroglycerine into 1 1/8-inch diameter tin cartridges either 4, 5, or 6 inches long, and place them in a wooden box. The most used were the 6" cartridges. They would take the cartridges to the tunnels where the **Chinese** tunnel crew would place them in 1 ¼ inch holes from 24" to 30" deep in the hard granite. One advantage of nitroglycerine was that the 1 ½ inch holes used for nitroglycerine were drilled faster than the 2 ½ inch holes used for black powder.

Since nitroglycerin could not be detonated with flame like black powder, a black powder exploder was placed on top of the cartridge of nitroglycerine in the hole and a common safety fuse was attached. Electric firing with a battery for the exploder was tried, but, according to Edwin Crocker, “electric battery too delicate a thing to put in hands if Irish foremen and had to give it up.” The advantage of electric firing was that multiple simultaneous blasts could be fired, whereas with the common safety fuse only allowed one hole to be fired at a time.

According to Gilliss, with nitroglycerine, the progress of the tunnel headings went from 1.18 feet per day to 1.82 feet per day, an increase of 54%. For the bottoms, the rate went from 2.54 feet per day to 4.38 feet per day, an increase of 74%. The construction of a central shaft allowed 4 headings to be worked on simultaneously. Only one death was attributed to nitroglycerine, and that was an Irish foreman.

The elevation at the west portal of approximately 7,030 feet, was the highest in the world when the tunnel was completed in late 1867. The challenge with the high elevation was dealing with the harsh winter in the High Sierra with the Chinese tunnel crews continuing to work through the winter. The average snowfall at Donner Pass is over 400 inches, with average depth of 140 inches, and much in areas with snow drifts. The winter of 1866-1867 was the worst recorded winter in the Sierra up to that time. Gilliss noted in his ASCE paper that the accumulated snow at the summit was not gone until July 1867, with snow depths on the site still at 15 feet in April and 11 feet in May. The snow drifts at the two portals were so deep that snow tunnels from 50 feet to 200 feet long were required for access to the tunnels. Short tunnels also frequently required to access the entrance to buildings. Survey control was set near the portals of each of the tunnels at the Summit to allow continued surveying of the tunnels in the deep snows.

5. Discussion of Comparable Projects

Two significant tunnels were under construction in the same period as the Summit Tunnel, The **Hoosac Tunnel** in Massachusetts and the **Mont Senis Tunnel** in Italy and France. Neither used nitroglycerine or dynamite before nitroglycerine was used at the Summit Tunnel.

The **Hoosac Tunnel** was under construction at the same time as the Summit Tunnel. Its construction started in 1857 but was intermittent with funding and construction challenges. The Hoosac Tunnel was much longer, at 20,080 feet, than the Summit Tunnel and was a larger cross section for two tracks, so was a much bigger project. But its first demonstration of the use of nitroglycerine was in June of 1866 when T.P. Shaffner, the holder of Nobel's patents on the east coast, experimented with its use in the west shaft. This was a month after the early-April 1866 nitroglycerine demonstration for the Central Pacific by Julius Bandmann, the holder of Nobel's patents on the west coast. The regular use of nitroglycerine for construction of the Hoosac Tunnel didn't start until December 1867, 10 months after its use started at the Summit Tunnel.

The **Mont Senis Tunnel** in Europe started construction in 1857 and was completed in 1870. It was 45,000 feet long and at an elevation of 3,680 feet. During most of its construction period, black powder was used for blasting. There is some evidence that dynamite was used in later years, but no evidence that nitroglycerine was used.

In an ASCE paper read before the Society on March 4, 1868, Edward P. North, M.ASCE, discusses the use of nitroglycerine in the summer of 1867. It was used in excavation of rock cuts on the **New Canaan Railroad** in Connecticut. This was also one of the earliest uses of nitroglycerine for construction, but it was 5 or 6 months after the Summit Tunnel's use started.

6. Uniqueness

Several of the unique characteristics have been presented in Section 4, Historic Significance, and are not repeated here. They include **the first use of nitroglycerine for construction blasting**, the **first on-site manufacturing of nitroglycerine,** and the **high elevation** of the site with the severe weather challenges.

One of most unique aspects of the Summit Tunnel construction was the use of **Chinese** workers for most of the skilled and unskilled labor required to construct the railroad and the tunnels. Most of the European labor pool either refused to do the hard work required or worked for only short periods of time before leaving for the next precious metal strike. The **Chinese** workers were skilled at their jobs and were much more reliable than many of the European workers.

To support fill over a low point between Tunnels 7 and 8, the Chinese constructed a high retaining wall of dry fitted stone. The close tolerances of the stone construction resulted in a structure so strong that no improvements were required with the much heavier locomotives and trains that used the line until 1993.

When the Lincoln Highway was constructed across Donner Pass in 1913 it crossed the Central Pacific's tracks near Donner Pass. At crossings where snow sheds existed, it was very dangerous for the vehicles since they could not see or hear the trains approaching in the snow shed. At the crossing between Tunnels 7 and 8, an underpass was constructed to separate the vehicles from the trains. There are claims that this was the first train/vehicle grade separation constructed specifically for the automobile.

7. Contributions

The use of nitroglycerine at the Summit Tunnel was the transition from centuries of black powder use to more modern and safer explosive such as dynamite and later trinitrotoluene (TNT) and others. Nitroglycerine's successful use by the Central Pacific's civil engineers and Chinese workers in the 1860s encouraged its use around the country until it was replaced by safer and easier to use dynamite.

Using nitroglycerine at the Summit Tunnel reduced the construction time of the tunnel which allowed the Central Pacific to quickly build the railroad across Nevada and into Utah where it met the Union Pacific building east. The transcontinental railroads received government bonds for each mile of track completed, so it was important to keep the track moving forward to keep the money coming in.

In the bigger picture, the completion of the Central Pacific over the Sierra Nevada contributed to the May 10, 1869 completion of the Transcontinental Railroad at Promontory Summit, Utah. The Transcontinental Railroad was a symbol of unity and progress, and vastly increased the exchange of goods between the east and the western states. It also made travel easier and more affordable, and it greatly contributed to the growth of California in population and economic importance.

8. Photographs

Hart 116. *Camp near Summit Tunnel*. *Mount King in distance*. Dutch Flat & Donner Lake Wagon Road in foreground.

Hart 117. *Bluffs in Donner Pass, Western Summit. 500 feet high. Altitude of Pass 7,000 feet.* The photo is looking west along the Dutch Flat and Donner Lake Wagon Road. The buildings which housed the Chinese and European workers are out of the frame to the right.

Hart 118. *Summit Tunnel, Eastern Portal. Length 1660 feet on Western Summit.*

East portal Summit Tunnel in 2022. Old Dutch Flat and Donner Lake Wagon Road going downhill to right.

Hart 119. Chinese at east portal of Summit Tunnel. They are drilling holes in large boulders to blast into smaller pieces.

Hart 120. Wagons on Dutch Flat & Donner Lake Wagon Road. Alfred Hart's photography wagon lower left. Water wagon for dust control going uphill. Building in background is at east portal of Summit Tunnel.

Hart 193. *Summit Station. Western Summit*. The snow shed closest to the viewer connects to the west portal of the Summit Tunnel almost below the photographer. Summit Hotel on left and turntable for turning helper locomotives on the right.

Hart 196. *Shaft House over Summit Tunnel. American Peak in distance*. The dark barn-like building is the shaft house which was constructed over the central shaft for the tunnel. An old steam locomotive boiler was used to power a hoist. Tracks for conveying the spoils from the shaft house to a dump site are on the right. Other buildings of the Summit Camp are in the background.

Hart 197. *Summit Tunnel, before completion-Western Summit-Altitude 7,042 feet*. The 7,042 elevation tells us that it is taken from the western portal with the setting sun lighting the tunnel. The eastern portal was at about 7,012 feet elevation, using the elevations from Gilliss' 1870 paper. Note the end of the tunnel where the arched "headings" are advanced ahead of the rectangular "bottoms."

Hart 198. *East Portal; of Summit Tunnel, Western Summit*. *Length 1,660 feet*. The photo shows a Chinese worker with a horse cart removing spoils from the tunnel after a blast.

Hart 200. *Bluff and Snow Bank in Donner Pass, Western Summit. Altitude 7,092 feet*. The photo is looking west towards the top of the pass. Hart's elevation of 7,092 feet puts the Pass about 50 feet above the bottom of the tunnel at the west portal. The Dutch Flat and Donner Lake Wagon Road curves up towards the Pass. Note children at lower left with what looks like a snowman.

Hart 202. East Portals of Tunnels No. 6 and 7, from Tunnel No. 8. Looking west towards summit. Note buildings for housing the workers on the left, and the Dutch Flat and Donner Lake Wagon Road sloping down to the right from the Summit Tunnel east portal.

Hart 204. Heading of East Portal. Tunnel No. 8, from Donner Lake Railroad, Western Summit. This is not a Summit Tunnel, Tunnel No. 6, photo but it's interesting because it shows a Chinese worker probably carrying hot tea in the buckets for the other Chinese workers. The Chinese stayed much healthier than the Europeans who drank the frequently polluted stream water.

This view shows approximate locations of structures at the Summit Camp. They include bunkhouses, storage buildings, the shaft house, and other work buildings. Approximately 400 Chinese that worked inside the tunnel stayed at the Summit Camp during the winter. The remaining Chinese workers that had been working outside on projects such as the retaining walls and cuts were moved down to the Truckee River Canyon to keep the line moving east during the winter months.

9. References

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4. *Blasting With Nitro-Glycerine*, American Society of Civil Engineers Transactions, A Paper Read Before the Society March 4, 1868, Edward P. North, Civil Engineer, M.ASCE.

5. *Nitro-Glycerine – Its Manufacture and Use*, American Society of Civil Engineers Transactions, A Paper Read Before the Society June 2, 1869, Stephen Chester, Civil; Engineer, M.ASCE.

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7. *Letter from Donner Pass, Nitro Glycerine and its Use, Donner Pass Nevada County, April 17, 1867,* Sacramento Daily Union, April 17, 1867.

8. *Nitro-Glycerine, North San Juan, June 8, 1867, from Nevada Gazette*, Marysville Daily Appeal, June 13, 1867.

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

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

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

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.

10. Additional Documentation

See Appendix

Two reports are included as an Appendix.

- *Tunnels of the Pacific Railroad, American Society of Civil Engineers Transactions, A Paper Read Before the Society Jan. 5, 1870, by John R. Gilliss, Civil Engineer.*
- *The Central Pacific Railroad's Summit Tunnel*, Pacific Coast Chapter, R&LHS, May 2023 Conference Presentation, Chuck Spinks.

11. Text for Landmark Plaque

Summit Tunnel The longest and most difficult of the Central Pacific Railroad's 15 tunnels across the Sierra Nevada was the 1,659' long Tunnel #6, the Summit Tunnel. In February, 1867 the Chinese workers started using Nitroglycerine in addition to black powder to blast through the hard Sierra granite. It was the first use of nitroglycerine high explosive for railroad construction in the U.S. At an elevation of over 7,000', the tunnel was the highest in the world when completed, with the heavy snow fall at the high elevation of the summit requiring snow tunnels for the Chinese workers to access the tunnel portals. Completed 1867 Designated 2024

12. Text for ASCE Website

For centuries, **black powder** was used as a blasting agent in construction to ease the burden on manual labor. It worked fine for most blasting needs, but was not very effective in blasting hard rock like granite.

Although nitroglycerine, was invented in 1846, it was considered too dangerous for use in blasting. **Alfred Nobel** developed methods for manufacturing and handling of nitroglycerine in **1865** that initiated its limited use in construction and mining in Europe. Nitroglycerine was much more powerful than black powder and was the beginning of the development of high explosives for construction. Nobel invented nitroglycerine-based **dynamite** in **1867**, but it was not widely used until the **1870s**. The manufacture and use of nitroglycerine was never patented so it was in the public domain.

The nitroglycerine used on the Summit Tunnel was manufactured on-site by chemist James Howden. Howden's Chinese assistants would pour the nitroglycerine into 1 1/8-inch diameter tin cartridges either 4, 5, or 6 inches long, and place them in a wooden box. They would take the cartridges to the tunnels where the Chinese tunnel crew would place them in 1 ¼ inch holes from 24" to 30" deep in the hard granite. Since nitroglycerin could not be exploded with flame like black powder, a black powder igniter was placed on the cartridge of nitroglycerine in the hole and a common safety fuse was attached.

With nitroglycerine, the progress of the tunnel headings went from 1.18 feet per day to 1.82 feet per day, an increase of 54%. For the bottoms, the rate went from 2.54 feet per day to 4.38 feet per day, an increase of 74%. The construction of a central shaft allowed 4 headings to be worked on simultaneously. Only one death was attributed to nitroglycerine, and that was an Irish foreman.

The elevation at the west portal of approximately 7,030 feet, was the highest in the world when the tunnel was completed in ate 1867. The challenge with the elevation was dealing with the harsh winter in the High Sierra. The average snowfall at Donner Pass is over 400 inches, with average depth of 140 inches. The winter of 1866-1867 was the worst recorded winter in the Sierra up to that time with the accumulated snow at the summit not gone until July 1867, with snow depths at the site still at 15 feet in April and 11 feet in May. The snow drifts at the two portals were so deep that snow tunnels from 50 feet to 200 feet were required for access and removal of spoils.

13. Proposed Landmark Plaque Location

View of Summit with central shaft at left of photo and area with plaques, markers, and kiosks at center. The red dashed line is the County line, with Nevada County to the north and Placer County to the south. The Donner Summit Association oversees the area.

Summit area surface view. Kiosks with historical information behind old 1930s California Division of Highways building.

Existing Summit Tunnel plaque by E. Clampus Vitus, 1999

The Summit in Winter.

14. Owner Letter of Support

April 4, 2024

American Society of Civil Engineers
History and Heritage Committee
1801 Alexander Bell Drive
Reston, VA 20191-4400

Re: National Historic Civil Engineering Landmark Application for Tunnel 6 on Donner Summit

Dear History and Heritage Committee,

The transcontinental railroad stands as a remarkable feat of engineering, spanning three thousand miles across mountains, deserts, ravines, and rivers. Upon completion in 1869, it enabled trains to travel at the incredible speed of 25 miles per hour, completing the cross-country journey in just 19 days.

One of the most impressive accomplishments of this endeavor was the construction of Tunnel 6 on Donner Summit, a 1,659-foot-long passage through solid granite. This engineering marvel was carved out over two years by the heroes of the project, the Chinese railroad workers, who braved avalanches, blasting accidents, rockslides, blizzards, and prejudice.

The railroad revolutionized transportation and connectivity in the United States. It opened up California to the rest of the country and the world, facilitating emigration, trade, and communication. The rapid transport of goods and mail accelerated economic growth and spurred innovation across the nation.

As the completion of the railroad approached, The Sacramento Union hailed it as "a victory over space, the elements, and the stupendous mountain barriers separating the East from the West, and apparently defying the genius and energy of man to surmount. Every heart was gladdened by the contemplation of the grand achievement" (*May 8, 1869*).

Sugar Bowl Resort appreciates your consideration of Tunnel 6 as an ASCE National Historic Civil Engineering Landmark, and enthusiastically endorses the application and installation of an ASCE plaque at the Lamson-Cashion Donner Summit Hub.

Sincerely,

Bridget Legnavsky
CEO, Sugar Bowl Corporation

Sugar Bowl Resort
PO Box 5
629 Sugar Bowl Rd. Norden, CA 95724
Resort Phone: (530) 426-9000
Customer Service: customercare@sugarbowl.com
www.sugarbowl.com

15. Section Commitment

Appendix

Two reports are included as an Appendix.

- *Tunnels of the Pacific Railroad, American Society of Civil Engineers Transactions, A Paper Read Before the Society Jan. 5, 1870, by John R. Gilliss, Civil Engineer.*
- *The Central Pacific Railroad's Summit Tunnel*, Pacific Coast Chapter, R&LHS, May 2023 Conference Presentation, Chuck Spinks.

XIII.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INCORPORATED 1852.

TRANSACTIONS.

TUNNELS OF THE PACIFIC RAILROAD.

A Paper read before the Society Jan. 5, 1870, by JOHN R. GILLISS, Civil Engineer, Member of the Society.

During the past summer the track has been completed across this Continent, and so much sooner than was thought possible, that the difficulties overcome are apt to be underrated. Some account of a single item in the great work may therefore be interesting.

Between Omaha and Sacramento there are nineteen tunnels. Four of these are on the Union Pacific, and fifteen on the Central. The latter, having been completed before those on the Union Pacific were commenced, will be spoken of first.

Central Pacific Tunnels.—The tunnels of the Central Pacific are nearly all near the summit, where it crosses the western range of the Sierra Nevada. The line here lies on steep hill-sides, in some cases being, for long distances, on a face of bare granite, more or less broken by projecting ledges and boulders, but with an average slope often greater than 1 to 1. In such places embankments were almost impracticable; the hills were too steep to catch the slopes, and most of the rock from cuts was thrown far down hill by heavy seam blasts. On these accounts the line for two miles east of Donner Pass was thrown further into the hill than on original location, thus adding to the depths of cuttings and increasing the number of tunnels, but saving retaining walls, and where tunnels were made enabling the work to be carried on in winter. Another important object was the saving of snow-covering where tunnels were made, and giving a good foundation for it where they were not. It is within these two miles that seven tunnels are crowded.

A detailed account of each tunnel would be tedious. Their characteristics have therefore been condensed into a table. See Appendix A.

Commencement of Work.—Tunnels 1 and 2 are both west of Cisco, a small track ninety-two miles from Sacramento, and within thirteen of the summit. They were both finished in 1866. During the fall of that year 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 in its vicinity. The year before, some gangs had been sent to summit tunnel No. 6, and commenced the cuts at its extremities; winter set in before the headings were started, and the work had to be abandoned. To avoid a repetition of such delay, the approaches to all the tunnels were covered with men, and worked night and day in three shifts of eight hours each. Thus time was saved, and the tunnel organization started at once. As an illustration of the hurry, I may mention 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 o'clock the men were at work.

In November and the early part of December there were several snowstorms, just enough to stimulate without delaying the work. The rough rocky sides of Donner Peak soon became smooth, slopes of snow and ice covering the trail that led from tunnel 8 to 9; it remained impassable until spring, and communication had to be kept up by the wagon-road, five or six hundred feet below. This, the Dutch Flat and Donner Lake wagon road, was opened soon after it was decided to adopt this route. From the Pass the descent toward the lake was over very rough ground, requiring heavy side cuts and retaining walls with numerous zig-zags to gain distance.

From this road the scene was strangely beautiful at night. The tall firs, though drooping under their heavy burdens, pointed to the mountains that overhung them, where the fires that lit seven tunnels shone like stars on their snowy sides. The only sound that came down to break the stillness of the winter night was the sharp ring of hammer on steel, or the heavy reports of the blasts.

Winter of 1866–7.—By the time winter had set in fairly the headings were all under ground. The work was then independent of weather, except as storms would block up tunnel entrances, or avalanches sweep over the shanties of the laborers. Before tracing the progress of the work underground, it will be well to see the character of weather outdoors.

A set of meteorological instruments was furnished by Colonel Williamson, of the United States Engineers, consisting of barometer wet, dry, maximum and minimum thermometers. These, with wind, clouds, etc., were recorded three times a day, and hourly during ten days in each month. From this record the table of storms given in Appendix C was made.

Snow-storms.—These storms, forty-four in number, varied in length from a short snow squall to a two-week gale, and in depth from a quarter of an inch to ten feet—none less than the former number being recorded, nor had we occasion to note any greater than the latter. This, the heaviest storm of the winter, began February 18th, at 2 P. M., and snowed steadily until 10 P. M. of the 22d, during which time six feet fell. The supply of raw material was then exhausted, but the barometer kept low and the wind heavy from the south-west for five days more, by which time a fresh supply of damp air came up from the Pacific, and then, as the machinery was still running full speed, this was ground up without delay. It snowed steadily until March 2d, making ten feet snow and thirteen days storm. It is true that no snow fell for five days, but it drifted so furiously during that time that the snow-tunnel at east end of tunnel No. 6 had to be lengthened fifty feet.

These storms were grand. They always began with a fall in the barometer and a strong wind from the south-west, hurrying up the tattered rain-clouds or storm-scud in heavy masses. The barometer, which averaged twenty-three inches, would drop sometimes as low as twenty-two and a half. The thermometer was rarely below twenty degrees at the beginning of a storm, and usually rose to thirty-two degrees before its close, so that the last snow would be damp and heavy, sometimes ending in a rain. The storms ended, and clouds were scattered by cold winds blowing over the eastern range of the Sierra Nevada; these raised the barometer and dropped the temperature at once. The lowest temperature of the winter was from a wind of this sort, five and a half degrees above zero.

Our quarters were at the east end of Donner Pass, but still in the narrow part. About the second or third day of a storm the wind would be a gale, sometimes ten pounds per square foot; and would plough up the new fallen snow to heap it in huge drifts beyond the east end of the pass. About thirty feet from our windows was a large warehouse; this was often hidden completely by the furious torrent of almost solid snow that swept through the gorge. On the cliff above, the cedar trees are deeply cut, many branches of the thickness of a man's wrist being taken off entirely by the drifting snow-flakes.

No one can face these storms when they are in earnest. Three of our party came through the pass one evening, walking with the storm—two got in safely. After waiting a while, just as we were starting out to look up the third, he came in exhausted. In a short, straight path between two walls of rock, he had lost his way and thought his last hour had come.

Road-breaking.—Of course these storms make the road impassable even for sleighs. They are opened by gangs of men kept there for the purpose with heavy ox sleds. The snow when new fallen is very light, so that a man without snow-shoes would sink to his waist or shoulders. Into this the oxen would flounder, and when they lay down, worn out, be roused by the summary process of twisting their tails. I saw three in one team so fortunate as to have had theirs twisted clear off, none left to be bothered with. The men were as regardless of themselves as of their animals. They took life easily in fine weather, but were out nearly all the time when it stormed. Late at night they could be seen shovelling on a bad drift at the corner of the warehouse, where the wind heaped in the snow faster than they could dig it out, and then a denser mass of flying snow would hide them altogether.

Snow-shoes.—We started with Canadian snow-shoes, but soon abandoned them for the Norwegian, each a strip of light wood ten to twelve feet long, four inches wide, and an inch and a quarter thick in the centre;

they taper in thickness towards the end, are turned up in front, and grooved on the bottom.

There is a broad strap in the middle to put the foot under, and a balancing-pole to steady, push, and brake with. The latter will be seen all-important, as a speed of twenty-five to thirty miles an hour is often attained on a steep hill side. During several winters the mails were carried across the mountains by a Norwegian named Thompson, on these shoes. It is said he made sometimes forty or fifty miles a day on them.

Snow-slides.—Snow-slides or avalanches were frequent. The storm winds being always from the south-west, form drifts or snow-wreaths on the north-east crests of hills. When these become too heavy, which is generally towards the close of the storms, they break off, and in falling start the loose snow below. This slides on the old crust. I never knew of a slide from the ground.

Near the close of one storm, a log-house with board roof, containing three Scotchmen, brothers, and sub-contractors with their gang, some fifteen or sixteen men in all, was crushed and buried up at day-break. The storm ended at noon Towards evening, a man coming up the road missed the house and alarmed the camp, so that by six o'clock the men were dug out. The bulk of the slide had passed over and piled itself up beyond the house, so that it was only covered fifteen feet deep. Only three were killed; the bunks were close to the log walls and kept the rest from being crushed. The snow packed around the men so closely that only two could move about; they had almost dug their way out; over the heads of the rest little holes had been melted in the snow by their breath. Most of them were conscious, and, strange to say, the time had passed rapidly with them, although about fourteen hours under the snow.

This event startled us, for at the top of the cliff, in front of the camp, was a snow-wreath forty or fifty feet long, projecting twenty feet, and of about the same thickness. We were uncertain when it would come down and where it would stop. A keg of powder was put down behind it next morning and fired. A white column shot up a hundred feet, and then the whole hill-side below was in motion; it came down a frozen cascade, covered with glittering snow-dust for spray. It was a rare sight, for snow-slides are so rapid and noiseless that comparatively few are seen.

They were so frequent across the trail leading to tunnel No. 9, that it had to be abandoned for some months. At tunnel 10, some fifteen or twenty Chinamen were killed by a slide about this time. The year before, two road repairers had been killed, and buried too, by a slide, as their bodies were not found until spring.

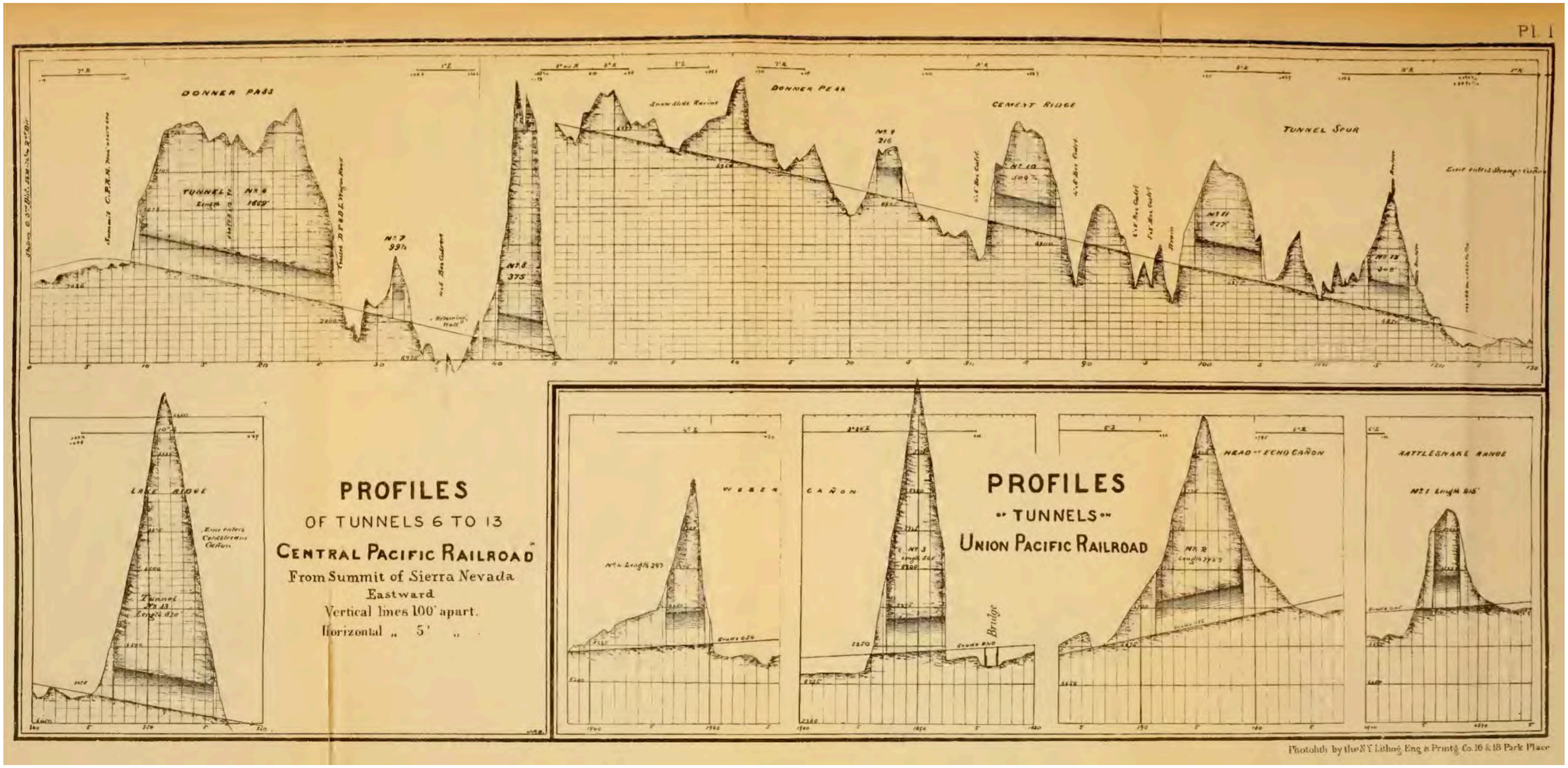
The name given to pass, peak, and lake, is itself the record of a tragedy. In the fall of 1846, the Donner party of emigrants from the East delayed crossing until too late. Nearly all died of starvation; the few survivors had prolonged their lives by cannibalism.

Snow-tunnels.—Before the snow had acquired depth enough to interfere much with the work, the headings were all started. The cuts at their entrances soon filled up with snow, but drifts were run through them, in some instances large enough for a two-horse team. Through these snow-tunnels, whose lengths varied from 50 to 200 feet, the material excavated was hauled in carts or on sleds to the waste banks. These snow-tunnels kept settling at the crown, so that they had to be enlarged from time to time, otherwise they were perfectly satisfactory.

The most remarkable snow-tunnel was made to connect the two ends of tunnel 8. The spur through which this is made terminates in a vertical bluff of granite a hundred feet high. To get around it during the fall, a rope was fastened to the rocks at a point where there was a steep descent of thirty or forty feet. During the early part of winter a snow-drift formed on the face of this bluff, descending in a steep slope from its top to the wagon road, two hundred feet below. On this slope a trail was cut and used for a month or two.

Later in the winter, when the accumulation of snow made it practicable, a snow-tunnel was excavated through the drift, and around the face of the bluff. Windows were made at short intervals for light, and to throw the material out in excavating, and steps cut where a descent was necessary. One flight of these led down to the blacksmith's shop, buried still deeper in the snow, while the main passage led into one already excavated at the east end of tunnel 8. The snow kept settling down hill and away from the bluff, so that there was an open space of three or four feet between it and the rock towards the close, which was far from inspiring much confidence in the route.

Between tunnels 7 and 8 there is a deep ravine, in crossing which the


Pl. I
DONNER PASS
DONNER PEAK
CEMENT RIDGE
TUNNEL SPUR
LAKE RIDGE
WEBER
CAÑON
HEAD OF ECHO CAÑON
RATTLESNAKE RANGE
PROFILES
OF TUNNELS 6 TO 13
CENTRAL PACIFIC RAILROAD
From Summit of Sierra Nevada
Eastward
Vertical lines 100' apart.
Horizontal „ 5' „
PROFILES
OF TUNNELS ON
UNION PACIFIC RAILROAD
Bridge
Photolith by the N.Y. Lithog. Eng. & Print'g Co. 16 & 18 Park Place

road has a 4x5-feet box culvert, and a retaining wall on the lower side of 75 feet extreme height. The foundation was begun in fall, but stopped by winter, and the ravine filled with snow. Next spring a snow-tunnel was commenced about two hundred feet down the ravine, and run in to strike the unfinished foundation. Smaller tunnels were run to quarry stone got out in fall, and a cave dug over the foundation large enough to work in. The culvert was built, and by the time it was finished the depth of snow overhead had decreased to twenty-five or thirty feet; this was excavated by a stream of wat r, and the retaining wall commenced.

Snow-cuts.—In spring, when the road has begun to be bare, so that sleighs can no longer be used, there are very heavy banks of snow to cut through to make the road passable for wagons.

In June I measured one of these cuts through the end of a snow-slide, and found it twenty-five feet deep. A week later the road was dusty in the centre, but the snow banks were not all gone until July, so that we had at that place the strange spectacle of sprinkling-wagons watering a road between two walls of solid snow.

Alignment.—As soon as each heading became sufficiently advanced, the centre line was secured, generally by small holes drilled in the roof, with wooden plugs and tacks. These points were placed as far apart as length excavated would permit, and from them the line produced as the work advanced. In most cases the entrances were afterwards so blocked up with snow that it was impossible to recur to the line outside, and the tunnels were completed from the points first put in.

In running lines outside during the winter, it was generally necessary to make deep cuts, and sometimes tunnels, through the snow, to get at the original transit points.

Most of the tunnels are on curves, No. 13 being on one of 573 feet radius, with 87 degrees of curvature inside the tunnel. In this, as in No. 11, 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, parallel to each other, but two inches apart In the other cases the discrepancies were too slight to notice.

Dimensions.—Most of the work was through solid rock, which did not require lining, and the following dimensions were adopted: Bottom, a rectangle, 16x11 feet; arch, a semi-circle, 16 feet in diameter; grade at centre of tie, and one foot three inches above sub-grade.

Tunnel 11 was partly, and tunnel 13 wholly, lined with timber in the following manner: 12″x12″ sills were placed on each side, and posts 12″x16″ morticed into them. The latter support arches, each composed of three thicknesses of 5″x12″ plank, breaking joints, and bolted with ¾-inch iron bolts, thus making a solid arch of 180 square inches sectional area. The distance from centre to centre of arches varies from one and a half feet to five feet, according to material. Over the arches, and, where the material required it, on the sides also, split lagging about two and a half inches thick was put in. The width at sub-grade inside of posts is seventeen feet; at springing line inside of arches, nineteen feet; giving a batter of one foot on each side. Height of crown above grade, nineteen feet nine inches, thus leaving room for masonry inside the temporary wooden lining.

Tunnels 1 and 2 were lined in a similar manner, except that the batter of side posts was only six inches.

In these tunnels, through soft material, the heading was supported by temporary timbers. Chambers were then excavated at the sides to below sub-grade, for the sills, and the central core left to support the shores which held the material above in place. As the timbering advanced, the core and false work were removed.

In tunnel No. 12, a short distance in the centre was found to be decomposed granite, and after the tunnel was excavated a light set of timbers was put in. They consisted of arches, each composed of seven pieces of 10x10-inch timber, with side-posts and sills similar to those already described.

In all the tunnels on curves, allowance was made for elevation of outer rail, so that top of cars would remain in centre of opening.

Laborers.—With the exception of a few white men at the west end of tunnel No. 6, the laboring force was entirely composed of Chinamen, with white foremen—the laborers working usually in three shifts of eight hours each, and the foremen in two shifts of twelve hours each. A single foreman, with a gang of thirty to forty men, generally constituted the force at work at each end of a tunnel; of these, twelve to fifteen worked on the heading, and the rest on bottom, removing material, etc.

When a gang was small, or the men needed elsewhere, the bottoms were worked with fewer men, or stopped so as to keep the headings going.

The Chinamen were as steady, hard-working a set of men as could be found. They were paid from $30 to $35, in gold, a month, finding themselves, while the white men were paid about the same, but with their board thrown in. The force at work on the road probably averaged from six to ten thousand, nine-tenths of them being Chinamen.

Progress.—Records were kept of weekly progress, and number of working days in tunnels 3 to 13 inclusive, from which the accompanying table, Appendix A, is principally taken. The headings were worked steadily until they were through; the force was then crowded on the bottoms, which had, by that time, fallen behindhand. The progress made on them, under these circumstances, is shown in the last column.

Cost, etc.—An approximate estimate of cost of excavation of tunnel No. 6 is given in Appendix D, showing it to have been about $14.80, gold, per cubic yard with powder, and $10 with nitro-glycerine.

Tunnel No. 6.—This, the longest tunnel of the road, is parallel to and about four hundred feet north of Donner Pass. Its length is 1,659 feet, and greatest depth below the surface, 124 feet, measuring from grade. The material is granite, of a medium quality, crossed by seams in every direction.

To expedite the work a shaft was sunk about the middle of the tunnel, its dimensions being 8x12x72.9 feet.

Work was commenced on the shaft August 27th, and for the first thirty feet it was sunk at the rate of a foot a day, after which its progress slackened, from delay in hoisting the material with a common hand derrick.

Meanwhile a house was being built over the shaft, and the hoisting engine was put up. The latter consisted of an old locomotive, the Sacramento, and, by an interesting coincidence, the first engine run in the State. This was geared to a drum six feet in diameter. The house was fifty feet square, containing, in addition to the hoisting apparatus, forges, fuel, tamping, etc., so that when snowed in, these articles would be close at hand. The shaft was divided by planking into two compartments, each five feet square; over these were two "jiggers" or transfer tables. The buckets were first of wood, then two additional ones were made of boiler plate, four feet nine inches square by two feet six inches high, outside dimensions, and fitted for side dumping. They were loaded at the face of the work below, run on trucks to the bottom of the shaft, hoisted and transferred to other trucks to run out on the waste bank.

Total days' work on shaft, 85; average progress, 0.85 feet in twenty-four hours. Nitro-glycerine had not yet been introduced; with it the progress would probably have averaged 1.5 feet.

Nitro-Glycerine.—This was introduced on the work early in 1867, to expedite progress of the summit tunnel. It was made on the spot by Mr. James Howden, and used in the four headings of tunnel No. 6 from Feb. 9th, and to some extent in tunnel No. 8, but not enough to give data for comparison. After the headings of these tunnels were through, it was used in the bottoms.

In the headings of summit tunnel the average daily progress with powder was 1.18 feet per day, with nitro-glycerine, 1.82 feet, or over 54 per cent. additional progress.

In bottom of summit tunnel, average daily progress with powder, full gangs, was 2.51 feet; with nitro-glycerine, 4.38, or over 74 per cent. in favor of nitro-glycerine. The same number of men were used with both explosives.

The additional progress in heading was due, principally, to the use of one and a quarter inch drills instead of two and a half inch, as required by powder.

In the bottoms the difference was principally due to fewer holes being required, and to the granite being broken into small pieces that seldom needed new holes to split them on. In both headings and bottoms less time was found to be required to clear the tunnels of smoke with nitro-glycerine than powder.

The cost of nitro-glycerine made at Donner Pass, according to Mr. Howden, was about 75 cents per lb.

It was considered there to be about eight times as powerful as the same weight of powder, which would make it the cheapest, viewed simply as to expense of producing a given effect.

Wherever practicable, I have no doubt that it is safest to manufacture nitro-glycerine on the site where it is to be used, and from day to day as required. At Donner Pass I only recollect two accidents, and those would have happened with powder.

The conclusion we may safely come to, from the Central Pacific work, is, that in hard rock tunnels, with the same number of men, over fifty per cent. additional progress can be made by using nitro-glycerine in place of powder, and the expense will be reduced proportionately.

Since papers have been read before this Society on the subject by Messrs. North and Chester, it is unnecessary to speak of the details of manufacture and use of this agent.

Tunnels of the Union Pacific Railroad.—A detailed list of these tunnels will be found in Appendix F.

Tunnel No. 1 is on St. Mary's Creek, about 680 miles west from Omaha, and 12 miles east of second crossing of North Platte River. It was commenced April 30th, 1868, and continued from each end until June 8th. At that time the two headings were in 86 and 87 feet respectively, the progress having averaged 2.22 feet per day. A soft spot was then found in the west end, and there being no means of lining without delay, the open cut was extended to cover the place, and the length of tunnel reduced to 215 feet.

This delayed the work, so that a temporary track had to be built around it.

Tunnel No. 2 is at the head of Echo Cañon, in Utah, about 972 miles from Omaha. Its length is 772.3 feet, being the longest of the Union Pacific. The approaches were started in July, 1868; they are heavy cuts through clay. Rock was struck about the end of August, and found to be like the prevailing formation in the vicinity, an indurated clay, with occasional streaks of soft sandstone. Most of it drilled very easily, but required as much powder in blasting as ordinary rock. While damp it stood firm, but after sufficient exposure to the air to dry out the moisture, it cracked and crumbled like lime in slacking. These qualities made the work very expensive; rock prices had to be paid, and earth slopes taken out.

In starting the headings they had to be supported the same day the excavation was made; but on getting fairly in, the roof would stand well a week or two.

There was an irregular streak of blue sandstone which ran completely through the tunnel near the springing line.

The headings were started at the west end August 29th, and at the east end September 5th; they met January 30th, 1869. The tunnel was finished April 3d, 1869.

When work was commenced on the tunnel the track was still three hundred miles east, and all the available transportation required to haul tools, materials, and provisions over this gap; it was useless even to think of getting cement in time. There was no suitable stone near the work, and the clay had too much lime to make brick. On these accounts the tunnel had to be lined with timber.

While waiting for the latter to be sawed, the headings were secured temporarily by bents framed as shown on Plate 2.

The permanent timbers consist of arches placed four feet apart, centre to centre, and similar to those already described on the Central Pacific Railroad. (See Plate 2.)

They differed from those of the Central Pacific in having a longitudinal stringer on each side at the springing line. This guards against the effects of unequal lateral pressure, and enabled the excavation to be taken out more economically. Instead of chambering to sub-grade and building up from the bottom sill, the chambers were cut only to the springing line, the stringers laid, and the arches raised and lagged. The bottom was then taken up, leaving a bench to support stringers. When the bottom was all out, the stringers were under-pinned, the benches cut away, and the lower timbers put in.

The roof was lagged throughout; the sides, for about two hundred feet at each end, and the remainder left to be finished after the track was laid. For lagging, round and split poles were first used, but afterwards two and a half inch plank.

The excavation of the tunnel was let by contract to Miller & Patterson; their expenses in timbering were paid as extra work. The detailed cost is given in Appendix F. The excavation required two pounds powder and two and seven-tenths feet fuze per cubic yard. The heavy work on each side of the tunnel was not ready for the track, and a temporary line of eight miles in length was built around it This line started about a mile west of Wahsatch—descended into the cañon by two Ys, and followed the main ravine to near Castle Rock station, where it regained the main line. The latter was finished May 25, 1869.

Tunnels Nos. 3 and 4. These are in the Weber Cañon, Utah, three-quarters of a mile apart, and about one thousand and five miles west from Omaha.

They were started under the direction of Thomas H. Bates, Division Engineer. When about one-third done, he was relieved by E. P. North, to whom I am indebted for the details of their construction. In January, 1869, it was feared these tunnels would not be through in time for the track, and Mr. North was directed to run temporary lines around them. Instead of that, he suggested hastening the work by using nitro-glycerine; which was done with very satisfactory results, as will be seen.

Tunnel No. 3.—This tunnel is through a sharp spur of black limestone and dark blue quartzite, two hundred and sixty-six feet of the former and two hundred and forty-two feet of the latter, total length five hundred and eight feet, on a 3 deg. 30 min. curve to the left. The headings were commenced about September 1, 1868, and met April 4, 1869. Until December 27th the work was part of Brigham Young's contract, and sublet to Sharp and Young. It was then carried on as company work, and let to Daniel McGee, a "Gentile," February 9th. Not being finished in time for the rails, a temporary track was built around it, partly on a 22 deg. curve, two hundred and sixty feet radius, around which trains of twenty-three cars were taken.

Nitro-glycerine was fairly introduced into the tunnel by February 23d. About twenty per cent. of the tunnel men struck on account of its use, and were not replaced as two shifts on the bottoms were found enough to keep them up with the headings, notwithstanding the additional progress they too were making; three shifts had been required with powder. The progress of this tunnel, under various circumstances, is given in Appendix E. It will be seen that, after allowing for the smaller force employed, about twice as much work was done per man, with nitro-glycerine as with powder. The use of nitro-glycerine in tunnel No. 3 saved the Company nearly $40,000.

Tunnel No. 4.—Length two hundred and ninety-seven feet; alignment

4 deg. to left; material, quartzite, similar to that in tunnel No. 3. Headings were commenced about September 10, 1868, and tunnel finished January 29th; nitro-glycerine was used to take up the last one hundred and eighty feet of bottom, which it did in eleven days; making the remarkable progress of 8.18 feet per day from each end. In tunnel No. 4, one thousand nine hundred and sixty cubic yards were taken out with powder, requiring two hundred and eighty-nine kegs and seven thousand feet of fuze, or three seven-tenths pounds powder and three six-tenths feet fuze per cubic yard.

Comparison between the two roads.—The total length of tunnelling on the Central Pacific is six thousand two hundred and thirteen feet, on the Union one thousand seven hundred and ninety two. The cross sections of tunnels on the two roads are practically identical.

The circumstances and materials varied too much to make an accurate comparison of progress in tunnels of the two roads. The greatest average daily progress of heading on the Central Pacific, through granite with nitro-glycerine, was 3.29 feet. On the Union Pacific, through quartzite about as hard as granite, 4.62 feet. Each road has done over eight feet per day at a single face in taking up bottom.

The laborers on the Central Pacific were mostly Chinamen, paid $30 to $35 gold per month, working three shifts per day in tunnels, and twelve to fifteen men in a heading. On the Union Pacific the laborers were white men, paid $3 to $4 per day currency, generally working two shifts per day, and eight to twelve men in a heading on tunnels 1 and 2, and three shifts of fourteen to sixteen on tunnels 3 and 4.

The Central Pacific Railroad was built under the direction of S. S. Montague, Chief Engineer. The location and construction across the Sierra Nevada were in charge of L. M. Clements, Resident Engineer. The account of tunnels on that work is principally compiled from a report on the subject written for the latter by the author, while engaged on tunnels 6 to 13 of that work.

The Union Pacific Railroad was built, and its location revised, under the direction of S. B. Reed, Engineeer and Superintendent of Construction. The accounts of tunnels 1 and 2 are from personal observation, and of tunnels 3 and 4 from data furnished by Edward P. North, Resident Engineer of work in Weber Cañon.

Appendix A.

Tunnels of Central Pacific Railroad.

S. S. Montague, *Chief Engineer.* I. M. Clements, *Resident Engineer.*

Number.	Distance in miles from Sacramento.	Locality.	Alignment.	Material.	Length. Not lined.	Length. Lined.	Length. Total.	Greatest depth.	No. of faces worked.	Heading. Total work'g days 24 hours.	Heading. Average daily progress.	Bottom. Total working days.	Bottom. Average daily progress.	Bottom. Daily progress, full gauge.
1	77	Grizzly Hill......	..	Conglomerate......	226	232	498	..	..	..	..	..	..	..
2	84	Emigrant Gap.....	..	"	..	271	271	..	..	..	..	..	..	..
3	92	Cisco.............	9° R	Hard trap.........	280	..	280	..	2	354	0.79	280	0.89	1.43
4	93	Red Spur..........	8° R	" "	92	..	92	..	1	128	0.72	101	0.91	1.63
5	97	Crocker's Spur.....	8° R	Granite...........	128	..	128	.	1	213	0.60	144	0.89	1.48
6	105	Summit...........	T	"	1659	..	1659	124	4	396	1.18	621	1.42	2.51
"	"	"	"	"	..	..	..	..	..	*a*655	*a*1.82	*a*178	*a*4.38	*a*1.38
7	105	"	T	"	100	..	100	41	1	113½	0.88	63½	1.57	2.00
8	106	Black Point.......	T	"	375	..	375	169	2	399½	0.94	260½	1.44	*a*3.82
9	106	Donner Peak......	T	"	216	..	216	46	1	171½	1.26	152	1.42	2.29
10	107	Cement Ridge.....	8° L & T	Conglomerate.....	509	..	509	67	2	202½	2.51	143	3.56	4.91
11	107	Tunnel Spur......	T & 8° R	Granite, partly	325	252	577	74	2	356	1.62	494½	1.17	*b*2.19
12	107	" "	8° R	Decomposed	262	80	342	78	2	268	1.28	184	1.97	1.97
13	112	Lake Ridge.......	10° R	Conglomerate.....	..	870	870	210	2	389	2.24	335	2.59	3.15
14	134	Alder Creek.......	..	Trachyte..........	200	..	200	..	..	..	..	..	..	..
15	137	Quartz Spur.......	..	Soft granite........	96	..	96	..	..	..	..	..	..	..
		Total....................................			4508	1705	6213							

a. Using nitro-glycerine ; all others with powder. *b.* In east end—hard granite.

Appendix B.

Abstract of preceding Table—Average Daily Progress in different Materials. The bottom progress is for full gangs.

MATERIAL.	EXPLOSIVE.	FROM TUNNELS	HEADING.	BOTTOM.
Hard Trap..............	Powder........	3 and 4.....	0.76	1.53
Hard Granite	"	5, 6, 7, 8, 9 ..	0.97	2.09
" "	Nitro-Glycerine	6...........	1.82	4.38
Conglomerate........ ..	Powder........	10 and 13....	2.38	4.03
Hard Granite	"	Shaft in No. 6	0.85	..

Appendix C.

Snow Storms at Donner Pass, California, Winter of 1866–67, during which most of the preceding work was done.

MONTH.	NUMBER OF STORMS.		DEPTH OF SNOW.		
	1' and over	Under 1'.	Fallen during Month.	Average Depth.	Maximum Depth.
			' ''	' ''	' ''
November, '66......	3	..	4 6	1 0	1 6 Nov. 4.
December, '66......	4	5	10 10½	5 0	9 0 Dec. 20.
January, '67......	3	7	11 00½	8 0	10 6 Jan. 24.
February, '67......	3	5	10 3½	10 0	12 8 Feb. 22.
March, '67......	2	9	4 2¼	12 6	14 4 Mar. 2.
April, '67......	1	1	3 6	13 0	15 1 Apr. 13.
May, '67......	....	1	3	8 6	11 0 May 1.
June, '67......	....	..	....	3 0	6 0 June 1.
Sums and means ...	16	28	44 7¾	7 0½	

Pacific Coast Chapter Conference
Railway and Locomotive Historical Society
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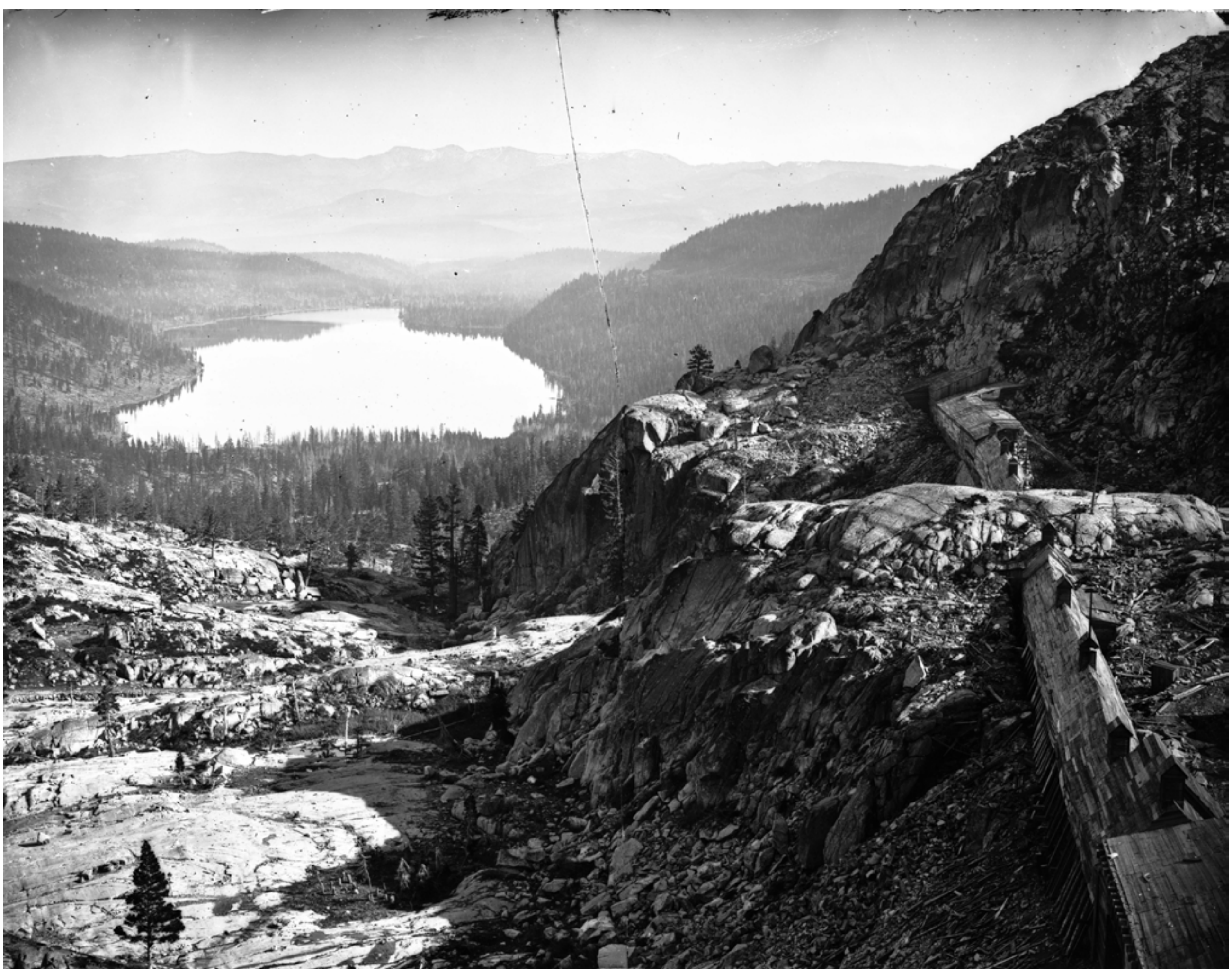
The CENTRAL PACIFIC RAILROAD'S SUMMIT TUNNEL

Chuck Spinks, PE
chuck.spinks@outlook.com



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

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. As the Chinese crews completed the track into Cisco the crews were released to work on the tunnels at the summit. 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

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

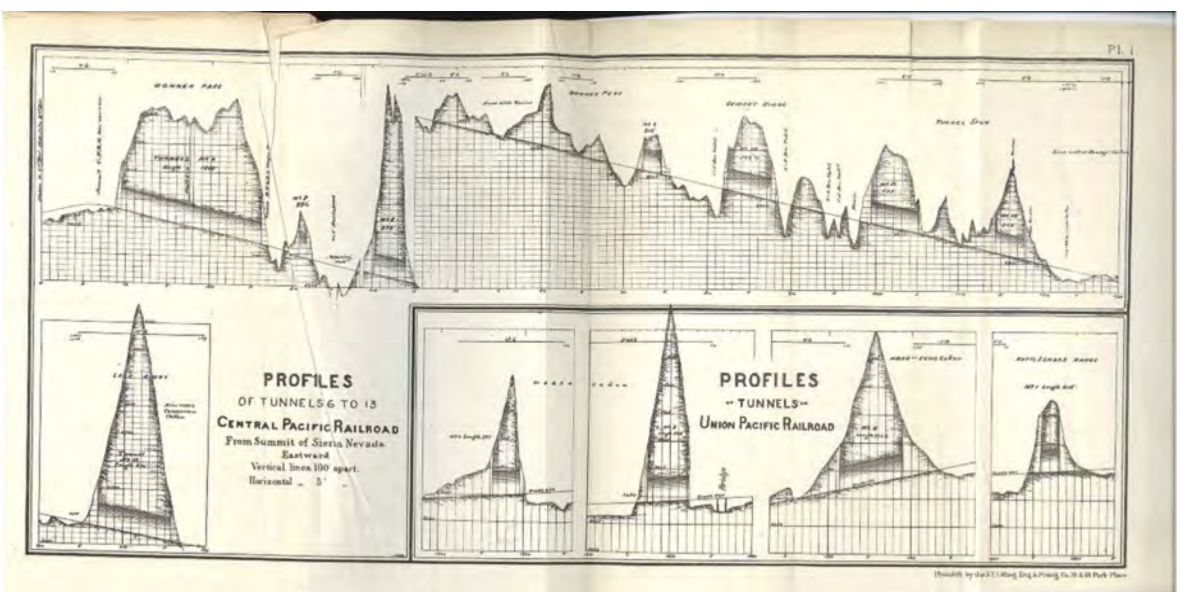
Alfred Hart #116. "*Camp Near Summit, Mt. King in Distance*"

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'

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 poses. (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.

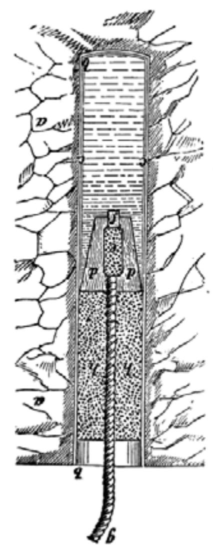
Nitroglycerine was used in the tunnel by pouring it into metal tubes or cartridges. A reporter with the Sacramento Daily Union described "Nitro Glycerine and its Use" in a visit to the site on April 17, 1867. (14)

> "*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 $\frac{5}{8}$ to $\frac{3}{4}$-in. diameter, with cartridges 4 to 8-in. in length and $\frac{5}{8}$ to $\frac{3}{4}$ 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.

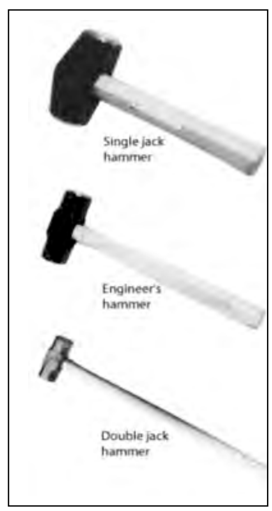
Noble patented Dynamite in the U.S. in 1868, and it started replacing the use of liquid nitroglycerine. Julius Bandmann of Bandmann, Nielsen & Co. was given the rights for the Noble patents in the U.S. west coast in late 1865, and on May 26, 1868 Noble assigned his patent for Dynamite to Bandmann. (18)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

<u>Labor</u>

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, Howdens assistants with the nitroglycerine, etc.

The Chinese became experts at double jacking the holes for the nitroglycerine. It 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 1877, 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

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.

Conclusion

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

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Alfred Hart photos

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

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Stanford University Libraries
Stanford Digital Repository
Alfred A. Hart photograph collection 1862 – 1869
Albumen prints. All 364 Hart Central Pacific photographs are available.
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