



San Francisco Tunnels

Past, Present and Future

By Victor S. Romero, PE, CEG

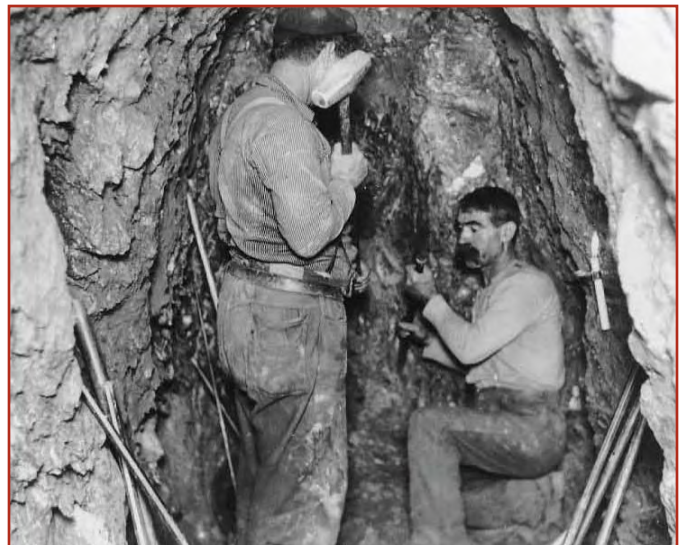
Being that the 2008 North American Tunneling conference is in San Francisco this month, many of our out-of-town guests may be casually curious about what sort of tunneling has been or will be going on in “The City” and the greater Bay Area. For anyone interested in tunneling, one of the first points of interest is the local geology. The Bay Area geology is as unique, interesting and eccentric as our culture and environs.

Bay Area Geology

The San Francisco Bay Area is characterized by northwest-trending mountain ranges and intervening valleys, the orientations of which are strongly controlled by numerous active earthquake faults. Our bedrock is an agglomeration of wildly different rock types that are the result of a former tectonic subduction zone which has more recently been deformed by movement related to the San Andreas Fault. The resulting mix of rock types includes pieces of the ocean floor, islands and micro-continents, and pieces of Southern California that have been smashed, squeezed, cooked and sheared into place. If Mother Nature is a cook, she mixed up quite a dish in Northern California.

Perhaps the most confused rocks, aptly named the Franciscan Complex, underlie San Francisco proper. Originally this

rock was named a geologic “formation,” but this geologic term applies to rocks can be correlated across distances, which is not so with the Franciscan Complex. The Franciscan Complex is typically faulted, fractured and folded, and generally comprises three predominant rock types: sandstone (usually referred to as greywacke), shale and “mélange.” The sandstones and shales are



Hand-mining in the Lock's Creek Tunnel
(1870, photo courtesy San Francisco Public Utilities Commission)

highly variable in their degrees of fracturing, strength, hardness and weathering. The *mélange* is characterized by a chaotic, heterogeneous mixture of competent masses that range from inches to miles in dimension. These masses are of different rock types—such as greywacke, shale, claystone, greenstone, chert, basalt and various metamorphic rocks—surrounded by a matrix of pervasively crushed rock material. If you have ever heard the term “California Rock” applied to tunnels, it is referring to this chaotic, generally poor-quality rock.

The surficial soils flanking the bedrock outcrops around the Bay comprised alluvial, colluvial, wind-blown, beach, estuary and marine deposits. In San Francisco, the most extensive soil deposits are the Dune Sand, Colma Sands, Old Bay Clay, and infamous Young Bay Mud, which is found around the Bay itself. Its frequently goeey quality can make for truly interesting tunneling.

Topping off the unique geology is the Bay Area’s status as one of the most seismically active regions in the world. The San Andreas Fault system forms the boundary between the North American and Pacific tectonic plates, and comprises numerous active, major strike-slip faults. Some of the major faults are the Calaveras, Hayward, San Andreas and San Grego-



The Yerba Buena Tunnel, at a span of 76 feet, held the record for the largest rock tunnel for many years (photo circa 1933)

rio. The San Andreas and Hayward Faults in particular have been the source of numerous moderate and large magnitude historical earthquakes, including the 1906 Magnitude 8 earthquake, which



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ruptured the ground surface for almost 300 miles along the San Andreas Fault.

Early Tunneling History

So why would anyone want to tunnel in these conditions? The equation is simple: gold + people + earthquake = tunnels. The Gold Rush of 1849 and the Silver Rush of 1859, also known as the Comstock Lode, brought an influx of people and commerce to Northern California, and the port city of San Francisco was the financial and industrial hub of this activity. Although precious metals mining tapered off after several years, the miners stayed,



The BART Berkeley Hills Tunnel hole-through in 1967

and business thrived. Some of San Francisco's first water infrastructure was built between 1861 and 1885, including several tunnels (e.g., Pilarcitos Reservoir Tunnel Nos. 1 and 2, Lock's Creek Tunnel, Upper Crystal Springs Tunnel, and Bernal Tunnel).

Just north of San Francisco in Marin County, a rail tunnel was constructed in 1879, and three more rail tunnels were added in 1884. Their purpose was to bring more redwood timber to San Francisco to feed the construction boom. While most of these tunnels are now abandoned, work will soon be under way to convert the Cal Park Tunnel into a unique, mixed-use tunnel accommodating pedestrian, bike and commuter rail traffic.

The 1906 Earthquake and Fire

Just as San Francisco was becoming known as the New York of the West, there came a sobering wake up call. At 5:12 a.m. on April 18, 1906, the San Francisco Earthquake and Fire almost completely destroyed the city. Astonishingly, residents rebounded within days to begin rebuilding. Their tenacity and speed was remarked worldwide. Plans were quickly drawn up to restore and improve infrastructure, including utilities and transportation. By 1915, San Francisco celebrated its rise from the ashes by hosting the Panama-Pacific Exposition. Major tunnels constructed at the time include:

- The Southern Pacific Tunnels (1907), which are now used by Caltrain Commuter Rail.
- The Ft. Mason rail tunnel (1914) is currently abandoned but may be restored for bike and pedestrian use, as well as possible use by San Francisco's Muni light rail.
- Mile Rock Sewer Tunnel (1915) is still in use.
- Stockton Street Tunnel (1915) is also still in use.
- Ft. Barry – Ft. Baker Tunnel (1918) was rehabilitated for

bike and vehicular use in 1993.

- Twin Peaks Tunnel (1918) is still in use by Muni light rail
- Claremont Tunnel (1929), a water conveyance tunnel in Oakland, is still in use. An extensive seismic upgrade was completed in 2007.
- Duboce Tunnel (1929) is still being used by Muni light rail.
- The Upper Alameda Creek Diversion Tunnel was completed in 1931.

The City Grows

The 1930s was a time of bridge building, with overlapping construction of two iconic bridges. The Presidio Tunnel (now the MacArthur Tunnel) and the Waldo Tunnel were both constructed in 1937 as approaches to the Golden Gate Bridge, while the Yerba Buena Tunnel was constructed in 1936 as an integral part of the San Francisco-Oakland Bay Bridge.

But perhaps the biggest tunnel project of the 1930s was construction of Bores 1 and 2 of the Caldecott Tunnel (now Highway 24). Constructed in 1934 through 1937, Bores 1 and 2 utilized the stacked drift method of excavation. The third bore was completed in 1964 using a top heading and bench excavation sequence.

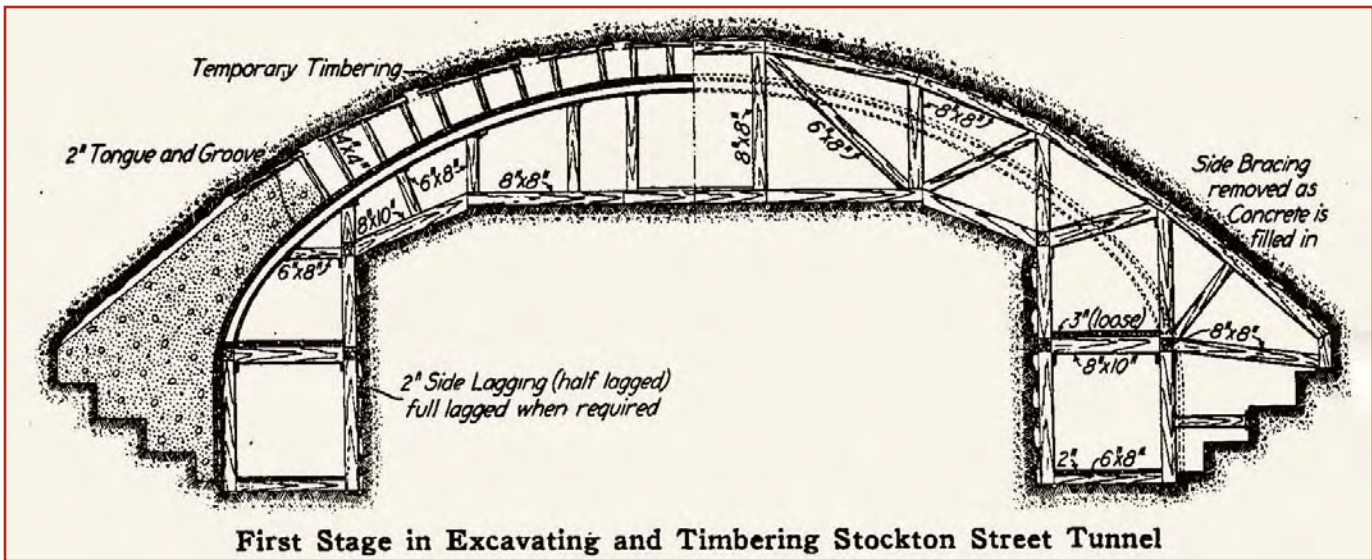
Also constructed during the '30s and '40s were two major sewer tunnels: the Richmond Sunset Tunnel in 1938 and the Lake Merced Tunnel in 1949. In 1953, the controversial Broadway Tunnel was completed for vehicular use.

The Modern Tunneling Era

The 75-mile Bay Area Rapid Transit (BART) system, which also included 3.5 miles of new Muni Metro line, was constructed from 1964 to 1972. BART represented a whole new generation of mass transit technology in the United States. Computerized train controls, modern rail vehicles, electronic fare cards, and faster trains were all revolutionary technologies.

The tunneling technologies were equally revolutionary. The Transbay Immersed Tube under the Bay was the first of its kind, and is still heralded as a modern engineering marvel. In addition, tunnels were excavated through the Berkeley Hills, in downtown Oakland, and across San Francisco. The tunnel segments between the Transbay Tube and Embarcadero Station, and between Embarcadero Station and Montgomery Station, were excavated by open-faced shields with compressed air. The tunnel segment between Powell Station and Civic Center Station was constructed using a compressed air, partial-face shield with cutter blade openings that could be adjusted based on ground softness. The tunnel segment between Civic Center Station and 16th Street Mission Station was excavated using a TBM with four hydraulically operated doors equipped with cutting edges. And the tunnel segment between 16th Street Mission Station and 24th Street Mission Station was excavated by an oscillating TBM equipped with four independent cutter blades (the infamous "windshield wiper" cutterhead). Finally, rock tunnels south of Fourth Street Mission Station to Glen Park Station were excavated by a primitive disc-cutter TBM.

Six tunnels were built for the San Francisco Clean Water Program during the 1980s and 1990s to reduce storm discharges into San Francisco Bay and the Pacific Ocean. These projects were the North Outfall Consolidation Sewer Tunnels N-1 (1981) and



Post-1906 reconstruction of San Francisco: stacked-drift construction of the Stockton Tunnel (Engineering Record, 1914)

N-2 (1980); Lake Merced Transport Tunnel (1993); Richmond Transport Tunnel (1996); and the Islais Creek Davidson Avenue Tunnel and Undercrossing Tunnel (1999).

Current and Future Projects

Given the number of tunnels that have been constructed in the Bay Area, and the often-challenging geologic conditions, the list of new tunnels that have been proposed or are being designed may appear ambitious. However, “the City that can” is still living up to its reputation for persevering in a course of development and growth.

Current and upcoming projects in the Bay Area include:

- Kiewit Construction is currently building the Devil’s Slide Tunnel for Caltrans as a bypass for Highway 1.
- Lenihan Dam New Outlet Tunnel is currently under construction for the Santa Clara Valley Water District.
- Four major projects are in progress for the San Francisco Public Utilities Commission: New Crystal Springs Bypass Tunnel, Bay Tunnel, New Irvington Tunnel, and Sunnydale Auxiliary Sewer Tunnel.
- A fourth bore of the Caldecott Tunnel is being implemented by Caltrans and the Contra Costa Transportation Authority.
- Muni Central Subway is in progress by the SFMTA.

- The Caltrain Extension to the Transbay Terminal is being undertaken by the TJPA.
- Silicon Valley Rapid Transit (extending BART to San Jose) is being implemented by the Santa Clara Valley Transportation Authority.

With all these tunneling projects, the Bay Area is a great place to live and work if you are into the underground scene (construction, that is).

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The N-2 Tunnel utilized the first Earth Pressure Balance TBM in the United States in 1980

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