The Caldecott Fourth Bore Project: Tunneling Through a Miocene Plate Boundary

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The story of the Fourth Bore of the Caldecott Tunnels reveals much more than just the rocks through which the tunnels were bored. It is at once a story of the geology of the East Bay Hills, a recounting of the population explosion of the East Bay, a history of tunneling concepts and methodologies, and a path for one of the great industrialists of the Bay Area. While we lay out a geologic history of the East Bay Hills, we'll also focus on how we design and construct a modern highway tunnel and compare and contrast that to the previous Caldecott Tunnel projects.

This guide tells the story of the Caldecott Fourth Bore by discussing different topics at relevant stops. The first stop will be the Caltrans Construction office in Lafayette for a brief overview of the purpose and need for the Fourth Bore as well as modern tunnel building using the New Austrian Tunneling Method. The next stop will be the location of the precursor to the existing Caldecott Tunnel: the original, single-lane bore connecting Alameda and Contra Costa Counties. Here, we'll talk about the history of these first tunnels, which allowed for the rapid growth of the East Bay. After a brief stop at the west portal of the Fourth Bore, we'll move on to our first outcrop to discuss the geotechnical investigation and design of the Fourth Bore. From there we'll examine the Claremont Chert and Shale and place it within the context of the history of the North American/Pacific plate margin during the Miocene. We'll finish up with a look at the
Orinda Formation and the valuable fossils that have been extracted from the Fourth Bore during the two years of mining and construction.

**Stop 1: Caltrans Construction Field Office, Lafayette**

Here we’ll have a brief overview of the Fourth Bore Project’s funding and construction. Ivy Morrison, Public Information Officer for the Fourth Bore Project, will provide an overview of the tunnel’s funding and partnerships. Chris Risden, Engineering Geologist for Caltrans, will discuss the New Austrian Tunneling Method (NATM) used to design and build the tunnel.

NATM (also known as the Sequential Excavation Method) is a widely recognized tunneling method developed in Europe in the 1960s that provides an approach for constructing tunnels using the surrounding rock mass as one of the main strength elements. The flexibility provided by this method allows engineers to adjust certain reinforcing elements based on observed rock behavior. These principles provide for a tunnel to be constructed at a reasonable cost without sacrificing safety to workers or the traveling public.

NATM deploys two types of support: an initial lining of sprayed fiber-reinforced concrete (known as shotcrete), rock bolts, and lattice girders; and a final lining consisting of traditional reinforced concrete. The initial lining is somewhat flexible and allows a controlled deformation of the rock to achieve equilibrium. By controlling the deformation of the rock using various initial lining elements, tunnel engineers can maximize the strength of the rock mass and reduce the stresses placed on the final lining.

Rock data were collected during the early stages of the design process by drilling several holes along the proposed alignment and collecting rock cores. Laboratory tests performed on the rock cores provided engineers with the data necessary to categorize the various rock types that would be encountered during tunnel construction. Each of these rock types has an expected strength and behavior when the tunnel opening is excavated and initial lining support is installed. Engineers described fourteen rock types along the tunnel alignment. Supporting these rock types required seven initial lining designs.

NATM allows for the length of each advance of the tunneling equipment (called a round), and the type and amount of the initial support installed, to be tailored to the immediate ground conditions. (Each round can vary in length from 8 to 12 feet, and the number of rock bolts and other structural supports can also vary depending upon ground conditions.) Because of the size of the Fourth Bore (total excavated dimensions are approximately 50 feet wide x 36-41 feet high), engineers designed the excavation to occur in stages, starting with a top heading excavation consisting of roughly half the opening followed by the bottom half, called the bench.

Depending on the strength of the encountered rock conditions, excavation methods can vary from the use of traditional excavators to specialized tunneling machinery called roadheaders to blasting with controlled explosives. Geologists identified the rock type and assessed the behavior of the rock mass immediately after each round of excavation.
Initial support elements were installed based on the initial lining design for the encountered rock type. Survey points were installed periodically throughout the tunnel to monitor deformation of the initial lining. Engineers used these points to monitor the behavior of the tunnel and, if necessary, install additional support measures until equilibrium was reached within the rock mass. Following the excavation and installation of initial lining along the top heading and bench for the entire length of the tunnel, the next step was construction of the final lining and the roadway, along with the installation and integration of a highly complex network of monitoring and operational systems. Following extensive testing of these systems, the tunnel will be ready to open to traffic.

**Figure 2:** Workers watch as the rock face is scanned during mining operations. High-resolution scans were taken after every stage of construction as a method of measuring the excavated profile.

**Stop 2: West Portal of Kennedy Tunnel**

This is the west portal of the original Kennedy Tunnel that first connected Alameda and Contra Costa Counties. The tunnel was completed in 1903, measured 1040 feet in length and 17 feet wide, and was lined with timber. It provided limited access between the counties due to its steep approaches and narrow width. With the population growing on both sides of the tunnel, commerce, especially heavy truck traffic, necessitated construction of additional lanes to handle more volume.

*(Much of the following comes from a brief history of the Caldecott Tunnel written by Ray Mailhot, longtime Superintendent of Tunnels and Tubes for Caltrans District 4. Mr. Mailhot retired from Caltrans several years ago.)*
In 1926, Alameda and Contra Costa Counties, along with the City of Oakland, created a commission to study the feasibility of relocating and expanding the Kennedy Tunnel. The feasibility study, released in 1928, identified a preferred alignment as well as numerous connecting roads. Alameda and Contra Costa Counties entered into a joint agreement and formed Joint Highway District No. 13 specifically for the purpose of constructing the Broadway Low Level Tunnel. Joint Highway Districts allowed for single projects to be funded using state gas-tax dollars between multiple jurisdictions, with the state assuming a maintenance role upon completion. These joint districts were typically formed for single projects and dissolved upon completion.

George Addison Posey, County Surveyor for Alameda County, supervised the early planning of the tunnels and served as Chief Engineer for Joint Highway District No. 13. Posey is best remembered for his namesake, the Posey Tube, connecting the cities of Oakland and Alameda via a tunnel under the Oakland Estuary. The tube was completed in 1928 and was recognized nationally for its innovative precast design.

Professor George D. Louderback was hired as a consulting geologist by the Joint Highway District for the purpose of evaluating the site geology along the proposed tunnel alignment as well as a couple of miles west into Alameda County. His report was completed in June of 1932 and was composed of mostly surface reconnaissance data of available outcrops. In an update prepared in July that same year, Louderback mentions work on a pilot tunnel, but this work was suspended pending review by the State Industrial Accident Commission. It is unclear whether this pilot tunnel was ever completed.

Fresh off a successful bid for the Hoover Dam project along the Colorado River, the Six Companies of California won the bid for construction of the Low Level Broadway Tunnels coming in at $4 million, a full million dollars less than the next highest bidder. Founding members of the Six Companies would go on to become household names in the construction business, including Kaiser, Bechtel, Morrison, Knudsen, and Shea. Steve Bechtel, son of founding member Warren “Dad” Bechtel, took an aggressive approach toward bidding the tunnel project, assuming hard rock tunneling, for which they would be paid for a rock mining operation, as opposed to cheaper and less complex earth excavation. The company’s overestimation of rock strength from the few cores taken and Louderback’s superficial investigation proved devastating. Much of the west side of the tunnel had to be supported and dewatered to make working conditions safe, and even then, three men died during a cave-in in 1936. Bechtel decided to send the Six Companies lawyers after the District’s relatively scant subsurface information, but other company members had reservations regarding this strategy, considering it bad for their reputation.

It was at this time that Henry Kaiser was brought in to take over for the younger Bechtel. Kaiser had a history in Washington, D.C., and it was hoped that he could secure additional funding from the federal government to complete the project. Washington rightly concluded that the Joint Highway District needed to request additional funds, but
they balked, and instead fired the Six Companies with only about two-thirds of the work complete. The George Pollock Company was brought on to complete the work and the tunnel was opened on November 13, 1937. Shortly thereafter, the Six Companies would lose out on the Shasta Dam contract and Kaiser would conclude that successful contract construction was too dependent on correctly guessing during the bidding process.

By the late 1950’s, daily vehicle counts through the Caldecott Tunnels (now named after Thomas Caldecott, long-time Alameda County supervisor and president of Joint Highway District No. 13 from 1929-1937) had reached levels well beyond the anticipated capacity. A third bore was started in 1960 to meet the ever-growing transportation demand in the area. As the first two bores had shown little signs of wear, the third bore was a near duplicate, except for its larger profile. The new third bore allowed traffic to flow along four lanes during commute hours and introduced an innovative “pop-up” lane change system that facilitated the redirection of traffic in the second bore depending on the time of day. After completion of the third bore, each of the first two bores was temporarily closed for renovation.

Figure 3: Miners excavate the bench in the Broadway Low Level Tunnel. The top heading was supported with timber and excavated in several drifts around a rock core. Pilasters were drilled and poured along the outer walls to connect the top heading to bench.
Stop 3: West Portal, Sobrante (?) Formation

Above the cul-de-sac is an outcrop of buff to tan, shaley sandstone typical of what is exposed throughout the western 200 meters of the Fourth Bore tunnel. From the outcrop, one can see the weak nature of this formation.

The geotechnical investigation for the Fourth Bore Project involved approximately 44 borings for the portals, tunnels, and retaining walls. The investigation was conducted by Geomatrix Consultants with assistance from Caltrans staff. Parsons/Jacobs and Associates designed the initial and final tunnel lining. Borings were recovered using a mud rotary drill rig and were generally more than 200 feet long. Rock cores were described in the field and each five-foot section of core was wrapped in plastic and tested for gas emissions. Cores were tested for unconfined compressive strength and abrasiveness, while in situ tests included downhole cameras and in-place strength (Goodman jack) tests. Finite element models were used during the design phase to determine rock behavior during excavation. From these models, reinforcement designs provided shotcrete thicknesses, rock bolt patterns, and invert geometries.

A Geotechnical Baseline Report (GBR) was produced to provide the contractor with baseline values of rock parameters as a basis for bidding as well as dispute resolution. The GBR is unique to the tunneling industry. By providing baseline values to the contractor, the owner and contractor are effectively splitting the risk. Rock that exceeds assigned baseline values allows for additional compensation. The GBR, in theory,
eliminates or limits the extensive claims process that can accompany large infrastructure projects.

Descriptions of physical rock characteristics, baseline properties, and expected behaviors are identified in the GBR. During the design phase, individual Rock Mass Types (RMT) are identified within each formation. Based on the geotechnical investigation, 18 RMTs were identified throughout the tunnel, requiring seven different ground support categories. Each excavated face was evaluated to determine the RMT and support needed. Generally, each RMT was assigned a specific support type, however, local variations in rock strength would require additional, or local, support. The work done during the design phase led to detailed rock descriptions that allowed for major rock property changes to be identified ahead of time within a couple of meters of excavation.

While much of the design work for the initial lining comes from anticipated behavior of rocks encountered within the tunnel, the final lining depends more on outside loads, specifically seismic loads. Because tunnels are not subject to inertial effects and structural deformations are limited by the surrounding ground, tunnels perform very well when exposed to strong ground motions.

This said, just to the west and down the hill of the tunnel is the active trace of the Hayward fault, considered to be one of the most dangerous faults in the world based on nearby population density and the amount of time that has passed since it has produced a large earthquake. Because Route 24 (which travels through the tunnel) is a crucial corridor between two heavily populated regions, it has been designated a vital lifeline to be used by first responders after a catastrophic event. This means the Fourth Bore must be able to reopen to emergency traffic within 72 hours after a major earthquake. While the tunnel is not bisected by an active fault, it is designed to withstand strong ground shaking. The tunnel and surrounding structures were designed to withstand a seismic event with a return period of 2,000 to 3,000 years.

**Stop 4: Claremont Chert and Shale (Type Locality), Claremont Avenue**

Here on the north cut slope, one can see the type locality for the Claremont Shale of Lawson (1914), now often referred to as the Claremont Chert or Claremont Chert and Shale. These rocks represent deposition in a much deeper ocean basin than any of the others exposed along the tunnel alignment, and they make for a great introduction to the history of this section of the East Bay Hills and its transformation from a convergent to a transform plate boundary.

**Geology of the Caldecott Tunnel and Route 24 Corridor**

*(The following is taken from two papers: Ben Page's 1950 report on the Caldecott Tunnel and Steven Graham's 1984 paper from the AAPG Bulletin.)*
The geology of the Caldecott Tunnel provides a unique opportunity to examine the changes in sedimentation that took place during the transformation from a convergent plate margin to a transform plate margin at this latitude.

Prior to the passing of the Mendocino Triple Junction and the birth of the San Andreas fault, the western edge of North America was part of a convergent tectonic regime. This is reflected to the east in the Sierra Nevada Batholith, the product of millions of years of eastward-directed subduction. In the Bay Area, Cretaceous and Early Tertiary marine rocks like those of the Tertiary Monterey Group represent much of this convergent environment. The Monterey Group is found throughout California and is a leading oil producer in the state. The Miocene Claremont Formation, a thinly-bedded chert and shale unit, is the predominant Monterey member in the Berkeley Hills. This unit comprises much of the west end of the tunnel and lies stratigraphically over Sierran-derived sands (the Portal Sandstone). The entire unit is overturned and dips steeply to the west. Bathymetry analyses indicate deposition of the Claremont Formation occurred at depths between 1,500 and 1,600 meters in a forearc basin west of the Sierra Nevada. Further east, the Monterey Group rocks become more clastic, consisting of sandstones, minor conglomerates and mudstones. This east-to-west Monterey transect reveals shallow, clastic, proximal deposition in the east, giving way to deeper water deposits in the west.

Figure 5 Geologic map of the Caldecott Tunnels area from Graymer (1995)
Stratigraphically above the Claremont Formation is the Upper Miocene Orinda Formation, part of the non-marine Contra Costa Group. Conglomerates, conglomeratic sandstones, and mudstones comprise the Orinda Formation in the vicinity of the Caldecott Tunnel. These were most likely deposited as part of an alluvial system originating from a western high. Provenance studies indicate that a majority of the sediments are reworked Franciscan rocks. Minor basaltic-andesite to andesite flows of the Grizzly Peak volcanics interfinger with fluvial sediments of the Orinda near the east portal. The contact between the Orinda and underlying Claremont is a shallow angular unconformity. Angular clasts of Claremont cherts and shales are found in conglomerate beds at the base of the Orinda.

The juxtaposition of these two formations provides a contrast in depositional environments and marks the onset of a transform tectonic regime. The Claremont Formation was deposited in deep waters within a forearc basin while the Orinda Formation is primarily fluvial in origin. Moreover, while Monterey sediments were shed from east to west, the paleoslope upon which the Orinda was deposited sloped west to east. The paleoslope direction, in conjunction with the Franciscan provenance, suggests a Franciscan high probably located near the modern San Francisco Bay. The cessation of subduction, the closing of the forearc basin, and the migration of what is now the Mendocino Triple Junction precipitated the ascension of the Franciscan high.

As subduction ended, mantle material quickly filled the region vacated by the downgoing slab and volcanism ensued. This period of volcanic activity is represented throughout California as a string of small basaltic to rhyolitic volcanic deposits. The volcanic flows and plugs in the Berkeley Hills (the Moraga volcanics or Grizzly Peak volcanics) are approximately 9.5 Ma and are thought to have erupted along a proto-Hayward fault. Volcanic units roughly along strike to the north of the Moraga volcanics have been dated to about 12.5 Ma, placing in doubt the hypothesis that volcanic centers formed in response to a migrating triple junction. Regardless of the ages of these rocks (which may yet be refined to reflect a northward migration of volcanism concomitant with a migrating triple junction), there is a distinct linear trend developed by these Late Tertiary volcanic centers. More importantly for the builders of the Caldecott Tunnel, these dikes are present throughout the tunnel’s length and, where abundant, have weakened the rocks as they weather to highly plastic clays.

Two features of the rocks within the limits of tunnel construction made building the tunnel difficult. Both igneous and sandstone dikes occur within the Claremont Formation, with the former occurring throughout the length of the tunnel. Page (1950) describes in great detail both of these geologic features and discusses their affect on the building of the tunnel. The following descriptions of these dikes are taken from Page’s work.

The sandstone dikes are thought to have originated from the “Second Sandstone” which lies stratigraphically below the more abundant cherts of the Claremont Formation. Upon deposition, the cherts and the shales became brittle and fractured much faster than the lithification of the Second Sandstone. Increased pore water pressures created by the
mobile hydrocarbons within the Monterey rocks prevented the sands from lithifying. Once fractures began to develop in the overlying strata, sand-rich fluids filled the voids and created dikes. During construction it was not uncommon to have these sandstone dikes “run”, or flow, out of the newly cut walls.

Similar problems were encountered in tunnel sections where igneous dikes are plentiful. The igneous dikes are primarily plagioclase and clinopyroxene and were described by Page as diabase, although he pointed out that diabase implies a specific texture which these rocks lack. When encountered during construction, the dikes made for very weak walls. Page concluded that some dikes had weathered to as much as 30% clay, thereby becoming extremely soft. Samples recovered from Caltrans Geologist Bob Baker during recent work in the tunnel were considerably harder and less weathered than those described by Page.

During construction of the Fourth Bore, geologists encountered both types of dikes. Confirming Page’s earlier work, the sedimentary dikes were identical in color, cementation, and grain size to the Second Sandstone. These were often hard and difficult to distinguish from the igneous dikes at a distance of several meters. One telltale signature of the igneous dikes gave them away: the bake zone. Both the sedimentary and igneous dikes crews encountered were buff to gray in color, fine grained, and hard. In hand, sample igneous dikes had a sugary, or almost aplitic texture, making them appear grainy. But in outcrop on the tunnel face, the igneous dikes stood in stark contrast to the dark bake zone impacted to the surrounding host rock.

Figure 6: Igneous dike exposed with the Claremont Shale. Note the dark bake zone around the edges of the lighter igneous intrusion.
Stop 5: East Portal, Orinda Formation

(Excerpted from the Caldecott Improvement Project Paleontological Mitigation Plan)

The Orinda Formation is composed of fining-upward sequences of bluish-gray conglomerate, conglomeratic sandstones, and siltstones with thick red mudstone interbeds. This rock unit is interpreted to be the product of non-marine, alluvial fan deposition, with sediment derived from a former source area of Franciscan and Great Valley Sequence rocks to the west when the San Francisco Bay Block was uplifted as a mountain. Marine invertebrate fossils about 305 meters above the base of the Orinda Formation indicate time-equivalence with the Upper Miocene Neroly Formation. The paleontological data provide strong evidence for correlating the two formations and support the hypothesis that the largely non-marine Orinda Formation interfingers with the largely marine sedimentary rocks of the San Pablo Group.

The lower part of the Orinda Formation contains a moderately diverse assemblage of estuarine and nearshore marine mollusk fossils, while the upper part of the formation has produced a relatively diverse assemblage of land mammals that includes horses, rhinoceroses, camels, pronghorns, oreodonts, and gomphotheres. Bones and teeth of these Miocene land mammals were collected by workers during earlier phases of tunnel excavations and serve as a basis for assigning a high paleontological resource sensitivity to the Orinda Formation. Further, the report on initial project mitigation results documents the discovery and salvage of significant terrestrial plant fossils and vertebrate remains from the eastern portal area. The vertebrate assemblage includes the first record of biochronologically important small mammals (shrew, mole, rabbit and mouse) from the Orinda Formation. Also recovered were well preserved remains of land mammals, including palates, jaws, isolated teeth and some postcranial elements representing species of extinct weasel, bear dog, rhinoceros, three-toed horse, oreodont, camel, and pronghorn.

Figure 7: Camel bone (Camels are indigenous to North America)

Excavation of the Fourth Bore required full time paleontology monitors as part of the environmental mitigation. These monitors sifted through the broken up rocks as they left
the tunnel. Because workers were not allowed to approach the open tunnel face during excavation, paleontology monitors could not view the rock in situ and were limited to the spoils. While some of the tunnel spoils came out as fine, pulverized earth, much of it was excavated as very blocky material, especially the Orinda Formation. That allowed for blocks of rock to be broken and inspected. It was a laborious process that for days yielded very little fossil material, but every once in a while a significant find would pop up. While the flora and fauna of Orinda Formation have already been very well described, new samples may have been found that better represent the Miocene at these latitudes.

Recovered fossils were sent to the University of California Museum of Paleontology (UCMP) for archiving and further study. Here they were added to the existing Caldecott Tunnel collection and made available for scientific research. Currently, the project has recovered over two thousand specimens, and the UCMP has been provided seed money to create a full time position specifically to catalog these fossils. During the Fall semester, plant fossils were used in two separate classes: Plant Physiology and an evolution class. The fossilized leaves provide an opportunity to examine the climate during the Miocene while Orinda deposition was ongoing.

This final stop also allows for a view of the Moraga Volcanics, visible where they flowed over the Orinda Formation by the brick red "baked zone". Tertiary volcanic rocks have long been studied throughout California as they occur in a neat north-south band along the Pacific/North American plate boundary. Work by Dickinson (1997) and Fox, et al (1985) describe the tectonic implications of these rocks. Here we summarize the work of Dickinson (1997).

Three pulses of volcanism are evident based on radiometric ages: one in the late Oligocene-early Miocene, a second in the mid-Miocene, and a third considered post-mid-Miocene. As the convergent plate boundary evolved to a transform one, a gap, or slab window, formed whereby upwelling mantle filled the space formerly occupied by the subducted slab. Palinspastic reconstructions place much of the older volcanism within a tightly confined area in present day southern California. Mid-Miocene volcanism is harder to explain than simple slab window magmatism. The prevailing hypothesis suggests much of it is due to extension development after lingering micro-plates were consumed. The final pulse of magmatism, observed in outcrops along Route 24, was the result of the passing triple junction and the expanding slab window.

Volcanism erupted locally from Roundtop Mountain to the south. Within the tunnel, the volcanic rocks are exposed as dikes cross-cutting sedimentary units. Baked zones have not oxidized and are black instead of red. The first two bores encountered more igneous rocks than the third bore, and the third bore more than the fourth. This is likely due to the proximity of the volcanic center to the first two bores. The igneous dikes of the first two bores were some of the worst rocks encountered, weak and soft when wet. In the Fourth Bore they were rarely weak, likely due to the extensive dewatering of successive probe hole operations.
The Caldecott Tunnels were bored through rocks that reflect a change in the Pacific/North American plate boundary during the Miocene. In the middle of the tunnels, fine-grained sedimentary rocks deposited at depths of 1500 meters are juxtaposed against fluvial gravels and coarse sands. Igneous dikes that cut through the various rock units reflect the end of subduction and the change to the transform margin seen today. Uplift of the East Bay Hills over the last several million years is a response to the continuing forces acting between the plates.

The tunnels themselves display a range of technologies in both tunnel design and construction. The latest tunnel to be constructed, the Fourth Bore, will be the most technologically advanced of the tunnels and will provide safe access to the traveling public for many years to come.

Figure 8: The 130-ton Wirth roadheader was custom-built for the Caldecott Fourth Bore Project. The electric-powered tunneling machine excavated 85% of the Fourth Bore’s topheading.

References:

Allen, J., 2011, *Caldecott Improvement Project Paleontological Mitigation Plan*


Mailhot, R., date unknown, “Caldecott Tunnel, Completed 1937” California Department of Transportation


Stop #1: Caltrans Construction Field Office

Stop #2: West Portal of Kennedy Tunnel
From Field Office, travel onto westbound Highway 24. Proceed on West 24 through Bore #3 (farthest right tunnel bore). Please stay in the right lane in Bore #3 to allow for an early exit on the west side). Exit onto Tunnel Road. Proceed straight through intersection and continue (this will be Caldecott Lane) for about a quarter mile. Turn right onto Tunnel Road (the Gateway Fire Memorial will be on the right side). Make a quick right again onto Tunnel Road. Continue on Tunnel Road for 1.6 winding miles to a pull-out just past the house located at 2560 Tunnel Road. There is a small plaque noting the location of the historic Kennedy tunnel. There should be ample parking.

Stop #3: West Portal of Caldecott Tunnel
From Stop #1, we proceed back down Tunnel Road towards Highway 24. Turn left at the Gateway Memorial Exhibit (also labeled Tunnel Road) and an immediate left onto Caldecott Lane. Follow the highway sign indicating to Walnut Creek, turning right over Highway 24. At the next light, turn left onto Broadway. Proceed on Broadway, being careful to stay to the right and do not merge onto the Highway 24 on-ramp. Shortly after the on-ramp, the road ends at the entrance to the tunnel’s Operations and Maintenance Control building.

Stop #4: Claremont Avenue
Proceed to the eastbound Highway 24 on-ramp several hundred yards west of Stop #2, and proceed east through the tunnel (Please stay in the right lane to allow for an early exit on the east side). Exit onto Fish Ranch Road. The road curves back around and above the tunnel, passing the art deco style portal building. Continue on Fish Ranch Rd. to the first stop sign. Proceed straight through and travel about a half-mile to a turnout on the left careful when parking.

Stop #5: East Portal of Caldecott Tunnel
From Stop #3, the tour will proceed back to the east portal of the Caldecott Tunnel. We ll drive to the front of the portals and park on the street where available. We ll then walk several hundred yards to an outcrop of the Orinda Formation.