

Excerpt from

Geologic Trips
San Francisco and the Bay Area

by Ted Konigsmark

ISBN 0-9661316-4-9
GeoPress

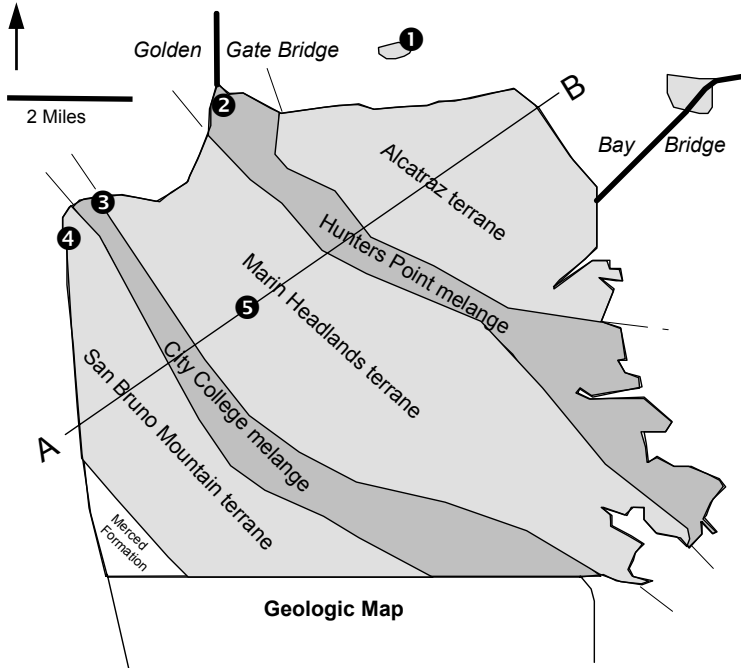
All rights reserved. No part of this book may be reproduced without written permission in writing, except for critical articles or reviews.

For other geologic trips see:

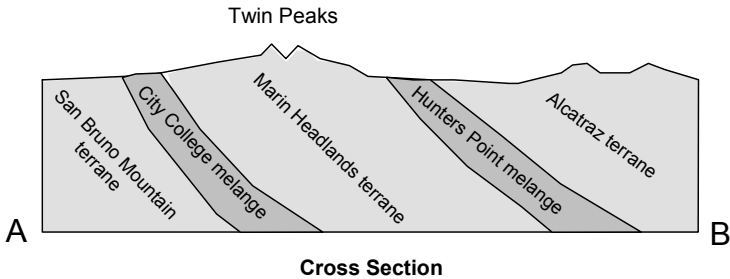
www.geologictrips.com

Trip 1. SAN FRANCISCO

- ❶ Alcatraz Island
- ❷ Fort Point
- ❸ Palace of the Legion of Honor
- ❹ Cliff House
- ❺ Twin Peaks



Geologic Map



Cross Section

The map and cross section show the distribution of the five major Franciscan rock units that underlie San Francisco. Examples of each of these rock units will be seen during the geologic trip to San Francisco.

Trip 1.
SAN FRANCISCO
The Franciscan

San Francisco rests on a foundation of Franciscan rocks. Although there are many different types of Franciscan rocks, they share a common parentage in that they were all brought together in the Franciscan subduction zone during the collision between the Farallon plate and the North American plate in Jurassic and Cretaceous time from 65 to 175 million years ago.

The Franciscan rocks in San Francisco have been divided by geologists into five different rock units. You will see examples of each of these rock units during this geologic trip to San Francisco. The trip can be easily completed by car in one day. These are the places you will visit:

Alcatraz Island: Alcatraz Island is made up of thick sandstones of the Alcatraz terrane. At Alcatraz you will learn where these sandstones came from and why they got sentenced to Alcatraz for life.

Fort Point: The fort at Fort Point is built on a large block of serpentine within the Hunters Point melange. This serpentine is a piece of oceanic crust from the lower part of the Farallon plate.

Palace of the Legion of Honor: Here you will see a landslide that was responsible for closing a half-mile section of El Camino del Mar. The landslide was caused by the weak rocks of the City College melange.

Cliff House: Cliff House is built on thick sandstone beds of the San Bruno Mountain terrane. These sandstones were deposited in a deep oceanic trough along the Franciscan subduction zone during upper Cretaceous time.

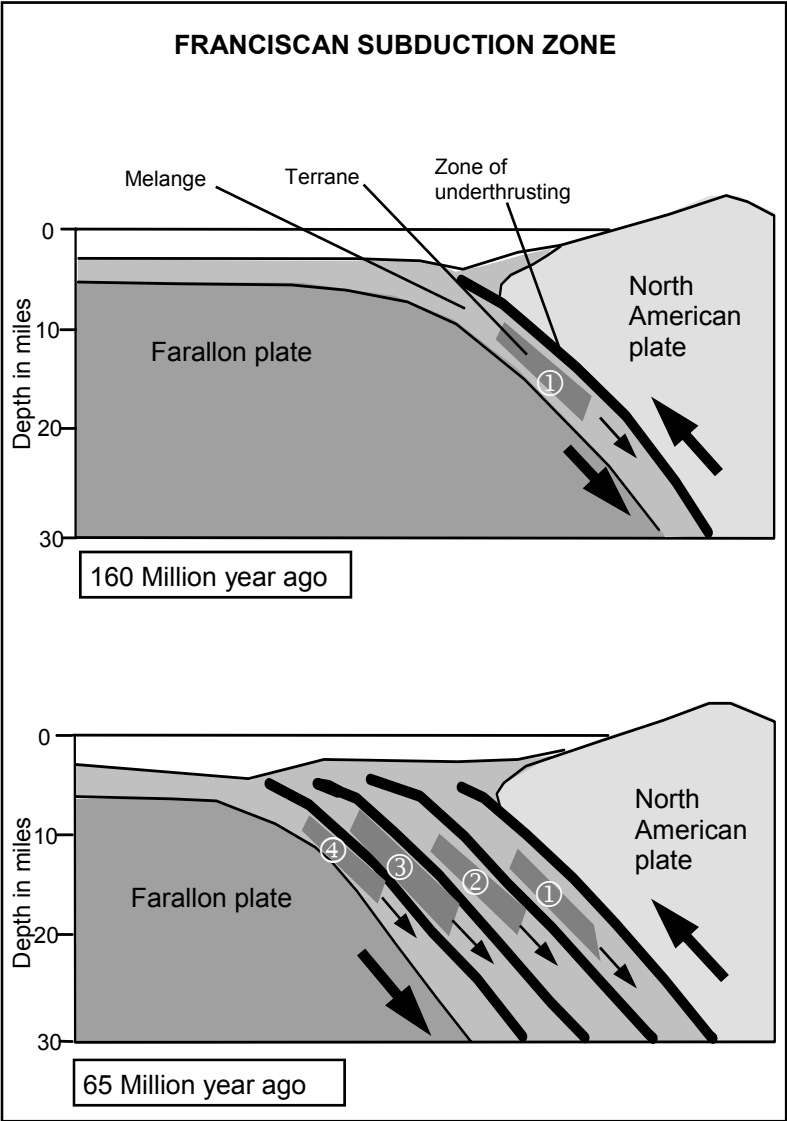
Twin Peaks: The Twin Peaks consist of pillow basalt and red chert of the Marin Headlands terrane. These rocks once formed the upper part of the Farallon plate when the Farallon plate was several thousand miles west of San Francisco.

The Franciscan rocks in San Francisco occur in five northwest-trending bands that cut diagonally across the city. If you were to trace these rocks deep below the earth's surface, you would find that the rocks form layers that are stacked like giant pancakes on a platter tilted to the northeast. The bands of rocks that you see on the surface are the uptilted edges of these rock layers.

This is not an ordinary platter of pancakes. In this stack, the oldest layer, the Alcatraz terrane, is on the top of the stack and the youngest layer, the San Bruno Mountain terrane, is on the bottom. The younger rock units were stuffed under the older rock units as the rock units entered the Franciscan subduction zone. It's as if the younger pancakes were stuffed under the older pancakes on the platter.

After the subduction was completed, the Franciscan rocks were uplifted and eroded. Rocks that had once been buried at depths of up to 30 miles in the subduction zone were eventually exposed at the surface of the ground. These rocks now make up the hills of San Francisco and many of the islands in the bay.

FRANCISCAN ROCKS San Francisco			
Locality	Rock Unit	Age	Description
Alcatraz Island	Alcatraz terrane	Lower Cretaceous	Graywacke sandstone, little or no K-feldspar
Fort Point	Hunters Point melange	Jurassic Cretaceous	Melange: large blocks of serpentine in soft clay and serpentine matrix
Twin Peaks	Marin Headlands terrane	Jurassic Cretaceous	Pillow basalt, red chert and sandstone, typically in thin fault slices
Palace of the Legion of Honor	City College melange	Jurassic Cretaceous	Melange: blocks of basalt, chert, and sandstone in soft clay and serpentine matrix
Cliff House	San Bruno Mountain terrane	Upper Cretaceous	Graywacke sandstone, contains K-feldspar



In this model of the Franciscan subduction zone, terrane ① went into the subduction zone first, followed by terranes ②, ③, and ④. These terranes entered the subduction zone during Jurassic and Cretaceous time. At the end of the Cretaceous, the rocks in the subduction zone were uplifted. Eventually, rocks that had been buried at depths of 30 miles were exposed at the surface by erosion of the overlying rocks.

Alcatraz Island

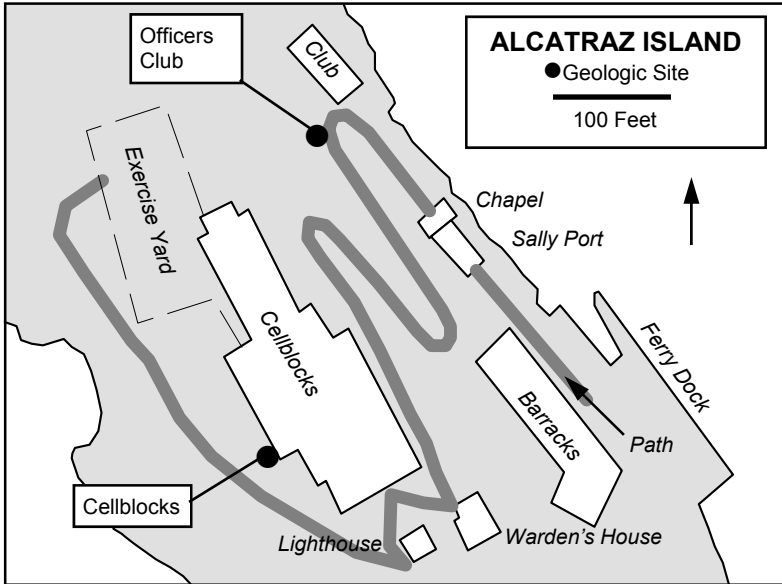
Alcatraz Island is the best place in the Bay Area to see the Alcatraz terrane of the Franciscan. The Alcatraz terrane is characterized by thick-bedded sandstones. These sandstones form many of the hills that give downtown San Francisco its unique character, including Telegraph Hill, Russian Hill, Rincon Hill and Nob Hill. However, in San Francisco, the Alcatraz sandstone is almost everywhere covered by buildings, streets and cable car tracks, so that good exposures are hard to find.

All of the rocks that you see on Alcatraz Island belong to the Alcatraz terrane. There are numerous good exposures of these rocks, but access is limited by the Park Service and the sea gulls. The trick is to find outcrops of the Alcatraz sandstones that are accessible. Two geologic sites will be described on this trip, the Officers Club and the Cellblocks. Along the path near the Officers Club you will examine the sandstone in detail and learn where the sand grains came from. At the Cellblocks you will see the thick and massive character of the sandstone beds that has made them so resistant to erosion.

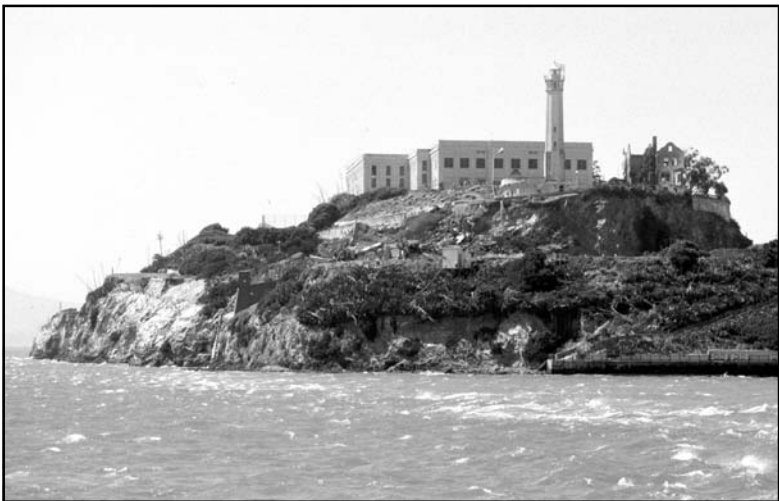
To get to Alcatraz Island, take a Red and White Ferry from Pier 41 at Fisherman's Wharf (Phone 1-800-BAY CRUISE). Departures are at 30-minute intervals throughout the day and tickets go on sale at 8 AM. During the summer you should make advance reservations.

In the late 1800's and early 1900's, Alcatraz Island was controlled by the U.S. Army, which used it as a fort and later as a military prison. The federal government took control in 1934 and used it until 1963 as a high-security penitentiary for criminals considered too dangerous to be held in conventional jails. In 1972 Alcatraz became part of the Golden Gate National Recreation Area. The GGNRA now provides an excellent self-guided tour of the penitentiary, and you should go on this tour while you are on "The Rock."

During the glacial stages of the Pleistocene, when sea level was exceptionally low, there was no water in San Francisco Bay and Alcatraz Island was connected by land to San Francisco. Alcatraz at these times was just another hill like Telegraph Hill, Nob Hill, Russian Hill, and Rincon Hill. During these periods of low sea level, the Sacramento River flowed westward through Raccoon Strait between Angel Island and the Tiburon Peninsula and then through the Golden Gate. There is still a deep channel in the bay through Raccoon Strait that follows this old river channel.



Alcatraz Island consists of sandstones of the Alcatraz terrane. These rocks form many of the hills in downtown San Francisco, but the best exposures are on Alcatraz Island.



The steep cliffs on the southwest shore of Alcatraz Island are formed from thick beds of the Alcatraz sandstone.

● **Officers Club**

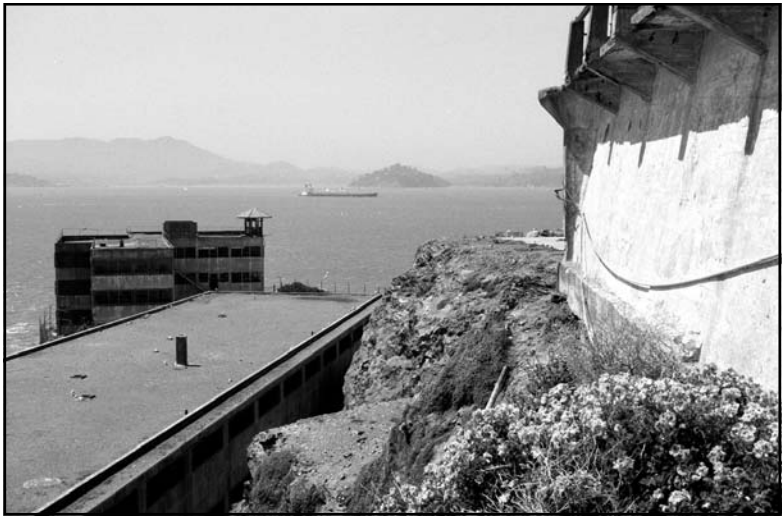
Follow the path from the ferry dock past the Sally Port and Chapel to the first switchback at the Officers Club. At this switchback you will see outcrops of the Alcatraz sandstone in the cuts along the path. If you look at the sandstone in detail you will see that it forms layers a foot or so thick and that these layers dip steeply to the east. The sandstone is light yellow-brown in color and feels like sandpaper when you rub it. If you examine the sandstone with a magnifying glass, you will see that it is composed of many small grains that are cemented together. It's like beach sand, only much harder. Most of the grains are about the size of a pinhead and are sharp and angular. Under a microscope, you would see that there are several different types of sand grains. Most of the grains are milky, opaque feldspar. About a third of the grains are clear, glassy quartz. The other grains include shale, volcanic rocks, metamorphic rocks, and red chert. The spaces between the sand grains are filled with clay and very small grains of other minerals and rocks.

The sand grains were derived from the many different types of rocks that were being eroded along the margin of the North American continent during early Cretaceous time. These rocks were broken into small sand grains by weathering and erosion. The sand grains were then carried by rivers to the ocean and deposited on the sea floor. The transportation and deposition of the sand grains took place rapidly. The sand grains would have been rounded if transportation had been for long distances. Also, the grains composed of soft volcanic rocks and shale would not have survived long transportation. The clay, mica, and chlorite that make up the matrix of the sandstone are mainly weathering products formed by chemical alteration of the less resistant rocks in the source area. Dirty sandstones such as these are referred to by geologists as graywackes. Most of the sandstones in the Franciscan are graywackes.

● **Cellblocks**

To get to this locality, follow the path to the west side of the island, where you can see the west side of the Cellblocks. The Cellblocks are built on very thick beds of Alcatraz sandstone. These thick sandstone beds form the steep cliffs on this side of the island. Note that the sandstones exposed in these cliffs form layers about 10 to 20 feet thick. When the sandstone was deposited on the sea floor during Lower Cretaceous time, it was deposited one layer at a time, each layer covering the previous layer on the sea floor. These layers of sand were horizontal when they were originally deposited. The tilting occurred during subsequent uplift and folding of the rocks. Probably most of the

tilting occurred when the Alcatraz sandstone was carried into the Franciscan subduction zone a few million years after it was deposited. Where these layers are especially thick, they are very resistant to weathering and erosion. These thick sandstones have given us many of the hills in downtown San Francisco.



The wall at the right is part of the exercise yard at Alcatraz. This wall is built on massive sandstone cliffs of the Alcatraz terrane in the center of the photo.

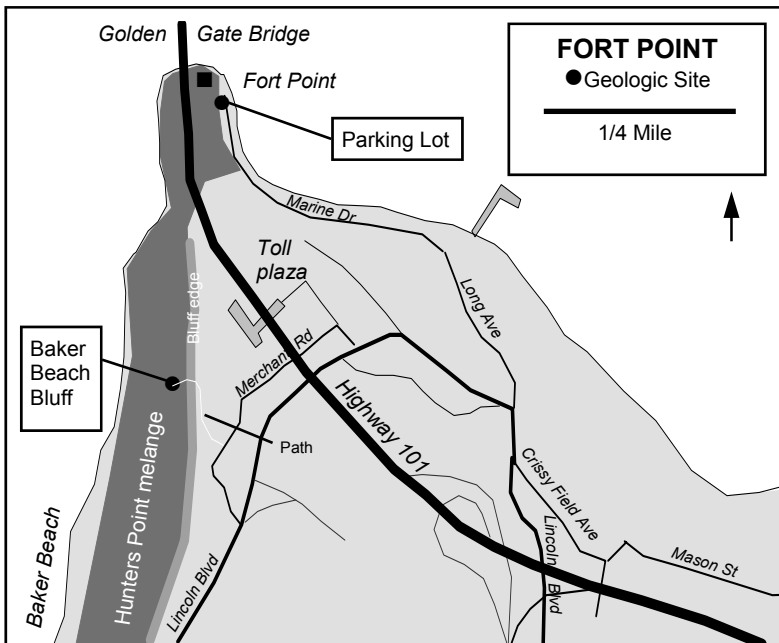
Telegraph Hill: If it is not convenient to get to Alcatraz Island, you can also see some exposures of the Alcatraz sandstone at Telegraph Hill. To do this, go to Sansome and Union Street on the east side of Telegraph Hill. On the west side of this intersection you will see a large cliff of Alcatraz sandstone. Years back, this cliff was the face of a rock quarry. The sandstone in the cliff is very massive; that is, it is not interbedded with soft shale beds. It is because this sandstone is so massive that Telegraph Hill has resisted weathering and erosion.

You can see other exposures of the sandstone along the pathway to Coit Tower that leaves from the intersection of Lombard Street and Telegraph Hill Blvd. Do not be fooled by the large red boulders along the road at the top of Coit Tower. These rocks are jasper, and were carried here by truck from somewhere else.

Fort Point

The point of land that guards the south side of the Golden Gate is a large block of serpentine that lies within the Hunters Point melange of the Franciscan. The fort at Fort Point was built on this block of serpentine. Another large block of serpentine supports the south tower of the Golden Gate Bridge. The Hunters Point melange contains a number of these large blocks of serpentine. During the trip to Fort Point you will visit the parking lot at Fort Point and the bluff at Baker Beach. At the parking lot you will see part of the serpentine block that underlies the fort and at the Baker Beach bluff you will see the Hunters Point melange where it contains smaller blocks of serpentine and many other rocks.

To get to Fort Point from Fisherman's Wharf, go west on Bay Street to Van Ness Ave., turn left and go three blocks to Lombard Street, turn right and go 1.2 miles to Lincoln Blvd. Turn right on Lincoln Blvd. then right on Long Ave. Follow Long Ave. and Marine Drive to the parking area at Fort Point. Fort Point National Historic Site is within the Golden Gate National Recreation Area. The fort is open daily 10 AM to 5 PM. For information, phone 415-556-1693.



Fort Point was built on a large block of serpentine that lies within the Hunters Point melange of the Franciscan.

● **Parking Lot**

The large serpentine block that forms the foundation for the fort is exposed in the small hill at the parking lot next to the fort. The serpentine in this exposure is light green, flaky, and intensely foliated with many curved surfaces along which the serpentine tends to break. The foliations wrap around smaller blocks of hard serpentine that are darker green. The serpentine feels very slippery and has a waxy luster. Some of the dark green blocks appear as if they have been polished. There are other good exposures of this serpentine in the road cuts all along Marine Drive.

Serpentine is formed at spreading centers. It consists of ultramafic rocks from the earth's mantle that were altered by hot seawater. The hot seawater reached the ultramafic rocks through cracks formed in the earth's crust during the spreading process. The serpentine was carried away from the spreading center as the oceanic plate moved away from the spreading center. Serpentine forms the lower part of the earth's oceanic crust worldwide.



Fort Point, which lies under the south approach to the Golden Gate Bridge, is framed by a special arch on the bridge that was built to preserve the fort. The serpentine of the Hunters Point melange is exposed in the small hill at the parking lot to the left of the fort.

Serpentine is very common in the Franciscan throughout the Coast Ranges. In some places the serpentinite occurs as small, isolated blocks and in other places as mountain-sized slabs. The most extensive exposures of serpentinite are along the eastern edge of the northern Coast Ranges where a large slab from one- to five-miles wide and 70 miles long separates the Franciscan from the sedimentary rocks that were deposited in the Great Valley. The sedimentary rocks in the Great Valley were apparently deposited on this oceanic crust, then the Franciscan was thrust under this oceanic crust during subduction.

Many of the smaller isolated blocks of serpentinite in the Franciscan represent pieces of the oceanic crust that were broken up and then squeezed upward through the overlying host rock like watermelon seeds. The serpentinite in these blocks tends to break into small, dark green fragments with curved polished surfaces. The polished surfaces have tiny grooves that formed when the fragments rubbed against each other as the serpentinite was squeezed through the rocks. Wherever you see serpentinite on land, you are looking at a piece of oceanic crust that is out of place and was somehow injected into or squeezed onto the land.



The large blocks of serpentinite in the foreground lie within the Hunters Point melange. The rocks in the surf zone have been excavated from the Hunters Point melange during erosion of the Baker Beach bluff.

● ***Baker Beach Bluff***

To get to the bluff at Baker Beach from Fort Point, return on Long Ave. to Lincoln Blvd., turn right on Lincoln Blvd., and then take the road that goes to the Toll Plaza. Follow this road under the Toll Plaza to Merchant Road and park in the large parking area on Merchant Road. Take the path to the Coastal Trail, then follow the trail north until you go down a short wooden staircase. At the base of the stairs leave the Coastal Trail and follow the path to the edge of the bluff.

The bluff here is made up of the Hunters Point melange. The melange consists of finely crushed serpentinite, shale and sandstone with large random blocks of serpentinite and many other rocks. There are many landslide deposits along the bluff and it is difficult in some places to distinguish between the landslides and the melange. Along the shoreline are numerous large boulders that have accumulated after being eroded from the melange. These boulders include sandstone and shale, basalt, chert, greenstone, serpentinite polished by wave action, serpentinite with small veins of asbestos, red jasper, yellow jasper, intensely deformed sandstone cemented by quartz and calcite veins, and metamorphosed gabbro. Since this beach is somewhat secluded, on a sunny day you may see much more exposed than just these rocks.

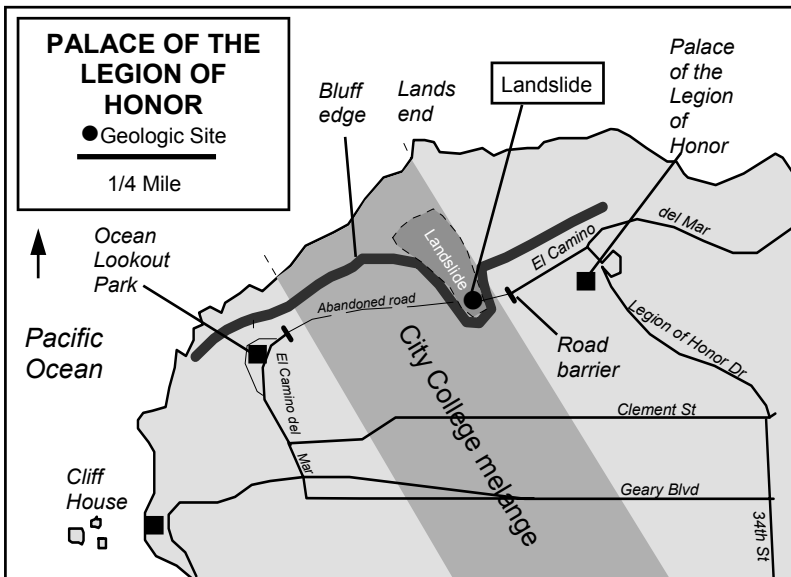
The Hunters Point melange occurs in a wide belt that trends southeast through San Francisco from Fort Point to Hunters Point. Because the clay in the melange is soft, there are few exposures of the clay along the outcrop belt. However, the large serpentinite blocks within the melange are hard and therefore typically form small hills along the outcrop belt.

During construction of the Golden Gate Bridge there was some controversy concerning whether the serpentinite block under the south tower would provide adequate support for the bridge. To settle this dispute, Andy Lawson, who was then a Professor of Geology at U.C. Berkeley, was lowered into the deep foundation hole that had been dug into the serpentinite. Professor Lawson proclaimed that the rock was satisfactory and construction of the bridge continued. Another large block of serpentinite forms the foundation of the New Mint building at Dubose and Church Streets. The mint building is built on a small hill, and the serpentinite can be seen directly under the mint building. This is probably the best exposure of serpentinite in San Francisco. The serpentinite under the mint consists of blocks of serpentinite a couple of feet in diameter that are surrounded by highly foliated serpentinite. Other large blocks of serpentinite form Portrero Hill and Hunters Point.

Palace of the Legion of Honor

Some years back you could drive west along El Camino del Mar from the Palace of the Legion of Honor to Ocean Lookout Park. This section of El Camino del Mar was built on the City College melange of the Franciscan and is now abandoned because of landslides caused by the weak and slippery clay in the melange. During the geologic trip to the Palace of the Legion of Honor you will visit one of these landslides.

To get to the Palace of the Legion of Honor from Fort Point, go west on Lincoln Blvd. to El Camino del Mar, and follow El Camino del Mar to Legion of Honor Drive. Do not turn left on Legion of Honor Drive, but continue west on El Camino del Mar about 200 yards until you reach the barrier across El Camino del Mar. This section of the road is now used as a parking area. Park here and go the road barrier.



The City College melange consists of soft clay that contains hard blocks of basalt, serpentine, sandstone and other rocks. The soft clay in the melange has resulted in landslides that have led to abandonment of a half-mile section of El Camino del Mar.

●Landslide

To get to the landslide, take the path going west from the road barrier at the end of El Camino del Mar. Immediately past the barrier, the path goes down a 100 or so steps and then crosses a small bridge. The steps are on the landslide and the bridge is in a gully that was formed by the landslide. Near the bridge there are large chunks of asphalt from the abandoned road, and just beyond the bridge there is a large section of asphalt with the white mid-line stripe still on the asphalt. These pieces of the roadway have slid downslope about 50 feet courtesy of the landslide.

If you have the time, continue west on the abandoned section of the road. By keeping track of the pieces of asphalt you can see where several sections of the road are missing. In less than half a mile you will reach the road barrier at Ocean Lookout Park, where El Camino del Mar continues to the west. While at Ocean Lookout Park you can see the memorial to the U.S.S. San Francisco, which was lost during the battle of Guadalcanal. Just north of the memorial you will find some wooden steps that go down to the Coastal Trail. Go down these steps, then along



If you travel west on El Camino del Mar, the road ends abruptly just beyond the Palace of the Legion of Honor. The section of the road beyond the barrier in the photo was removed by a landslide in the soft rocks of the City College melange. The pathway to the right of the barrier goes down the landslide and then follows the abandoned road to Ocean Lookout Park, where you will find the continuation of El Camino del Mar.

the Coastal Trail a few feet to the east to where you can get a view along the bluff to the east toward Lands End. Be careful and don't go on the bluff where it is unsafe.

Most of the rocks exposed along the bluff between Ocean Lookout Park and Lands End are the City College melange. The melange consists of hard blocks of serpentine, schist, gabbro, basalt, chert, and sandstone in a soft matrix of fine clay and serpentine. As this section of the bluff has been eroded by the ocean waves, the hard boulders in the melange have remained behind and accumulated at the base of the bluff. These boulders now protect the bluff from rapid erosion.

In the early 1880's, a rail line had followed this same route and took people from downtown San Francisco to the Cliff House. The rail line was abandoned at the turn of the century because of maintenance problems related to the unstable roadbed. The fine clay matrix of the melange tends to hold the water near the surface and therefore becomes very slippery when wet. The clay then flows downhill, taking with it the roads, buildings, and whatever else has been built on the melange.

The clay matrix in the melange provides weak and slippery rocks wherever exposed in San Francisco. The rocks along the bluff are especially susceptible to landslides because the rocks are on a very steep slope. This combination of weak rocks, steep slope and heavy rainfall conspired to do away with this section of El Camino del Mar.

The City College melange cuts across San Francisco from Lands End through Golden Gate Park and McLaren Park to San Francisco Bay just south of Candlestick Park. The melange was formed along the zone of thrusting between the rocks of the San Bruno Mountain terrane and the Marin Headlands terrane while the rocks were in the Franciscan subduction zone. The fine clay matrix of the melange was formed from rocks that were thoroughly ground up by the thrusting. The blocks in the melange are pieces of hard rock that survived the grinding.

Melanges are very common in the Franciscan throughout the Coast Ranges of Northern California. Large random boulders on rolling hillsides are a tip-off that the rocks may be a melange. The boulders are very hard and stand out from the soft greenish-gray or bluish-gray clay matrix, which is seldom seen. The clay matrix does not have the thin layering of typical Franciscan shale. Landslides are especially common where the melange occurs on a steep slope.



These steps go down the landslide at the end of El Camino del Mar. The landslide removed a several-hundred-foot section of El Camino del Mar. Pieces of the old asphalt road surface can be seen in the landslide debris near the base of the steps.

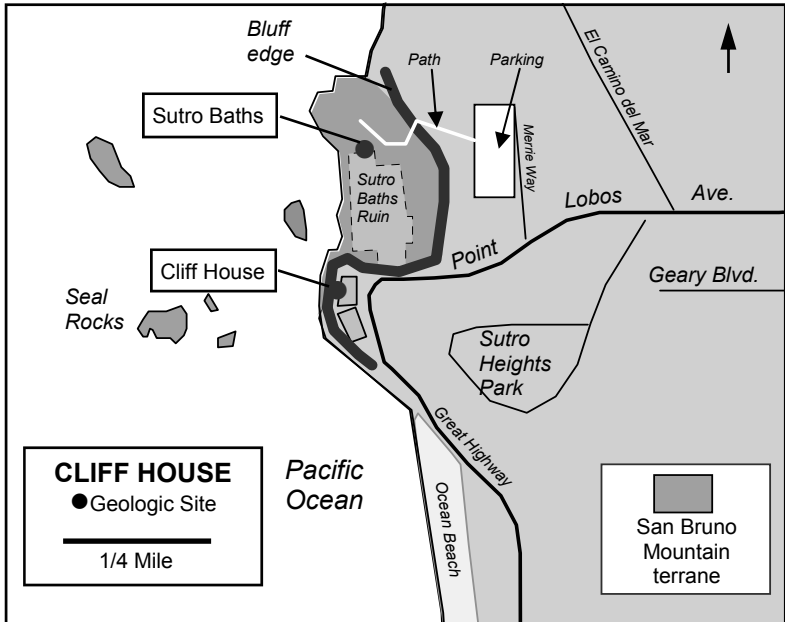


The small islands and rocks that can be seen along the shoreline east of Ocean Lookout Park represent hard blocks of serpentine, basalt, chert and sandstone that have been eroded from the soft clay matrix of the City College melange.

Cliff House

The sandstones of the San Bruno Mountain terrane were deposited as a series of submarine fans that filled a deepwater trough that had formed along the Franciscan subduction zone during late Cretaceous time. At the Cliff House and nearby Sutro Baths you will see some of these deepwater sandstones. The Cliff House was built on thick sandstone beds that had been deposited in the central parts of one of the submarine fans. The Sutro Baths are located in thinly bedded sandstone and shale that had been deposited along the edges of the fan.

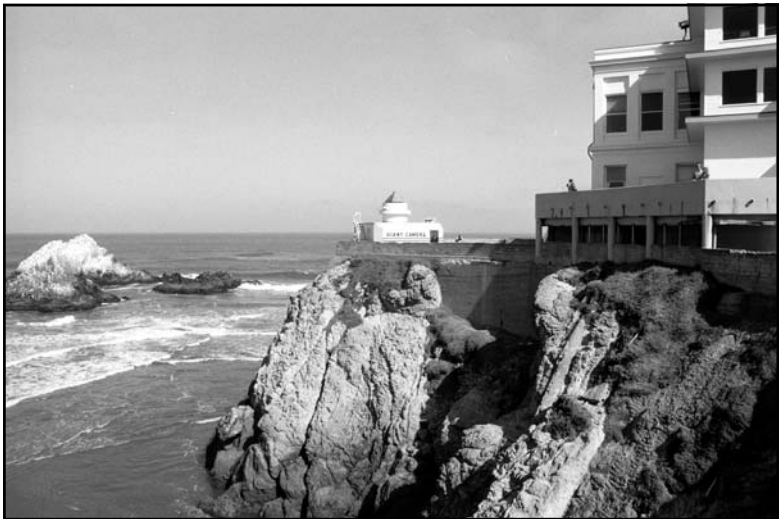
To get to the Cliff House from the Palace of the Legion of Honor, follow Legion of Honor Drive to Geary Blvd. and turn right. Follow Geary Blvd. to Fortieth Avenue and then continue on Point Lobos Ave. to the Cliff House. Since the 1850's the Cliff House and its predecessors, including the Ocean House and Seal Rock House saloons, have been prime tourist destinations. The Cliff House is in the Golden Gate National Recreation Area. For information from the Park Service, phone 415-556-8642.



The Cliff House and the Sutro Baths are built on sandstones of the San Bruno Mountain terrane of the Franciscan.

● **Cliff House**

To see the thick sandstones of the San Bruno Mountain terrane, go down the steps leading to the visitor center on the observation deck at the Cliff House. The sandstone beds are exposed in the cliff below the observation deck. Continue south along the deck to where some of the sandstone is exposed along the path. The sandstone is light yellow brown, and the beds are very thick. There are almost no layers of black shale between the sandstone beds. The sandstone appears similar to the massive sandstone below the cellblocks at Alcatraz. However, there are a couple of differences. The sandstones of the San Bruno Mountain terrane are younger than the sandstones of the Alcatraz terrane. They were formed in late Cretaceous time during the later stages of subduction, whereas the rocks in the Alcatraz terrane were formed in early Cretaceous time during the earlier stages of subduction. Also, the sandstone in the San Bruno Mountain terrane contains K-feldspar, a variety of feldspar that is rich in potassium. The K-feldspar was derived from weathering of granitic rocks in the ancestral Sierras. These granitic rocks had been formed in the Franciscan subduction zone. There is almost no K-feldspar in the sandstones of the Alcatraz terrane since the Alcatraz sandstones were formed in the early stages of subduction before the Sierra granite had been subjected to erosion.



The massive sandstones of the San Bruno Mountain terrane are highly resistant to erosion and provide a firm foundation for the Cliff House.

● **Sutro Baths**

The Sutro Baths were built by Adolph Sutro, a popular San Francisco philanthropist. The indoor bathhouse was opened in 1896 and had seven separate pools spread across a three-acre site. The baths were enormously popular into the 1920's, but declined thereafter, and were destroyed in a fire in 1966.

The ruins of the Sutro Baths lie immediately north of the Cliff House. To get to the ruins from the Cliff House, go east on Point Lobos Ave. one block to Merrie Way, turn left, and park in the parking area. Take the path that leads to the tunnel immediately north of the ruins. At the entrance to this tunnel there are good exposures of interbedded sandstone and shale of the San Bruno Mountain terrane. The sandstone beds are similar to the sandstone at the Cliff House except that the beds are thinner, from one- to ten-feet thick. The hard sandstones form ridges that stick out from the soft black shale that occurs between the sandstone beds. Because the sandstone beds here are thin and interbedded with the soft shale, they are eroded more easily than the massive sandstone under the Cliff House. The cliff thus makes a reentrant in these softer rocks.

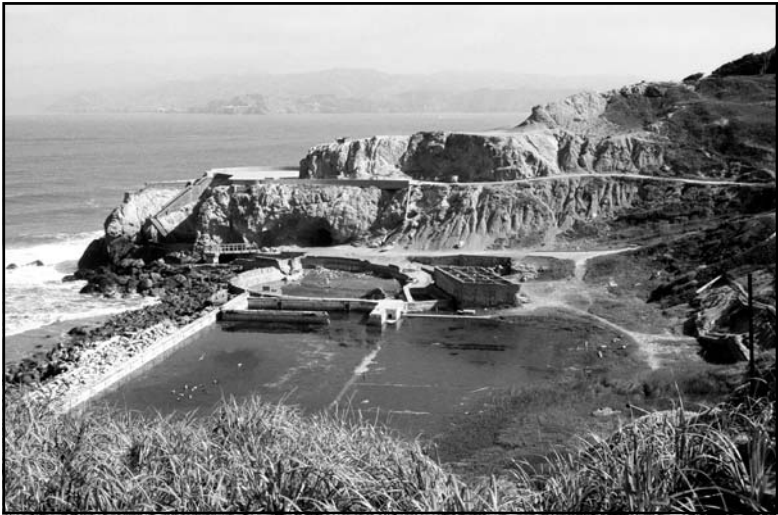
The sandstone that makes up the San Bruno Mountain terrane extends southeast from Cliff House through San Bruno Mountain to Oyster Cove on San Francisco Bay. There are extensive exposures of the sandstone in San Bruno Mountain State Park and San Bruno Mountain County Park.

From studies of sandstones in many other parts of the world, we know that the sandstones in the San Bruno Mountain terrane were deposited in deep ocean water by *turbidity currents*, dense mixtures of water and sediments that flow down the slope of the sea floor like underwater avalanches. A huge amount of sand and other sediments was required to form the widespread sandstones of the San Bruno Mountain terrane.

Most of the sediments that make up the San Bruno Mountain terrane were derived from the weathering and erosion of granitic rocks of the ancestral Sierras. These sediments were carried westward from the Sierras by ancient rivers to the ocean, and then carried along the coast until they reached a submarine canyon. The sediments accumulated on the sea floor near the head of the submarine canyon until they became unstable, perhaps because of a violent storm or earthquake. When the sediments became unstable, they slumped, mixed with ocean water, and formed a turbidity current. Since the turbidity current was heavier

than the ocean water, it flowed down the submarine canyon until it reached the base of the canyon. At the base of the canyon the turbidity current would spread out onto a large fan in deep water and the sand and mud were deposited on the surface of the fan. The sand settled out of the turbidity current rapidly, and the fine mud settled out slowly at the end of the flow.

Each turbidity current flow typically resulted in deposition of a flat layer, or “bed” of sediments, with sand at the base and mud at the top. Over time, many beds of sand and mud accumulated on the fan in this manner, one on top of the other, eventually forming a unit of sandstone and mud several thousand feet thick and covering several hundred square miles. The mud is now represented by the layers of shale that occur between the sandstones.

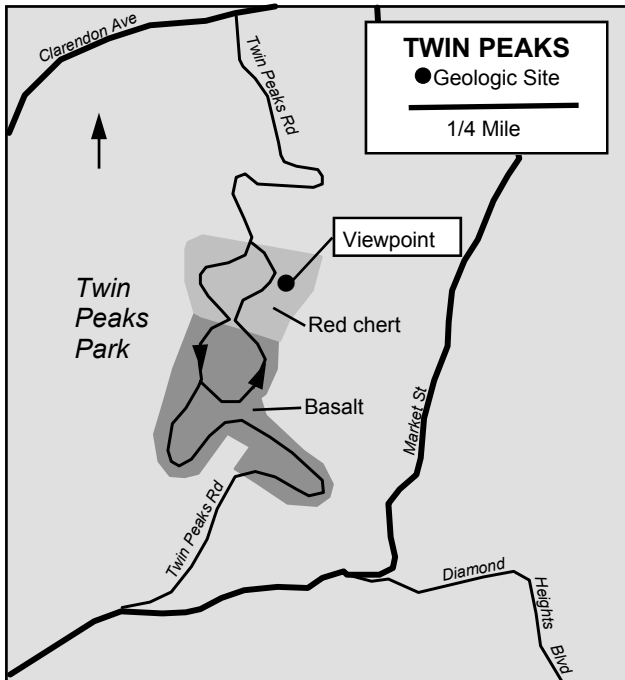


The Sutro Baths lie in a reentrant along the bluff just north of the Cliff House. Here, the sandstones in the San Bruno Mountain terrane are interbedded with many layers of soft black shale. The interbedded rocks in the reentrant were more easily eroded than the thick massive sandstones under the Cliff House.

Twin Peaks

San Francisco's famous Twin Peaks are formed from red chert and pillow basalt of the Marin Headlands terrane of the Franciscan. On this trip you will park at the viewpoint at the top of Twin Peaks and then take a short walk along the loop road to see these rocks.

To reach the Twin Peaks viewpoint from the Cliff House, go south on the Great Highway to Sloat Blvd., turn left and follow Sloat Blvd. to Portola Drive. Follow Portola Drive to Twin Peaks Blvd., and then continue on Twin Peaks Blvd. to the parking area for the viewpoint. The viewpoint is in Twin Peaks Park, and provides an excellent view of San Francisco, looking directly down Market Street to San Francisco Bay.



The red chert and pillow basalt that make up much of the Marin Headlands terrane are well exposed along the loop road at the top of Twin Peaks. The northern peak consists of red chert and the southern peak is pillow basalt.

● **Viewpoint**

Upon arriving at the viewpoint, be different from everyone else. Instead of going to the observation area to look at the city, take a walk on the one-way road that circles the two peaks. On this walk you will see that the Twin Peaks are not identical twins, but fraternal twins. The southern peak consists of pillow basalt and the northern peak consists of red chert.

If you start from the parking area for the viewpoint on the northern peak and follow the loop counterclockwise, you will first see the red chert in the road cuts. The red chert appears as bands about one- to two-inches thick. The chert is very hard and will scratch a knife blade or glass. The hard, red chert resists weathering and therefore tends to form ridges and hill tops. As you continue on the loop you will see that the road cuts in the southern peak are quite different. They consist of pillow basalt, which on these weathered exposures looks chunky and yellow-brown.

The red chert and the pillow basalt were formed along the East Pacific Rise spreading center during Jurassic time when the spreading center was far west of the North American continent. As the rocks were formed, they became the upper part of the Farallon plate and were carried hundreds of miles eastward into the Franciscan subduction zone. You will see these same rocks on the trip to the Marin Headlands and learn in more detail how the red chert and pillow basalt were formed.

As you leave the Twin Peaks, return to San Francisco by taking Twin Peaks Blvd. to the north. Along this road you will see many more exposures of the red chert that forms the northern peak.

The rocks of the Marin Headlands terrane extend as a broad band from Baker Beach through the eastern part of Golden Gate Park to Candlestick Hill. This band of rocks includes several hills that are formed primarily from the red chert, including Mt. Sutro, Diamond Heights, Bernal Heights, Mt. Davidson, and Candlestick Hill. These hills formed where the chert was especially thick. In other areas along the outcrop belt, where the red chert in more poorly developed, the Marin Headlands terrane occurs as small random exposures of pillow basalt, red chert and sandstone. These rocks can be seen at Billy Goat Hill near Diamond Heights, the Corona Heights Playground, and Glen Canyon Park. At Billy Goat Hill, the pillows in the pillow basalt form a short staircase up the side of the hill.