Excerpt from

Geologic Trips
San Francisco and the Bay Area

by Ted Konigsmark

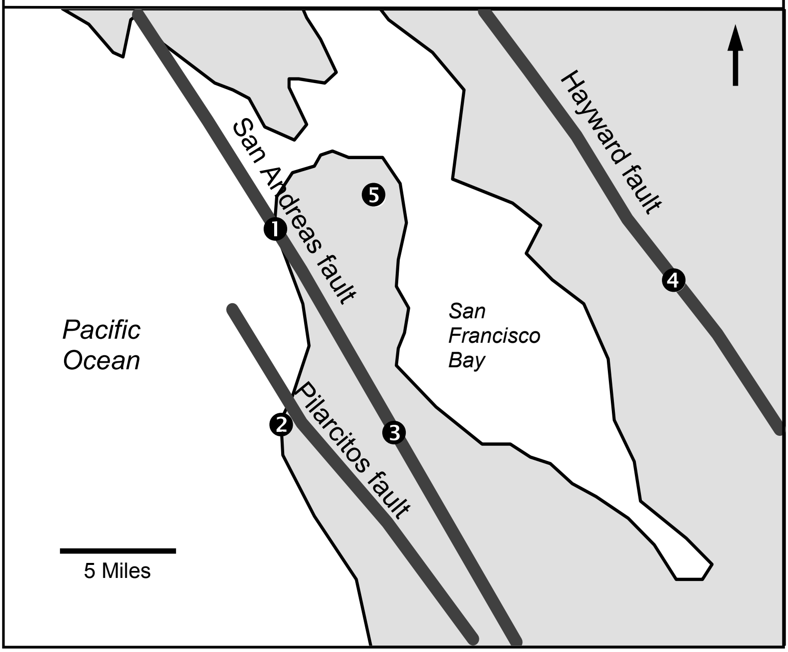
ISBN 0-9661316-4-9
GeoPress

For other geologic trips see:

www.geologictrips.com

Trip 6. BAY AREA FAULTS

❶Mussel Rock
❷Devils Slide
❸Crystal Springs Reservoir
❹Hayward
❺South of Market



The bay area is cut by several large faults that are part of the San Andreas fault system. Two of these faults - the San Andreas and Hayward - are very active and have had a number of major earthquakes over the last 150 years. On the trip to the bay area faults you will investigate these faults and see how they affect roads, houses and buildings in the Bay Area.

Trip 6.

BAY AREA FAULTS

Living with Some Big Faults

During this trip you will see the San Andreas and Hayward faults, two of the largest and most active faults in the San Andreas fault system. The trip involves a 70-mile drive and several short walks, and should take about a day if you go at a leisurely pace. You will visit these localities:

Mussel Rock: The San Andreas fault enters the Pacific at Mussel Rock after a 500-mile journey across southern and central California. On the face of the bluff near Mussel Rock there is a massive landslide formed from crushed rocks of the Merced Formation caught up in the fault zone.

Devils Slide: At Devils Slide, Highway 1 travels high along the face of a steep sea cliff that is cut by a large landslide that periodically closes the highway. The slide occurs in weak rocks along the contact zone between Paleocene sedimentary rocks to the north and a large block of granite to the south that makes up most of Montara Mountain.

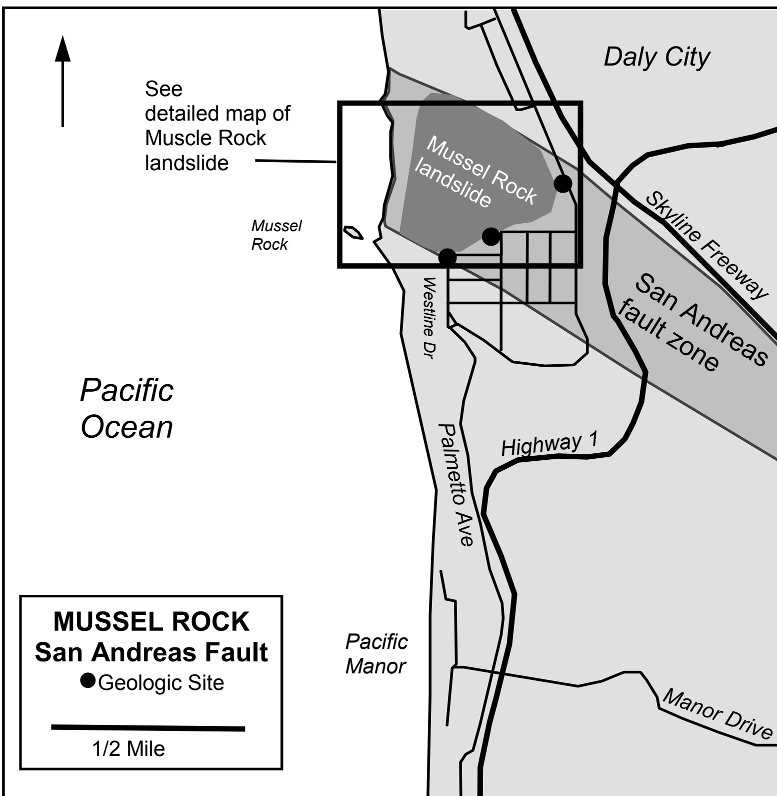
Crystal Springs Reservoir: The Crystal Springs and San Andreas Reservoirs lie in a linear valley carved out along the San Andreas fault. Here you will see where the fault that was formed during the 1906 San Francisco earthquake cut through these reservoirs.

Hayward: The Hayward fault cuts through downtown Hayward. In Hayward, you will see a fault scarp near Prospect Street, and where a curb on D Street is being slowly offset by creep along the Hayward fault. You will also drive along Mission Blvd. from Hayward to Fremont and see where recent fault scarps are covered by houses and roads.

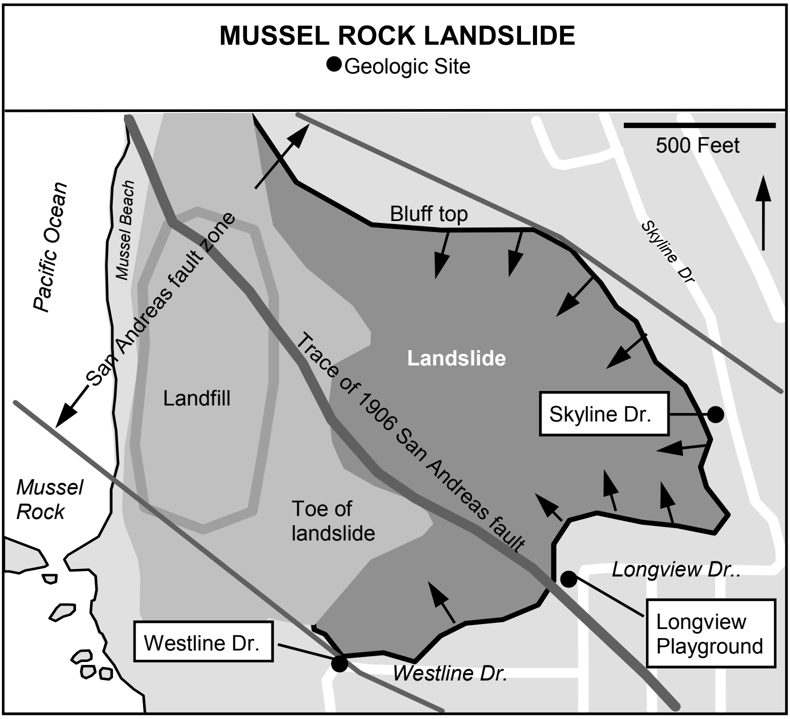
South of Market: The area south of Market Street was heavily damaged in the 1906 San Francisco Earthquake and again in the 1989 Loma Prieta Earthquake, largely because the area is underlain by thick unconsolidated water-saturated sediments that shake violently during earthquakes. On the trip to this area you will see places where streets and buildings are slowly sinking because of compaction of these soft sediments.

Mussel Rock

After a 500-mile trip from the Gulf of California and through south and central California, the San Andreas fault leaves the California coast at Mussel Rock and enters the Pacific Ocean. As it leaves the coast, it leaves behind a geological disaster area and a good lesson on how not to use land that is geologically unstable. Several geologic phenomena occur in this area, and all are bad: the area is in a major active fault zone; the rocks in the fault zone are loose and unstable; and the bluff is steep and high. The steep, unstable rocks have caused a major landslide in the bluff. Because of the landslide, the edge of the bluff is rapidly receding, at a rate of up to three feet per year. Land slippage is accelerated when the ground is wet from heavy winter rains. Many houses built at the top of the bluff have been threatened by the landslide and several have been removed as the bluff has receded.



The San Andreas fault enters the Pacific Ocean immediately north of Mussel rock. The landslide in face of the bluff is caused by the weak rocks in the fault zone.



Mussel Rock consists of Franciscan rocks and lies at the south side of the San Andreas fault zone. The fault zone extends from Mussel Rock northward for about one-half mile and includes most of the reentrant in the bluff north of Mussel Rock. The rocks in the fault zone are mainly crushed soft sandstones and shales of the Merced Formation, and it is these rocks that have slumped to form the large landslide that occupies the reentrant. The steep face of the bluff immediately north of the landslide represents the north side of the fault zone.

This area has had several land uses over the last century. From 1905 to 1920, the Ocean Shores Railroad had a rail line along the coastline near the toe of the landslide. The rail line was partly destroyed during the 1906 earthquake and had numerous problems with landslides at many other times. The Coastal Highway was opened in 1936 and followed the old rail line along the coast. This highway also had serious problems with landslides and was finally abandoned in 1957 after an M5.3 earthquake that had its epicenter near Mussel Rock. In the early 1960's, the area along the top of the bluff came under development and many houses were built precariously at the edge of the unstable bluff. From 1963 to 1979, a sanitary landfill was operated in the depression at the base of the landslide. After the sanitary landfill was abandoned, the area of the landfill continued to be used as a dumpsite for construction materials.

Three geologic sites will be visited at Mussel Rock. The first site, on Westline Drive, is at the edge of the bluff overlooking the landslide. Here you'll see cracks along Westline Drive caused by landslides in the unstable rocks at the top of the bluff. The second site, the Longview Playground, is near the fault that was formed during the 1906 San Francisco Earthquake. The third site, on Skyline Drive, is in the San Andreas fault zone and overlooks the landslide scarp formed by the fault zone.

●*Westline Drive*

To get to this site, follow Highway 1 south from San Francisco to Daly City. Continue on Highway 1 through Daly City. Take the Manor Drive exit 1.5 miles south of the Highway 1 - Highway 35 interchange. Go north on Palmetto Ave. to Westline Drive then follow Westline Drive to the north. Park where Westline Drive turns sharply east at the edge of the bluff.

At the bend in Westline Drive you are at the top of the bluff and near the south edge of the San Andreas fault zone. Several homes at the edge of the bluff in this area have been removed and others are seriously threatened as the bluff has receded because of the landslide. You can see evidence of the land slippage in the arc-shaped cracks in the street and sidewalk along the bend in Westline Drive. These cracks indicate active slumping of the edge of the bluff. From here you also get a good view of the landslide along the face of the bluff to the north.

●*Longview Playground*

Continue east on Westline Drive one block to Longview Drive, then follow Longview Drive one-half block to the Longview Playground. The Longview Playground is at the south side of the San Andreas fault zone and at the edge of the bluff overlooking the landslide in the bluff. The fault zone consists of hundreds of offsets along the San Andreas fault. The most recent of these offsets was caused by the 1906 San Francisco Earthquake. The trace of the 1906 fault crosses Longview Drive 100 feet south of the playground and then goes through the southwest corner of the playground and continues northwest down the landslide scarp just to the north of the steep gully below the playground.

From the bend in Westline Drive, this photo looks northeast across the San Andreas fault zone. The road is at the south side of the fault zone and the opposite cliff follows the northeast boundary of the fault zone. The road at this location is close to the edge of the bluff and the arcuate cracks in the road show that the bluff top is slipping downslope into the soft rocks of the fault zone.

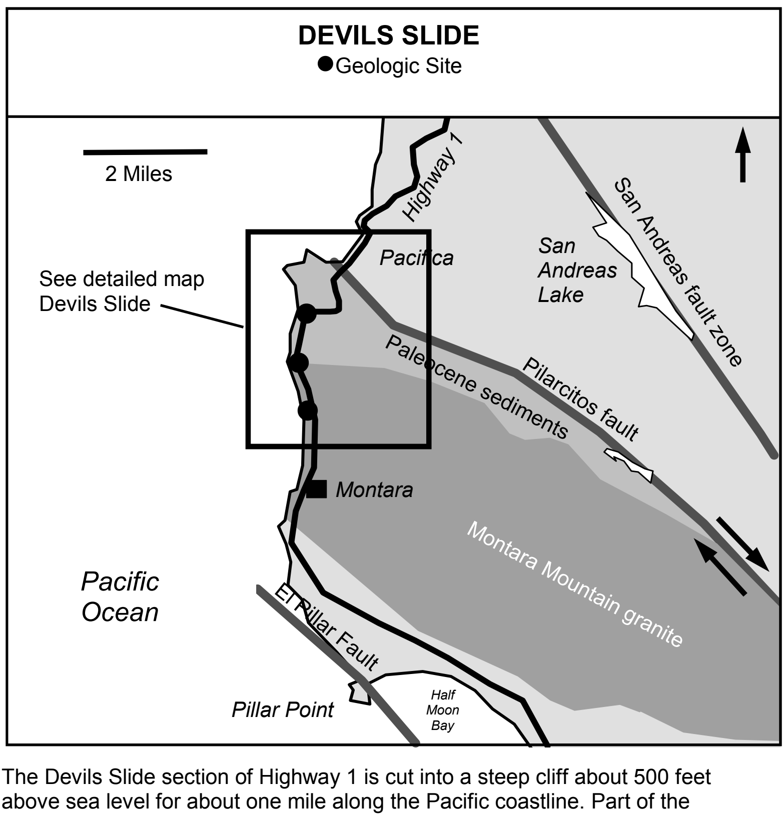
The trace then crosses the north end of the landfill and goes into the ocean about 500 feet north of the landfill. There is little evidence of the trace of the fault now, since it is largely covered by houses, roads, landfill and beach sand.

●*Skyline Drive*

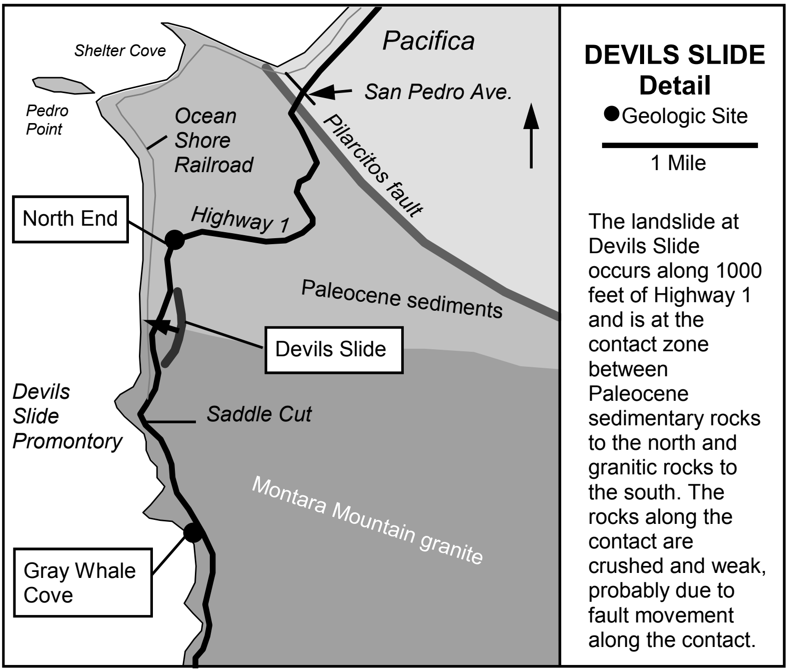
From the Longview Playground continue east on Longview Drive three blocks to Skyline Drive, turn north, go 0.1 miles and park. This part of Skyline Drive lies within the San Andreas fault zone and is at the top of the bluff along the steep part of the scarp caused by the landslide. The houses along the cliff here were mostly built from 20 to 40 years ago. Several houses have been removed because of land slippage and several others are threatened. Photos have shown there was twenty feet of cliff erosion in this area from 1979 to 1986.

Devils Slide

The Devils Slide area gets its name from the Devils Slide promontory on the coast about three miles south of Pacifica. There is a large scoop-shaped area on the north side of the promontory that early travelers thought would make a suitable slide for plunging the Devil into the Pacific. Immediately south of this promontory, Highway 1 is precariously cut into the face of a steep cliff about 500 feet above the ocean. A portion of the highway, about 1000 feet long, is built on weak rocks that have formed a landslide. This landslide has the disturbing habit of carrying portions of Highway 1 down the hillside after heavy rainstorms. Even before Highway 1 was built in 1937, these landslides caused much grief to the Ocean Shore Railroad when it ran a rail line through the Devils Slide area from 1908 to 1920. The tracks were removed in 1920 because of high maintenance costs, the constant landslides and other financial problems.



The Devils Slide section of Highway 1 is cut into a steep cliff about 500 feet above sea level for about one mile along the Pacific coastline. Part of the cliff is made up of a major landslide that periodically causes part of Highway 1 to slip toward the Pacific.

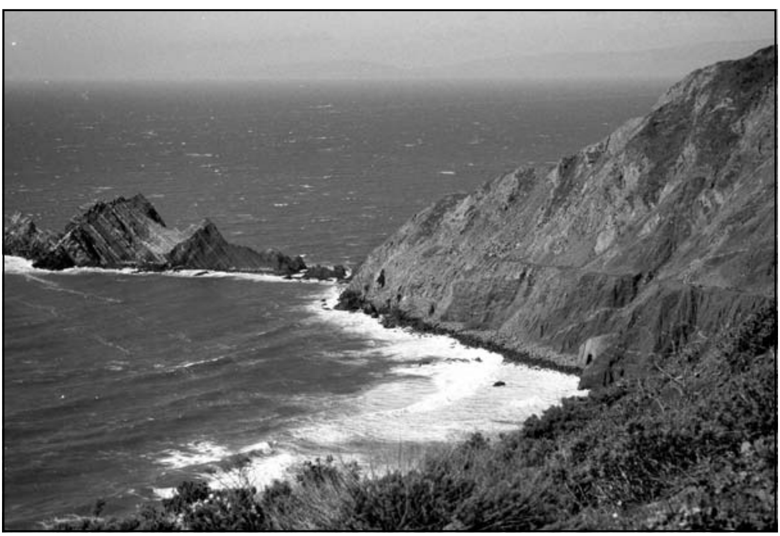


The rocks at the north end of the landslide are severely folded and faulted sandstone and shale of Paleocene age, whereas the rocks at the south end of the landslide, including the Devils Slide promontory, are part of the Montara Mountain granite. The landslide occurs along the contact zone between the Paleocene sedimentary rocks and the granite. The landslides occur because the rocks in the landslide zone are very weak, because there is a steep slope along the shoreline, and because the base of the sea cliff is being constantly removed by marine erosion. As the base of the cliff is removed, the cliff face becomes oversteepened, the weak rocks in the cliff become unstable, and another landslide occurs. After each landslide this entire process starts again.

From detailed studies of Devils Slide area, it appears that the entire cliff, which is 1000 feet high, may be ready to slide into the Pacific. The slide would occur along a slippage surface that is about 300 feet back from the face of the cliff and extends from the top of the cliff to sea level. The slippage surface can be seen at the top of the cliff as a steep scarp about 30 feet high and over 1000 feet long.

On the trip to Devils Slide you will see three geologic sites. At the north end of the landslide, you will see the Paleocene sedimentary rocks that make up the north part of the landslide. The second site is a drive along the landslide. Because this part of Highway 1 is narrow and unstable, you may not be permitted to park, but you can see the rocks in the landslide as you drive by. The third site is at Gray Whale Cove State Beach where you will see the granitic rocks that make up the south part of the landslide.

The Devils Slide section of Highway 1 is particularly susceptible to sliding in the winter after heavy winter rains. The rains saturate the weak rocks in the slide area and these rocks begin to move downslope. These landslides have been responsible for closing Highway 1 for many days, and in some cases for weeks. Because of the problems with closures and the high cost of road maintenance, an alternate 4.5 mile route has been proposed that would be built one mile inland and bypass Devils Slide. This alternate route is highly controversial since it would cut through McNee Ranch State Park and would require extensive tunneling and deep road cuts that would cause many ecological and environmental problems.

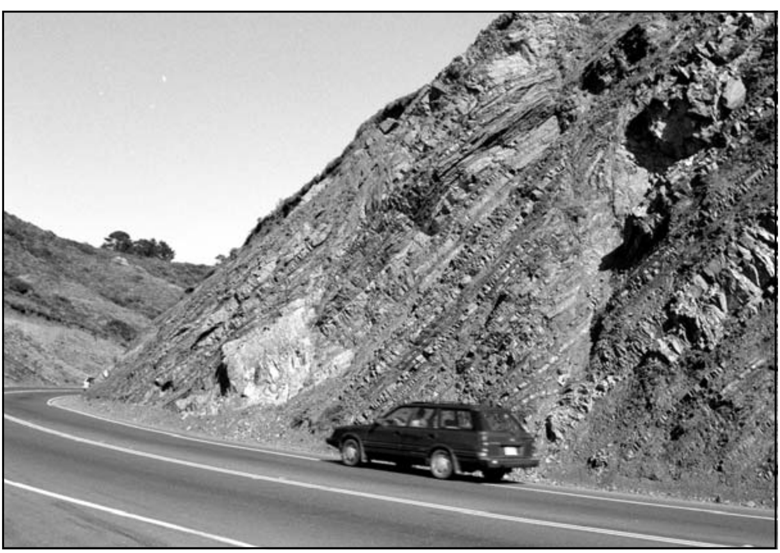


This photograph, from the north end of Devils Slide, shows the steeply dipping layers of Paleocene sedimentary rocks that form Pedro Point. The abandoned roadbed of the Ocean Shore Railroad can be seen sloping down the cliff toward the point.

●*North End*

The trip to Devils Slide starts in Pacifica at the intersection of Highway 1 and San Pedro Ave. Set your odometer at 0.0 miles at this intersection. Going south from this intersection, Highway 1 leaves the coast and climbs into the hills. These hills were formed by uplift along the Pilarcitos fault. Although there has been little or no movement on the Pilarcitos fault over the last million years, it was at one time very active, and still leaves its mark on the landscape. The Pilarcitos fault follows the San Pedro Valley to the southeast, then continues through Pilarcitos Lake and joins the San Andreas fault just west of Stanford University. The San Pedro Valley and Pilarcitos Lake were eroded in the fractured rocks along the fault zone.

As you drive to the first stop you will pass several road cuts of thinly layered sandstone and shale of Paleocene age. At 1.2 miles Highway 1 returns to the coast and immediately on the right there is a pullout with a large metal equipment cage. Park in this pullout. At this locality you are at the north end of Devil's Slide and the Highway is 465 feet above sea level. The Paleocene sedimentary rocks are well exposed in the road cut behind you. These rocks were originally deposited in southern California about 60 million years ago and have been carried north to



This photograph shows the Paleocene sedimentary rocks at the north end of Devils Slide. The rocks consist of interbedded sandstone and shale and dip steeply to the north.

their present position by the Pilarcitos and San Andreas faults. The rocks are mainly sandstone and shale, but siltstone and conglomerate also occur. Some of the conglomerates have cobbles of granite similar to the Montara Mountain granite, indicating that they were derived from erosion of the granite. The Paleocene rocks are steeply tilted to the northwest, and in some outcrops the beds are also bent into small folds. These folds formed when the soft sedimentary rocks in the vicinity of the Pilarcitos fault were squeezed by the fault movement as they were carried north on the west side of the fault.

Looking north from the pullout you can see Pedro Point. The Paleocene sedimentary rocks are exposed along the cliff face from the pullout to and including Pedro Point. The Ocean Shore Railroad followed the coast around Pedro Point, and you can still see the rail bed gently cutting down the face of the cliff toward Pedro Point.

During the last 10,000 years the bluff you are standing on extended several tens of miles further west. As sea level rose after the last glacial period, the bluff has eroded eastward to its present position, and the bluff is still being eroded to the east.

●*Landslide*

Continue driving south on Highway 1. At 1.6 miles you will reach the landslide and you will be in the landslide for the next thousand feet. You may not be able to stop or park on this section of the highway, but you can observe the rocks in the road cuts as you drive by. Note that the Paleocene rocks at the north end of the landslide are highly contorted and mashed. At about the middle of the landslide you cross the contact between these contorted Paleocene sedimentary rocks and the granite. The granitic rocks along this contact zone are also crushed and weak. As you continue south past the landslide, note that the granite is quite different from the Paleocene sediments. There is no bedding in the granite. South of the landslide the granite weathers into large blocks that are yellow-brown in color.

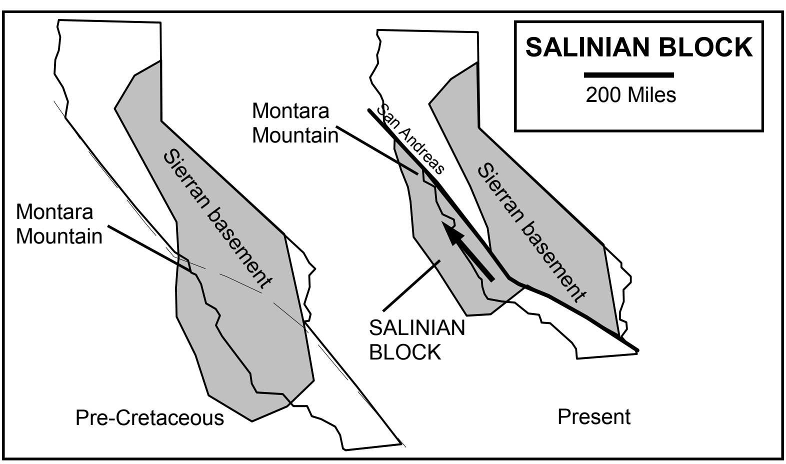
At 1.8 miles you will pass through a very steep road-cut in the granite called the Saddle Cut. Devils Slide promontory, also granite, juts out into the Pacific to the west of this cut. The old rail line along the coast to Pacifica went through Saddle Cut. The rocks from Saddle Cut to Gray Whale Cove State Beach are all granite. The next stop will be the parking area for the State Beach.

●*Gray Whale Cove*

At 2.8 miles pull into the unmarked parking area on the left for Gray Whale Cove State Beach. The rocks in the parking area and in the small hill just north of the parking area are granite. This granite extends from the landslide at Devils Slide south through Montara and makes up all of Montara Mountain. The granite is massive, without layering, but tends to form large blocks as it weathers. Where it is weathered in the parking area and in road cuts, the granite is colored yellow-brown, but is light gray where it is fresh and not weathered.

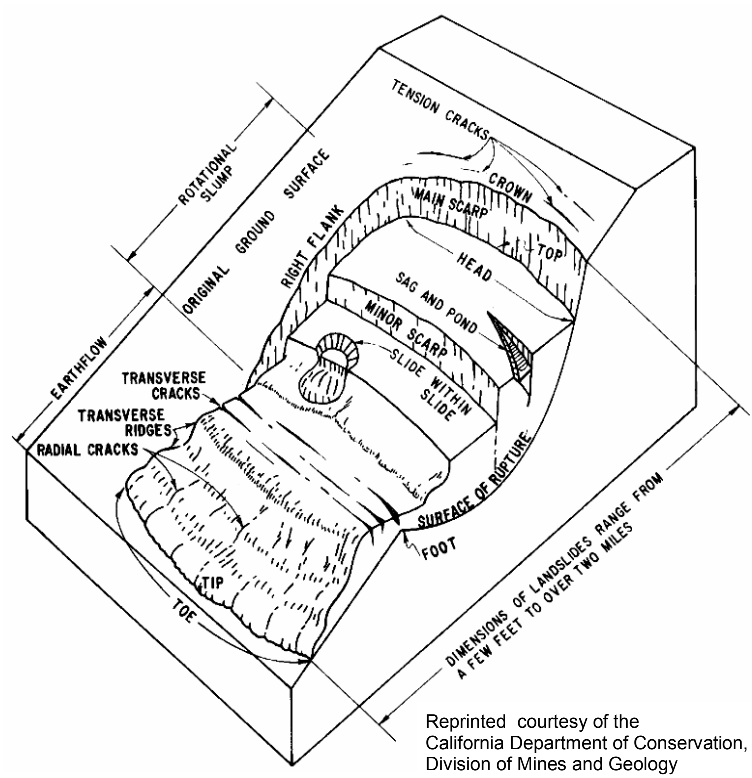
If you look at the granite in detail you will see that it is composed of many sharp grains about the size of a small pea. Most of the grains are light colored, but about 20% are black. The light-colored grains are quartz and feldspar, and the black grains are biotite and hornblende. For a more detailed description of the granite and how the granite was formed, see the discussion of the granite at the Point Reyes Headlands on the trip to the Point Reyes Peninsula.

If you wish to see fresh exposures of the granite, take the trail to Gray Whale Cove State Beach. However, be forewarned that this is a clothing-optional beach and you may see much more than just granite. Alternately, you will see more weathered granite in the road cuts along Highway 1 to Montara.



The granite at Montara Mountain is similar to the granite at Point Reyes, the Farallon Islands, Bodega Head, and in the Santa Lucia Range. All of this granite is part of a large basement block called the Salinian block. The Salinian block was cut off from the southern Sierras by the San Andreas fault and has been slowly moving northward over the last 25 million years.

FEATURES OF LANDSLIDES



Reprinted courtesy of the
California Department of Conservation,
Division of Mines and Geology

Landslides

There are many landslides in the Coast Ranges of northern California, where slopes are steep, rocks are weak, and there is high rainfall. A typical landslide has a number of characteristic features that are usually formed as a result of the slide. There is usually a steep scarp shaped like an amphitheater at the top of the slide. This scarp is the exposed portion of the rupture surface along which the rocks are sliding. The rupture surface is shaped like a scoop. The lower part of the scoop comes out on the surface further downslope, where it is called the *toe* of the landslide. The rocks within the slide tend to form rotated blocks. The rocks below the toe have flowed downslope and tend to form arcuate bulbous transverse ridges. Depending on the type of rocks in the landslide and the amount of water in the rocks, the movement of the slide can be rapid, in feet per minute, or slow, in inches per day or week. With time, erosion modifies the landslide features so that it is difficult to identify older inactive landslides. Many hillsides in the Coast Ranges consist of multiple landslide scars in different degrees of weathering, resulting in an irregular lumpy appearance.

In addition to steep slopes and weak rocks there are several other factors that may contribute to landslides. Heavy rainfall over a long period of time can increase the moisture content of the rocks on the hillside and reduce the strength of the rocks. Earthquakes may also trigger landslides. The large 1906 San Francisco Earthquake caused numerous landslides in the vicinity of the fault. Man-made cuts for roads or other construction may remove support from the toe of slopes, thereby contributing to landslides. Septic systems can add to the moisture to the soil, weakening the strength of the rocks.

Many houses and buildings in northern California are built on land subject to landslides. If you own a house in California that is on or near a steep slope, consider having the location checked by a certified geologist or engineer.

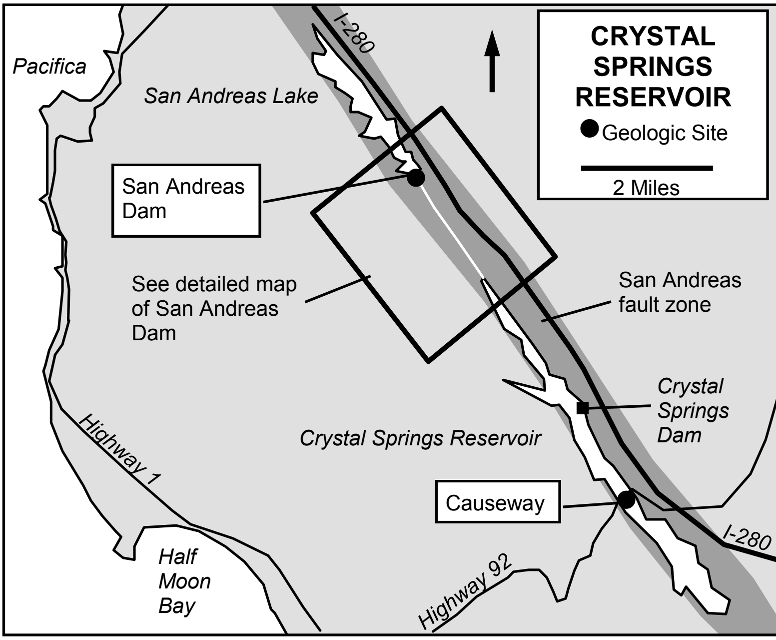
Crystal Springs Reservoir

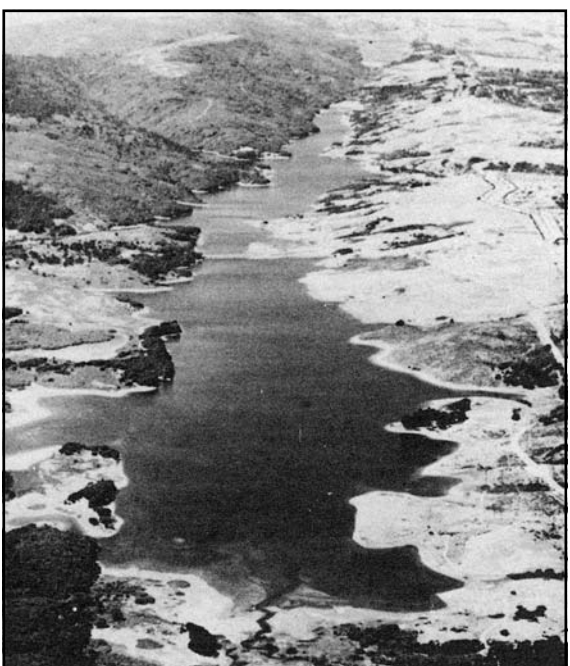
The Crystal Springs Reservoir lies within the San Andreas fault zone. On this trip you'll see many of the topographic features that are characteristic of the fault zone. During the Great San Francisco Earthquake of 1906, the active trace of the San Andreas fault cut through the Crystal Springs Reservoir, San Andreas Lake, and through the stream valley between the lake and the reservoir. This is one of the few places near San Francisco where the trace of the 1906 earthquake can still be seen. In most other places near San Francisco the fault has been covered over by roads and buildings.

On the trip to the Crystal Springs Reservoir you will visit two geologic sites that were affected by the San Andreas fault during the 1906 earthquake. The first site is the causeway that crosses Crystal Springs Reservoir. The old causeway across the reservoir was offset eight feet during the 1906 earthquake. At the second site, the San Andreas Dam, you will see where the east abutment of the dam was offset nine feet during the 1906 earthquake.

The San Andreas fault has affected the topography in many places along its 750-mile journey from the Gulf of California to Cape Mendocino on the northern California coast. The fault zone is typically about half-a-mile wide. Within the fault zone there are many old fault breaks that were made at different times by movement along the fault. These fault breaks are separated by blocks of more competent rocks that form linear ridges and linear troughs. Some of the linear ridges have steep scarps from recent faulting. Some of the fault troughs have no drainage and therefore form lakes called *sag ponds*. The Crystal Springs Reservoir and San Andreas Lake are like large sag ponds in the fault zone, but they have been enhanced by the Crystal Springs and San Andreas dams.

The Crystal Springs Reservoir supplies water to San Francisco and many other peninsular towns. Most of the water comes from Hetch Hetchy Valley in the Sierras. The Crystal Springs Dam was completed in 1888, and was then one of the largest concrete dams in the world. The foundation of the dam is in fractured Franciscan graywackes. Despite this uncertain foundation, the dam had no damage during the 1906 earthquake, even though the fault offset was in the lake only 1000 feet west of the dam.





This air photo looks northwest along the Crystal Springs Reservoir. The reservoir lies in an elongated valley formed along the soft rocks of the San Andreas fault zone. The causeway can be seen in the center of the photo. (From Wallace, 1990)

●*Causeway*

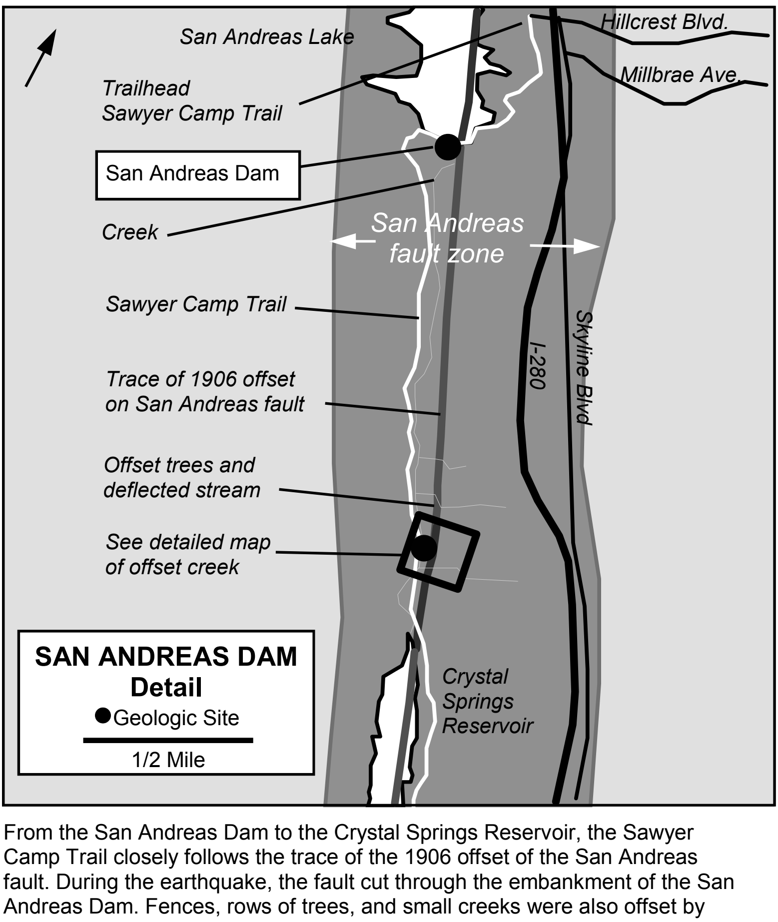
To reach the Crystal Springs Reservoir from Devils Slide, go south on Highway 1 to Highway 92 at Half Moon Bay, then go east 6.8 miles on Highway 92 to the Crystal Springs Reservoir. You will not be able to stop on the causeway, so continue east across the causeway, stay right on Highway 92 and pull over into the first parking area. From here you can get a good view of the causeway and the reservoir.

The causeway that takes Highway 92 across the Crystal Springs Reservoir crosses the most recent trace of the San Andreas fault. During the 1906 San Francisco Earthquake the old causeway across the reservoir was offset eight feet, with the west side going north. The new causeway crosses the reservoir at the same place, but unfortunately the new causeway was straightened out and all traces of the earlier fault movement have been obliterated. The causeway was just one of many places where roads, fences, and stream valleys were offset during the 1906 fault, always with the west side moving north. From this viewpoint you can look north and south along the reservoir and see the northwest-trending linear valley that was formed along the San Andreas fault zone.

The old causeway across the Crystal Springs Reservoir was offset eight feet to the north during the 1906 San Francisco earthquake, as can be seen in this photo. (Photograph courtesy of Branner Library, Stanford University)

●*San Andreas Dam*

To reach the San Andreas Dam from the causeway, continue east on Highway 92, then turn north on I-280. Go north 6.5 miles on I-280 then take the Millbrae Avenue exit. Do not turn on Millbrae Avenue, but continue north to Hillcrest Blvd. Go west on Hillcrest Blvd. under I-280 to the trailhead for the Sawyer Camp Trail. Follow the trail to the dam. This is a hike of about 1.0 mile round trip and will take about one hour. Allow another hour and a half if you wish to continue south from the dam on the Sawyer Camp Trail to see some other features along the trace of the 1906 fault.

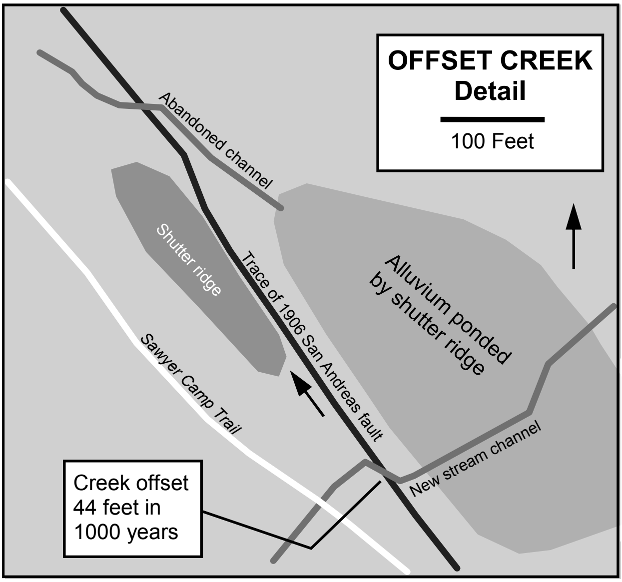


From the San Andreas Dam to the Crystal Springs Reservoir, the Sawyer Camp Trail closely follows the trace of the 1906 offset of the San Andreas fault. During the earthquake, the fault cut through the embankment of the San Andreas Dam. Fences, rows of trees, and small creeks were also offset by the fault in this area. The detailed map shows offset of one of these creeks.

This view of San Andreas Lake looks northwest from the San Andreas Dam. The trace of the 1906 San Francisco earthquake passes through this point toward the small peninsula, left center.

The San Andreas Dam is an earthfill embankment that is 720 feet long and was built across the valley that was formed by the San Andreas fault zone. The original dam was completed in 1870, and then raised in 1875 and again in 1928. The trace of the 1906 earthquake did not cut the earthfill dam, but cut through the ridge that forms the abutment immediately east of the dam. The dam was displaced nine feet to the northwest during the earthquake, but did not fail. From the east abutment of the dam, the fault goes into San Andreas Lake, and then closely follows along the eastern shore of the lake. It is this lake that gave its name to the San Andreas fault. In 1991 a monument was placed at the spot where the fault cut through the abutment.

<u>Sawyer Camp Trail:</u> If you have time, you may wish to continue south from the dam along the Sawyer Camp Trail for another 1.6 miles. The trail lies immediately west of the trace of the 1906 San Francisco fault. Along the trail there are many topographic features that were formed or altered during the 1906 earthquake and by numerous earlier earthquakes along the fault. About 1.5 miles south of the San Andreas Dam there is a fence and row of cypress trees that were offset nine feet during the 1906 earthquake. A little further south, there is a stream that has been offset about 200 feet during the 1906 earthquake and several earlier earthquakes. This 200-foot offset would represent at least 20 earthquakes of the magnitude of the 1906 earthquake.



A small creek near the Sawyer Camp Trail has been offset 44 feet during the last 1000 years by a recent trace of the San Andreas fault.

At 1.6 miles south of the San Andreas Dam, just before the trail crosses the creek between San Andreas Lake and the Crystal Springs Reservoir, there is a small creek that has been offset 44 feet by the fault. Detailed studies using radiocarbon dating suggest that this offset occurred during the last 1000 years, an average rate of about one-half inch per year. According to this study, a small stream flowed across the San Andreas fault in this area several thousand years ago. The old abandoned stream channel north of the ponded alluvium is a remnant of this early drainage. Following a major earthquake, a shutter ridge formed along the west side of the fault. The shutter ridge blocked the old stream channel and formed a pond on the east side of the fault. Continued movement along the fault carried the shutter ridge north until finally the shutter ridge was out of the way and a new stream channel was cut across the fault. The pond was drained when the new channel was cut. Radioactive dating shows that the pond dried up 1000 years ago. When the new stream channel was formed 1000 years ago, it flowed directly across the fault trace. During the last 1000 years, this channel has been offset 44 feet by several movements of the fault, including the movement in 1906.

Hayward

The Hayward fault is over 60 miles long and trends northwest from San Jose through Fremont, Hayward, Oakland, Berkeley, and Richmond into San Pablo Bay. This is a heavily populated area and many buildings and houses have been built directly on the fault. This trip will begin at Hayward with a nine-mile drive along the fault following Mission Blvd. from Hayward south to Fremont. On this drive you will see some of the topographic features caused by the Hayward fault. You will then return to downtown Hayward to see the Hayward fault at D Street and on Prospect Street.

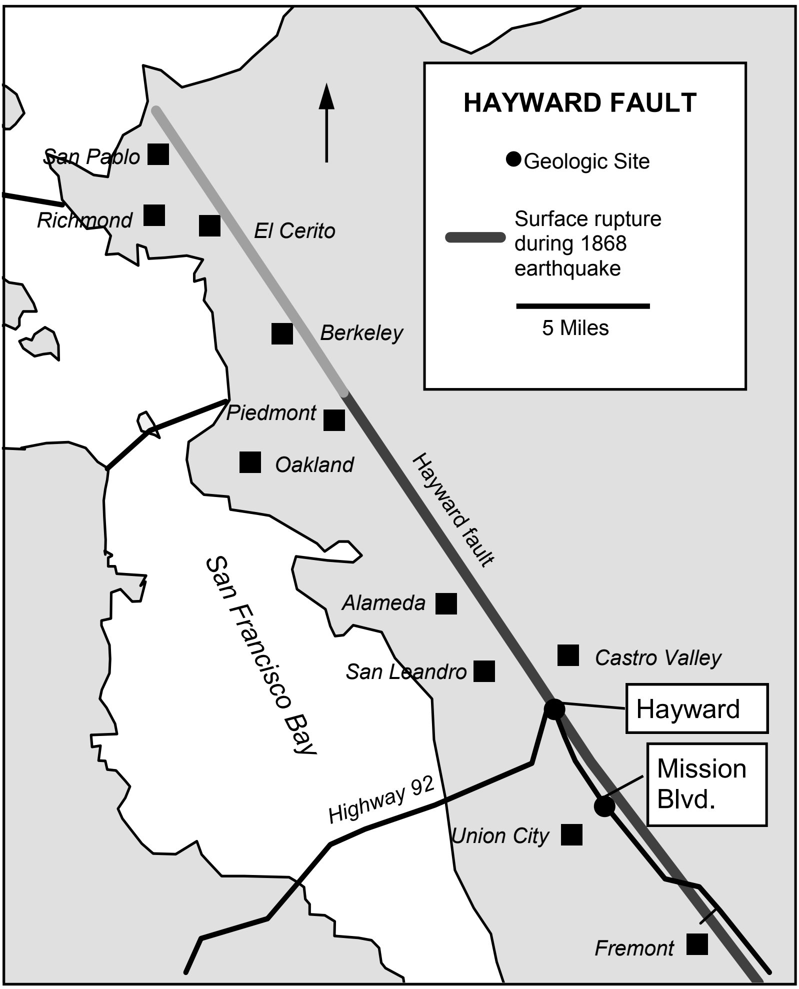
The Hayward fault is one of the most active faults in the entire San Andreas fault system. Some of the movement along the fault has been by slow creep. The land on the west side of the fault is creeping north at a rate of about 0.2”/year relative to the land on the east side of the fault. In places, buildings have been built across the fault and the fault is slowly tearing the buildings apart. The Old Court House in Hayward lies directly over the fault, as does the stadium at the University of California at Berkeley. In five million years the west half of the Old Court House in Hayward will adjoin the east half of the stadium at Berkeley. If you waited in the court house long enough you could see half of the Berkeley-Stanford football game from your chair in the court house.

In addition to the creep along the fault, there have also been several major earthquakes on the Hayward fault, accompanied by offsets of a couple of feet or so. In 1836 there was a M6.8 earthquake north of San Leandro; in 1858 there was a M6.3 earthquake near San Jose; and in 1868 there was a M7.0 earthquake near Hayward.

During the 1868 Hayward Earthquake the earth was ruptured for a distance of 35 miles, from Berkeley to Warm Springs near the Santa Clara line. Maximum reported offset was three feet with a slight downthrow on the southwest side. Nearly every house in the town of Hayward was thrown off its foundation and many buildings were destroyed. On page 162 of this book there is an eyewitness account of the effects of this earthquake on downtown Hayward.

Shortly after the earthquake, a committee of scientific men made an investigation of the fault, but their report was never published. Indications are that the report was suppressed by authorities through fear that its publication would damage the reputation of the city.

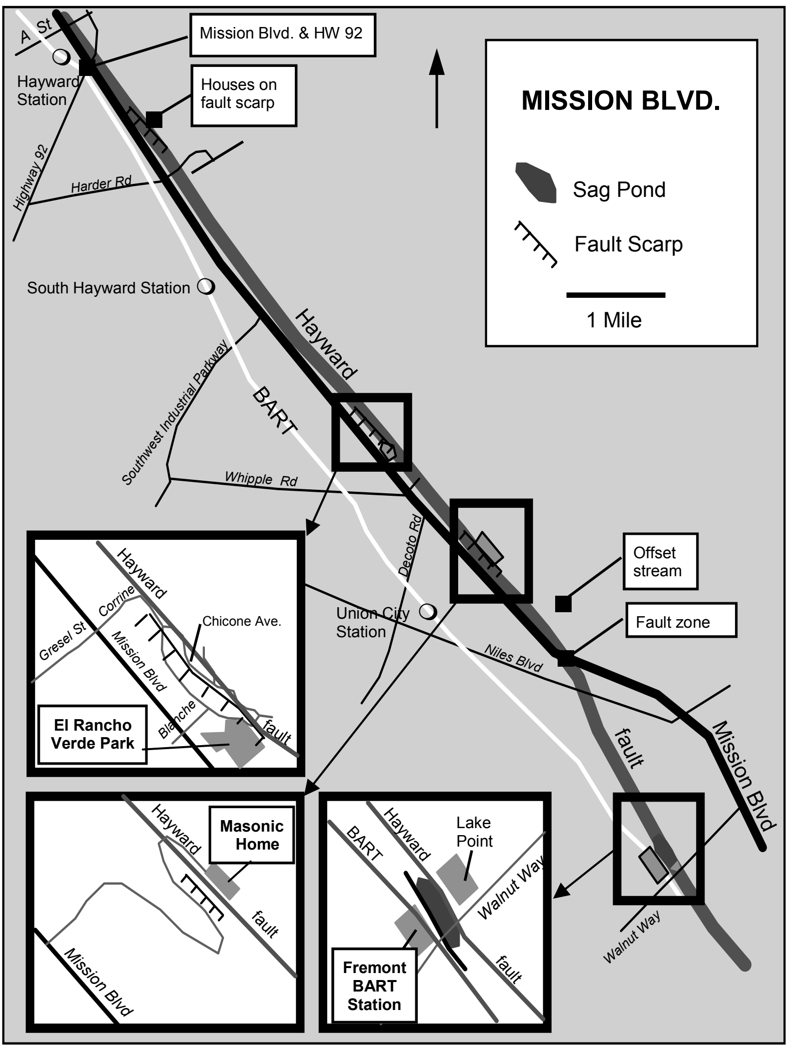
There have been several attempts to predict the probability of future earthquakes along the Hayward fault. In 1988, the U.S. Geological Survey estimated that there was a 20% probability of a M6.5 to M7.0 event in the interval from 1988 to 2018. A 1996 report by the Association of Bay Area Governments ups the chances to one in three that the Bay Area will have a major shock in the next ten years. Some seismologists think that this earthquake could be as large as M7.5.



The Hayward fault, one of the most active faults in the San Andreas fault system, goes through many communities in the East Bay. These communities are at high risk for major damage in the event of a large earthquake on the fault.

●Mission Blvd.

To get to Mission Blvd. from the Crystal Springs Reservoir, continue east on Highway 92 across San Francisco Bay to Hayward, then turn right on Mission Blvd. The drive along Mission Blvd. starts at the intersection of Highway 92 and Mission Blvd. Set your odometer at 0.0 miles at this intersection. From here you will drive south on Mission Blvd. toward Fremont.



0.0 Miles, Mission Blvd. & HW 92: This intersection is in the fault zone of the Hayward fault. The fault zone is about 0.25 miles wide and consists of many fault traces from earlier faults and earthquakes. The fault zone is paved over in this intersection, so don't expect to see any indications of the fault.

1.0 Miles, Houses on Fault Scarp: On your left, note the rows of houses built on the top of a steep cliff. The cliff is a fault scarp. A recent trace of the Hayward fault lies near the base of the scarp.

3.3 Miles, El Rancho Verde Park: Note the houses built on the top of the fault scarp above El Rancho Verde Park. You can take a short loop and drive up the fault scarp and along the top of the scarp. See the detailed map on the opposite page. Bernice Way is on the top of the fault scarp and Trevor Avenue is at the base of the scarp.

5.3 Miles, Masonic Home: The most recently active strand of the Hayward fault lies at the foot of the slope in front of the Masonic Home. There was movement on this strand of the fault in 1868.

6.1 Miles, Offset Stream: As you enter Fremont, look on the hill ahead and to your left. You will see a stream valley that has been offset by the Hayward fault. There are many other similar offset streams along the fault zone.

7.0 Miles, Fault Zone: Mission Blvd. bends to the east. At this point you are crossing the fault zone. The remainder of the trip will be on the northeast side of the fault until you reach the Fremont BART Station.

8.7 Miles, Fremont BART Station: Turn right from Mission Blvd. onto Walnut Way and go 1.0 mile to the Fremont BART Station. The Hayward fault is immediately east of the BART Station. There is a small sag pond in the fault zone between the station and the Lake Point development on Walnut Way.

The next two geologic sites are in downtown Hayward, so retrace your route along Mission Blvd. to Hayward. In Hayward, continue north on Mission Blvd. across Highway 92, and then go one block to D Street. Park at Mission Blvd. and D Street.

●***D Street***

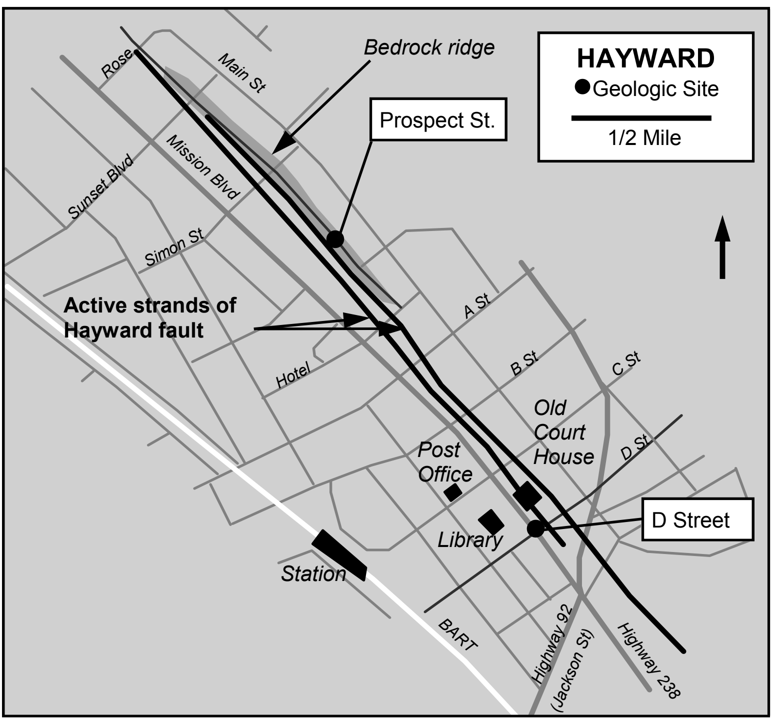
The Hayward fault goes directly through downtown Hayward, and there are at least two active traces of the Hayward fault between Mission Blvd. and Main Street. The effects of these faults can be seen on nearly every cross street from D Street to Sunset Blvd. The fault effects include offset curbs, sidewalks, foundations, and cracks in the street.

One of the best places to see fault offset is on D Street between Mission Blvd. and Main Street. Take a walk along this section of D Street and look for offset curbs and other fault features. The curb on D Street has been offset by creep along one of the strands of the Hayward fault. Precise surveys on this curb show that the southwest side of the fault is moving north at an average rate of about 0.1"/year. Other strands of the Hayward fault are also active, so that the total displacement along all strands of the fault in Hayward is about 0.2"/year. Creep along the Hayward fault took a siesta after the 1989 Loma Prieta earthquake, but recent indications are that the creep has resumed.

This curb on D Street in downtown Hayward has been offset by creep along an active segment of the Hayward fault. Precise measurements over a twenty-year period show that the curb is being offset at an average rate of 0.1”/year.

●*Prospect Street*

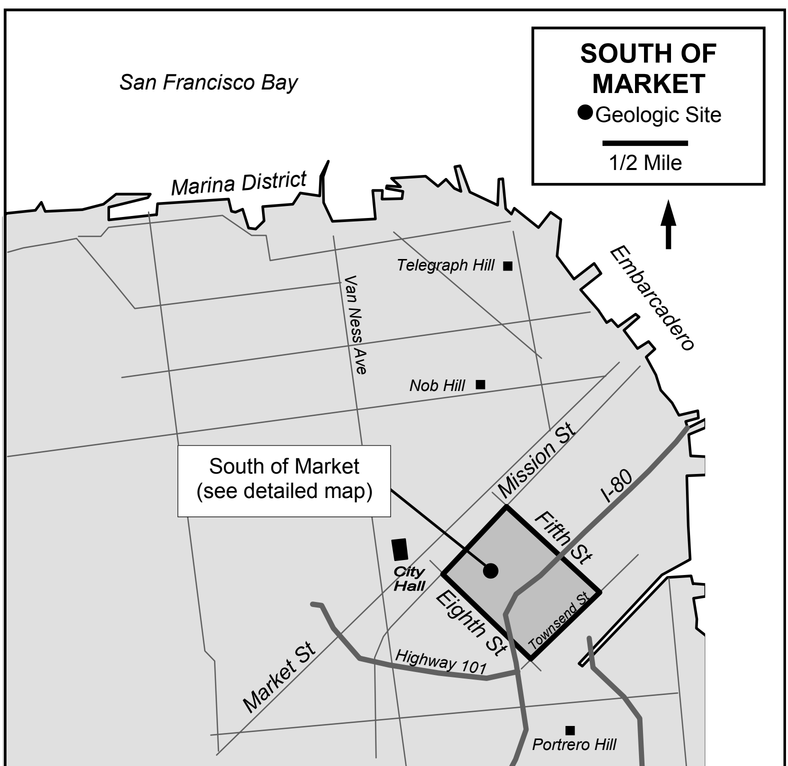
Another remarkable fault feature in downtown Hayward is a well-defined bedrock ridge that has been uplifted along the Hayward fault. Prospect Street is situated on the top of this ridge and the steep slope between Prospect Street and Mission Blvd. is a fault scarp. To get to Prospect Street from D Street, go north on Mission Blvd. 0.4 miles to Hotel Street. Turn right on Hotel Street and go one block. Turn left on Prospect Street. As you drive north on Prospect Street note the steep drop-off to the east and to the west. Turn left at Rose Street and go back to Mission Blvd. Turn left on Mission Blvd. toward downtown Hayward. As you drive south on Mission Blvd. you will get good views of the very steep fault scarp between Simon and Hotel Streets. The top of the ridge on Prospect Street is about 60 feet higher than the base of the scarp on Mission Blvd.

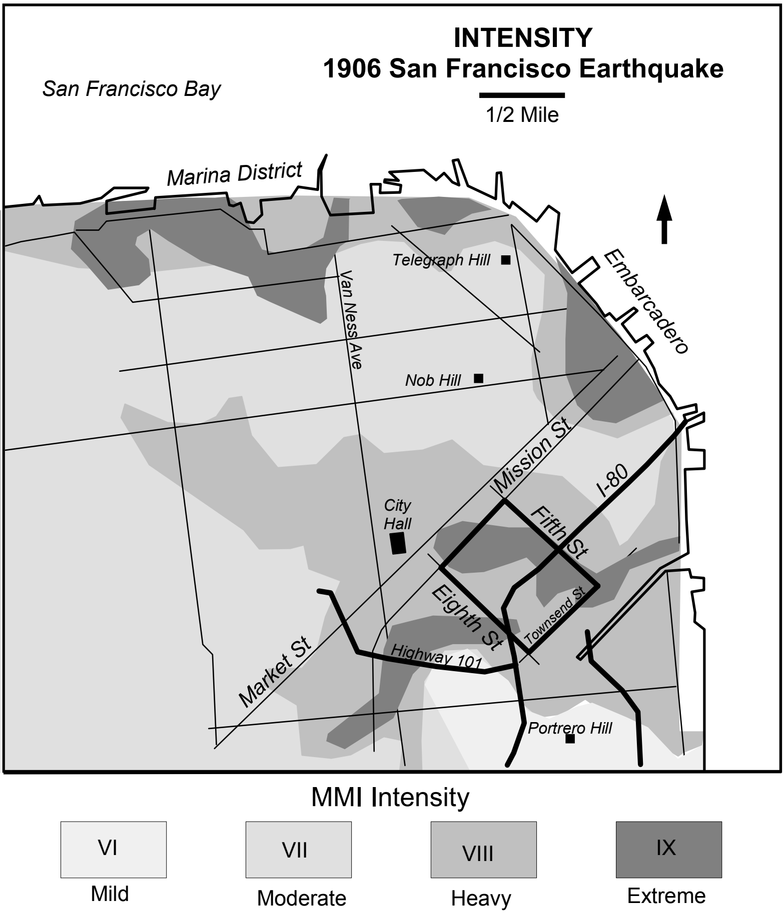


The Hayward fault goes directly through downtown Hayward. Structures on the west side of the fault in Hayward, including the library and post office, are moving north at about 0.2"/ year relative to structures on the east side of the fault. Scarps occur along the fault in many places. The bedrock ridge along Prospect Street is along the top of one of these scarps.

South of Market

Although the South of Market area is not on the San Andreas or Hayward faults, it has been especially susceptible to heavy damage during earthquakes because the area is underlain by thick, unconsolidated water-saturated sediments. Shaking is intensified in these loose sediments during major earthquakes. Modified MercalIi Intensity readings for this area during the Great San Francisco Earthquake of 1906 were IX and X, compared to readings of VII and VIII for most of the other parts of the city. This area was again shaken violently during the Loma Prieta Earthquake of 1989, with intensities of VIII and IX compared to VI to VII for most of the city. During the 1989 Loma Prieta Earthquake, liquefaction also occurred in local areas, causing some structures to settle a foot or more. Earthquake damage has been especially severe between Fifth and Eighth Streets and Mission and Townsend Streets. On the geologic trip to this area, you will walk along Clara Street, where you will see how these buildings are slowly subsiding in these loose sediments.





The intensity of the 1906 San Francisco Earthquake varied considerably throughout San Francisco, depending on whether structures were built on hard rock or on loose unconsolidated sediments. The highest earthquake intensities were recorded in the areas built on loose unconsolidated sediments - the South of Market area, along the Embarcadero, and the Marina District. These areas had the highest earthquake intensities again in the 1989 Loma Prieta Earthquake. The parts of the city built on hard Franciscan rocks felt only mild and moderate shaking during these earthquakes. These areas included Nob Hill and Telegraph Hill, built on hard Alcatraz sandstone, and Portrero Hill, built on a block of hard serpentine in the Hunters Point melange.

●*Clara Street*

To get to Clara Street from Hayward, go north on Jackson Street to Foothill Blvd., continue north on I-580 to I-80, then follow I-80 across the Bay Bridge. In San Francisco, take the Fifth Street exit, go one block past Harrison Street and turn left onto Clara Street.

Most of the buildings along Clara Street are old, but all were built after the 1906 earthquake. The earlier buildings were destroyed in the 1906 fire and earthquake. As you walk along Clara Street, look for the following:

1. Side alleys and side yards that are several feet lower than the street. Main roads and utility lines were periodically raised to grade, whereas the buildings, yards and side alleys continued to subside.

2. Houses where the original entrance is below street grade. In these houses, short steps now lead up several feet to an entrance on the second

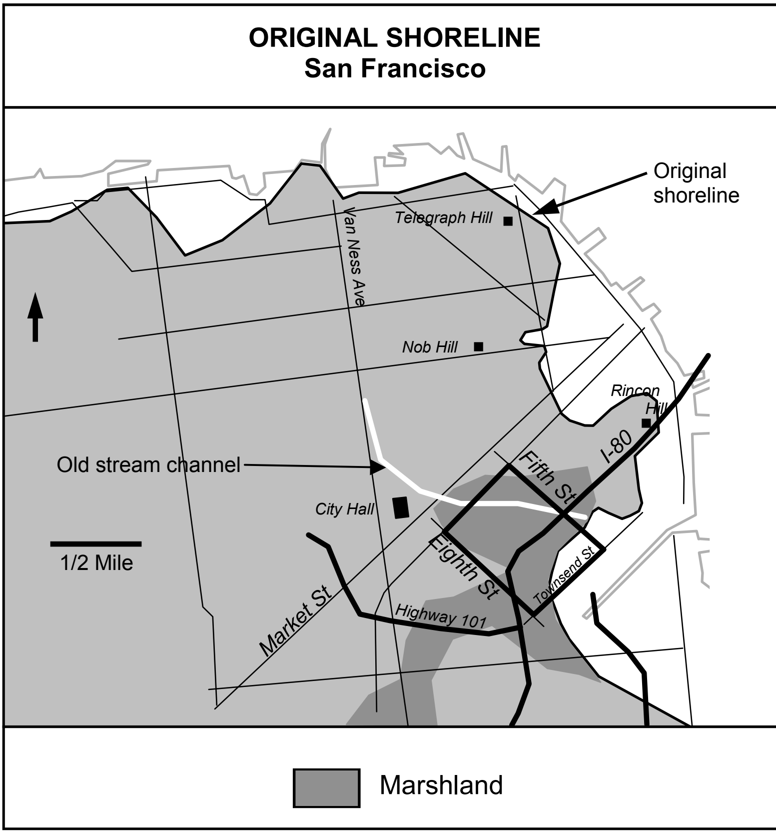
Many of the buildings on Clara Street have subsided several feet because of compaction of the loose unconsolidated sediments that underlie this part of the city. As the buildings subsided, Clara Street has been built up to maintain the original elevation. Thus, the side yards and entrances to the buildings are now several feet below grade.

floor. The first floor is the basement. This architectural problem occurred when the street level was brought up to grade, yet the front entrance to the house remained several feet below grade.

3. Leaning buildings, caused by uneven subsidence.

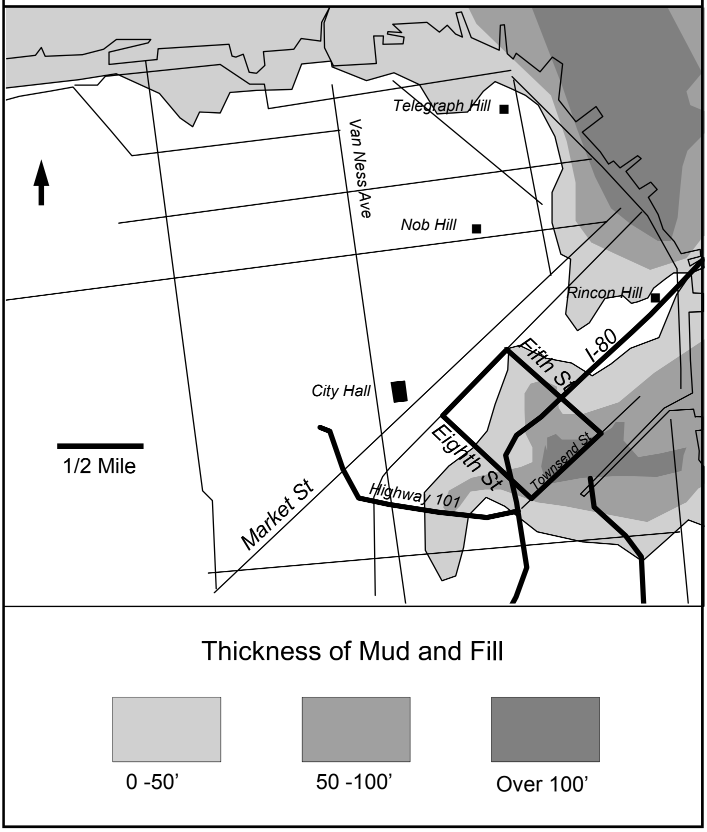
Other good places to see similar subsidence features are Shipley Street from Fifth Street to Sixth Street, and Natoma Street from Fifth Street to Eighth Street.

This building on Clara Street shows the effects of subsidence due to the thick soft sediments that underlie the South of Market area. The building has subsided several feet. The sidewalk and street have been built up to maintain the original grade level of the street. The top of the garage door is at waist level. The entrance door to the house has been repositioned to enter the house at mid-level. The window on the right was once on the second floor of the house.



Prior to the Gold Rush, the shoreline along San Francisco Bay was considerably different from today's shoreline. The original shoreline roughly followed Marina Blvd. and Bay Street, then wrapped around Telegraph Hill and followed Montgomery Street to Market Street. The shoreline then wrapped around Rincon Hill. Much of the area south of Rincon Hill and Market Street was marshland and the marshland extended almost to City Hall. A small stream flowed across the marshland from the Civic Center to Fourth and Bryant Streets where the stream emptied into the bay. The area bounded by Mission, Townsend, Fifth and Eighth Streets is built on this old marshland.

UNCONSOLIDATED MUD AND FILL
San Francisco



During the Gold Rush, San Francisco was expanding rapidly and developers considered the marshland south of Market Street as prime real estate. They filled the marsh with garbage, quarry rubble and dune sand, and proceeded to build. Little did they know, or perhaps care, that they had piled this rubble on top of soft, unconsolidated, water-saturated sediments. In some places, as along Townsend Street, the unconsolidated sediments were over 100-feet thick. Most of the fill in Marina District came later, and was mainly rubble from the 1906 earthquake. This rubble was also dumped on soft, unconsolidated sediments along the shoreline, and buildings were constructed on the fill. The 1989 Loma Prieta earthquake showed that this was not a red-hot idea.