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Geologic Trips
San Francisco and the Bay Area

by Ted Konigsmark

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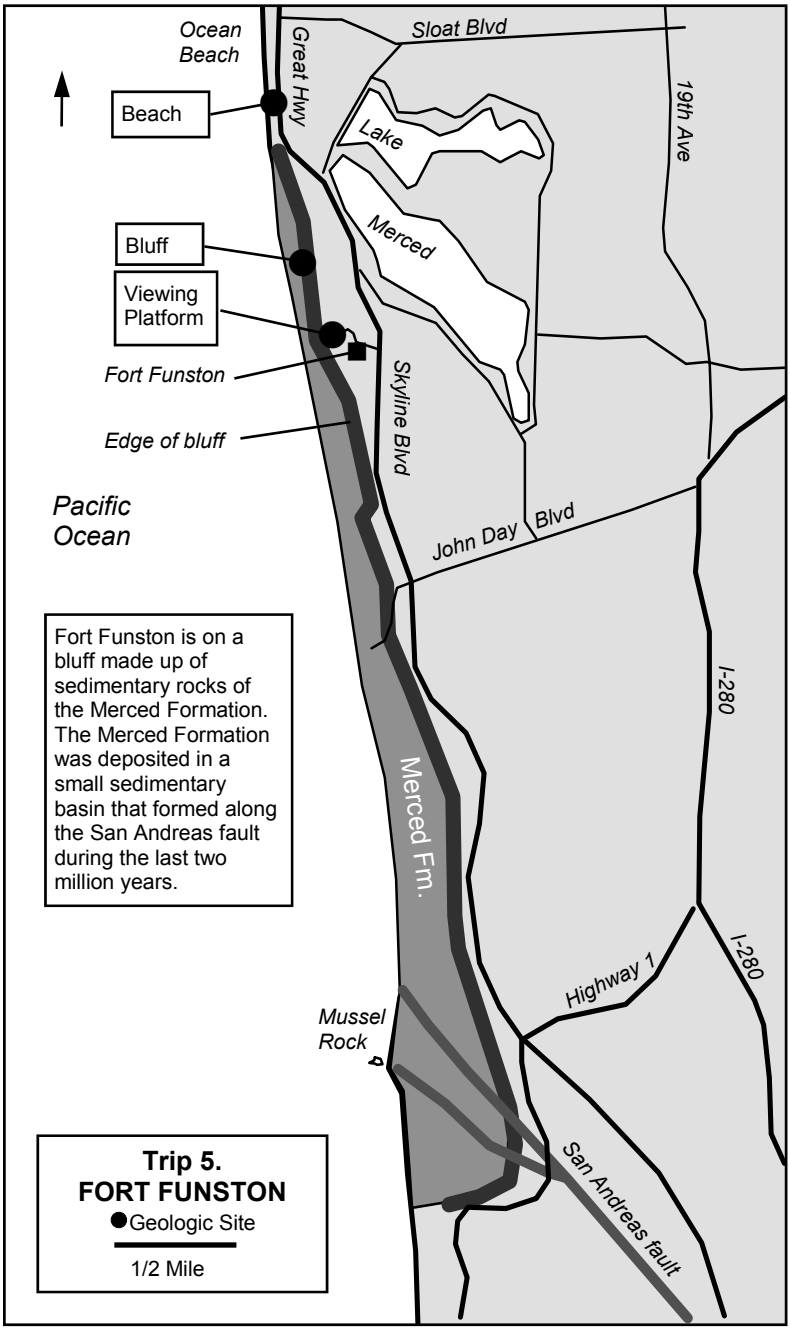

Ocean Beach
Great Hwy
Sloat Blvd
19th Ave
Beach
Lake
Merced
Bluff
Viewing Platform
Fort Funston
Edge of bluff
Skyline Blvd
Pacific Ocean
John Day Blvd
Fort Funston is on a bluff made up of sedimentary rocks of the Merced Formation. The Merced Formation was deposited in a small sedimentary basin that formed along the San Andreas fault during the last two million years.
I-280
Merced Fm.
Highway 1
I-280
Mussel Rock
San Andreas fault
Trip 5.
FORT FUNSTON
Geologic Site
1/2 Mile

Trip 5.

FORT FUNSTON

Recent and Ancient Beaches and Dunes

The Franciscan rocks are covered by a blanket of younger sedimentary rocks at many places in and around San Francisco. During the trip to Fort Funston you will learn how these sedimentary rocks were formed. The first stop is at Ocean Beach, where you will see how beach sand and sand dunes are presently being deposited along the shoreline. You will then continue to Fort Funston, where you will see how similar sedimentary rocks, called the Merced formation, were deposited in a small basin along the San Andreas fault about half-a-million years ago. The trip to Ocean Beach and Fort Funston should take about half a day.

Sedimentary rocks of the Merced Formation are exposed in the bluff at Fort Funston. These rock layers were deposited about half a million years ago along a shoreline very similar to the present shoreline along Ocean Beach. The upper part of the path from the viewing platform (top center, with flag) to the beach can be seen at the upper right, marked by the fence.

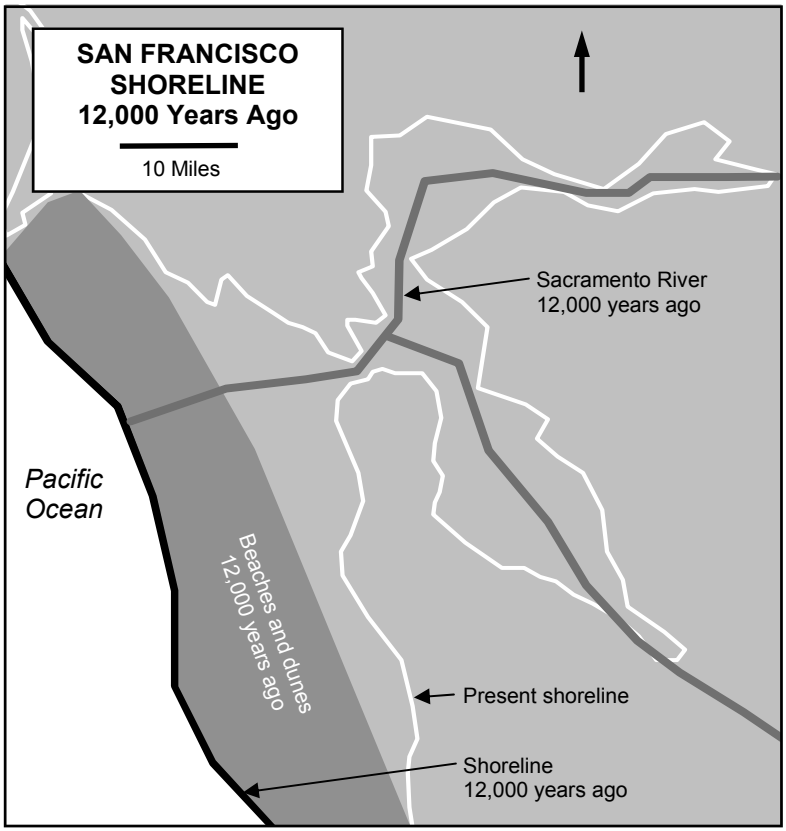
Ocean Beach

Ocean Beach lies to your right as you drive along the Great Highway the four miles from Cliff House to Fort Funston. On your left, as you pass Golden Gate Park, you will see two large windmills. These windmills were originally used to pump water to a reservoir in Golden Gate Park for use in the park. The Murphy Windmill was built in 1905, and the Dutch Windmill was build somewhat later. The Dutch Windmill was restored in 1981, and is worth a visit. At the turn of the century, these windmills were at the leading edge of a large area of sand dunes that reached east from Ocean Beach through Golden Gate Park and covered much of northern San Francisco. It is hard to see these dunes now, since they are covered by buildings, roads and landscaping, but you may catch a glimpse of the dunes here and there in places like Golden Gate Park and the San Francisco Zoo.

The windmills were powered by the same prevailing westerly winds that carried the sand from Ocean Beach to downtown San Francisco. It is obvious that a huge quantity of sand was required to form Ocean Beach and these sand dunes. Yet there are no rivers currently supplying sand to Ocean Beach. So where did all of this sand come from and how did it get here?

The sand at Ocean Beach and in the sand dunes of northern San Francisco is really a relic, a gift from the past. These sands were deposited along the western shoreline of the San Francisco peninsula during the Wisconsin glacial period, from 10,000 to 15,000 years ago, when sea level was low and the Sacramento River flowed through the Golden Gate. If you had visited Ocean Beach at that time, you would not have seen this shoreline. Sea level was about 200 feet lower than now, there was no water in San Francisco Bay, and the shoreline was about 20 miles west of Ocean Beach. Large quantities of sand were carried from the Sierras by the Sacramento River and deposited to form beaches and dunes along this shoreline. As the glaciers melted, sea level rose and the shoreline, beach sand, and sand dunes moved eastward with the rise of sea level. Ocean Beach represents the present location of this shoreline. With falling sea level, the shoreline will retreat to the west, and with rising sea level, the shoreline will continue to move eastward.

In places, some of the old beach sands and sand dunes were overtaken and covered by the advancing sea. These areas now can be found as patches of sand several miles offshore. Potato Patch Shoal off the Golden Gate is an area of old sand dunes now covered by the ocean.



GLACIAL CHRONOLOGY				
Epoch	Glaciation	Interglacial	Years before present	Sea level
Holocene			0 - 10,000	High
Pleistocene	Wisconsin		10,000 - 15,000	Low
		Sangamon	15,000 - 130,000	High
	Illinoisian		130,000 - 270,000	Low
		Yarmouth	270,000 - 350,000	High
	Kansan		350,000 - 600,000	Low
		Afton	600,000 - 1,000,000	High
	Nebraskan		1,000,000 - 2,000,000	Low

San Francisco Bay has been filled and emptied of sea water many times during the Pleistocene as sea level rose and fell in response to glacial advances and retreats.

●*Beach*

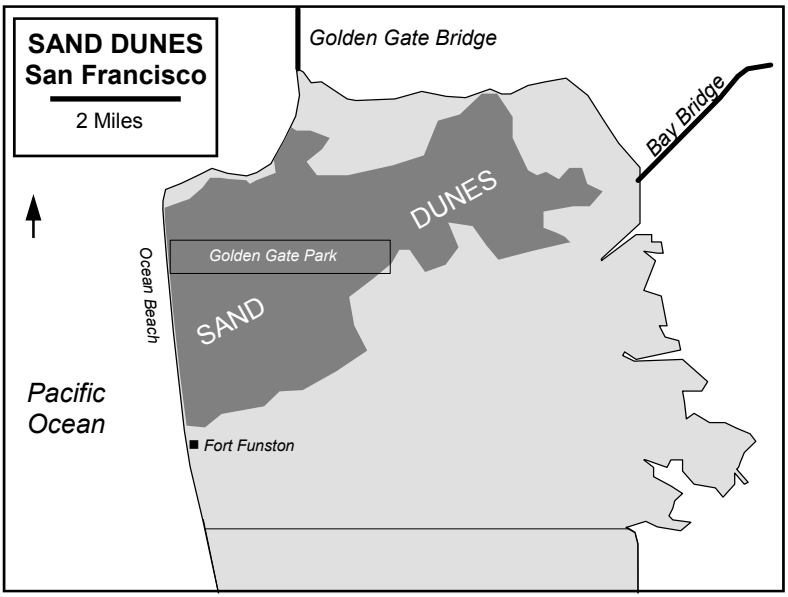
Stop anywhere along Ocean Beach and walk down to the beach. If you take a handful of sand and look at it with a magnifying glass, you'll see many different types of grains. These grains were formed from the different types of rocks that have been subjected to weathering and erosion in the drainage of the Sacramento River. Most of the clear grains and white grains are quartz and feldspar. Quartz and feldspar are two of the main constituents of granite, and these grains were derived from the weathering of granite in the Sierras. Quartz is extremely hard and feldspar is fairly hard. The quartz and feldspar grains easily survived the long and arduous trip from the Sierras down the Sacramento River, through the Golden Gate and into the Pacific. Most of the sand grains are rounded. The original grains were angular, but became rounded by constantly rubbing against each other as they were transported down the river and moved along the shoreline in the surf zone.

Note that most of the sand grains along the present beach are about the same size. If you look at the sand in several places, starting low in the surf zone then going higher up the beach, you will find that the grains in the lower part of the surf zone are smaller that those in the upper part. The grains have been neatly sorted by the wave action in the surf zone.

The wave action in the surf zone concentrates most of the sand in a narrow zone along the shoreline. Further offshore, in deeper water, the sea floor may be muddy, may have rock outcrops, or there may be patches of sand left over from earlier beaches or dunes that are now submerged. The sand along the shoreline is kept there by the wave action and by currents that carry the sand along the shoreline. High waves in winter will remove some of the sand from the beach and deposit it further offshore. Low summer waves will return the sand to the beaches, thus restoring the beaches. Storms will tear into one part of a beach and build up another part, and then redistribute the sand in another way in another storm. Sandy beaches are mother nature's sand box, and a tremendous amount of wave energy is invested in moving this sand from one place to another, and back again.

On the bluff at Fort Funston you will see some layers of sandstone that represent beaches and dunes that were formed several hundred thousand years ago. These ancient beach and dune sandstones were formed by depositional processes similar to those now in action at Ocean Beach.

These sand dunes occur at the south end of Ocean Beach near the San Francisco Zoo. At the turn of the century similar sand dunes covered most of Golden Gate Park as well as much of northern San Francisco.



The sand dunes of northern San Francisco were formed from sand that was blown inland from Ocean Beach by the prevailing westerly winds. The sand was brought to Ocean Beach by the Sacramento River when it flowed through the Golden Gate at times of low sea level during Pleistocene glacial episodes.

Fort Funston

To get to Fort Funston from Ocean Beach, continue south on the Great Highway to where it intersects Skyline Blvd. The entrance to Fort Funston is on Skyline Blvd. 0.7 miles south of this intersection. Fort Funston provided defense to San Francisco during World War I and World War II and in the cold war thereafter. Fort Funston is now part of the Golden National Recreation Area. The fort has excellent coastal views, short hiking trails, and is a favorite site for hang gliders. There is also a visitor center. For information, phone 417-556-8371.

●*Viewing Platform*

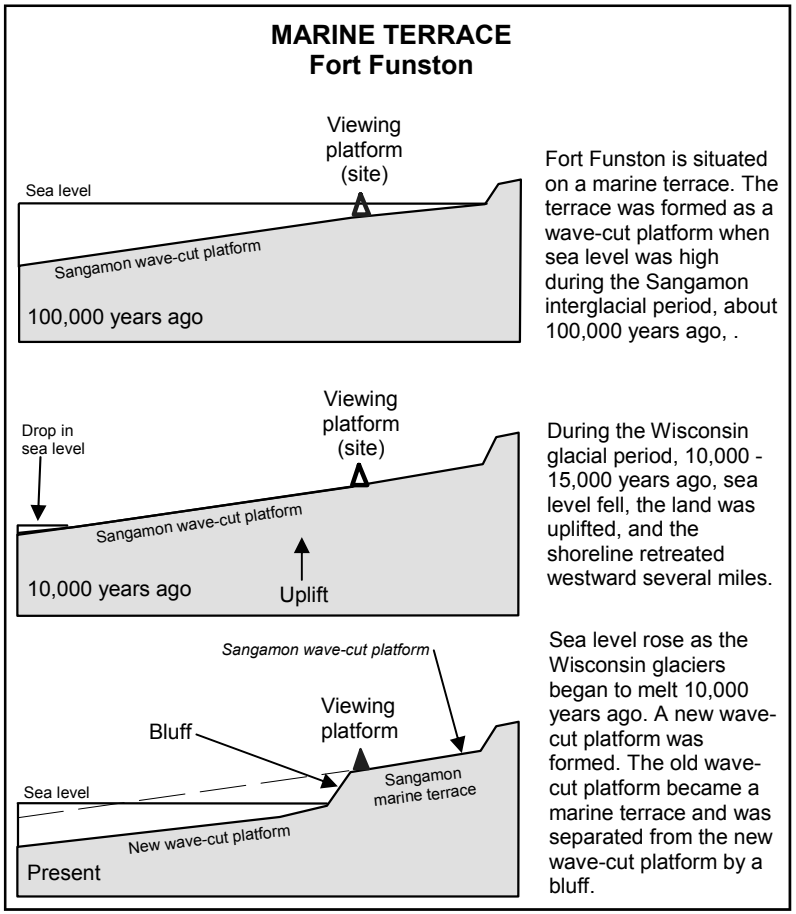
Park near the Viewing Platform at Fort Funston, and walk on out to the platform. The Viewing Platform lies at the edge of a steep bluff that faces the Pacific. Ocean breezes collide with the bluff, and in their effort to get over the bluff provide support for hang gliders and birds that effortlessly glide along the upwelling currents. Although the bluff may appear to have been here forever, in geologic terms it has been here only an instant. From the Viewing Platform we will consider how the bluff was formed.

The flat surface upon which the Viewing Platform, parking area, and the remainder of Fort Funston are situated is called a *marine terrace*. This terrace, which is now 150 feet above sea level, was cut by wave action during the Sangamon interglacial period, about 100,000 years ago, when sea level was higher than it is now.

As the climate became cooler during the Wisconsin glacial period, glaciers formed, sea level fell, and the shoreline retreated to the west of Fort Funston. The land along the shoreline was also uplifted slowly, a few tens of feet. By the end of the Wisconsin, about 10,000 years ago, the shoreline had retreated westward ten miles or more. As you stand on the Viewing Platform, imagine that there is no bluff and that the terrace you are standing on extended so far to the west that you cannot even see the Pacific Ocean.

As the Wisconsin glaciers began to melt during the last 10,000 years, sea level rose and the ocean began cutting a new wave-cut platform into the rocks along the shoreline at a lower level. The old wave-cut platform was separated from the new platform by a sea cliff, or bluff. As the new wave-cut platform cut further east, the bluff retreated east an inch or so a year until it arrived at its present position. The bluff is still being cut eastward, and in a few tens of years will claim the Viewing Platform and then Highway 1 sometime thereafter. The remaining part of the old wave-cut platform is now preserved as a marine terrace.

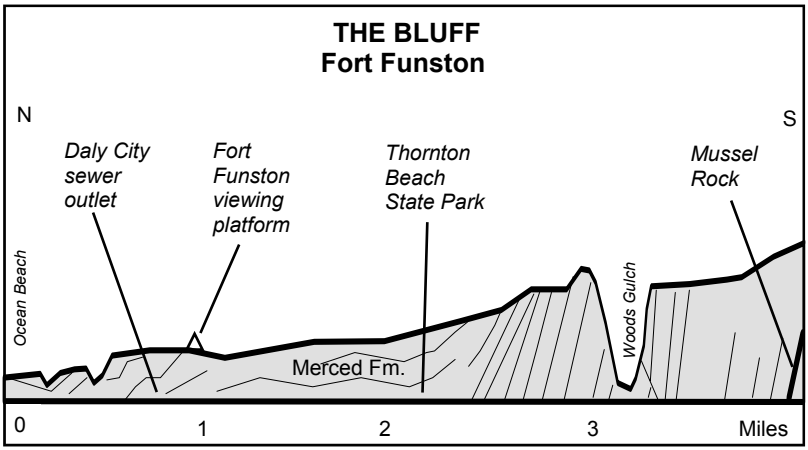
Marine terraces are common along the California coast north and south of San Francisco. The terraces were preserved because most of the California coastline has been slowly uplifted several hundred feet over the last million years. In general, the highest terraces are the oldest and were cut during the early interglacial stages, and the lowest terraces were cut during the late interglacial stages. Because there have been many fluctuations of sea level during the glacial period, and because the amount of uplift has varied along the coast, it is difficult to correlate specific terraces over long distances. There are no terraces between Fort Funston through the Marin Headlands. This area subsided during the Pleistocene. Indeed, there would be no San Francisco Bay if this area had been uplifted as were the areas to the north and south.



●*Bluff*

The bluff at Fort Funston is made up of sedimentary rocks that were deposited in a small sedimentary basin that had formed along the San Andreas fault during Pleistocene time. These sediments, called the Merced Formation, are exposed as distinct layers that can be seen along the bluff from Lake Merced southward to the San Andreas fault near Mussel Rock, a distance of about four miles. Some of the layers of sedimentary rocks are nearly horizontal and some are tilted to the north, indicating that the rocks have been uplifted and folded in the few hundred thousand years since they were deposited.

To get a good look at the rocks in the Merced Formation, follow the path south of the Viewing Platform down the bluff to the beach. Continue north along the beach to the Daly City sewer outlet 500 feet north of the Viewing Platform. Note that the rocks that form the bluff occur in layers from several inches to several feet thick. These layers are all sedimentary rocks, and include gravel, sandstone, siltstone and mudstone. The gravel has large pea-sized grains. The sandstone is mostly white and light gray and is made up of smaller sand-sized grains that are easily visible. The grains in the siltstone are too small to see without a magnifying glass, but the siltstone feels gritty. The claystone feels smooth and is medium-to- dark gray in color.



This cross section shows the rock layers in the Merced Formation that are exposed along the bluff from Fort Funston to Mussel Rock. The beds have been gently folded and generally dip to the north. The vertical scale is highly exaggerated.

The Merced Formation near the Daly City sewer outlet (left) consists of nearly-horizontal layers of gravel, sandstone, siltstone and mudstone. The gravel and sandstone were deposited mainly along ancient rivers and beaches, whereas the siltstone and mudstone were deposited in ancient bays or in deeper water.

Each layer of rock in the bluff represents sediments that were deposited during a specific interval of geologic time. Most of the siltstone and fine-grained sandstone was deposited offshore as *marine sediments* in water depths of 30 to 300 feet. As these fine-grained sediments were being deposited offshore, coarser sand and gravel were being deposited along the shoreline. Further inland, *nonmarine sediments* were being deposited as sand dunes, as sand or mud along rivers, and as mud in swamps and coastal embayments.

Since the layers in the bluff alternate between marine, shoreline and nonmarine sediments, this shows that the shoreline of the Merced sea was constantly moving landward and seaward during deposition of the sediments. The movement of the shoreline depended on how fast the basin was subsiding, on the rate at which sediments were supplied to the basin, and on changes in sea level caused by the glacial and interglacial episodes of the Pleistocene. Landward movement of the shoreline is referred to as *transgression* and seaward movement as *regression*. During a transgression, layers of marine sediments extend inland. During a regression, layers of nonmarine sediments extend seaward. Dozens of transgressions and regressions of the sea are recorded in the sedimentary layers along the bluff.

The layer of silt and clay above the Daly City sewer outlet was deposited in a restricted bay landward of the shoreline. Look for shells of fossil mollusks in the clay. Directly above the silt and clay is a thin layer of coarse sand and pebbles. This sandstone marks an eastward transgression of the shoreline over the earlier bay sediments. The fine-grained sand above the coarse sand was deposited in shallow ocean water, indicating that the shoreline had transgressed even further east. The sandstone at the top of this bed was deposited as sand dunes during a westward regression of the shoreline.

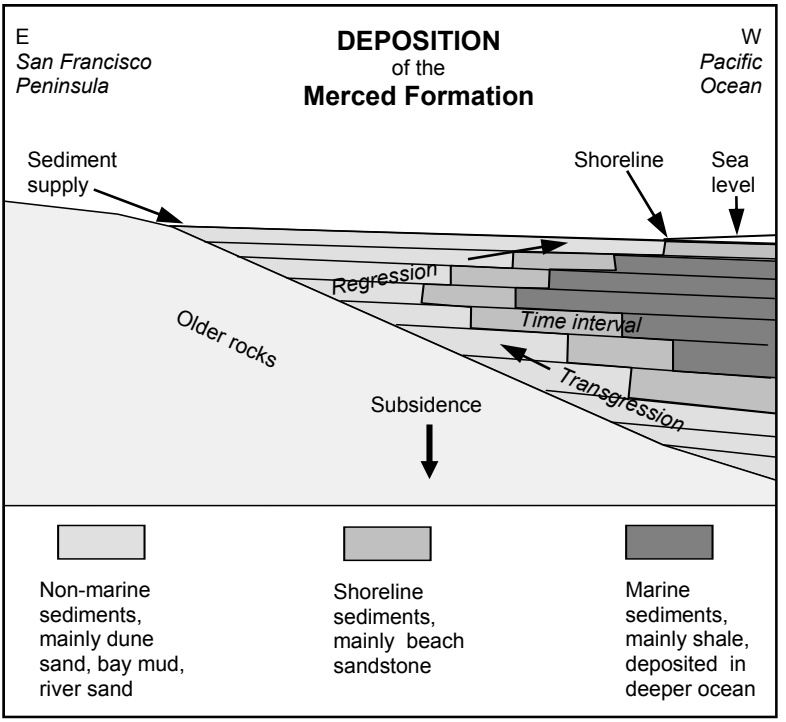
Several other fossils can be found in these sediments in addition to the fossil mollusks. Some of the sediments have sinuous tubes filled with light sand. These were caused by sediment-eating organisms similar to those found along the present shoreline. There are also shells, molds, and siphon tracks of clams and other burrowing bivalves. Rarely, footprints of hoofed mammals have been found in the nonmarine sediments.

This photo shows a layer of light gray mud in the Merced Formation near the Daly City sewer outlet. The small curved white flakes are pieces of fossil sea shells that were deposited in a bay in this area about 500,000 years ago.

In the middle of the bluff below the Viewing Platform there is a layer of white volcanic ash about one foot thick. This ash bed dips north and can be found in the bluff just above the Daly City sewer outlet. This ash layer was deposited in the Merced Formation following a violent eruption of Lassen Peak 400,000 years ago. The ash layer was deposited while this part of the Merced Formation was above sea level. From the amount of ash, it is thought that the eruption was at least as large as the one responsible for the Mazama ash from Crater Lake, Oregon.

The sedimentary layers of the Merced Formation that are exposed along the bluff are mostly tilted to the north. These sediments were horizontal when deposited. The oldest sediments, which are located at the base of the Merced Formation near Mussel Rock, were once buried at a depth of one mile. Following deposition, the sediments were uplifted. The sediments near Mussel Rock have been uplifted about one mile, and tilted to the north. The sediments near Lake Merced have been uplifted only a few hundred feet. The part of the Merced Formation that was uplifted above sea level was subjected to erosion. Because of the tilting, the exposed rocks become progressively older to the south and provide a cross section of the many different layers of rocks that make up the Merced Formation.

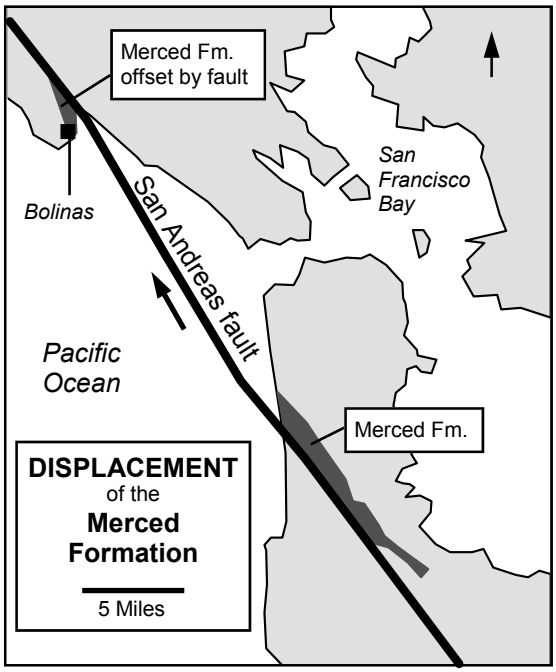
By analysis of these rock layers, we know that the sedimentary rocks of the Merced Formation were deposited during Pleistocene time in a small sedimentary basin that had formed in a low spot along the San Andreas fault. Sediments accumulated in this basin because the floor of the basin was continually subsiding, probably because of movement along the San Andreas fault. The sediments were brought to the basin by the Sacramento River system before San Francisco Bay was formed. Eventually, a thickness of about one mile of sediments accumulated in this basin. While the Merced Formation was being deposited, the San Andreas fault was still active. The fault cut the basin into two pieces and moved the pieces apart. The sediments at Fort Funston represent the part of the Merced Formation that was deposited on the east side of the San Andreas fault. The part of the Merced Formation that was deposited on the west side of the fault has been carried slowly northward over the last million years. The town of Bolinas is built on these rocks, and the rocks and the town are still moving north away from Fort Funston.



This diagrammatic cross section shows how the Merced Formation was deposited. The rocks consist of many alternating layers of sandstone and shale. During the entire depositional period, the land along the shore was slowly subsiding and sediments were being supplied to the subsiding basin from land areas to the east. Each layer (bed) in the Merced Formation represents sediments deposited during a specific interval of time, and consists of nonmarine sediments to the east, marine sediments to the west, and shoreline sediments inbetween. When sea level rose, the shoreline *transgressed* landward and a layer of deeper-water sediments was deposited on top of the underlying sediments. When sea level fell, the shoreline *regressed* seaward, and shallower-water sediments were deposited over the underlying sediments. The many beds that make up the Merced Formation record the many transgressions and regressions of the shoreline.

Sedimentary Basins in the Coast Ranges

The Merced Formation was deposited in one of the smallest and youngest of many sedimentary basins that were formed in the Coast Ranges during late Cretaceous and early Tertiary time. The first of these sedimentary basins began to form as the Franciscan subduction zone became inactive toward the end of Cretaceous time and the Franciscan rocks were uplifted. This uplift continued throughout Tertiary time and is still in progress. As parts of the Coast Ranges were uplifted, other parts subsided below sea level. The uplifted areas were eroded, and the eroded sediments accumulated in the sedimentary basins. The locations of the uplifts and of the basins changed over time, so that some of the uplifted areas later became basins and some of the basins were later uplifted. The basins were mostly filled with sandstone, shale, siltstone and conglomerate. The type of sediment depended on rates of uplift and deposition, the climate, and the types of sediments being supplied to the basins.



After deposition, the Merced Formation was cut by the San Andreas fault and the rocks on the west side of the fault were carried 20 miles to the north. These rocks are now exposed in the cliffs near Bolinas (see Bolinas Bluff, Trip 7).