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Geologic Trips
San Francisco and the Bay Area

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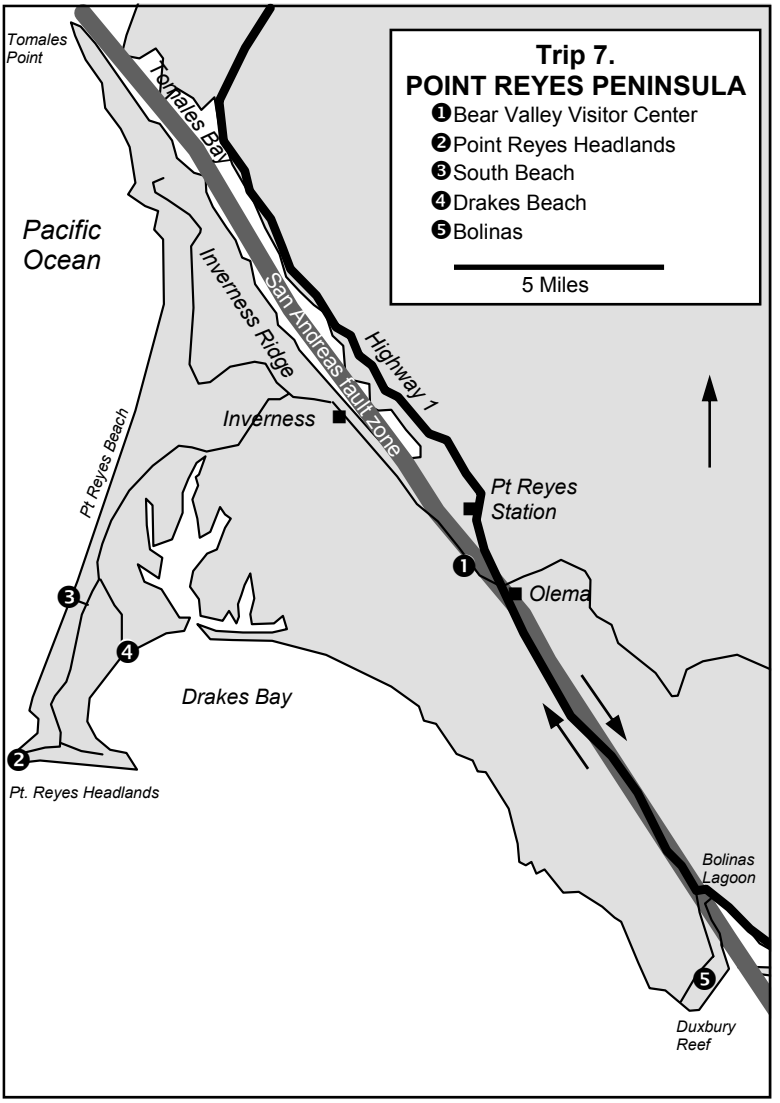


The Point Reyes Peninsula is separated from the mainland by the San Andreas fault. Many of the rocks on the peninsula are from south and central California and have been carried to their present position by movement along the San Andreas fault over the last 25 million years.

Trip 7.
POINT REYES PENINSULA
The Long Trip North

The Point Reyes Peninsula is a piece of southern California that has been carried north by the San Andreas fault several hundred miles during the last 25 million years. As it moved north, the peninsula accumulated rocks from several different places in south and central California and carried these rocks with it, like a tramp steamer adding cargo to its deck. You will see several of these well-traveled rock units during the geologic trip to the Point Reyes Peninsula. It would be best to allow two days for this trip. The Point Reyes Peninsula lies within the Point Reyes National Seashore, and is administered by the National Park Service (Phone 415-663-1092). These are the places you will visit:

Bear Valley Visitor Center: On the Earthquake Trail near the visitor center you will walk along the San Andreas fault zone.

Point Reyes Headlands: At the Point Reyes Headlands you will see the granite that forms the basement rocks that underlie the entire Point Reyes Peninsula. You will also see the Point Reyes Conglomerate that covers the granite and forms the east and west tips of the headlands.

South Beach: This beach has some of the largest waves along the entire California coast. You will see how these waves play a major role in shaping the shoreline of the Point Reyes Peninsula.

Drakes Beach: At Drakes Beach you will see the white cliffs of the Drakes Bay Formation. When Sir Francis Drake was here in 1579 these cliffs reminded him of the white cliffs of Dover.

Bolinas: At the bluff near Bolinas you will see rocks of the Merced Formation that have been carried here from the Fort Funston area by the San Andreas fault. At nearby Agate Beach you will see the Monterey Shale, which covers much of the southern part of the Point Reyes Peninsula. These rocks probably came from the Monterey Bay area.

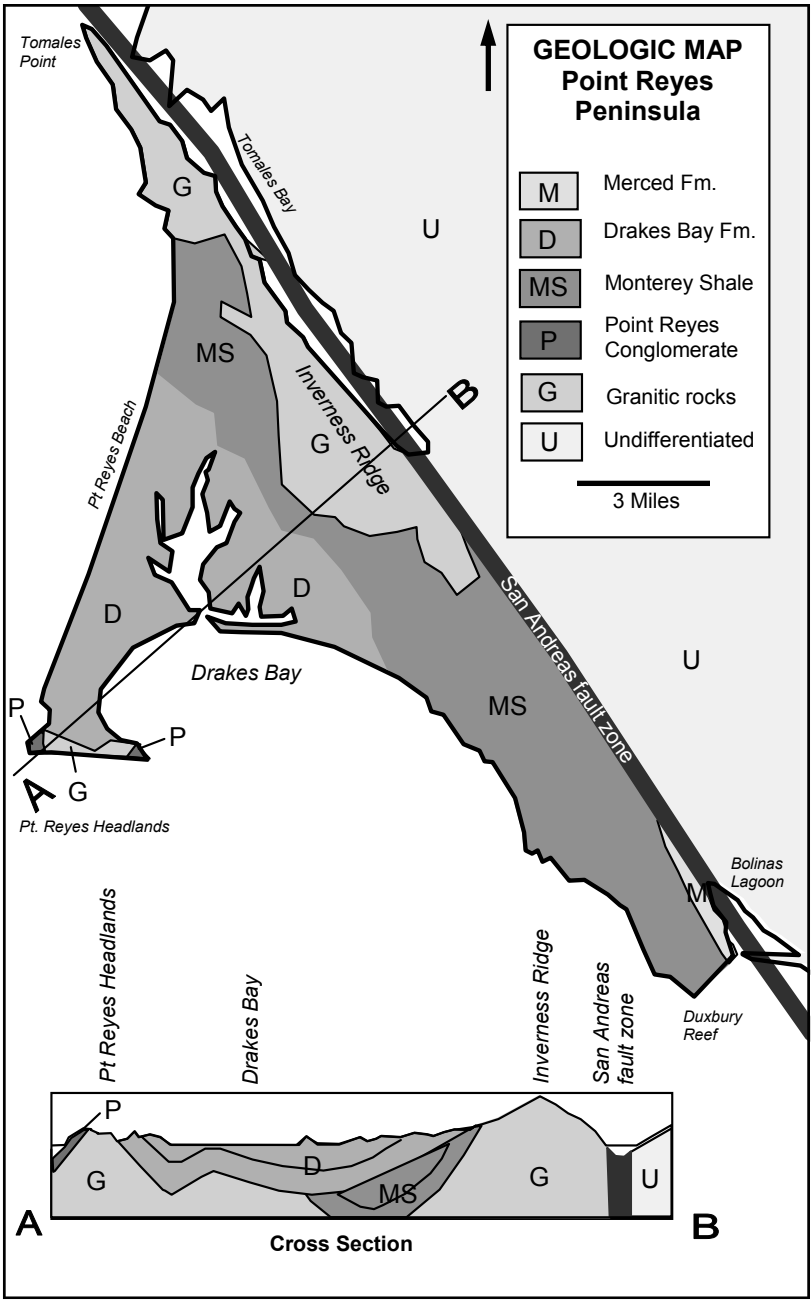
Geologic Map

The geologic map on the opposite page shows the main rock units that make up the Point Reyes Peninsula. The granite underlies the entire peninsula and is exposed along the Inverness Ridge, at Tomales Point, and at the Point Reyes Headlands. The Point Reyes Conglomerate rests on top of the granite, but is found only at the east and west tips of the Point Reyes Headlands. The Monterey Shale covers most of the southern part of the Point Reyes Peninsula and is well exposed along the coastline south of Drakes Bay to Duxbury Reef. The Drakes Bay Formation covers most of the western part of the Peninsula and is exposed along the cliffs of Drakes Bay. Exposures of the Merced Formation are quite limited, but these rocks can be seen on the west side of the Bolinas Lagoon near the town of Bolinas.

The cross section shows the rocks as they appear at depth under the peninsula. The rocks have been uplifted to form two broad anticlines, one along the Point Reyes Headlands and one along the Inverness Ridge. The Monterey Shale was folded, then partly eroded before deposition of the Drakes Bay Formation.

ROCK UNITS
Point Reyes Peninsula

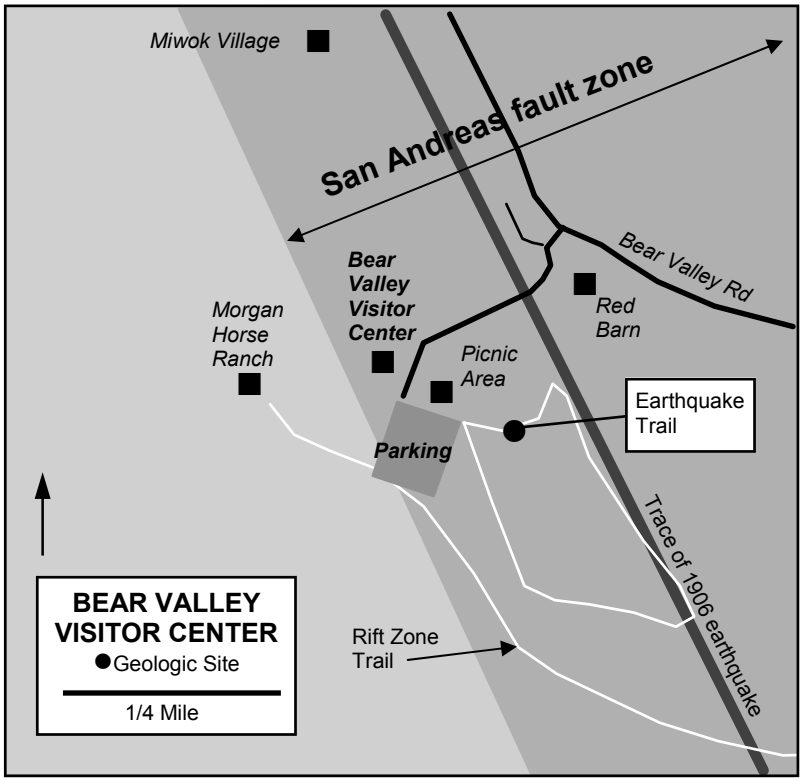
Locality (Geologic Site)	Rock Unit	Age	Description
Bolinas (Bolinas Bluff)	Merced Formation	Pleistocene	Blue-gray siltstone and soft brown sandstone, very soft.
Drakes Beach	Drakes Bay Formation	Pliocene	Cream-colored siltstone and gray-to-yellow mudstone.
Bolinas (Agate Beach)	Monterey Shale	Miocene	Thinly bedded light-gray shale; breaks into sharp fragments.
Point Reyes Headlands (Lighthouse)	Point Reyes Conglomerate	Paleocene	Very hard conglomerate with boulders of chert, volcanic rocks. and granite.
Point Reyes Headlands (Sea Lion Overlook)	Granitic rocks	Cretaceous	Granite, light gray, coarse grained, hard, similar to granite in the Sierra Nevada.


GEOLOGIC MAP
Point Reyes
Peninsula
M Merced Fm.
D Drakes Bay Fm.
MS Monterey Shale
P Point Reyes Conglomerate
G Granitic rocks
U Undifferentiated
3 Miles
Tomales Point
Tomales Bay
Pt Reyes Beach
Inverness Ridge
San Andreas fault zone
Drakes Bay
Pt. Reyes Headlands
Bolinas Lagoon
Duxbury Reef
A
B
Cross Section

Bear Valley Visitor Center

The Bear Valley visitor center lies within the San Andreas fault zone and provides a good opportunity to look at the fault zone in detail. To reach the visitor center, follow Highway 1 to Olema, then turn west on Bear Valley Road and go 0.7 miles to the visitor center.

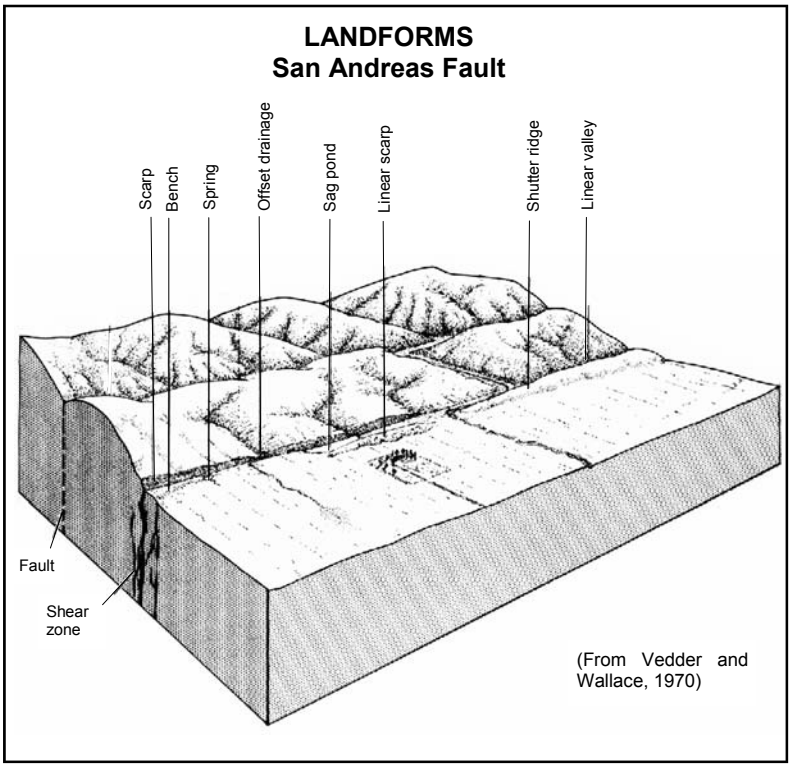
The San Andreas fault zone in this area is from one-half to one-mile wide. The rocks within the fault zone have been shattered and weakened by the faulting so they have been eroded to form the broad topographic low that extends from Bolinas Lagoon to Tomales Bay. The fault zone consists of hundreds of smaller faults along which movement has taken place over millions of years. Although most of this movement has been



The Bear Valley visitor center lies within the San Andreas fault zone and is near the fault trace of the 1906 San Francisco earthquake. You will see many of the fault features that are characteristic of transform faults along the Earthquake Trail and the Rift Zone Trail. Both trails leave from the visitor center.

horizontal, there was also some vertical offset. These numerous faults have formed a messy and jumbled topography. Features to look for within the fault zone include linear ridges, small fault scarps, stream drainage that has been offset or disrupted by the fault movement, sag ponds formed in low areas with no outlet, meadows that were once sag ponds but have been filled in, streams separated by linear ridges that flow in opposite directions, and rows of trees that have been offset.

The Bear Valley visitor center lies near one of the faulted linear ridges in the San Andreas fault zone. You can see many more of the topographic features that are characteristic of the fault zone by a short walk along the Earthquake Trail near the visitor center. Other good places to see the fault are along the Rift Zone Trail and along Highway 1 from Olema to the Bolinas Lagoon, where Highway 1 follows the rift zone.



This diagram shows some of the topographic features that have been formed by the San Andreas fault.

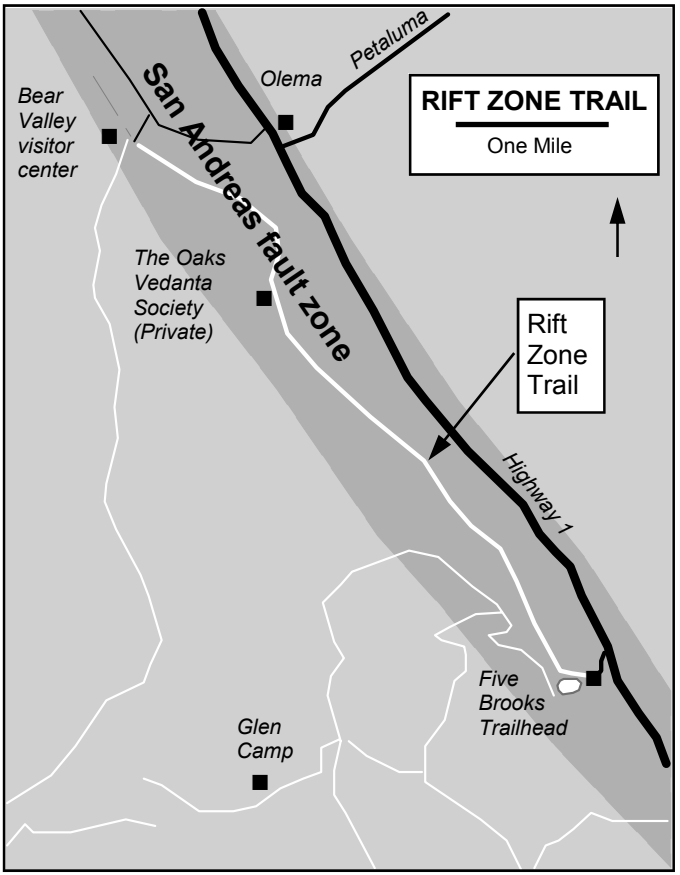
●*Earthquake Trail*

The trailhead for the 0.5-mile Earthquake Trail is east of the visitor center next to the picnic area. This trail has a number of exhibits that explain the San Andreas fault and the Great San Francisco Earthquake of 1906. During this earthquake the ground along the San Andreas fault was fractured for a distance of 270 miles, from San Juan Bautista in the south to Alder Creek in the north, where the fault enters the Pacific. Over this entire distance, fences, roads, railroad tracks, and buildings that crossed the fault trace were offset from a few feet up to 21 feet. In each case, the land on the west side of the fault moved north. The entire Point Reyes Peninsula lurched north about 20 feet relative to the mainland.

The epicenter of the 1906 earthquake was offshore, between Mussel Rock and the Point Reyes Peninsula. The largest recorded offset of 21 feet was on a road near the visitor center. In most places, the roads, buildings, and fences that were offset have been repaired so that evidence of the offset is obscure. However, on the Earthquake Trail you will see where the 1906 fault offset a fence by 17 feet, then cut along a hillside and sliced the corner off the Skinner Barn. The fence has been reconstructed to show the offset. Posts show where the fault cut along the hillside toward the Skinner Barn.

The posts mark the trace of the fault line that was formed during the 1906 San Francisco earthquake. This fault cut through the corner of the old Skinner barn in the center of the photo, but the barn has been rebuilt.

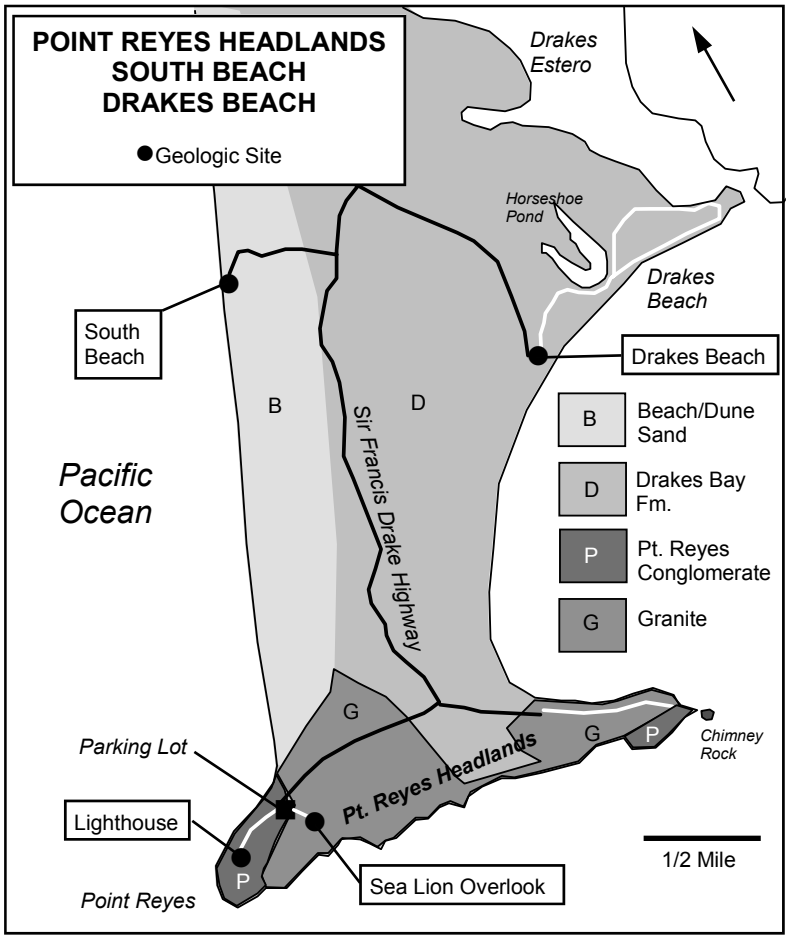
Rift Zone Trail: If you have time to make this 4.4-mile hike, you will be walking along the San Andreas fault zone for the entire distance. If you can arrange it, get dropped off at the Five Brooks trailhead and walk north to the visitor center. While on this trip you will see some of the topography characteristic of the San Andreas fault zone, especially the linear ridges and meadows formed from sag ponds that have been filled in. During the wet season, the trail is often wet and muddy due to the poor and interrupted drainage along the fault zone. Three miles north of the trailhead the trail passes "The Oaks", an old Victorian house that was built in 1869 and survived the 1906 earthquake without serious damage.



The Rift Zone Trail follows the San Andreas fault zone from the Bear Valley visitor center to the Five Brooks trailhead.

Point Reyes Headlands

The Point Reyes Headlands jut out southward into the Pacific from the Point Reyes Peninsula and intercept the full fury of the large Pacific waves. The headlands have survived this onslaught because they are made up of very hard granite and conglomerate. The granite forms the backbone of the headlands and the conglomerate caps the east and west tips of the headlands. You will see the granite at the Sea Lion Overlook and the conglomerate at the Point Reyes Lighthouse. To reach the Point Reyes Headlands from the Bear Valley visitor center, go north on Bear Valley Road. At 1.8 miles it changes to Sir Francis Drake Highway. Continue north on Sir Francis Drake Highway 18.7 miles to the parking area for the Point Reyes Lighthouse.



●*Sea Lion Overlook*

To get to the Sea Lion Overlook, go to the south end of the parking lot for the Point Reyes Lighthouse and take the path about 100 yards to the overlook. The rock that is exposed along the path and at the overlook is granite. The granite is light-colored and is composed of coarse grains that have sharp edges. If you examine a fresh piece of this granite with a magnifying glass, you will see that most of the grains are about the size of a small pea and that there are several types of grains. Most of the grains are feldspar. The feldspar grains are white or milky and have flat surfaces that reflect light. Feldspar is a very common mineral found in many different types of igneous rocks. The next most common mineral is quartz, which appears as light gray translucent grains with curved fractures. The quartz fills the irregular spaces between the other grains, since the quartz was still liquid after the other minerals had crystallized. Hornblende appears as black elongated rods with striations, and makes up about 10% of the rock. Mica appears as small shiny plates, some black and some light colored.

This granite is similar to the granite at Montara Mountain, and is part of the large Salinian block that was transported northward from the southern Sierras by the San Andreas fault. The Salinian block, which includes most of the granitic basement rocks west of the San Andreas fault and north of Santa Cruz, was discussed in more detail at the Devils Slide locality during the trip to the Bay Area faults.

Most of the granite in the Salinian block was formed in Cretaceous time while the Franciscan subduction zone was active. The granite was formed during the subduction process. Rocks carried into the subduction zone were heated to form a silica-rich magma and this magma was then intruded into the overlying rocks. The magma did not reach the surface of the ground, but cooled slowly under a blanket of rocks several miles thick. Because the granite cooled slowly, the large crystals that are characteristic of granite had time to form.

Although the entire Point Reyes Peninsula is underlain by granite, it is covered by younger sedimentary rocks in most places. It is exposed only in the Point Reyes Headlands, along the Inverness Ridge, and at Tomales Point. Most of the granite along the Inverness Ridge is weathered to a depth of about 30 feet and looks like coarse sand where exposed in road cuts.

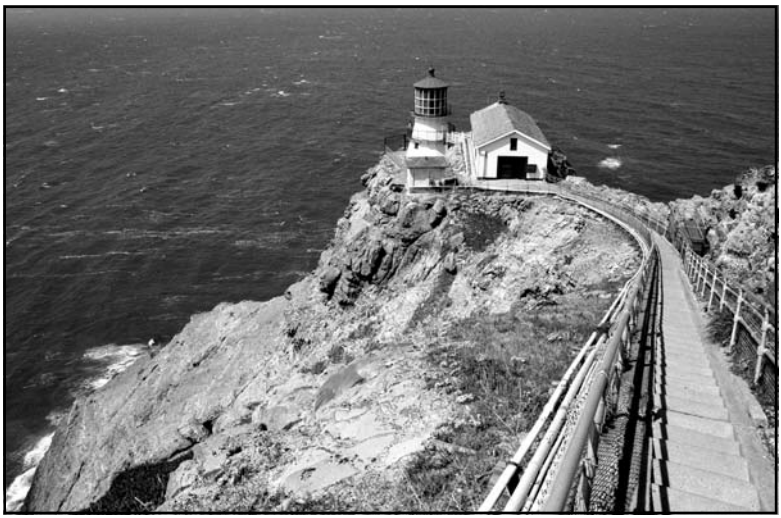
●*Lighthouse*

The conglomerate that caps the east and west tips of the Point Reyes Headlands is of Paleocene age, and is referred to as the *Point Reyes Conglomerate*. This conglomerate is well exposed along the path from the parking area to the Point Reyes Lighthouse and visitor center. The visitor center is an easy 0.5-mile walk from the parking area. From the visitor center you can go down the 308 steps to the lighthouse. The cliffs below the lighthouse are the home to thousands of common murres. You may also see sea lions on the offshore rocks, and gray whales during their migration from January to April. The lighthouse and visitor center are open Thursday through Monday, weather permitting. Expect wind, and dress warmly. For information phone 415-669-1534.

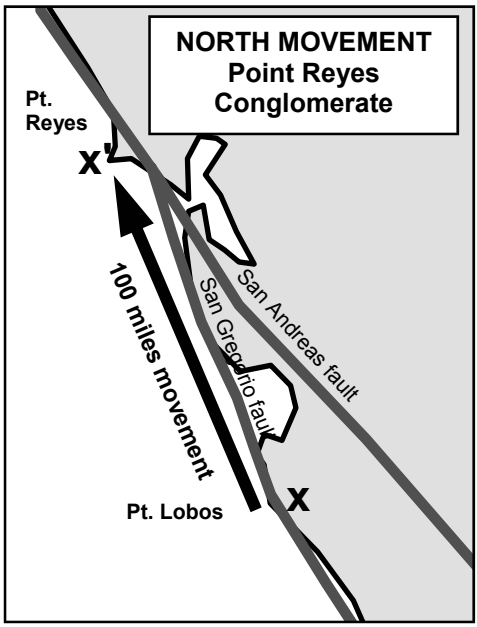
In exposures of the conglomerate near the visitor center you will see that the conglomerate occurs in beds that are from one- to ten-feet thick that are interlayered with beds of sandstone that are several feet thick. The conglomerate is composed of pebbles and boulders of granite, volcanic rocks and chert in a matrix of coarse sand. Some of the boulders are several feet in diameter. The largest boulders are usually granite. The granite boulders were derived from the same granitic rocks that form the basement of the Point Reyes Peninsula. The conglomerate is extremely hard and has resisted weathering and erosion. Indeed, if it were not for the armor plating provided by this conglomerate there would probably be no Point Reyes Headlands.

The Point Reyes Conglomerate is found nowhere else on the Point Reyes Peninsula. However, conglomerate of the same age and with the same types of boulders occurs near the Monterey Peninsula, 100 miles to the south. It is likely that the Point Reyes Conglomerate and the conglomerate near the Monterey Peninsula are the same conglomerate, and that the Point Reyes Conglomerate was carried northward from the Monterey area by the San Gregorio fault, one of the many faults of the San Andreas fault system.

The granite and the Paleocene conglomerate in the Monterey area are on the west side of the San Andreas fault, so the rocks in both of these areas have been moved north a considerable distance by the San Andreas fault. However, the rocks on the west side of the San Gregorio fault got an extra 100-mile shove by the San Gregorio fault, like one slow tramp steamer passing another going in the same direction.



The Point Reyes Lighthouse is built on the Point Reyes Conglomerate. This conglomerate is extremely hard and has resisted erosion so that it now forms the east and west tips of the Point Reyes Headlands.



Conglomerate that is similar to the Point Reyes Conglomerate is found at Point Lobos near Monterey. It is likely that the Point Reyes Conglomerate was deposited in the Monterey area and then moved 100 miles north by the San Gregorio fault, from **X** to **X'**. The San Gregorio fault is part of the San Andreas fault system and was probably active earlier than the San Andreas fault.

South Beach

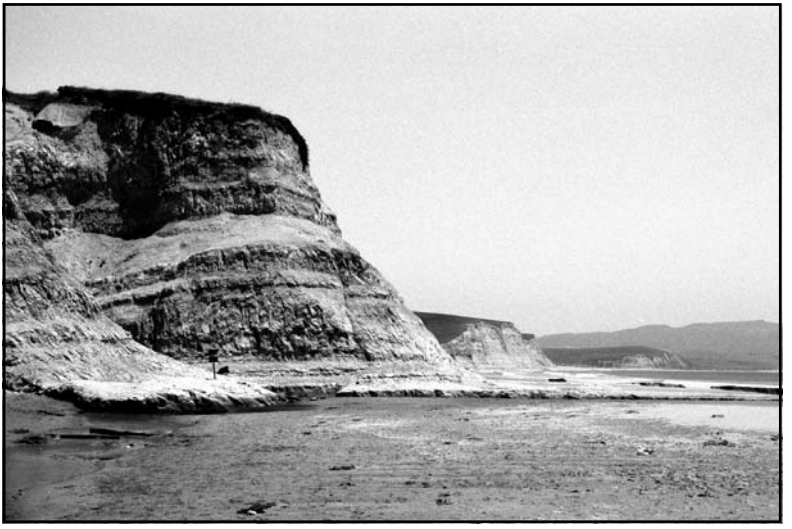
South Beach, which lies at the south end of Point Reyes Beach, faces directly into the prevailing northwest winds. This results in some of the largest waves along the entire California coast. To reach South Beach from Point Reyes Headlands, follow Sir Francis Drake Highway 4.8 miles to the turn-off to South Beach, then follow the road 0.8 miles to the parking area. The pounding surf and rip currents are very dangerous, so stay away from the water. Also check the tide table before walking on the beach so that you will not get trapped by the high tide.

●*South Beach*

South Beach has been carved into the soft rocks of the Drakes Bay Formation. It would seem that the gigantic waves at South Beach should rapidly erode the soft rocks of the Drakes Bay Formation. However, this erosion has been slowed down by the large amount of sand on the beach. Much of the wave energy is spent in moving this beach sand from one place to another and back again. In winter, gigantic storm waves remove sand from the beach and place it offshore in bars that run parallel to the beach. The winter waves then break on these bars and the beach is protected from the full onslaught of the waves. In summer, the smaller waves remove the sand from the offshore bars and place it back on the beach, building the beach back up. This sand movement is typical of many beaches. Much of this sand would probably like to escape this constant thrashing, but it finds it difficult to get around Tomales Point and Point Reyes. It is thus held firmly on Point Reyes Beach to stoically endure its fate of eternal beatings. The beach sand does, however, have one method of escape: it can become airborne in the strong prevailing winds and escape from the beach to become part of a sand dune. The major fields of sand dunes on the Point Reyes Peninsula are directly inland from Point Reyes Beach and are made up of sand that has escaped from the beach in this manner. Most of the sand dunes along the California coastline occur at the south end of sandy beaches where the sand has been driven by the prevailing northwesterly winds.

If you look at the sand from South Beach with a magnifying glass, you will see that it is composed of many different types of grains. Some are clear and others are yellow, red, black, brown, or green. The sand grains are made up of opal, quartzite, chert, granite and conglomerate. Most of the grains are highly polished and well rounded due to the constant reworking by the waves. It is unusual for sand to be composed of this many different types of grains. Obviously the sand was derived from a great variety of igneous, sedimentary and metamorphic rocks.

South Beach faces directly into the prevailing northwesterly winds and has some of the largest waves on the California coast. The sand on this beach is composed of many different types of grains, suggesting a variety of source areas for the sand.



The sea cliffs at Drakes Beach consist of siltstone and very fine-grained sandstone of the Drakes Bay Formation. Drakes Beach is on the protected leeward side of the peninsula so that the waves are smaller and the beach sand is very fine grained.

Drakes Beach

The white cliffs that form the backdrop for Drakes Beach consist of siltstones and mudstones of the Drakes Bay Formation. These cliffs reminded Sir Francis Drake of the white cliffs of southeast England when he stopped here in 1579 to make repairs of the *Golden Hind* before continuing across the Pacific on his circumnavigation of the globe. You can get a good look at these sea cliffs at Drakes Beach.

The turnoff to Drakes Beach is on Sir Francis Drake Highway 5.3 miles north of the parking lot for the Point Reyes Lighthouse. Follow the access road 1.7 miles to the Kenneth C. Patrick visitor center. The visitor center has exhibits on the plant and animal life of Drakes Bay and on 16th Century exploration during the period of Sir Francis Drake's visit. It is open weekends and holidays. For information, phone 415-669-1250.

●*Drakes Beach*

The Drakes Bay Formation is well exposed in the sea cliffs adjacent to the visitor center. The sedimentary rocks in the sea cliffs consist mainly of claystone, siltstone and fine-grained sandstone, and these rocks occur in near-horizontal beds from several inches to several feet thick. The claystone is like hard mud. The siltstone is composed of very small grains that feel gritty, but are to small to see. The fine-grained sandstone is composed of very small sand grains, but you can see the individual grains without a magnifying glass. All of these rocks are very soft and can be easily broken by hand. Note that the beach sand here is very fine grained, since it was derived from these fine-grained sedimentary rocks.

The sedimentary rocks of the Drakes Bay Formation were deposited in an ocean basin during Pliocene time from two to five million years ago. This ocean basin once covered most of the Point Reyes Peninsula. However, the rocks along most of the edges of that basin have been eroded, so we do not know the exact extent of the basin. Fish and marine vertebrates lived in that ocean and left some of their remains as fossils. These fossils mainly occur in the claystone at the base of the formation. A total thickness of about 1500 feet of sediments accumulated in the basin.

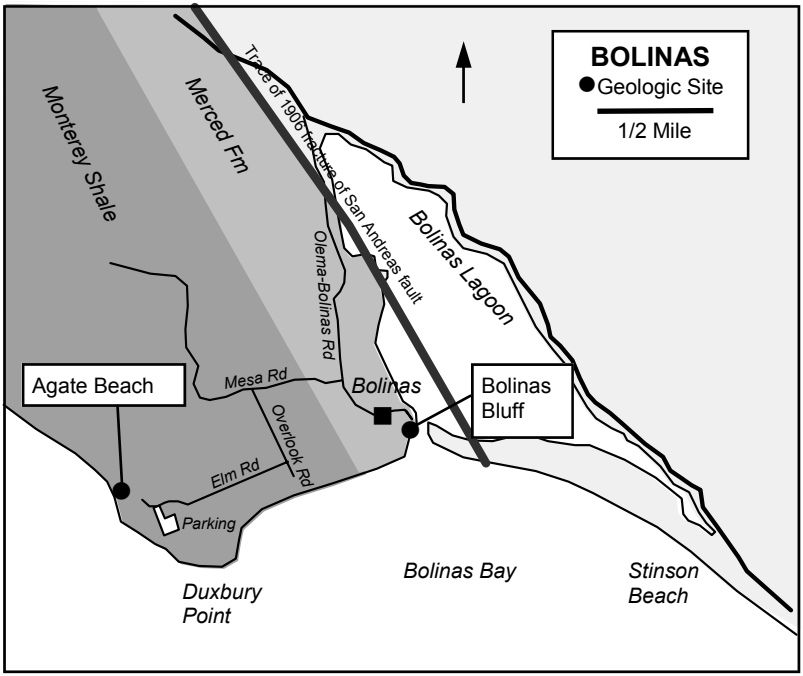
The rocks of the Drakes Bay Formation are similar to the Purisma Formation in the Santa Cruz Mountains, and it is likely that the Drakes Bay Formation was deposited when the peninsula was in the area of the Santa Cruz Mountains.

Bolinas

Bolinas is a small town that lies at the mouth of the Bolinas Lagoon on the west side of the San Andreas fault. There are two geologic sites near the town, the Bolinas bluff where you will see the siltstones and sandstones of the Merced Formation and Agate Beach where you will see the Monterey Shale. The people of Bolinas have a reputation of being somewhat private, to the extent that there are few road signs advising you of the existence of the town. However, once you find your way there, the town is very scenic and worth a trip on its own.

●*Bolinas Bluff*

To get to the Bolinas bluff, follow Highway 1 to the Olema-Bolinas Road, 9.5 miles south of Olema, then go south on the Olema-Bolinas Road. At 2.0 miles from the turnoff you will reach the town of Bolinas. Continue through the town 0.5 miles to the parking area for the beach near the mouth of Bolinas Lagoon. Walk west along the beach a couple of hundred feet to where the rocks that form the bluff are well-exposed.



The bluff near the town of Bolinas consists of siltstones and sandstones of the Merced Formation. The bluff at Agate Beach is formed from the Monterey Shale.

The bluff at Bolinas consists of soft sand and silt of the Merced Formation. The siltstone contains some layers of shale with concretions that contain fossils. These sediments were deposited in a nearly closed-in bay along the west side of the San Francisco peninsula in late Pliocene and early Pleistocene time. This bay had the misfortune of lying across the San Andreas fault. After the rocks were deposited, the sediments that had been deposited on the east side of the fault remained in the San Francisco area near Fort Funston and the sediments that had been deposited on the west side of the fault were carried north by the fault to their present location at Bolinas.

The San Andreas fault goes directly through the Bolinas Lagoon, and is responsible for the lagoon. The Stinson Beach spit lies across the mouth of the lagoon and can easily be seen from the bluff at Bolinas. During the Great San Francisco Earthquake of 1906, the western tip of the spit was offset several feet to the north by the active trace of the fault.

●*Agate Beach*

The Monterey Shale was deposited in Miocene time and is one of the most widespread and distinctive sedimentary units in the Coast Ranges of central California. These rocks cover much of the south part of the Point Reyes Peninsula and are well-exposed in the sea cliffs from Drakes Bay south to Duxbury Point. Agate Beach is one of the best places on the peninsula to get a look at the Monterey Shale.

To get to Agate Beach from Bolinas, go north on the Olema-Bolinas Road 0.5 miles to Mesa Road and follow Mesa Road 0.6 miles to the west, turn left on Overbrook Road, go 0.5 miles, then turn right on Elm Road and go 0.9 miles to the parking area for Agate Beach County Park. Follow the path to the beach. The Monterey Shale is exposed in the cliffs along the beach.

When you look at these rocks in detail, you will see that they consist almost entirely of very thin-bedded shale. The shale readily breaks into small sharp fragments and is easily eroded by the waves. From Agate Beach south to Duxbury Point, wave action has cut a broad platform near sea level, as if the rocks had been cut off horizontally by a chain saw. There are a number of small, thin ridges on the surface of this wave-cut platform. The ridges represent the edges of the steeply dipping beds of shale. From Agate Beach you can see these thin ridges of shale extending southward to form Duxbury Point and Duxbury Reef.

This photo, which looks south from Agate Beach toward Duxbury Reef, shows thin beds of Monterey Shale tilted steeply to the right.

Further north toward Drakes Bay much of the Monterey Shale is very rich in silica. The shale picked up this extra silica from widespread volcanic activity that occurred while the sediments were being deposited. Fine silica-rich volcanic ash thrown into the atmosphere from erupting Miocene volcanoes fell into the ocean waters and then settled on the sea floor where it formed beds of chert and silica-rich shale. The volcanic ash also saturated the seawater with silica so that small silica-rich aquatic plants, called diatoms, became abundant. These diatoms settled onto the sea floor to form beds of punky shale. The punky shales are white and very light weight. They look somewhat like chalk; however, chalk is formed from skeletons of soft calcium carbonate rather than the hard silica.

These rocks are very distinctive because of the silica-rich shale and punky shale. You can see good exposures of the Monterey Shale at the Point Arena Lighthouse 90 miles to the north, at Natural Bridges State Park near Santa Cruz, and at Shell Beach in San Luis Obispo County.