

Excerpt from

Geologic Trips
San Francisco and the Bay Area

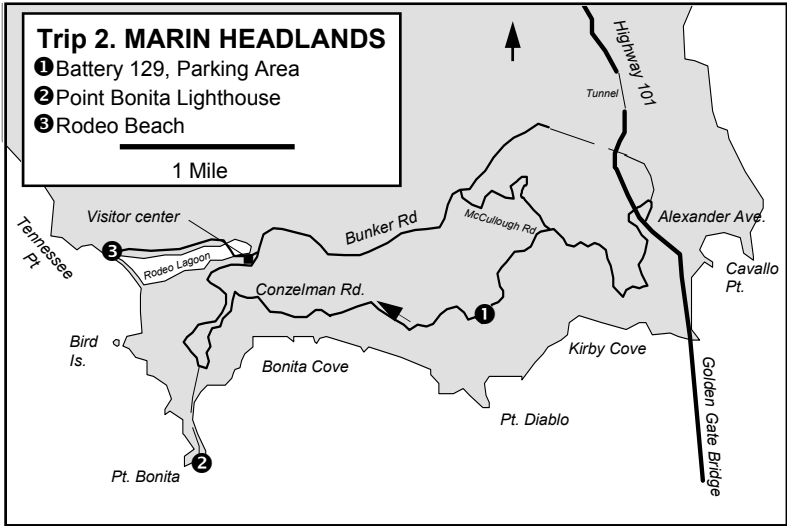
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The Marin Headlands are formed from pillow basalt, red chert, and sandstone of the Marin Headlands terrane of the Franciscan. This photo looks west across Bonita Cove to the Point Bonita Lighthouse. The rocks in Bonita Cove are mainly sandstone. The lighthouse is on a peninsula made up mainly of pillow basalt.

Trip 2.

MARIN HEADLANDS

A Look at the Farallon Plate

The Marin Headlands are made up of some unusual Franciscan rocks called the *Marin Headlands terrane*. These rocks are mainly pillow basalt, red chert and sandstone and were once the ocean floor of the Farallon plate. When these rocks were formed, the Farallon plate was very large, and underlay most of the eastern Pacific Ocean. During the subduction process, almost all of the Farallon plate was devoured as it crept eastward into the Franciscan subduction zone. As these rocks were crammed into the subduction zone, they were broken into numerous thin fault slices, so they now lay scattered around the Marin Headlands like pieces of cucumbers, tomatoes, and cauliflower in a giant salad.

During the trip to the Marin Headlands you will see examples of all of the major rock types of the Marin Headlands terrane. At Battery 129 you will see some of the most spectacular exposures of red chert that can be seen anywhere in the world. The Point Bonita Lighthouse is built on pillow basalt, and you can see excellent pillows in the sea cliff immediately under the lighthouse. Finally, at the north end of Rodeo Beach you will see good exposures of the thick-bedded sandstones that occur in the Marin Headlands terrane.

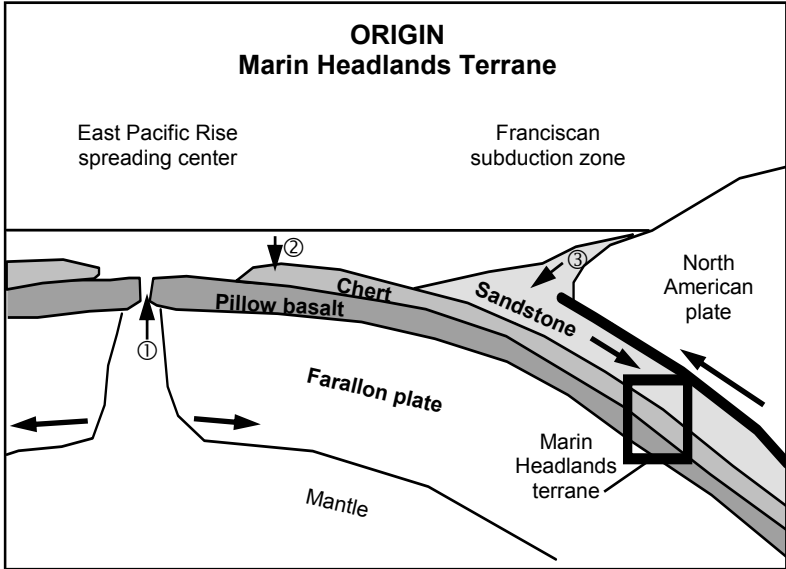
The trip to the Marin Headlands can easily be done by car in one day, with time to enjoy many of the other attractions in the headlands. To reach the Marin Headlands from San Francisco, cross the Golden Gate Bridge and take the Alexander Ave. off-ramp just beyond the view plaza. Turn left at Alexander Ave, go beneath the freeway and follow the signs into the Marin Headlands. As you drive into the headlands you will be on Conzelman Road.

The Marin Headlands are in the Golden Gate National Recreation Area. For information on the Marin Headlands go to the visitor center at the head of Rodeo Lagoon (Phone 415-331-1540).

Farallon Plate

The pillow basalt, red chert, and sandstone that make up the Marin Headlands terrane once formed oceanic floor of the Farallon plate. The pillow basalt was formed when magma flowed out from the East Pacific Rise spreading center when the spreading center was far west of the North American continent. The chert was derived from silica-rich seawater and was deposited on top of the pillow basalt as the pillow basalt moved away from the spreading center. The pillow basalt and red chert were then carried eastward on the Farallon plate, as if on a conveyer belt, and the sandstone was deposited on top of the chert as the Farallon plate approached the North American continent. The sandstone was derived from erosion of rocks on the continent. As the pillow basalt, chert, and sandstone were carried into the Franciscan subduction zone, they were severely folded and faulted and cut into numerous thin fault slices.

During Tertiary time, the rocks of the Marin Headlands terrane were uplifted out of the subduction zone to form mountains and the rocks were subjected to erosion. The uplift and erosion of these rocks is still in progress. Each of the different types of rocks in the Marin Headlands terrane erodes in a different manner, so that there is a close relationship between the different types of rocks and the topography. The basalt, which is quite resistant to marine erosion, forms most of the points around the Marin Headlands, including Cavallo Point, Lime Point, Point Diablo, Point Bonita, Bird Island and Tennessee Point. The red chert is highly fractured and easily eroded by ocean waves, so that it forms coves along the shoreline. However, it forms hilltops and the crests inland, where it is resistant to erosion. The sandstone is resistant to erosion both along the shoreline and inland if the beds are thick, but is easily eroded where beds are thin and interbedded with silt and shale. The ridge that supports Battery Wallace is formed from thick resistant sandstones, whereas the valley occupied by Rodeo Lagoon is carved from soft thin sandstone and shale. The Marin Headlands are a patchwork of these different types of rocks.



The Marin Headlands terrane consists of three very different types of rocks - pillow basalt, chert, and sandstone:

- ① The pillow basalt was formed from magma rising from the East Pacific Rise spreading center.
- ② The chert was deposited on top of the pillow basalt from silica-saturated seawater while the spreading center was far from any land areas.
- ③ The sandstone was derived from the North American plate and deposited on top of the chert as the Farallon plate entered the Franciscan subduction zone.

ROCK TYPES Marin Headlands Terrane		
Locality	Rock Unit	Description
Battery 129	Red chert	Thinly banded layers of hard red chert and soft red clay; the red chert fractures into sharp tabular plates a few inches across.
Point Bonita Lighthouse	Pillow basalt	Dark green on fresh surfaces; red, brown, or yellow where weathered; well-defined pillows in some places.
Rodeo Beach	Sandstone	White or buff colored; composed of sand grains cemented to form hard rock.

Battery 129

Battery 129, also known as Construction 129, is on a hill that is formed of red chert of the Marin Headlands terrane. This hill is a classic viewpoint for Golden Gate Bridge. In September and October, thousands of migrating birds of prey concentrate at this hill, called Hawk Hill, before crossing the Golden Gate. Battery 129 is on Conzelman Road 1.8 miles west of the intersection of Conzelman Road and Alexander Road. The red chert is well-exposed in the parking area for the Battery.

●Parking Area

At the north end of parking area the chert rests on pillow basalt, just as it did when it was deposited on the sea floor during early Jurassic time 150 million years ago. This red chert is also referred to as ribbon chert for its characteristic alternating layers of hard red chert and soft red shale. The chert layers are about two inches thick, and the red shale layers are usually less than one-half inch thick.

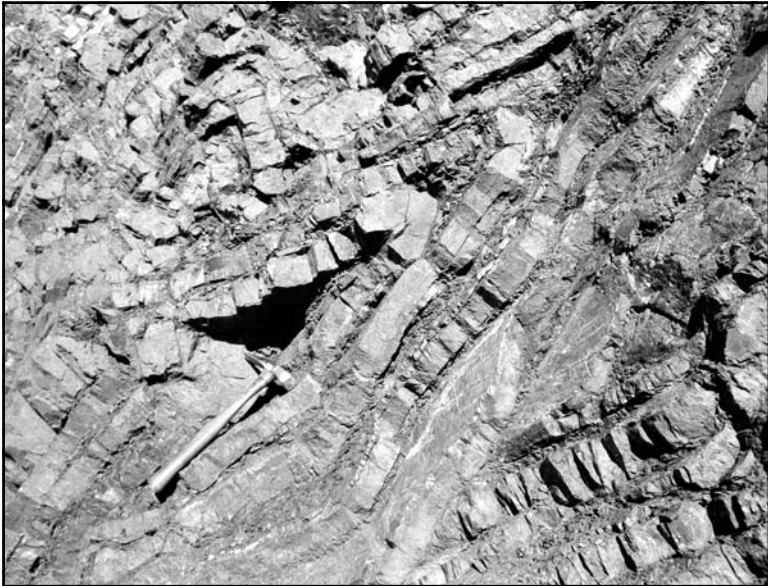
The chert is composed of silicon dioxide, the same chemical composition as window glass. It formed when hot ocean water in the vicinity of the spreading center became saturated with silica derived from the volcanic activity along the spreading center. As the seawater cooled it could no longer hold all of the silica, so the silica was deposited on the sea floor as a gel. The silica-saturated seawater also supported a large number of Radiolaria, one-celled floating animals that live in seawater and have a silica shell. As the Radiolaria died, their shells fell to the sea floor and were incorporated into the silica gel. With a magnifying glass you can see the Radiolaria as very small white specks in the chert. Radiolaria commonly make up from 10% to 50% of the chert. The formation of the red chert in this manner was slow, so that most beds of red chert are only a few tens of feet to a few hundred feet thick. Most of the chert was formed far from land areas because sediments from nearby land areas would have drowned out the chert.

The red shale between the chert layers is fine mineral dust from the atmosphere that fell into the ocean and accumulated in the silica gel on the sea floor. The thin layers of red shale segregated from the silica as the silica hardened into chert.

Small sharp folds can be seen in many outcrops of red chert. Some of these folds may have occurred by slumping of the still soft chert beds and others by later deformation of the hard chert in the subduction zone.



The layers of red chert in this road cut near Battery 129 were horizontal when deposited, but were sharply folded while the rocks were in the Franciscan subduction zone.



The thin bands of hard red chert in this photo about two inches thick and are separated by thin layers of soft red shale. The chert has been bent into a small fold along the axis of the hammer.

Point Bonita Lighthouse

It is usually difficult to see good pillows in pillow basalts because the rocks are commonly highly weathered and the outlines of the pillows are obscure. However, you can see some good pillows at the Point Bonita Lighthouse. To get to the lighthouse from Battery 129, continue west 2.3 miles on the one-way road to the parking area for the lighthouse, then follow the half-mile path to the lighthouse. The lighthouse is open seasonally on weekends. Call 415-331-1540 for hours and information. Try to get to the lighthouse when it is open; but if it is closed, you can still see some good pillows along the path to the lighthouse.

●Lighthouse

To see some excellent examples of pillow basalt, follow the path through the tunnel to the lighthouse. Before crossing the suspension bridge to the lighthouse, look at the rocks in the surf zone to the left of the lighthouse. You will see a large dark-green rock on the other side of a small sea arch. This rock is about 20 feet thick and 50 feet high, and is made up of a number of pillows a foot or so in diameter and a couple of feet long. You can see the rounded outlines of the pillows that have been etched by the constant wave action. These pillows were formed during Jurassic time when basaltic magma flowed out onto the sea floor from the East Pacific Rise spreading center when the spreading center was far west of the North American continent. As the basalt magma came into contact with the seawater, the outer margin of the magma chilled before crystals could form, giving the pillow a fine-grained outer rim. The fluid magma in the center of the pillow would break through the chilled rim and form another pillow, and so on. As the pillows were extruded onto the sea floor from the spreading center, the pillows were stacked one above the other so that the bottom of each pillow conformed to the convex top of the underlying pillow. Each new pillow added to the top of the stack was sufficiently mobile to mold itself to the irregular surface below.

On your return from the lighthouse, look at the rocks along the path immediately beyond the tunnel. Note the large rounded pillows in these rocks. As you continue on the path you will see many other basaltic rocks, including basalt flows without pillows, diabase dikes, tuffs, and agglomerates. The diabase dikes formed from basaltic magma that cooled in fractures before reaching the sea floor. The tuffs formed from ash thrown up into the air during volcanic eruptions. The agglomerates formed from loose volcanic rocks caught up in the basalt flows. It is difficult to distinguish these different types of volcanic rocks when the rocks are highly weathered.



The path to the Point Bonita Lighthouse passes through a tunnel (center) in this small rugged peninsula. The rocks that make up the peninsula are mainly pillow basalt. Look for the pillows as you go along the path to the lighthouse and also in the surf zone near the bridge to the lighthouse.



The sea cliffs at the north end of Rodeo Beach (left) consist of sandstone. The cliffs at the south end of the beach (right) include pillow basalt, chert, and sandstone.

Rodeo Beach

Rodeo Beach is the easiest place to reach the beach in the Marin Headlands. Here you will have an opportunity to see good examples of the different rocks that make up the Marin Headlands terrane. At the north end of Rodeo Beach, you will see exposures of the sandstone that makes up most of the ridge that runs from Battery Wallace to Rodeo Lagoon. Along the main part of Rodeo Beach, you will see many pebbles of red chert along with the sand that forms the beach. If lucky, you may find some semi-precious carnelians among these pebbles. At the south end of the beach you will see thin fault slivers of the many different types of rocks that make up the Marin Headlands terrane.

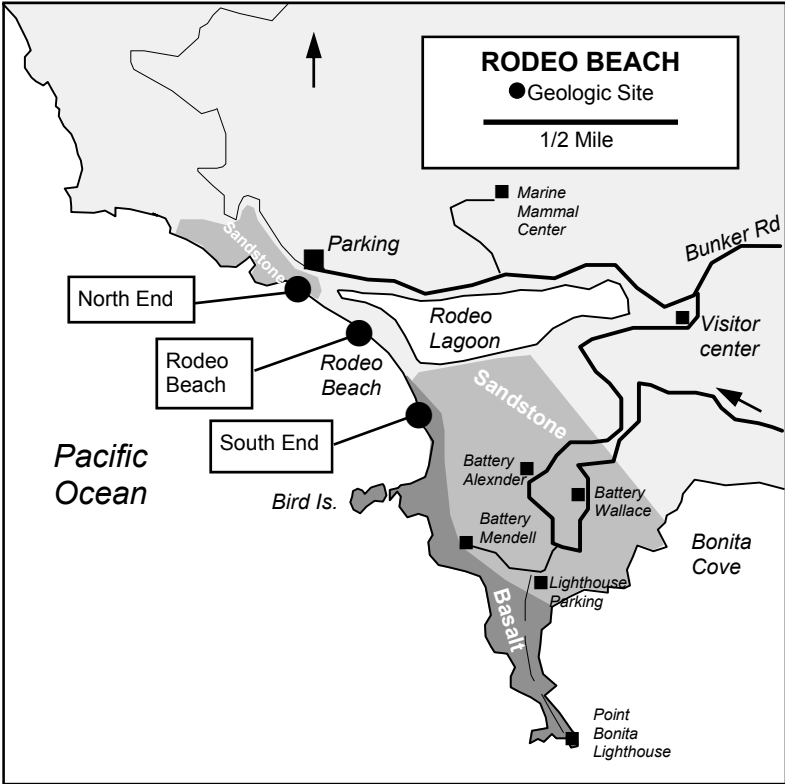
To get to Rodeo Beach from the Point Bonita Lighthouse, continue on the loop road past Battery Alexander and the Marin Headlands visitor center. Turn left just beyond the visitor center, follow the signs to Rodeo Beach and park.

●North End

The cliffs at the north end of Rodeo Beach consist of sandstone. The beds are several feet thick and tilted steeply. Because the sandstone exposures are fresh, you can see grading and cross bedding in the sandstone. The sandstone also contains fragments of clay and volcanic rocks. Like the sandstones in the Alcatraz terrane and the San Bruno Mountain terrane, these sandstones were derived from erosion of the rocks of the North American plate and dumped on the top of the Farallon plate as it approached the North American plate.

●Rodeo Beach

The sand that forms Rodeo Beach is a good place to look for interesting pebbles that have eroded from the basalt and chert along the shoreline. Note the large amount of dark red pebbles on the beach. These have eroded from the red chert that is exposed on the hillsides and along the shoreline at the Marin Headlands. The pebbles have been rounded by the wave action, just as if placed in a rock tumbler. Among these pebbles, if you look hard and are lucky, are carnelians, a semi-precious translucent red-to-orange type of chalcedony, which is a form of quartz. The carnelians originally formed when silica-rich groundwater filled small round cavities in the basalt, called vesicles, that were caused by expanding gas while the basalt was still fluid. When the pillow basalt was subjected to weathering, the other components of the basalt broke down into sand and clay, leaving behind the hard carnelians.



Rodeo Beach is at the mouth of Rodeo Lagoon. The lagoon was formed in an old river valley that was drowned as this part of the California coast subsided over the last million years. There are few lagoons like this along the California coast since most of the other parts of the northern California coast have been uplifted rather than drowned.

● **South End**

The cliffs at the south end of Rodeo Beach are formed from thinly faulted slivers of basalt, diabase, chert, and sandstone. Here you will see some fresh exposures of pillow basalt up close, which you could not do at the Point Bonita Lighthouse. The following rocks are encountered as you go southward along the cliff:

1. red chert,
2. sandstone and siltstone; repeated several times by faulting,
3. mixed pillow basalt and chert,
4. large sandstone blocks, probably from a landslide,
5. a promontory of pillow basalt that blocks further access to the south.