Rocks on the Move
Teacher notes – Geologic investigation "A"

Information on student resource sheet – Investigation A

Photo: Path to Point Bonita lighthouse, circa 1940s.

Location: #12 on the map. Near the southeastern end of the suspension bridge, facing nearly west.

The metal tower in front of the lighthouse is the old radio/radar, used before the radar was built near #2 on the map.

Lighthouse keepers used this path day and night, in all kinds of weather, including storms with high winds.

What geologic process is occurring under the suspension bridge?

What are the advantages of building a suspension bridge, instead of the path shown in this photo?

Additional information and guiding questions for the teacher:

The geologic process that is occurring underneath the suspension bridge is erosion. The rock under the bridge is highly weathered diabase and greenstone, which is much weaker than the less fractured pillow basalts nearby. There are two main causes of the weathering of this rock, one from above and one from below: rainwater and undercutting action from the waves.

Look at the 1940s photo for evidence of landslide activity (the small hole beneath the path). The suspension bridge was not built until 1954!

1. How is the rock underneath the bridge different from rocks nearby?

The diabase and greenstone under the bridge is highly weathered. Diabase has large crystals of a clay mineral called feldspar. Feldspar is an unstable mineral and is most commonly responsible for weathering. Feldspar weakens rock when it is exposed to rain water. Wave action from below undercuts the rock and creates slide conditions.

2. Is this a slow or a fast geologic process?

Compared to other geologic processes that can take thousands or millions of years, erosion is a quick process. A landscape can change drastically in one slide event, or over a period of time in several smaller slide events. Overall, erosion is considered to be a fast process.

3. What are common causes of erosion?

Rain water, wind, and wave action are all common causes of erosion. In this investigation, rain water and wave action are the two main contributors, with rain water being the most significant agent. All rainwater, even from the cleanest air, is mildly acidic. The average pH of rain water is around 5. Ocean salt water is mildly basic with a pH of about 8.

Rocks on the Move
Teacher notes – Geologic investigation "B"

Information on student resource sheet – Investigation B

Photo: Pillow basalt arch at Point Bonita

Location: #12 on the map. Near information panel at southeast end of suspension bridge, looking southwest.

Compare the two photos of the pillow basalt arch. What has changed? How can you explain this?

Maximum daily difference between high and low tide for the Bay Area is approximately 3 meters (9 feet).

The yellow line in the picture represents a height of about 16 meters (50 feet).

Additional information and guiding questions for the teacher:

Geology does not only describe the past, it can also be used to think about the future. In these photographs a drastic change in sea level is depicted. In light of global warming and climate change, sea level rise may become a significant factor for geologic change in the future.

1. Is the water rising or is the arch sinking?

The water level is rising. The pillow basalt stacks are very stable. No changes in the rocks of the pillow basalt arch have been detected since the late 1870s.

2. Could the changing tides be responsible for the raised water level?

No. Notice that the water level change depicted in the picture is much greater than the maximum tide differential (3 meters or 9 feet). The tide at the time the photo was taken was approximately 1 meter (3 feet.)

3. What geologic process is responsible for this change?

Here we would like the students to recognize rising sea level as a geologic process. Climate change can produce higher sea levels, as sea ice and glaciers melt. Coastlines will shift as a result of changing sea levels and global warming. Shifting coastlines will alter the pattern of deposition of sediments from rivers. New patterns of sedimentation and beach formation will result in changes in the Earth's crust; thus climate change is a component of geologic change.

Rocks on the Move
Teacher notes – Geologic investigation "C"

Information on student resource sheet – Investigation C

Photo: Marine terrace, 2008

Location: #14 on the map. Standing near the northeast end of the suspension bridge, facing north. The marine terrace looks like a **sand dune** on top of the cliff.

A marine terrace is an **ancient beach**. Marine terraces are common along the California coast. They often look flatter than the one you see here. Parts of the Coast Highway are built on top of marine terraces.

This terrace is now about 50 meters (150 feet) above sea level.

Additional information and guiding questions for the teacher:

The marine terrace you see in this transparency is a remnant of an ancient beach. In tectonically active coasts, such as California, marine terraces are the result of episodes of coastal uplift. They are also called wave-cut platforms, and the flat surfaces of the terraces are prime locations for development. Although living in a house on a marine terrace offers a great view of the ocean, the sandy sediments of the terraces are easily eroded by waves during big storms or rising sea level. Sometimes buildings on marine terraces end up falling into the ocean.

1. How does the marine terrace appear different from the rocks around it?

It looks like very fine sand. There are no noticeable large rocks imbedded in the sand. It is a different color than the rocks around it.

2. Was the shoreline always where it is today?

No. During the last ice age (20,000 years ago) the shoreline was about 40 km (26 miles) west, near the Farallon Islands. Why is sea level lower during an ice age?

3. How did the sand get there?

As you explore the area around Rodeo Beach and Point Bonita, you may find several places where very fine sand is beneath your feet. Some of the sand was deposited by wind during the ice age, when sea breezes blew fine sand inland from the beaches (which were then located near the Farallon Islands). Some of the sand is a remnant marine terrace, which is evidence of a period of coastal uplift.

Remember that the Franciscan rocks were all formed deep underwater. About 3 million years ago, crumpling of the Earth's crust raised the Franciscan rocks above sea level. Over the last 100,000 years or so, several ice ages and interglacial periods resulted in dramatic changes in sea level.

Rocks on the Move
Teacher notes – Geologic investigation "D"

Golden Gate
National Park Service
U.S. Department of the Interior

Information on student resource sheet – Investigation D

Photo: Fog signal building, 1924.

Location: Between #11 and #12 on the map. Looking southeast from southern end of plastic bridge.

This building was built in 1874 for the stream siren fog signal. When the Lighthouse Service moved the fog signal to the cliff west of the lighthouse in 1903, this building was used for storage.

The San Francisco earthquake in 1906 destroyed a small house at the top of the trail, leaving the families of the lighthouse keepers homeless. For a few years after the earthquake, this building was used as a keeper's home.

Keeper Alexander Martin lived here with his family. He was very nervous about letting his children play outside the house, near the cliffs. Keeper Martin made harnesses for them. Whenever the Martin children played outside, they wore the harnesses and were tied to the house.

Look at the foundation of the old building. What is happening along the eastern side?

Additional information and guiding questions for the teacher:

Erosion is the main cause of geologic change at this site. The rocks that make up the southern-most end of Point Bonita are highly fractured and prone to landslides. Several significant slides have occurred here before and after this photo was taken in 1924. The erosion that is taking place at this site is similar to the erosion under the bridge in Investigation A.

1. Why do you think the house is no longer here?
On-going erosion caused the Coast Guard to demolish this building in the 1960s –it would have been very costly for them to make the building safe to occupy.

2. Is this a slow or a fast geologic process?
Take a look at the part of the building foundation that extends beyond the fencing. Quite a lot of erosion has occurred since the 1924 photograph. In this case, the erosion here is a fairy fast geologic process.

3. What are common causes of erosion?
Rainfall, infiltrating the rocks from above, is the greatest agent of weathering, and thus, contributes to erosion. Wave attack from below, during big storms, can undermine the cliffs and cause landslides. A large landslide occurred here in 1992. Boulders the size of cars toppled into the sea below.

Rocks on the Move
Teacher notes – Geologic investigation "E"

Golden Gate
National Park Service
U.S. Department of the Interior

Information on student resource sheet – Investigation E

Photo: Inclined tram and boat landing. Photo circa 1943.

Location: #11 on the map. Looking north, from cut off pole near the southern end of the old generator building.

The tram and boat landing were first built in 1871, so that the Lighthouse Service could bring supplies to the Point Bonita fog signal.

A horse walked in circles at the top of the tram, pulling the carts of supplies up the hill. In 1902, an engine (called a "donkey engine" replaced the horse.

What kind of rock was the 1871 boat landing built upon? Look at the condition of the landing. Does this tell you anything about the strength of the rock?

Additional information and guiding questions for the teacher:

1. What does the rock look like where the boat landing was constructed?
The rock looks pretty much the same today as it does in the photo.

2. Of the different rock types we've learned about, which one does it resemble the most?
If the lighting conditions are good, you will see sandbag or jelly bean-shaped, dark rocks (pillow basalts) stacked at a sharp angle, beneath the boat landing.

3. Is this rock strong or weak? How can you tell?
Strong. It hasn't changed much since the photo was taken.

4. How is what you see when you look at the historic photo (magic window) different from what you see today?
Although the cut in the slope is still there, the tram no longer exists.

- ✓ Many of the sea stacks in the Marin Headlands area are made of pillow basalt. They are what remain after the less resistant rocks weathered away.