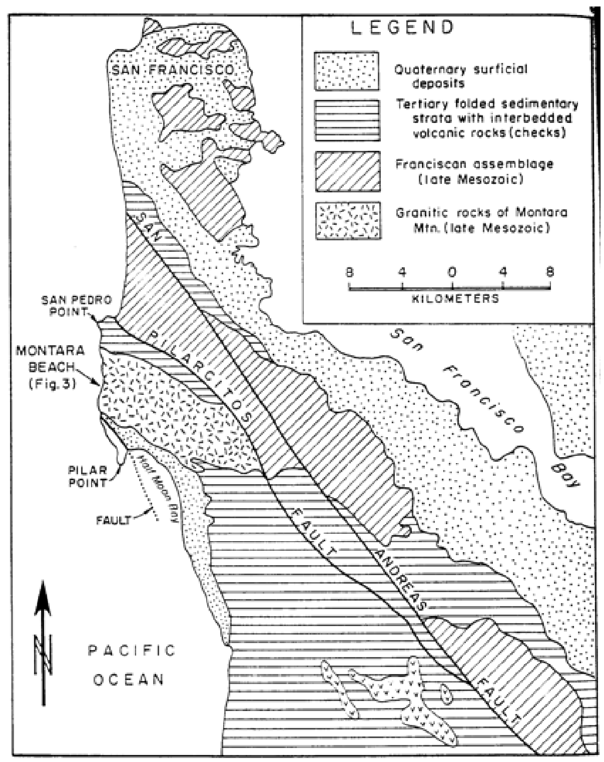
Structural Geology and Tectonics EPS116

Field Trip and Lab Exercise #7: The San Gregorio fault zone near Half Moon Bay (Pillar Point, Moss Beach and Montara Beach)

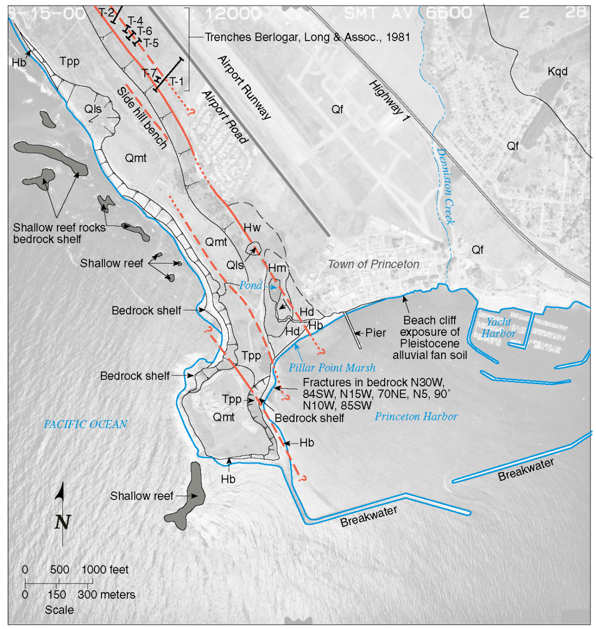
What to do before the field trip:
You will need a notebook, clipboard, pencils, and a ruler. Bring water and lunch supplies and dress appropriately for a windy beach in March and walking on slippery rocks and loose sand. We will bring Brunton compasses. **Note:** We are not allowed to collect stuff or use rock hammers. A ranger will provide us with information regarding seal location and off limit areas for the day.

On the way to Half Moon Bay, please try to review the information below and the handout on taking field notes.



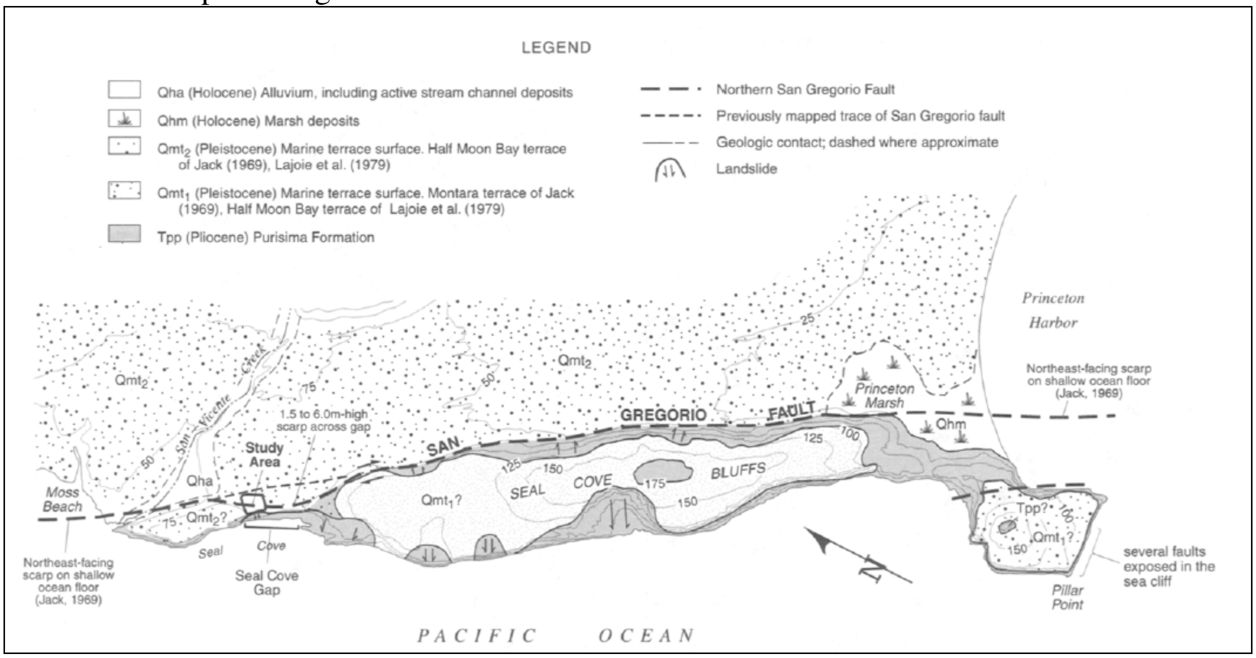
How to Get There: We will take Interstate 280 and go west on 92 to Half Moon Bay. We will have a brief stop at the San Andreas fault near Crystal Springs Reservoir. One mile past Skyline Boulevard (Highway 35) we cross the Pilarcitos fault which separates Miocene strata belonging to the Salinian block on the west from Franciscan rocks on the east. The Pilarcitos fault is thought to have been the main active plate-boundary fault until about 2 million years ago when active slip transferred to the San Andreas fault. Over the next mile, road cuts expose Cretaceous granitic rocks of Montara Mountain. These granites are part of Salinia, thought to be a block originally located in the southern Sierra Nevada, sheared off and transported all the way to the Bay area by the San Andreas fault system. Down-canyon, the granite is overlain by Tertiary sandstones and then by terrace deposits, which we will see along the coast. From 2 to 5 miles down Highway 92 from Skyline the route is down the Pilarcitos Valley, whose alluvial floor is graded to the level of a marine terrace, about 100,000 years old, on Half Moon Bay.
We turn north on Highway 1, which is built on the surface of this terrace. Two older terraces are plainly visible in the hills north of the intersection, and at least two more terraces, even higher, have also been recognized locally. The raised terraces are evidence of active tectonic upwarping along the coast. As we approach Moss Beach, to the west we can see the Seal Cove fault scarp breaking the marine terrace surface, just behind the airport of Half Moon Bay. We will head out to Pillar Point to look for traces of the fault in the coastal outcrops there, and will make it to Moss Beach at relatively low tide (Low tide is at 2:01 PM; http://www.tides.net/california/2193/2016/03/05/).

Simpson et al. (1997, BSSA) conducted a paleoseismic and archaeological study south of Moss Beach. They excavated the fault and determined the times of past earthquakes and the rate of fault slip from offsets of native Californian artifacts from A.D. ~1300. A ~5m deflected midden deposit suggests that a $M_w \approx 7$ earthquake occurred here since A.D. 1300, but before the 1775 arrival of Spanish missionaries. Slip-rate estimates are 4-10 mm/yr.



Field study site I: Moss Beach

To get to Moss Beach, we turn west on California Ave. at the wooden sign that says James V. Fitzgerald Marine Reserve just south of the town of Moss Beach. At the end of the road there is a parking lot, pine trees, and access to Moss Beach. We will check in with the rangers to get instructions on protecting local wildlife etc.



Geologic Backround: The rocks at Moss Beach belong to the Pliocene Purisima Formation which is as much as 5000 feet thick in some locations (e.g., Madrid, V.M., R.M. Stuart, and K.L. Verosub, Magnetostratigraphy of the late Neogene Purisima Formation, Santa Cruz County, California, *Earth Planet. Sci. Lett.*, *79*, 431-440, 1986). The Formation here consists of mudstones, siltstone, sandstone, and conglomerate. Some of the rocks are highly fossilifereous and contain pelecypods, gastropods, foraminifera, and also whale and dolphin ear bones. The Purisima Formation contains pebbles and cobbles derived from the nearby Montara Granite (Cretaceous), which it unconformably overlies. Although we are here to collect structural data on the Moss Beach fold, you might notice evidence for sea cliff erosion and the absurd lengths to which homeowners have gone to combat this erosion.

The Moss Beach area is bounded to the southwest by the Seal Cove fault, which is an extension of the San Gregorio fault and to the north by granitic rocks, which extend along the coastline. The Seal Cove fault, indicated by extensively disrupted mudstone and sandstone, used to be spectacularly exposed in the sea cliffs next to the path down to the beach and it juxtaposes different facies of the Purisima Formation. It is now covered by a big pile of rocks, but is exposed in the wave-cut terrace during exceptionally low tides. The Montara Granite forms part of the Salinian block, which is believed to have moved northward from southern California along the San Andreas fault. Limited paleomagnetic data suggests it may have originated even farther south in Guatemala, but most workers are unconvinced by this interpretation.

North of the fault trace, a gently plunging syncline is exposed in the shallow waters of the bay. At low tide we can walk out on the limbs of the fold and measure bedding attitudes. This fold, its relation to the Seal Cove fault and secondary fracturing are the main focus of this field project.

Purpose of Lab:
To refresh how to use a Brunton compass to take careful and accurate strikes and dips of bedding and fault surfaces. To practice mapping techniques and to map sedimentary contacts on a topographic base map. To analyze map scale structures utilizing structural data, cross sections, and stereographic projections of structural data. To practice taking accurate and meaningful field notes that accompany the data you collect.
While the deformation at Moss Beach is dominated by a ductile fold, we would like you to also pay particular attention to all brittle structures accompanying that deformation (joints and small faults) in your analysis.

What to do in the Field:
Begin by looking over the entire structure to get your bearings and become accustomed to the map scale. Both the topographic contours and the distance scale are in meters. You will need to locate yourself accurately on the map.

1. Measure the attitudes (strike and dip) of bedding surfaces around the Moss Beach fold. Position the locations of these measurements carefully and draw strike and dip symbols labeled with their values on your map as you go along (use your protractor), and tabulate your measurements in your notebook. As a group, try to cover the whole area of the structure; i.e., you want measurements from both limbs of the fold and from the hinge area. Around fifty well-distributed measurements (collected by the whole group) would be nice. Be sure you utilize the lowest point in the tide to take measurements along the beds that are farther away from shore and generally underwater. Whether you use your clipboard or sight to measure bedding attitudes, be sure you are careful in approximating their true attitude. *Quality of data is as important as quantity*.
2. Map out the bottom contacts of two notable conglomerate units you recognize on the beach and other beds you can trace over some distance. Each of these contacts will be a line on your map. Use dashed lines where contacts are inferred. Take the appropriate field measurements to calculate the thickness of the section between these two units.
3. Note facing of top criteria present in the beds to determine if the beds are right-side up or overturned.
4. Measure the **axial trace** of the fold by sighting along a line connecting points of maximum curvature of beds. What is its trend? The axial trace is the intersection of the axial surface of the fold (or hinge surface) with the surface of the ground. Make sure you remember to do this!
5. Map and measure the orientation and character of **brittle structures** (try to distinguish joints and faults) you can find within a small area you focus on, approximately 10-by-10 m square.

To do when you get back:

1. Clean up and finalize your field notes. On Friday **March 11** please bring and submit copies of your final field notes. Send an Excel spreadsheet with your field measurements to Chris and Marissa before 10am the day of lab (strike/dip, trend/plunge, explanation of location, type of measurement etc.). Your final map, analysis and report using everybody's data are due a week later (submission as an electronic file or bring to class on **March 18**).

2. Plot strikes and dips and contacts on a clean map (we will have extra copies). Label the bottom contacts of the two conglomerate units $Tpcg_1$ and $Tpcg_2$. Draw the axial trace of the fold on your map. Use symbols from handout on the map.

2. Carry out a sterographic analysis of the data on the fold as outlined below. Be sure to label all features on your stereonets.

a. Which stereonet projection will you use and why?

b. Plot bedding planes as great circles using a computer program (e.g., Stereonet by Rick Allmendinger). Pool your data with your classmates and also include previous years' data.

c. Make a separate stereonet diagram showing only poles to bedding.

d. What is the attitude of the fold axis?

e. Plot the axial trace of the fold that you measured in the field on a stereonet (assume it is a line with zero plunge) together with the fold axis. What is the attitude of the axial plane of the fold (i.e., The plane that contains the fold axis and the axial trace)?

f. Plot the strike and dip of the Seal Cove fault (earlier mapping reported by Simpson et al., 2006 suggests that the principal fault surface within the 30- to 40-m-wide zone at this location strikes N18-35W and dips 65 to 80E (Leighton and Associates, 1971).

g. Use your data to address the question: Is the fold a cylindrical fold?

2. Draw a cross section of the structure along the line A-A' indicated on the map. Make your cross-section 1:1, with no vertical exaggeration. Think carefully about what the geometry of the Moss Beach fold will look like in cross-section. Let the map pattern on either side of your line of cross section be your guide as to the geometry of the structure as you extrapolate to depth.

a. Make a cross section of the topography.

b. Project the dips of units onto the line of cross section. Be sure to calculate apparent dips to do so, measuring the angle between the strike and line of section. Remember: tan(apparent dip) = tan(true dip) * sin (angle between strike and cross-section).

c. After doing the above, draw the axial plane of the fold on your cross-section. The apparent dip of the axial plane in your cross-section will help you determine the geometry of the fold in cross-section.

e. Show the location of the Seal Cove fault on your cross section. Could the folding be related to movement on the fault? Why or why not?

4. Please, explain how the brittle fractures you mapped may be mechanically related to the fold? Can you infer principal stress directions from their orientations and sense of slip?

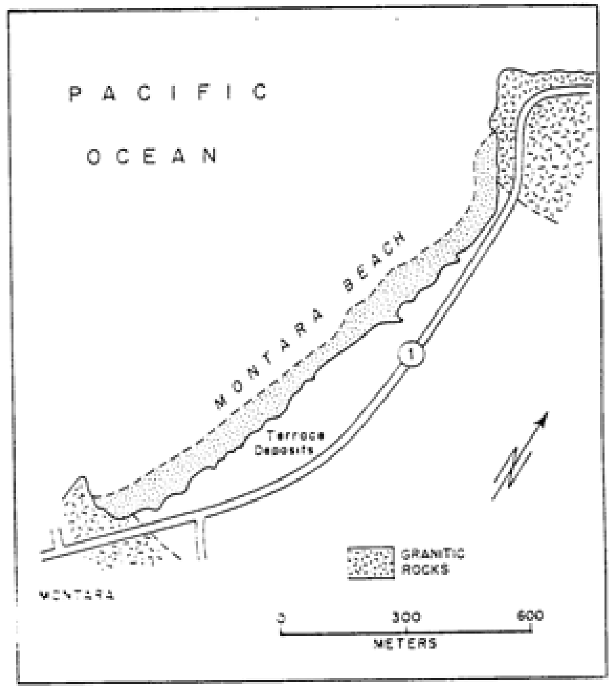
5. Hand in your final report including stereonets, map and cross section, together with a typed write up no longer than one page, concisely describing the style and geometry of the fold in three dimensions (answering the questions above) together with your stereonet data. Make sure that you adequately label and describe all diagrams.

Field study site II: Montara Beach:

On the drive N on Highway 1 to Montara Beach, note that the terrace has been completely eroded away just north of Moss Beach village, then reappears at the parking lot where we stop. The bedding of the marine terrace deposits dips gently to the north here.

At Montara Beach your goal is to carefully observe and document the geology and then interpret the features you see. Take note of geomorphic features, rock outcrops, the composition of the beach sand and terrace deposits, and of course the structural geology.

Objectives: Try to develop a geologic history of the area based on your careful observations. Participate in the discussions, take detailed field notes, make field sketches of structures, identify unconformities etc. Measure strikes and dips of planar features as appropriate and include a structural analysis of the brittle structures we encounter at Montara Beach.



To do when you get back: (1) At the beginning of lab on **March 11**, hand in a copy of your final field notes and sketches. For your report due a week later on **March 18**, write a one-page typed summary describing what you observed and how you interpret the observations. You can add sketches or diagrams as you see useful. Put your observations in the context of the regional geology and develop a tectonic history deduced from the outcrops at Montara Beach and surrounding geology.