Structural Geology and Tectonics EPS116

Field Trip and Lab Exercise #5: Montara Beach and Moss Beach

What to do before the field trip:
You will need a Brunton compass (we will bring those), a notebook, pencils, ruler, and later protractor, stereonet, and tracing paper or stereonet computer program. Bring water and lunch supplies and dress appropriately for a windy beach in February and walking on slippery rocks.

Note: We are not allowed to collect stuff or use rock hammers.

Tide information:
Low 2:49 PM -1.0

Our window of opportunity to access the limbs of the Moss Beach syncline and Seal Cove fault will be between 1:30 and 4:30 PM.

How to Get There: We will take highway 280 south and go west on 92 to Half Moon Bay. One mile after we cross 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 be the main active plate-boundary fault until about 2 million years ago when active slip transferred to the San Andreas. 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 uplifted terraces are evidence of active tectonic upwarping along the coast. To the west we can see the Seal Cove fault scarp breaking the marine terrace surface.

To get to Moss Beach, we turn west at the wooden sign that says James V. Fitzgerald Marine Reserve just before the town of Moss Beach. At the end of the road there is a parking lot, pine trees, and restrooms.

We will continue on to Montara Beach for our first stop.
To get oriented in space ...

Stop I: Montara Beach:
On the drive 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 dip gently to the north here.

At Montara Beach your goal is to first 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. The maps above, and the geologic quad map we will bring along, will allow you to put your observations in the context of the regional geology and tectonics.

Objectives: Try to develop a geologic history of the area based on your careful observations. Take detailed fieldnotes, make field sketches etc. of structures, identify unconformities etc. Secondly, observe, measure and do a complete structural analysis of all brittle structures you encounter at Montara Beach. Use sketches, block diagrams, stereonets, and Mohr circles to do this analysis.

To do when you get back (Lab): (1) Hand in a copy of your field notes and sketches and write up a few paragraphs describing what you observed and how you interpreted it. (See attached information on writing field notes).
Stop II: Moss Beach:

Geologic Background: 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 fossiliferous and contain pelecyods, 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.

The Moss Beach area is bounded to the south 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. 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 some workers are unhappy with this interpretation.

Recently, (Simpson et al., 1997, BSSA, v. 87, p. 1158-1170) conducted a paleoseismic and archaeological study just 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 = 7 earthquake occurred here since A.D. 1300, but before the 1775 arrival of Spanish missionaries. Slip-rate estimates are 4-10 mm/yr.
Although we are here to collect structural data on the Moss Beach fold, you might want to notice evidence for sea cliff erosion and the absurd lengths to which homeowners have gone to combat this erosion.

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 is the main focus of our field project.

**Purpose of Lab:** To practice mapping techniques and to map sedimentary contacts on a topographic base map. To refresh how to use a Brunton compass to take careful and accurate strikes and dips of bedding surfaces. To analyze map scale structures utilizing structural data, cross sections, and stereographic projections of structural data. While the deformation at Moss Beach is dominated by a ductile fold, we would like you to 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 with values on your map as you go along (use your protractor). Be sure you cover the area of the structure, i.e. you need measurements from both limbs of the fold and from the hinge area. 20 to 30 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 the two largest conglomerate units.** Each of these contacts will be a line on your map. Use dashed lines where contacts are inferred. Label the units. 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.** Are the beds overturned? Look for indicators of paleocurrent indicators. If there are clear cut examples, measure the plunge and bearing of these indicators so that you can restore them back to their original configuration prior to folding.

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 all brittle structures you can find within a small area you focus on, approximately 10-by-10 m square.**
To do when you get back:

1. Plot strikes and dips and contacts on a clean map (There are extra copies of the map). Label the bottom contacts of the two conglomerate units $T_{pcg_1}$ and $T_{pcg_2}$. Draw the axial trace of the fold on your map. Use symbols shown on the handout or from Marshak and Mitra p. 7 and p. 394-397 for map and cross-section.

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.
   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. (See Marshak & Mitra, p. 56).
   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.
   d. 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.
   e. Show the location of the Seal Cove fault on your cross section. Could the folding possibly be related to movement on the fault? Why or why not? How? (There might not be a known “true” answer, but you should argue convincingly based on the evidence and your geologic intuition).

3. Carry out a sterographic analysis of the data on the fold as outlined below:
   a. Plot bedding planes as great circles using your stereonet or one of the software packages (e.g., Stereonet by Rick Allmendinger). Pool your data with your classmates.
   b. Make a separate diagram showing only poles to bedding.
   c. Have a look at Marshak and Mitra Sec. 6-1, 6-2, and 8-5 to see how folds are presented on the sterographic projection and the definition of a cylindrical fold.
   d. What is the fold axis?
   e. Plot the axial trace of the fold that you measured in the field (assume it is a line with zero plunge). What is the axial plane of the fold? (The plane that contains the fold axis and the axial trace). Label these on your stereonet.
   f. Use your data to address the question: Is the fold a cylindrical fold?

4. After you have learned something about the 3-D geometry of this fold, use this data to restore your paleocurrent readings back to their horizontal (original) attitudes. (See Marshak and Mitra Sec. 6-4)
   What if you didn't find any paleocurrent directions? Well, try these:
   bedding: N5W, 25SW; paleocurrent direction N82W, 25NW flowing from E to W; bedding N44W, 40NE; paleocurrent direction N66W, 20SE flowing from SE to NW. What assumptions have you made in order to restore these?

5. Make a clean copy of your close-up map of brittle structures showing your measurements. Please, explain how the brittle structures you mapped may be directly related to the fold?

6. Hand in your map and cross section, with a paragraph or two, concisely describing the style and geometry of the fold in three dimensions (answering the questions above) together with your stereonet data on both the fold and the paleocurrent data. Make sure that you adequately label and describe all diagrams.