GEOLOGY OF THE PALOS VERDES PENINSULA LOS ANGELES CA

A FIELD GUIDE FOR THE NON-GEOLOGIST

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Fig. 1) Local map of the South Bay Los Angeles area (directions to each stop are described in detail below). You can locate the starting point – California State University Dominguez Hills (CSUDH) - on the map by finding Home Depot Center, which is on the CSUDH campus.

The primary purpose of the photos in this guide is to direct your attention towards interesting topics at each field trip locality. The field trip takes on average about 4 hours to complete, including drive time from CSUDH. If you can't make the drive, the photos can also serve as a virtual field trip!

STOP 1a) Los Angeles Harbor

Directions from CSUDH to Los Angeles-Long Beach Harbor & Point Fermin:

1. *Head west on E Victoria St*
2. *Take the 3rd right onto Avalon Blvd W, go 0.5 mi*
3. *Turn right to merge onto CA-91 W, go 0.7 mi*
4. *Take exit 6 to I-110 S toward San Pedro, go to end, 9.6 mi*
5. *Turn left onto N Gaffey St; go ~2.4 mi (there is one traffic light at a fork where you'll need to bear left)*
6. *Before you get to Point Fermin, on the left you will see some large pullouts. Park here.*

Here, you immediately see views of the Port of Los Angeles, aka Los Angeles Harbor. The Los Angeles Harbor sprawls 7,500 acres inside San Pedro Bay. With the adjoining Port of Long Beach, it is the busiest container port in the US. The downside of all that shipping volume is increased air pollution, particularly to the nearby areas of San Pedro, Wilmington, Torrance, and Lomita.

Interesting historical fact: San Pedro Bay was discovered in 1542 by Juan Rodriquez Cabrillo, a time when the south-facing harbor was a shallow mudflat which could not be traversed by ships. A different look today…

Fig. 2) This photo taken from the San Pedro viewpoint shows a breakwater extending towards the south and curving to the east (left). The breakwater protects the LA Harbor from incoming ocean swells. Just past the distant palm trees, a jetty extends to the west (right) at the southern end of Cabrillo Beach. This jetty traps sand for western beach. However, the beach to the east (left) has more sand than the western beach due to the fact that it is more protected from incoming swells.

Fig. 3) This aerial view taken from a plane shows Cabrillo Beach and the breakwater (bottom lower left) and large shipping piers and port facilities (photo courtesy USGS).

Fig. 4) This photo shows the same piers from the San Pedro viewpoint. Note the brown haze - or smog - hovering over LA. This air pollution is from the burning of fossil fuels in cars, trucks, ships and industrial plants. More specifically, smog is due to the chemical reaction of sunlight, nitrogen oxides and volatile organic compounds in the atmosphere, producing airborne particles and ozone (“photochemical smog”).

Fig. 5) Aerial view looking north towards western San Pedro (housing tracts), Pt. Fermin (left edge of photo), and Cabrillo Beach (bottom). Pt. Fermin’s famous landslide and “Sunken City” (next field trip stop) are located just south of the triangular-shaped treed area towards upper left. The breakwater is seen in the bottom part of the photo, with LA County beach to the west (left) and LA City beach to the east (right; photo courtesy of CSULB).

STOP 1b) / Point Fermin

1. *Continue west on Gaffey St*
2. *Turn left onto W Paseo Del Mar*
3. *End at Point Fermin Park: 500 W Paseo Del Mar, San Pedro*

Now… on to the rocks! Almost all of the rocks you will see today are part of what is known as the Monterey Formation. The Monterey Formation is a large assemblage of sedimentary rock layers that extends through much of southern and central California. The strata (layers) within this formation are Miocene in age (~8 to 15 million years old), relatively recently in the eyes of a geologist! The Monterey Formation is subdivided into three members - the Altamira Shale, Valmonte Diatomite, and Malaga Mudstone, all of which have been studied extensively. Why? The Monterey Formation contains oil, and it is these rocks that petroleum companies want to drill offshore. These sedimentary rocks were deposited in a deep marine environment at water depths of a mile or more, and because they are now exposed on land, the strata had to have been uplifted - or brought up out of the sea - by plate tectonic forces.

Fig. 6) This aerial view shows Pt. Fermin and the Sunken City slide, with LA Harbor in the background. Look for a road in the middle of the photo that terminates abruptly – this is the very edge of the land slide. You'll soon walk on this road (photo courtesy of CSULB).

Access to Pt. Fermin landslide, aka Sunken City, varies. Sometimes the gate is open; other times it is closed. When the gate is closed, geologists - and others - have been known to climb under or around the fence towards its far western end…

The land first started sliding in 1929. At this time - during the Prohibition and just prior to the Great Depression – Pt. Fermin was a hopping LA hotspot, complete with a trolley stop, bootleg liquor, and superb sightseeing with panoramic views of Santa Catalina Island and LA Harbor. More catastrophic sliding began in 1940, taking parts of what used to be the old Coast Highway (now Paseo del Mar) down into the surf below.

Fig. 7) After passing the fence/gate, walk to the right and you can see the remnants of the actual rail lines of the trolley tracks (shown here).

Fig. 8) Walk a short distance until you see what looks like an old road – this is in fact a remnant of the old Coast Highway.

Fig. 9) Follow the road towards where it ends and look over, not too close to edge of course. This is the start of the landslide. You are looking out over what is called the “head scarp”, or the cliff where the rocks broke free.

Fig. 10) Down below, you see pieces of what was the old Coast Highway, now adorned with graffiti.

Fig. 11) From this vantage point, look north. Here, under the Pt Fermin lighthouse, bedding (layering of the rock) tilts with a slight 10 degree angle - or "dip" - towards the ocean.

So, why do landslides occur along the coast in Palos Verdes? There are many reasons:

- wave erosion cuts away at the bottom of cliffs, over-steepening the slope
- the ocean creates what can be called a "free face", that is, the rocks simply have somewhere to go, much like when Caltrans dynamites a passage through a hill and the rocks subsequently cave in
- gravity acts to pull the rock down
- the rocks are weak, made of mudstone and shale (pick up any rock, you can break most rocks in your hands)
- the bedding (layering of the rock) tilts slightly toward the ocean (Fig. 11)
- some surfaces act like a plane of weakness or slide surfaces, in particular layers of clay called bentonite
- rain seeps into the ground and can facilitate slip along these slide surfaces.

STOP 2a) Royal Palms State Beach, aka White Point State Park

Continued directions (to White Point):

1. *Head northwest on W Paseo Del Mar toward Roxbury St, 0.5 mi*
2. *Turn right onto S Emily St, 472 ft*
3. *Take the 1st left onto W 37th St , 161 ft*
4. *Take the 1st right onto S Alma St, 0.6 mi*
5. *Take the 3rd left onto W 25th St, 0.8 mi*
6. *Turn left onto S Western Ave, 0.5 mi*
7. *Turn right onto W Paseo Del Mar, 0.1 mi*
8. *Make a U-turn at Graysby Ave*

Fig. 12) Before you walk down the road to the beach, look to the north to see this view of marine terraces. The houses built on the prominent flat surface are built on a marine terrace. Marine terraces are platforms that were cut by the waves a long time ago and which are subsequently uplifted out of the sea to become land. This is due to what geologists call tectonic uplift, produced by compressive stresses within tectonic plates. Marine terraces make great flat surfaces for developers to build on, and most of the developments you see in Palos Verdes are built on uplifted marine terraces. As you look down the road to the beach, notice the steep cliff faces, ripe for landslides like the one you just saw at Pt Fermin, and which you'll see shortly at STOP 2b.

Fig. 13) Look along the beach and you see a point of rock sticking out. These points are made of stronger more erosion-resistant rocks; in Palos Verdes these are typically comprised of basalt. Basalt is a dark iron-magnesium rich volcanic rock that poured out on the earth's surface as lava. Some of these lavas spill out onto the ocean floor and are called submarine basalts. Closer to you in the photo (and lining the beach in front of the white van) is a long strip of rip-rap, or large strong boulders intentionally placed to prevent erosion. When you get down there, go stand on them. Based on what you've seen so far, do these rocks look like they come from a local source?

Fig. 14) On the walk down, look to your right to see tilted bedding. These are layers of mud that were deposited horizontally on the ocean floor and have since been solidified, folded and tilted. You'll see a spectacular fold very shortly.

Fig. 15) Here is a excellent example of a recumbent fold, which like a Lazy Boy recliner, is in recumbent - or lying down - position. Horizontal rocks are first folded into a downwarp called a syncline (looking like a taco of sorts), or into an upwarp or anticline. Here the rocks have been further folded and turned over on their side. This geologic deformation is due to compression caused by plate tectonic stresses.

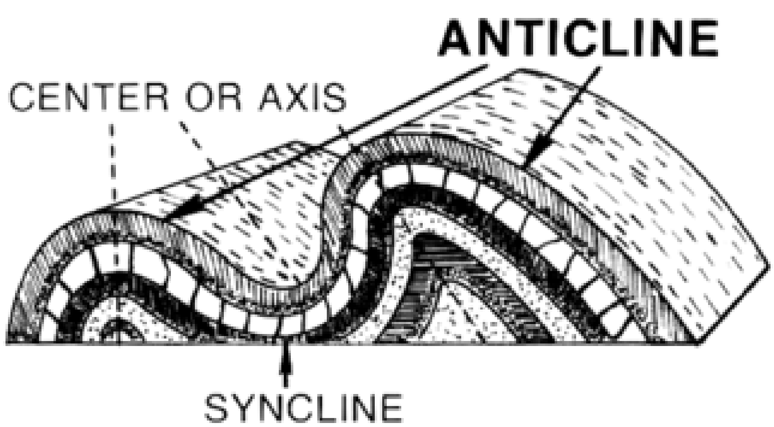

Fig. 16) Cartoon showing an anticline-syncline pair.

Fig. 17) The rip-rap here is made of granite and is not local in source. It was trucked in from one of the granite-bearing areas, either Riverside County, or the San Gabriel Mountains. There are many different kinds of “granite” here, including granodiorite, diorite, and gneiss (a metamorphic rock). All of these rocks originated as igneous rocks (from magma) and are plutonic (cooled underground, giving larger crystals). The word ‘plutonic’ comes from Pluto, the Greek god of the underworld; ‘volcanic’ (magma that make sit to surface as lava) drives from Vulcan, the Roman god of fire.

STOP 2b) Recent landslide slide south of Royal Palms State Beach

Walk about a hundred yards south and you'll run into a fenced area. This part of the road slid in 2011, similar to the slide you just saw in Pt Fermin.

Fig. 18) The view from the south, from the closed Paseo del Mar (as of May 2012). For a sense of scale, there is a man standing at the edge of the slide.

Fig. 19) Aerial view of the slide (AP photo). For scale, you can see people standing on the road to the far left.

Fig. 20) Note the section of road which moved as a solid block and the large palm tree which survived happily in that block. This block moved down and to the right towards the ocean (the free face) as a solid unit, whereas the road section in between (to the right of the people) collapsed into rubble (AP photo).

Fig. 21) Here you can see how the whole block detached and slid towards the ocean. Note the brown color of the water. At the time this photo was taken, sediment was being transported from the loose slide debris into the ocean, and that is why the ocean color is brown (AP photo).

STOP 3a) … not really a stop, but you will drive through….

Continued directions (to Terranea):

1. *Head north on S Western Ave toward W 25th St, 0.5 mi*
2. *Turn left onto W 25th St, 1.3 mi*
3. *Continue onto Palos Verdes Dr S, 2.3 mi*
4. *Keep left at the fork,1.8 mi*

Fig. 22) Trump National Golf Course, viewable to the left as you drive by. One the Donald's holes collapsed but he quickly had it rebuilt.

Here is some additional information for the student who has had some geology courses already… if some of these ideas appeal to you, you could take EAR 450 (Plate Tectonics and the Rock Cycle), a course I teach at CSUDH.

Deformation. The geologic deformation in Palos Verdes (folding and faulting) is caused by plate tectonic stresses. Folding is produced by compression ultimately rooted to transpression, i.e., compression within a transcurrent fault system. Transpression in southern California is largely due to the left bend in the right-lateral San Andreas fault. Locally, the main player is the Palos Verdes fault, which trends NW and extends along the northeastern side of Palos Verdes, from the LA Harbor (Figs. 2-4) to south Torrance (just past the outcrops in Fig. 42). The Palos Verdes fault is an oblique-slip fault, with a ratio of strike-slip to dip-slip of 10:1, a relatively small dip-slip component, but yet enough to a) create the Palos Verdes hills, b) uplift the Monterey Formation from a marine to a terrestrial setting and c) create 13 marine terraces via sequential uplift.

Depositional Environment. We know that deposition of the Monterey Formation occurred with a deep marine environment because of the presence of diatoms, chert, turbidites, and marine fish fossils. In addition, there is the presence (and large volume) of thinly-bedded mudstone and shale, the absence of high energy deposits, and a very low volume of sand in the depositional system.

Fig. 23) This aerial view shows Trump's Golf Course, with Portuguese Bend landslide in the background. The Portuguese Bend landslide is marked by the more vegetated area in the middle of the photo and the prominent steep cliffs (landslide scarps) behind. Behind that you can see Santa Monica Bay and the Santa Monica Mountains (just below the clouds). Abalone Cove is a nice beach to visit if you have extra time – it is the furthest (to the north) pocket-shaped beach on this photo (photo courtesy of CSULB).

Soon you will drive through the Portuguese Bend landslide. The slide is about a ½ mile wide and ¾ mile long. This area has been sliding for about ¼ million years, which sounds like a along time but to us geologists that's a blink of an eye. More recent sliding began in the 1950's, just after many houses were built in the post-WWII building boom. Sliding increased as ground water levels rose, the latter due to homeowner irrigation, and installation of pools and septic tanks. Almost all of these houses have since been destroyed by landslide activity. The homes that survived now have water and sewage lines above ground, so sliding can still occur under the lines.

The slide moves slowly, currently about 14 feet per year, yet this is fast enough that multiple sections of the road have to be re-patched every year. Note the large pipes which parallel the road – these pipes transport water off the slopes in an attempt to mitigate the sliding (water acts as a lubricant).

STOP 3b) Terranea Resort, aka Marineland

Continued directions (to Terranea Resort):

1. *After driving through the Portuguese Bend landslide, continue until you reach Terranea Way (traffic light).*
2. *Turn left onto Terranea Way.*
3. *Continue to Visitor parking area to the left. If the lot is full, you are allowed to park on the south side of the entrance road.*

Fig. 24) This is a fault – a planar fracture across which there has been significant earth movement during an earthquake, or series of earthquakes. The fault here is marked by truncation – or offset – of bedding (rock layers). Note the color change going from left (mostly whitish-yellowish rocks) to right (many orange rocks). There is also a small gully along the fault filled with vegetation. These gullies form as the result of fault action, which breaks the rock. As the rock breaks, it is easier to erode, and it thus becomes a weakness through which water can flow. When it rains, this turns into a waterfall, and the vegetation is there because the water is there. Geology, at its core, is simple and intuitive. But, as with most things in life, the more you know, the less you know….

Fig. 25) Can you find the two prominent faults in this photo? Look for the color changes which mark offset bedding.

Fig. 26) A close-up of one of the faults. Faults become obvious once you know what to look for, in this case - offset bedding.

Fig. 27) This is an even closer view along the same fault. Towards the bottom right, you'll see rock that looks crushed, with little boulders sticking out. This is - in fact - crushed rock. Simple, right? We geologists call this rock "cataclasite." It is another line of evidence for faulting. If the pieces are extremely fine, like a powder, the crushed rock is called "fault gouge."

Fig. 28) Walk to the end of the beach and climb over a small mound of rock. Looking to the left, you'll see this sea cave. Walk inside. To the back there are old pieces of shipwreck. Look up and you'll see cataclasite. You are within - and right under - a fault. The sea cave was created in the same way the water gully was. Earthquakes along faults break the rock, the rock erodes away, in this case augmented by wave erosion, leaving a cave.

Fig. 29) Now look up on the walls of the cave and you'll see lines and grooves like this. These are "slickenlines", or scratches in the rock left from faulting. Put your hand on the surface of one of these. Feel how smooth the rock is? That is the result of polishing from fault friction – geologists call these polished fault surfaces "slickensides." Slickensides and slickenlines are further evidence of faulted rocks. Slickenlines are an especially powerful piece of geological evidence for faulting. If the lines are horizontal, the rocks moved horizontally during the earthquake; geologists call these "strike-slip" faults. The San Andreas Fault is a major strike-slip fault. If the lines are vertical, the rocks moved up and down during the earthquake; geologists call these "dip-slip" faults. The Northridge earthquake in 1994 occurred along a dip-slip fault.

So you have now had a mini-course in the evidence for geological faulting, and you know what to look for if you suspect a fault (truncated bedding, cataclasite, fault gouge, slickensides, slickenlines). The presence of gullies, vegetation and/or sea caves support the likelihood of faulting, but these features can be caused by other reasons. We then say these observations are supportive but not conclusive of faulting. You are now on your way to being an armchair geologist!

STOP 4) Bluff Cove

Continued directions (to Bluff Cove):

1. *Turn left onto Terranea Way, 0.1 mi*
2. *Turn left onto Palos Verdes Dr S, 2.7 mi*
3. *Turn left onto Paseo Lunado, 0.3 mi*
4. *Continue onto Paseo Del Mar*

Fig. 30) On this drive, you'll pass many magnificent views. Here is a view towards the south end of Bluff Cove. You can kelp beds in the foreground and waves bending toward the point further out. This bending is called wave refraction.

Fig. 31) This is the promontory on the north end of Bluff Cove. The land sticks out as a point because it is made of harder rock (again, mostly basalt). To the left, you can see a trail that goes down to the beach.

Fig. 32) The same promontory, now looking down from the road. The waves are breaking on the headland, made of the stronger basalt rock. There is a pullout here, mostly used by surfers who hike down to Bluff Cove. It is a nice short hike if you have extra time.

Fig. 33) A view along the road. Kelp beds of foreground; Redondo Beach and Torrance in the background.

STOP 5) Malaga Cove aka, Rat Beach, aka Haggerty's

1. *Keep going east (follow coast) on Paseo Del Mar*
2. *Turn left onto Palos Verdes Dr W*
3. *Turn left at Via Almar.*
4. *Turn right at Via Arroyo. Go to junction with Paseo del Mar.*
5. *Park right into big parking lot (school just behind lot).*

NOTE:
If you would like to go directly to **Malaga Cove**, skipping all previous stops, here are directions from CSUDH:

1. *Go west on W 190th St (same street as Victoria St), ~4.3 miles*
2. *Turn left onto Hawthorne Blvd, 1.4 mi*
3. *Turn right onto Torrance Blvd, 1.9 mi*
4. *Turn left onto CA-1 S (PCH), 1.4 mi*
5. *Turn right onto Palos Verdes Blvd, 1.4 mi*
6. *Turn right onto Palos Verdes Dr W*
7. *Turn right at Via Almar.*
8. *Turn right at Via Arroyo. Go to junction with Paseo del Mar.*
9. *Park right into big parking lot (school just behind lot).*

Fig. 34) Aerial view of Malaga Cove. The parking lot you parked in is clearly visible in the center; Haggerty's surf spot is at the bottom (what surfers call a "left-breaking point"; Rat Beach - where you will walk - is located to upper left (photo courtesy CSULB).

Fig. 35) On the walk down the road to the beach, you'll see this outcrop at a right turn in the road. In the photo, at about two-thirds up you can see a horizontal line that marks what geologists call an "angular unconformity." An angular unconformity is a buried erosion surface. The rocks below the unconformity are older and tilted (folded) mudstones; the rocks above the unconformity are younger and undeformed gravels. Angular unconformities are important to geologists because they mark a significant break in the geologic record. The rocks below were deposited, solidified, tilted and then eroded, after which the younger gravels were deposited.

Fig. 36) Wise place to build a house?

Fig. 37) The white rocks on top are diatomite – a rock containing the preserved remains of diatoms, a type of hard-shelled algae made of silica (SiO_2). Diatomite forms in the deep sea, indicating a) these rocks were at one time under the water and b) the rocks have since been uplifted. Based on what you've learned so far, how do you think these rocks were uplifted? Between the steep cliff and the beach is a rock fall, where blocks of the diatomite have fallen due to gravity. Pick up a piece of diatomite from the bottom of the cliff… describe its weight. Why do you think it weighs what it does?

Fig. 38) Note the tilt of these rocks – they are tilted at an angle of about 45 degrees to the left (north).

Fig. 39) This is a close-up view of the tilted rocks; these rocks are also diatomite, as indicated by their white color, low density, high porosity, and other properties.

Fig. 40) Stand way from the cliff, as close to the water as possible, and look back at the cliff. You are looking at a syncline, where layers on opposite sides tilt towards each other. These layers were folded and the youngest rocks remain in the center. This syncline is a bit more complicated, as it appears a landslide has eroded out the core of the fold. You can see the head scarp of the ancient landslide just below the building.

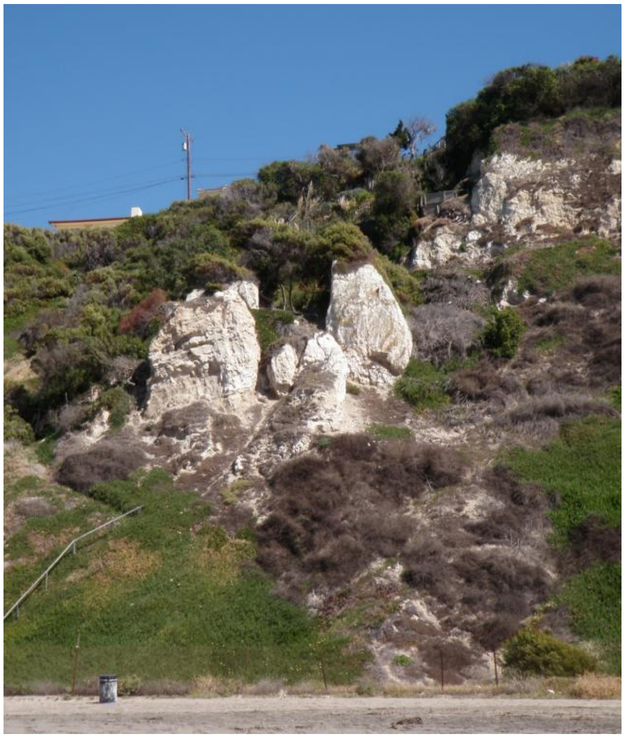

Fig. 41) In the foreground is a slide block of diatomite that slid from higher up on the cliff. The difference between a rock slide and rock fall is that material in a rock slide moves coherently as a large intact block (usually on top of a low-angle curved surface), whereas a rock fall involves a steep slope with rocks falling and shattering chaotically. (Recall the aerial photos of the recent landslide along Paseo del Mar, showing both a slide block and a rock fall area.)

Fig. 42) The brown rocks in the bottom center of the photo are much younger rocks than those you have been observing all day (Monterey Formation). These younger rocks belong to a different rock formation (Repetto Formation) that is Pliocene in age (5 to 10 million years old). The brown clump of rock was originally attached to the higher part of the cliff just under the houses, and like many of the rocks in Palos Verdes, is the remnant of a landslide. Good place to build a house?

Fig. 43) Marine terraces. First note the modern day marine terrace (wave-cut platform) you are walking on, that is, the beach and its substrate. Now look up to the next flat surface you see (there is a large white building with an orange roof towards the right - a church) – the church is built on an uplifted marine terrace. Look up to the left to see the second horizontal tier of houses – these are built on an older (and thus higher) marine terrace. Look up further and you'll see a third tier of houses near the skyline– another marine terrace. These marine terraces in Palos Verdes (13 in total) were uplifted by movement along faults (earthquakes) due to compression from plate tectonic forces.

Fig. 44) What do you think created these holes in these rocks? Answer: worm burrows.

Fig. 45) Here you see obviously different rock types; the dark grey rock is basalt (same as you saw at previous stops); the light rock is silicified diatomite (chert) – a landscaping rock used around the South Bay (for example, at CSUDH).

Fig. 46) Chert rock used for landscaping.