Quick Overview of Palos Verdes Geological History and Landslides

The Palos Verdes Peninsula used to be an island! It was just another Southern Channel Island, part of the Peninsular Ranges Geomorphic Province.

You can see an entire topography offshore, of extensions of the California coast offshore, including submerged shallows or seamounts that would become islands or peninsulas if the sea level were to drop.

The Los Angeles Basin was underwater for much of its history until tectonic uplift and accelerated deposition of materials eroded from that raised landscape built up enough of the shallows to connect Palos Verde Island with the mainland.

You might remember from physical geography or general geology how wave energy is concentrated against headlands and islands and how the area behind the headland or islands is a low wave energy environment. The low energy of spent waves allows deposition behind the prominent feature. Deposition can connect a free-standing rock or island to the mainland, a feature called a tombolo. The Palos Verdes Peninsula and the extended Los Angeles Coastal Plain is a sort of tombolo, forming at the same time that the whole area itself is being uplifted. Uplift is occurring in association with the Palos Verdes Fault, just to the north of the PV hills and extending offshore to the southeast, and the Newport-Inglewood Fault (of Long Beach Earthquake fame). The compressional forces in the landscape under Palos Verdes created an anticline there, a bunched up pile of originally horizontal marine and alluvial beds. The axis of this anticline parallels the Palos Verdes Fault.

Palos Verdes Island began to connect with the mainland sometime during the Pleistocene, the era of repeated ice ages and ocean level drops over the last couple million years through this combination of renewed uplift and filling in of the shallow seas to the north and east. The rate of uplift is quite fast by geological standards, actually -- something like 6.4 cm/century over the last 2.8 million years.

This uplift hasn't been even through time or through space, and the unevenness has been accentuated or offset by ice age related changes in sea level. The result of this unevenness has been the development of an impressive "stairway" of marine terraces on the PV coast. In the eastern peninsula, you can actually make out 13 of these terraces (several visually and the rest through detailed lab and field work)!

The terraces are created by wave action against the then shoreline. The ocean's waves will cut into a coast, creating cliffs with a wave-cut notch at the base. The notch then expands under the cliff, and the cliff will eventually fail as its mechanical support goes away. Meanwhile, wave swash and backwash will cut into the beach in some places and throw the eroded cliff and beach materials into a bench offshore. The combination of this cutting and benching is the formation of a distinctive flat area along any beaches that have stood there long enough.

If tectonic uplift accelerates again (or if an ice age pulls up so much water that ocean levels drop), the cliff and the bench below it are hoisted up above the reach of the waves. Eventually fluvial erosion and mass wasting of the area at and above the cliff will drop alluvial materials over the cliff and onto the bench. This new structure may itself be hoisted higher as the process repeats. In Palos Verdes, this has happened at least 13 times in the last 2.8 million years. Our ability to pick out these features indicates that the process is going on so fast that it can't be hidden by erosion and deposition smoothing away the surface evidence.

Now, one big mass wasting consequence of all this uplift is landslides, which Palos Verdes is famous for. Basically, the earth is rising so fast along the Palos Verdes anticline and fault system that the land is unable to resist the downward pull of gravity: The potential energy of gravity eventually overcomes the inertial cohesion of the rock materials.

Lots of places in Southern California are uplifting fast but not all of them are slipping as fast as Palos Verdes. It seems there are some special plot complications here, which have to do with its geological history.

If you could see Southern California back at the end of the age of dinosaurs, 65 million years ago, you would not at all recognize the place. Much of it was under the ocean. Far offshore was a plate tectonic spreading zone, the East Pacific Rise, complete with an island arc of volcanoes. To its west, the Pacific Plate was moving off to the west and north. The ocean floor to the east, a plate called the Farallon Plate, was sliding toward and subducting under North America. A lot of the uplift that characterizes the American West got going as the North American plate rode up over the Farallon Plate and something like 29 or 30 million years ago began to cover up the East Pacific Rise. This put the North American Plate in contact with the Pacific Plate and eventually gave birth to the San Andreas regional system of right-lateral faults.

This completely altered and redistributed the forces operating in the region. As the new plate contact "zipped up" over the old East Pacific Rise, bits and pieces of land (terranes) broke off from the North American Plate and were moved and spun around. The Transverse Ranges were one of these: They were originally oriented north-south offshore and were turned around clockwise to run east-west, giving Southern California the only east-west trending ranges in North America! The modern. recognizable San Andreas Fault goes back about 8 million years.

Among the stresses and strains in the new landscape was the creation of the Palos Verdes anticline, a hump of rock sediments compressed upward along a spine running southeast-northwest. It is the buckling upward of this feature that pushed Palos Verdes up out of the ocean floor so fast.

Another plot complication was an outburst of vulcanism back in the Miocene. The Miocene dates from about 20 million years ago to about 10 million BP. The volcano heyday was in the middle Miocene, peaking around 15 million years or so ago. Some of these volcanoes dribbled basalt all over (and we see basalt layers here and there all over PV, including some pillow basalts formed when basalt erupted or flowed out into the sea). Much more important to the history of landsliding, however, was the spewing of volcanic ash and cinder all over. This stuff formed a rock called tuff, in some places as much as 15 or 16 meters thick and in other places just forming thin bands.

Subsequent interactions of tuff with water (in marine deposits later uplifted or rain, groundwater, or even hydrothermal action) caused the tuff to interact with water and undergo chemical alteration into bentonite clay. You may be familiar with bentonite if you're into gardening: It's something you can add to potting soil to make it absorb and hold water. Bentonite swells when exposed to water and becomes this kind of greasy glop, not what you need when that glop layer is supporting the weight of layer upon layer of heavy rock above. The presence of Portuguese tuff and bentonite layers amid the Miocene Monterey Formation sediments creates lubricated layers that can enable a large chunk of overlying terrain to slide as coherent units down a slide plane (translational slides, like the Portuguese Bend slide) or detach and crumple backward (rotational slides, like the Point Fermin slide). Further adding to the slide-proneness of the area is the way that the bedding planes of the anticlinally-tilted sedimentary beds parallel or even exceed the slope angle, almost inviting it to shave off in layers, especially as the sea undercuts the support at the end of the layers out on the wave cut cliff faces.

There is a gigantic slide that was active about 37,000 years ago, which is locally called the "Ancient Landslide." This landslide stabilized for a long time, for unknown reasons. Its upper layers then reactivated in 1956, after Rolling Hills was developed and suburbanites put in septic tanks and lines and began irrigating their lawns and *Sunset Magazine* landscaping. This human activity apparently introduced enough extra water (and detergent chemicals) into the bentonite layers to detach the landslide along a plane higher up than the original Ancient Landslide translational plane. About 270 acres have moved something like 600 feet toward the sea over the last half century. This is the Portuguese Bend Landslide. It is still very active, with such constant motion that Palos Verdes Drive has to be resurfaced and repositioned constantly, as the rough ride on that stretch of road will show.

In 1978, another slide began near the Wayfarer's Chapel and Abalone Curve. This is called the Abalone Cove landslide. Fortunately, this one has stabilized and isn't creeping along the way the Portuguese Bend slide is still doing.

Point Fermin's landslide activity became apparent in 1928 and 1929, when a 6 acre chunk of countryside began detaching and creeping toward the ocean at the end of Paseo Del Mar. There was enough time for most of the houses that were then there to be moved out, but the ones on the end eventually slipped into the sea, where you can see their concrete foundations and slabs of sidewalk and street. This rotational slide stabilized after more homes fell down in 1940. But then parts re-activated in 2011, taking out a section of Paseo Del Mar in front of the White Point Preserve.