

Geologic Points of Interest

Crystal Cove State Park

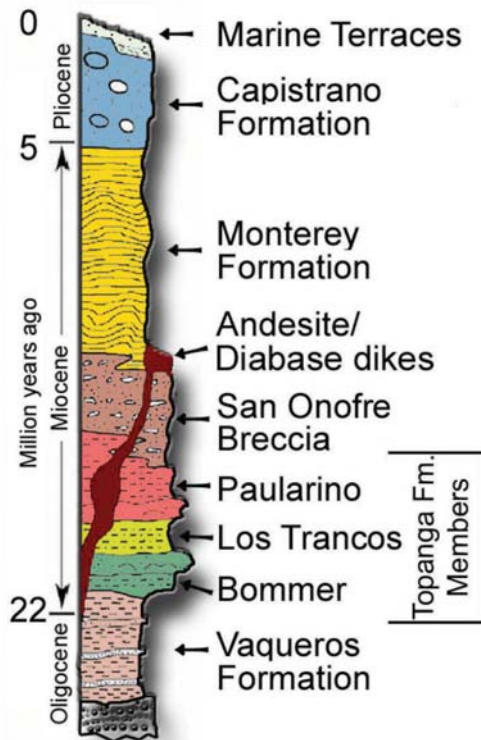


Spectacular ocean panoramas and contorted rocky cliffs are yours to enjoy on this self-guided tour of Crystal Cove State Park. Whereas the **Geology Discovery Trail Guide** focuses on the 25 to 15 million-year-old *Vaqueros* and *Topanga Formation* rocks and geologic history of the park back country, this **Geologic Points of Interest** guide takes you to the shore where the (locally) 12 to 6 million year-old rocks of the *Monterey Formation* crop out.

The ocean environment, marine life and sediments combine to produce fossils, concretions and one of California's richest petroleum source rocks – the *Monterey Formation*.

Beginning 25 million years ago sediments (sand, silt, clay, and organism skeletons) slowly accumulated in shallow Pacific Ocean waters and formed the geologic layer known as the *Vaqueros Formation*, the oldest exposed rock unit in the park.

Sediments deposited over the next several million years formed the *Topanga Formation* in an oceanic environment deeper than the *Vaqueros*. Composed of units slightly varying in rock characteristics, the *Topanga Formation* is subdivided into three separate **members**. The oldest and lowest member is the *Bommer*, overlain by the *Los Trancos* and *Paularino Members*.



Between 15 and 12 million years ago sediments forming the *San Onofre Breccia* were deposited from islands offshore (no longer nearby because of erosion and faulting) as California was torn apart by tectonic forces. **Magma** (molten rock) worked its way up through **joints** (cracks) and faults forming andesite and diabase **dikes** (igneous intrusions cutting across the rock fabric) and **flows**.

Between 12 and 6 million years ago fine-grained sediments including microscopic plankton accumulated (in water depths up

to 1700 meters) to form the *Monterey Formation*. (Elsewhere *Monterey Formation* ranges from 18 to 6 million years in age.)

The last major rock formation deposited was the *Capistrano Formation*, which covered the *Monterey*. However in Crystal Cove, most of the *Capistrano Formation* has been eroded away so that 120,000 year-old *Marine Terrace* deposits lie directly on the *Monterey*.

Beginning 4 million years ago and continuing today, the area was uplifted, faulted and folded while ocean waves carved marine terraces at sea level. Terraces can now be seen in the surrounding hills at various elevations up to 1000 feet above sea level.

Catastrophic geologic processes, including floods, landslides and earthquakes, continue today in the park. Although the youngest evidence of volcanism in the park is about 6 million years old, even the magma could arise again!

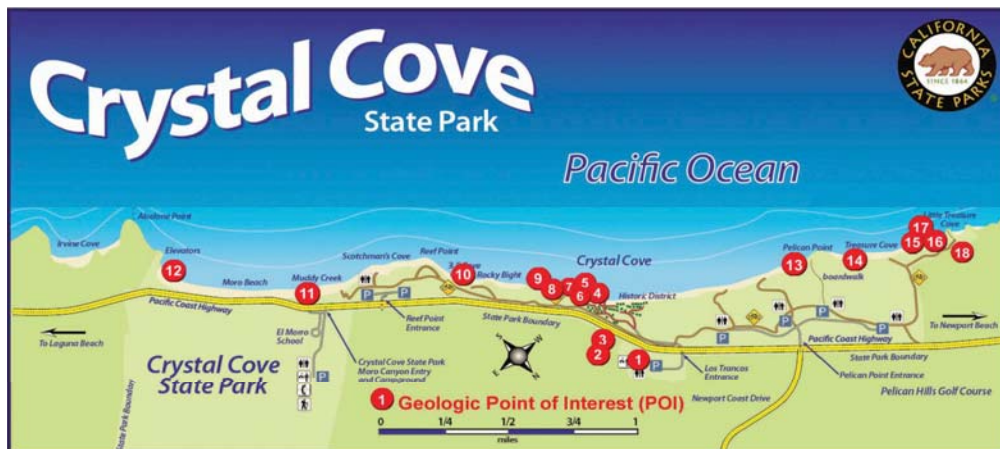


Points of Interest

#1 Sidewalk Cracks

33°34.670'N 117°50.439'W

Our first Point of Interest (POI) is along the south side of the Los Trancos parking lot. Observe the cracks in the sidewalk and adjoining asphalt pathway. Why are they here?



#2 Urban Runoff – Part 1

33°34.676'N 117°50.450'

Ground movement is the answer. But what kind? **Faulting**, **clay soil expansion** and **contraction**, **mass wasting** (the downward movement of rocks or soil due to gravity – ranging from high speeds such as **rock fall** to very slow **creep**), or some other movement? All are possible and occur in the park. Here, expansive clay soils and soil creep are most likely (although large faults – the Newport-Inglewood, Pelican Hills, and Shady Canyon – occur in and near the park). Cracks nearly paralleling streets as in the picture below, indicate creep is a likely culprit.



Why does the water run year round even long after the rainy season? Why does it commonly flood the tunnel under Pacific Coast Highway just ahead? The answer is **urban runoff**. This is water from homeowners' landscape, city streets, and the golf course. Despite the constant flow, runoff is now much reduced since the installation in 2007 of an elaborate water capture and storage system. The steel doors in the pavement (photo below) hide the system's water pumps.

Urban runoff is an environmental concern because the water is polluted with detergent (car washing), fertilizer (lawns and gardens), and petroleum (dripping oil from cars causes more pollution each year than the celebrated Exxon Valdez oil spill of 1989 estimated at 500,000 barrels of crude).



#3 Igneous Rocks

33°34.577'N 117°50.391'W

Just before the tunnel you will see hard crystalline boulders embedded in the concrete. These **igneous** rocks (rocks formed from molten magma), are not natural to the park but were imported to minimize erosion. Nonetheless, look closely at their grain size and color. On this side of the tunnel, most are coarse grained (you can see individual crystals with your naked eyes) and dark in color due to iron and magnesium (**mafic** rocks). These igneous rocks are **gabbro**. When magma cools slowly within Earth's crust, the crystals have time to grow and produce coarse-grained **plutonic** texture.

Volcanic rocks (**POI #14**) cool quickly at Earth's surface and are therefore fine-grained.



Travel through the tunnel and on the beach side of the highway you will find the rocks are mainly coarse-grained and light in color due to feldspar and silica (**felsic** rocks). These plutonic igneous rocks are **granite**. Upon careful inspection you may see some gray igneous rocks (intermediate between gabbro and granite) and these are called **diorite**.



#4 Magnetite in the Sand

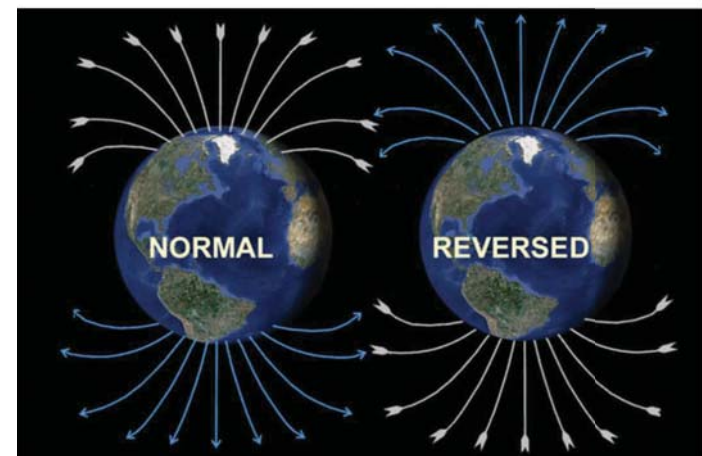
33°34.441'N 117°50.429'W

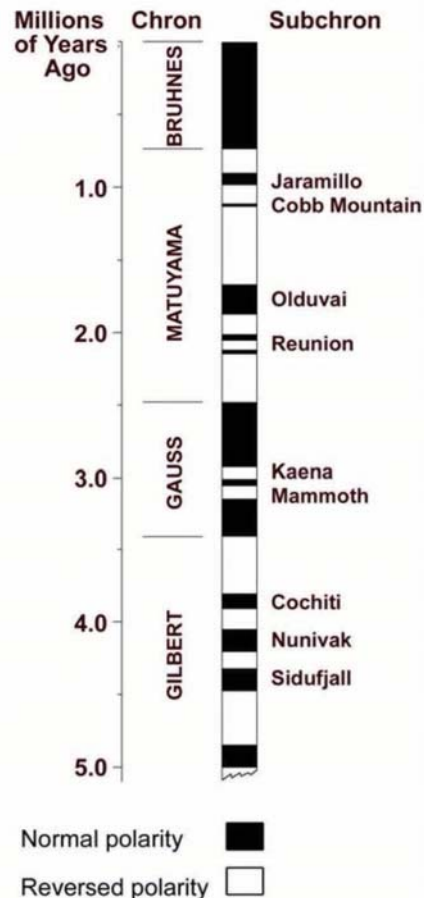
At some places in the sand you will see streaks of fine black particles. Without really analyzing it, some people conclude these are crude oil or tar. However, if you run a magnet through the streaks, the particles will stick. The black needles are the mineral **magnetite**, a component of ocean floor **basaltic** (volcanic) igneous rock. These needles have a positive and negative pole and orient according to the magnetic field in which they are placed (in this case, in the field of the magnet). As it forms at ocean ridges, sea floor rock is molten and magnetic minerals align with the Earth's prevailing magnetic field – just like a compass. When the rock cools below the **Curie temperature** about 620C° (1256F°) the needles become fixed



in their orientation and thus record the Earth's magnetic field direction at that time. When Earth's magnetic field reverses, as it has at unpredictable and irregular intervals in the past, the magnetic crystals record a reversed polarity.

Many geologists studying **paleomagnetism** (ancient magnetism) believe that Earth is presently undergoing a magnetic reversal. What will the consequences be? As Earth's present polarity becomes weaker and weaker during the reversal process, navigation by compass will become impossible. Migrating animals whose geographic orientation depends upon magnetism (pigeons, honey bees, etc.) may be unable to retrace traditional routes. As Earth's magnetic field weakens, solar radiation will become more intense and satellite communications may be disrupted and G.P.S. (global positioning systems) no longer work. The present field has existed about 700,000 years and so humans have experienced reversals before – but not humans using electronic technology. It remains to be seen how we will be affected.





**Paleomagnetic Time Scale
for the last 5 million years**

In the three **Chron**s (major paleomagnetic episodes) previous to the **Brunhes**, many **Subchron**s (short duration episodes such as **Jaramillo**) occurred. The present Brunhes Chron is undivided by Subchrons and appears overdue for a reversal. During dinosaur times (225 to 65 million years ago) periods of more than 30 million years passed without a reversal.

#5 Meandering “River” and Migrating Ripple Marks

33°34.441'N 117°50.429'W

Unlike mountain streams which run quickly and fairly straight and produce V-shaped canyons, streams in areas of low gradient (slope) run slowly and **meander** (make snake-like curves in their beds) and produce wide U-shaped flood plains. Here you see a scale model of the latter. The outside walls of the bends are called **cut banks**. As time goes by the stream laterally cuts into this bank and carries away the eroded sand. In contrast, sand is deposited on the inside of the bends called **point bars**. Erosion occurs where the stream runs more quickly (the outside of bends) whereas deposition occurs where the stream runs more slowly (the inside of bends). Look carefully and you may witness the sideways movement of the entire stream bed. Over time, meandering rivers move sideways through the landscape just like some snakes move sideways over sand dunes.

Notice also the ripples in the stream bed. These are small migrating sand dunes. Sand on the upstream side of the dunes erodes away whereas the same sand is deposited on the downstream side of each dune. The result is that through time the ripples march downstream. If you are here on a windy day, you may observe dry beach sand in the form of tiny dunes migrating down wind in much the same way the water ripples migrate down stream.

So in this one spot you've witnessed migration of two types – *sideways* in the stream bed and *downstream* in the dunes.



#6 Monterey Formation and Mass Wasting

33°34.441'N 117°50.429'W

Walking south you see the last historic cottage. The “Beaches Cottage” was featured in a 1988 film starring Bette Midler, Barbara Hershey and John Heard. Despite its fame and photogenic character, it was one of the last Crystal Cove cottages to be restored. Why? Because mass wasting of an unstable cliff of *Monterey Formation* in its back and side yards threatens its destruction.

The *Monterey* threatens landslides and slumps wherever it crops out in cliffs from San Onofre northward through Crystal Cove, Newport Back Bay, Santa Barbara, Lompoc, Santa Cruz, to Monterey. Mass wasting has taken down houses, roads and even people along with the rocks. Geologists know to be especially wary when building structures on or beneath this unstable formation.



#7 Concretions in the Monterey Formation

33°34.441'N 117°50.429'W

Although parts of the *Monterey* are hammer-ringing rock-hard **chert** (the same chemical formula and hardness as the mineral quartz), it is commonly layered with **diatomite** (a rock formed by the accumulation of diatoms – a type of planktonic algae) and clays. It is the latter layers that have a tendency to slip and slide, especially when wet.

In the Beaches Cottage photos below you can see the dramatic difference in sand height at different times. Beach frequenters may know that sand height varies with wave size, length and direction. Visitors may not realize that along our shores over 200,000 cubic meters of sand are moved each year by the **longshore** (wave-generated) current. If nourishment sands were not added along our coast, we'd lose our sand permanently to the offshore submarine canyons where the current dumps it.



Visitors to Crystal Cove often ask about the hamburger bun-shaped or UFO-shaped rock “formations” littering the beach especially in the vicinity of the Beaches Cottage. These features range in size from a few inches to more than 12 feet in diameter. Look carefully in the cliff towering over the side yard of the cottage.

You will see several examples embedded in the *Monterey*. Geologists call these bodies **concretions**. Although small examples are common, large specimens like many here are relatively rare - although do occur elsewhere in California such as along the Santa Barbara Coastal Plain and at Bowling Ball State Beach near Point Arena.



How these large concretions formed is a fascinating story. A favorite hypothesis is that the rounded masses are like tumors growing in the body of an organism. If you are unfortunate enough to get a splinter under your skin, your body reacts. The site may become infected by bacteria or other microorganisms, and a “tumor” forms walling off the splinter from healthy tissue. The *Monterey* also grew “tumors” by being infected. How? The *Monterey* formed in a mile plus deep marine environment. Clay and other fine-grained sediment such as diatom and calcareous plankton **tests** (skeletons) accumulated to form an **ooze** (a marine sediment with more than 30% organic material). Heavy rain and flooding brought wood to the beaches. Some drifted out to sea, became water-logged, and sank into the ooze. These “splinters” became infected with bacteria which interacted with the sediment and the wood to produce swelling. The ooze with the nodules ultimately turned to stone.



#8 More Concretions

33°34.334'N 117°50.333'W

What proof do we have of this fantasy? In many instances the concretions have broken open revealing petrified wood – in some instances bark, branches and roots – at the core of the nodules. Some are still visible at the beach and some, like the two below, are on display at the El Moro Visitors' Center.

Note the changes due to weathering in only five years (bottom row). Not only has it disintegrated, it fell over sideways!



#9 120,000 Year-Old Fossils and an Unconformity

33°34.334'N 117°50.333'W

Walk further south and you will see these shells embedded in sandstone on the beach (adjacent to the cliffs). You may not give them a second thought. Although to the casual observer they appear modern, they are about 120,000 years old. This seems a great age to humans, who typically consider time in hours, days, weeks, years, and human lifetimes. To geologists 100,000 years is just a blink of an eye in a world exceeding 4.5 billion years in age. Because 100,000 years is so little geologic time, these fossils look like modern shells.



Another aspect of these fossils is that they are out of place. You will see the fossil bed from which they originated $\frac{3}{4}$ of the way up the cliff. This bed lies immediately above the *Monterey Formation*. Since the youngest *Monterey* is about 6 million years old and these fossils are about 120,000 years old, lots of time is missing from this locality. Missing time? Well not really time, but rocks deposited during the interval between 6 million and 120,000 years are missing. Prior to the deposition of these fossil beds, erosion obliterated nearly 6 million years of rocks of the *Capistrano Formation*. Geologists call this time gap an **unconformity**. This feature is easily seen on a clear day as you walk south along the beach. The younger beds are typically dark brown and contrast with the lighter underlying *Monterey*. In many places, the unconformity appears as an overhanging fossil bed “shelf”.



#10 Groundwater Seepage

33°34.042'N 117°50.004'W

Like an ink blot test, this colorful naturally-occurring wall mural is whatever your imagination conjures up. Geologically it is a spring where ground water has infiltrated porous layers of the *Monterey Formation* and percolated downward until an impermeable layer (probably **clay**) was encountered. At this point it migrated laterally down slope until it surfaces here. The red and yellow colors are iron oxide (the minerals **goethite** and **limonite**).



#11 Badlands and Heavily-folded Beds

33°33.833'N 117°49.591'W

Badlands topography is a deeply-gullied surface of erosion caused by occasional rapid runoff in arid or semiarid climates. Here the soft and easily eroded badlands rocks are underlain by deeply-folded *Monterey Formation*. Similar badlands topography can also be seen inland on the **Geology Discovery Trail**.

Folds in the *Monterey* most likely occurred soon after the water-laden sediment was deposited in a deep-water slope environment. Perhaps earthquake-induced slipping and sliding of the partially-consolidated sediments produced the wrinkling preserved in the now hard rock.



#12 Columnar Jointing in Volcanic Rock (Andesite)

33°33.399'N 117°49.177'W

At the southern most point of Crystal Cove you will find cliffs of **andesite**. Andesite is a fine-grained (individual grains are not visible with the naked eye) igneous rock which cooled from lava at or near Earth's surface. Geologists term this kind of rock **volcanic** as opposed to coarse-grained **plutonic** rock which cooled deep in Earth's crust. (Recall **POI #3**.) Here the lava cooled quickly and produced a well-defined prismatic columns. Two world famous locations visited by tourists for these **columnar joints** are Devils Post Pile near Mammoth Mountain, California, and the Giant's Causeway in Northern Ireland.



#13 Clam-drilled Rocks

33°34.792'N 117°51.209'W

Careful observers will see many examples of "Swiss-cheesed" rocks at Pelican Point. You may even see the remains of the drillers in some of the holes. **Piddocks** or **angelwings** belong to the boring clam family Pholadidae. Members of this **bivalve** (two shell) family have a set of "teeth" on the larger end of one of their shells. Using these teeth the clams bore into rock to make a burrow. Since these clams grow as they bore, the burrowed hole tapers from the thick end of the shell to the trailing end. Consequently, the clam is trapped for life (about 8 years) in its burrow. It lives by circulating water and nutrients through a siphon protruding into the water from the smaller end of the shell.



#14 Urban Runoff – Part 2

33°34.914'N 117°51.358'W

Water supplying the falls (which usually run year round) is from gardens, golf courses and streets. (see **POI #2 Urban Runoff – Part 1**). Many tide pool organisms do not do well with too much fresh water, fertilizer, detergent, pesticides, and automobile-related waste including oil, asbestos, and pavement break-down products.



#15 Gentle Folds Anticlines and Synclines

33°34.994'N 117°51.602'W

When the sand and tide are low enough, you will be able to see gently undulating **anticlines** (upfolds) and **synclines** (downfolds) in the *Monterey Formation* exposed at beach level. Folds can be caused by compressional forces deep within Earth's crust, where heat and pressure combine to alter the originally horizontal sedimentary layers. Commonly, folds are associated with faults, another indicator of stress.



#16 Recumbent Folds

33°35.029'N 117°51.635'W

The severely folded *Monterey* beds exposed in the cliff at the south end of the beach at Crystal Cove are textbook examples of **recumbent folds**. These layers are so tightly contorted that it is hard to imagine solid rock bending like this – even under high heat and pressure. Despite the extreme folding, no visible faults are associated with this outcrop. Consequently, these rocks likely folded, not deep within Earth's crust, but at the surface before the sediments **lithified** (turned to stone). Imagine a deep water slope environment (as in **POI #11**) and picture yourself pushing it, like a carpet, up against a wall until it folds. The water-saturated sediments probably slid (triggered by an earthquake) down slope until they folded as you see here.



#17 Cave and Oil

33°35.002'N 117°51.638'W

You may have already noticed black oily patches on some of the rocks or the beach sand. Be careful with your identification. Some of the spots may actually be “tar spot algae” or magnetite (**POI #3**). On the other hand, some may indeed be petroleum.



On a clear day you can see oil platforms off shore Newport and Huntington Beach. These platforms may host several dozen wells radiating like spokes from the hub of a wheel and extending down to various **reservoir rocks** (porous, permeable rocks capable of yielding oil and gas). One thing these platforms and many other land-based California oil wells have in common is that the source of oil is the *Monterey Formation* (although it has since migrated to various reservoir rocks).

Nearly all oil originates from plankton in shallow marine environments – not from land plants, which when preserved as fossil fuel produce coal. Despite old TV ads to the contrary, neither dinosaurs nor other land animals produce oil. Why? The answer, in part, is related to biomass. Even though individual plankton are small, total planktonic organic carbon (the raw material for oil and gas) dwarfs that in whales, dinosaurs and all other animals combined. It is primary producers (the photo- and chemo-synthesizers) which manufacture food for all other creatures and oil and gas.

In the *Monterey* the chief primary producers, which sometimes produce an ooze exceeding 30% of the rock volume, are **diatoms**. Diatoms not only produce the raw material for petroleum but also for the rock itself. These microscopic photo-synthetic plants manufacture porous “skeletons” of glass (SiO_2 , the chemical composition of the mineral quartz and of common window glass).

Diatoms are not the only marine algae to produce rock and oil. In the North Sea and throughout other regions of the world and especially during the Mesozoic Era (the dinosaur ages), calcareous nannoplankton produced a great deal of oil and the rock **chalk** (CaCO_3). Yes, the same stuff teachers used to write on black boards (as opposed to the oily pens now used to write on whiteboards). At other times in the past various marine plankton produced oil and gas as evolution and extinction of various algal groups progressed.

Their environment of origin is one thing all the oil-producing primary producers have in common. Most primary production occurs in shallow marine well-lighted near-shore water. The light is needed for photosynthesis and near shore is concentrated with the nutrients needed by the plants. In **upwelling** zones nutrients (like nitrogen, potassium and vitamins) are brought up to the surface from the ocean floor below. You may have a mental image of the Middle East oil fields being in a sandy desert environment far removed from marine upwelling zones. That certainly describes their present condition, but 100 million years ago when much of that oil originated, the environment was shallow marine.

#18 Newport Jetty Overlook and a Vexing Problem

33°35.027'N 117°51.642'W

From the beach climb the steps up to the bluff top and follow the path left to the Newport Jetty overlook. When looking north toward Corona del Mar, you will see the *Monterey* cropping out all along the beach. Now observe the rocks exposed on the inland side of the trail. They appear very similar to *Monterey Formation* rocks rising out of the beach sand and making up the cliffs of the cave and surrounding areas. But we are standing on the 120,000 year-old soils and elevated terrace deposits which overlie the *Monterey* cliffs.



What is the problem? How can *Monterey Formation* be both above and below the terrace deposits? Has a fault thrust old rock up and over younger rocks producing a reversed age sequence of layers? Look at the *Monterey* exposed above the trail very carefully. You may have figured out the solution. The rocks above the trail are fake, bogus, manmade! They cover a retaining wall meant to look like the rocks in the vicinity. Nice!

From this last point of interest, you may retrace your steps along the beach or continue along the terrace trail weaving through California Coastal Sage Scrub Community ecosystem, several picnic areas, and overlooking view points.

Hope you enjoyed the geology.

