California Dreaming

Department of Geology and Geological Engineering

University of North Dakota

Spring Break Field Trip Guidebook 2006

Preface and Itinerary

This guidebook was prepared by students who accompanied Dexter Perkins on a trip to California in March 2006. It is really a combination of two different trips, together designed to provide a view of a "cross-section of Earth's crust."

There are probably too many stops described here for a single trip, but we present them in an order that is feasible if you have two weeks or so of time.

day 1	Arrive in San FRancisco, pick up cars, and proceed north to the first stop at the Ring Mtn. Open Space Preserve in Tibuon. Here you will see various lithologies associated with ophiolites. Continue on to camp in one of the parks near Bodega Bay – Doran Beach is especially nice.
day 2	Start with a visit to the classic blueschist locality at Ward Cr., near Cazadero. See additional references listed below. Then, in the afternoon, visit the eclogite/blueschist on the beach just north of Jenner. Return to campground for the night.
day 3	Drive south 5 hours to a campground near Pinnacles National Monument. The Pinnacles Campground on the east side of the monument is nice but expensive. (Alternatively, rustic camping is free in the Clear Creek Rec. Area near the New Idria serpentinite – approach from the south). Be sure to drive Hwy 1 south of Bodega Bay all the way south, rather than going inland. Stop at Pt. Reyes along the way, if time permits. Farther south, stop at the Anderson-Coyote Reservoir to seek xenoliths and/or visit Hollister to see the San Andreas Fault trace in town.
day 4	Visit the serpentinite body at New Idria. Collect gemmy jadeite from veins. See additional references listed below. Late in the day, drive a bit farther south to the spectacular San Andreas Fault outcrops near Priest Valley. Return to Pinnacles for the night.
day 5	Visit the classic blueschist localities at Pacheco Pass and at Panoche Pass. See additional references listed below. In the evening, a two hour hike allows you to do a spectacular loop through Pinnacles National Monument. Return to Pinnacles for night.
day 6	Take the back roads to Carmel, then stop to see geology at Pt. Lobos. Continue down the Big Sur coast, visit granulite outcrops along the coast highway and elephant seals at San Simeon. Then camp in one of the many state parks. See additional references listed below.

day 7	Continue south with a brief stop at Morro Rock. Pt. San Luis has spectacular pillow basalts and a great seafood lunch on the dock. Then continue east, perhaps stopping to see San Andreas Fault on the Carizo Plane. Near Palmdale there are some nice exposures of the San Andreas Fault in roadcut. Arfrive in Joshua Tree N.P. late in the day. Group campsites are nice but reserve ahead of time.
day 8	Drive the Geology loop in J.T., taking time to hike in to Malapais Hill to see some nice volcanics and collect (small xenoliths). In the afternoon, hike into the Wonderland of Rocks – check with rangers for directions to see spectacular weathered granite and other desert features. Spend night in J.T. again.
day 9	Drive north from the park, stopping for a while at Deadman Lake and Dish Hill to see the classic xenolith sites. These sites have mostly been picked over. Drive farther north into the Mojave Preserve and excellent camping at Hole in the Wall.
day 10	Visit Kelso Dunes, then drive north of Kelso Junction toward Baker. A right turn (east) on any of several dirt tracks (the one toward the Aiken Mine is best) provides access to many cinder cones where unlimited quantities of xenoliths may be found. They range from granulite to ultramafic. Return to Hole in the Wall for the night.
day 11	7 hour drive to Yosemite Valley
day 12	tour Yosemite Valley
day 13	back to San Francisco and home

Additional Important Information

This guidebook is not complete. In some places it refers to appendices which are not provided. The appendix material comes from some key sources of additional information, listed below. Depending on where you are going, you may wish to track them down.

1. For key information about the xenolith localities: Wilshire et al. (1988) Mafic and Ultramafic Xenoliths from Volcanic Rocks of the Western United States. U.S.G.S. prof. Paper 1443.

2. For a comprehensive summary of the geology near Cazadero (Ward Cr.): Erickson, R.C. (1995) The Geology of the Franciscan Complex in the Ward Creek-Cazadero Area, Sonoma county, California. California Geology, November-December 1995.

3. Seminal paper on blueschists in the Daiblo Range: Ernst, W.G. (1965) Mineral Parageneses in Franciscan Metamorphic Rocks, Panoche Pass, California. GSA Bull.

76, 879-914.

4. More on blueschists in the Diablo Range: NCGS Field Trip to the Franciscan Metasedimentary Section at Pacheco Pass. Reported by Richard Cardwell. Photos by Mark Detterman and Keil Albert.
http://www.ncgeolsoc.org/FieldTripInfo/Pacheco%20Pass%20Field%20Trip.htm

5. To navigate the New Idria serpentinite area: Coleman, R.G. (1986) Field Trip Guide Book to New Idria Area, California. 14th General Meeting of the International Mineralogical Association, July 1986.

6. Finally, these three provide more information on some of the stops in this guide, and also contain many additional stops you may care to consider:

Alt and Hyndman (2000) Roadside Geology of Northern and Central California. Mountain Press.

Alt and Hyndman (1975) Roadside Geology of Northern California. Mountain Press

Sharp and Glazner (1993) Geology Underfoot in Southern California. Mountain Press.

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1. Definitions

Mélanges

The definition of mélange found in the average dictionary is a mixture of incongruous elements, or a varied mixture. The definition of mélange in the geological sense is not far off the mark. Geologists use this term to refer to either (1) a chaotic mess of rocks swept together within an ocean trench, and later exposed through obduction and uplift; or (2) a tectonic mixture of highly sheared and brecciated rocks, generally associated with a fault zone or some zone of very great strain.

Olistostomes

Olistostromes are a chaotic mess of rocks, usually consisting of ophiolitic blocks set in mudstone and serpentinous mudstone matrix. After extensive searching in many references, I have determined that olistostomes, aka olistostromes aka olistostzomes, are European terms for rock assemblages similar to the first type of mélange, described above. Often, the two terms are often interchangeable. Olistrostromes seems to be favored by the Italians and the United States, olistostzomes more by the Germans and Scandinavians, and olistostomes by the Russians and Great Britain collectively.

Ophiolite complex

Ophiolites are sections of oceanic crust and the adjacent upper mantle that have been uplifted through geologic forces to be exposed within continental crustal rocks.

Much of what is known about oceanic crust comes from the study of these large rock formations. Since we have only been able to drill a small fraction of the way into oceanic crust, scientists have relied on the information provided by ophiolite complexes.

The structure of an ophiolite is layered much like an onion. The different layers represent changes in the environment where it was formed. Top layers typically include sedimentary rocks like black shale, chert, and limestone. Volcanic activity can leave a layer of basaltic pillow lavas or sheeted dike intrusions. Most of these formations will be fine grained due to quick cooling. Bottom layers usually consist of intrusive gabbro and peridotite.

Further analysis is ongoing around the world on ophiolite complexes. Scientists are still trying to find evidence of the large magma chambers it would require to create the thick layers of intrusive gabbro seen in many ophiolites at mid ocean ridges. Some of the minerals found in these huge rock formations may answer many questions about hydrothermal metamorphism in oceanic crust. California has some spectacular examples of ophiolite complexes, namely in the Klamath Mountains near the Oregon border.

Franciscan Complex

The Franciscan Complex refers to a group of mixed rock that is found in western California. This complex consists of three different belts: the eastern, central and western. Each of these complexes shows an increase in metamorphic grade rock and age as it moves eastward. This complex was formed by the subduction of the oceanic plate under the western portion of the North American plate.

Western (coastal) Belt

The coastal belt is composed of the least metamorphosed rock in the complex and ranges in age from 40 to 100 Ma (Eocene to middle Cretaceous). Typical rocks located in this belt consist of arkosic sandstones, andesitic graywackes, and quartzofeldspathic graywackes.

Central Belt

The central belt of the Franciscan Complex is composed of greater metamorphosed rock consisting of blocks of graywacke, greenstone, chert, limestone and blueschists. Rock ages in this belt range from 60 to 150 Ma (Paleocene to late Jurassic).

Eastern Belt

The Eastern belt contains the highest-grade metamorphosed rock. These rocks generally consist of quarts, lawsonite, and mica schist accompanied by metachert and some serpentinite. Jadeite and aragonite are locally present putting major constraints on pressures and cooling paths (high P). These rocks have been dated anywhere from 80 to 160 Ma.

Blueschist

Blueschist refers to a low-temperature, high-pressure metamorphic facies. It is also a term used for rock that form under those conditions: generally obtaining a bluish color because of the presence of glaucophane, a sodium-rich amphibole.

There are two types of blueschists within the Franciscan Complex, each with different origin and history: (1) relatively fine-grained "coherent" mélange (metagraywackes, metashales, cherts, metabasalts) and serpentines, which constitute the basic mapable thrust sheets; and (2) coarse-grained exotic blocks or "terranes" (metabasalts, metacherts), which represent garnet-amphibolite to (possibly) granulite slabs that were later overprinted by blueschist to eclogite metamorphism.

Blocks, frequently contained within mélange, are particularly unusual because Franciscan blueschists are considered colder than most blueschist rocks; thus, any explanation of their origin must account for their original high temperature features.

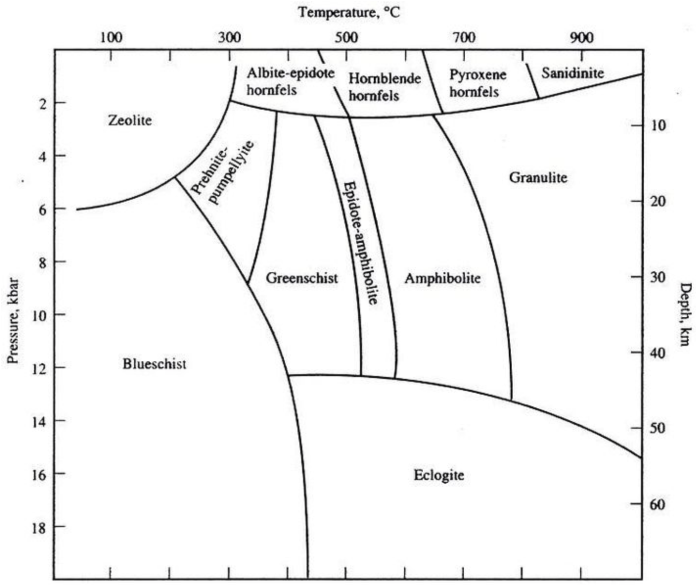
An interpretation of these blueschists from John Wakabayashi (2001):
“In the beginning (150 to 160 Ma), eastward subduction occurred underneath a trapped piece of hot ocean crust, which later became the Coast Range Ophiolite. Initial subduction beneath hot, young ocean rocks overlying suboceanic mantle caused the subducting slab to heat to high temperatures resulting in metamorphism to amphibolite or granulite grade. Little sediment were associated with the young ocean crust, thus the

earliest rocks subducted were likely basalts and cherts, which became heated to high grade due to residual heat from suboceanic mantle. As subduction continued, heat quickly dissipated so that a refrigeration effect controlled thermal regimes within the subduction zone. Refrigeration induced blueschist metamorphism at depth, overprinting the early-formed amphibolite rocks, which were later exhumed towards the surface. In time, graywackes, cherts and muds accumulated on the seafloor, which were dragged into the subduction zone and transformed into mélange of the Franciscan coherent blueschist facies. As subduction continued refrigeration prohibited heating of these rocks at depth, resulting in the development of the distinctive high pressure blueschist minerals (glauconite, lawsonite, and jadeite) which give these rocks their unique character."

Eclogite

Eclogites are similar to blueschists in that they form at similar pressures, but they form at higher temperatures. Eclogite is a coarse-grained mafic-to-ultramafic metamorphic rock, containing garnet (pyrope to almandine) plus pyroxene (omphacite). Eclogite is of special interest because eclogite is an unusually dense rock; it can play an important role in driving convection within the solid Earth. Eclogite typically results from high-pressure metamorphism of mafic igneous rock (typically basalt or gabbro) as it plunges into the mantle in a subduction zone.

Some eclogites may be formed from precursor mineral assemblages typical of blueschist facies metamorphism, and many seem to have developed from amphibolite facies rocks. Eclogite can also form from magmas that crystallize and cool within the mantle. Signs of greenschist metamorphism, amphibolite and granulite metamorphism are rarely preserved because these metamorphic trajectories allow the rocks to heat up too much, allowing partial melting (at which point, the rock ceases to be a metamorphic rock).



A P-T diagram showing curves of many of the rocks discussed in this field guide.

2. Cazadero (Ward Creek)

This famous bluschist locality is in a creek bottom in hilly terrane near Cazadero. It is really quite a small exposure but contains very interesting rocks.

The location is on private property. As of spring, 2006, the best way to gain access (and to get a knowledgable guide) is to contact Rolfe Erickson, erickrol@sonoma.edu , who has mapped the area. He acts as a sort of unofficial gatekeeper and liaison with the property owner.

At Ward Creek, near Cazadero, we can see classic Franciscan blueschists and related rocks.

Access is via a small mountain road. The location is on private property, address is 19650 Fort Ross Rd. Park on the main road and walk down the driveway.

See Rolfe Erickson's Field Guide (Appendix to this document)

The owner (March, 2006) is Kent Look. Phone numbers are (707)632-5388 in Cazadero, or (510)843-5469 at his Berkeley home.

Generals store at Cazadero - a good meeting spot

Talking geology at Ward Cr.

Blueschist at Ward Cr.

3. Eclogites and Blueschists: Jenner Beach

There are several excellent blueschists associated with the Franciscan Complex in central California.

This photograph shows the mouth of the Russian River looking south 1 mile north of Jenner, California. The scatter rocks on the beach north of the river are all eclogite/blueschist.

Fascinating blueschist-eclogite boulders can be found on the beach just north of Jenner, California.

Jenner is on Hwy 1, about an hour's drive north of the Golden Gate Bridge, where the Russian River reaches the Pacific Ocean. The blueschist/eclogite outcrops are exposed north of where the river reaches the ocean.

To reach the beach outcrops, drive north out of Jenner on the coast highway. After a mile or so, there is a pullover on the left side of the road. A steep trail leads down to the sandy beach.

The rocks at Jenner are course grained, containing two basic lithologies mixed together: eclogite and blueschist. The textures suggest that the eclogite formed originally and later retrogressed to form blueschist.

At Jenner, one can actually collect specimens of these spectacular coarse-grained blueschists as well as sphene-bearing omphacite-garnet eclogites. Exotic blocks at this locality near Jenner lie within a structurally low mélange zone, opposite the situation at Tiburon. While some petrographic studies show the same counterclockwise P-T path preserved at Tiburon, there are additional, more complicated deformational and metamorphic crystallization events, which indicate a far more complex history. Some studies propose that similar blocks may have been exhumed early on, eroded and

Blueschist-eclogite boulder at Jenner

resedimented into the trench, then later resubducted with the associated mélange.

Jenner information respectfully stolen from: Brewschist and Breweries (Brewschist II): A Tour of Fine Rocks and the West Coast Brewing Art Field Trip. By Elizabeth A. Gordon. 2005. Photos by Phil Garbutt. http://norcalgeol.web.aplus.net/Blueschist%20II.htm. Eclogite info from: "Eclogite." 2006. Wikipedia. Wikipedia Foundation Inc. http://en.wikipedia.org/wiki/Eclogite

Another blueschist boulder at Jenner, showing alternating "veins" of blueschist and eclogite.

4. Geology near the Golden Gate Bridge, San Francisco

The San Andreas Fault passes the Golden Gate about two miles offshore. The rock foundations of the Golden Gate Bridge are interesting. The northern pier of the bridge stands on a broad base of reasonably solid Franciscan rocks-no cause for concern here. The south pier stands on serpentinite, a notoriously weak and slippery rock.

Twin peaks offers the best panoramic view of the city and its bay. Exposures of reddish ribbon chert exist on both of the peaks, especially on their southwest sides. The chert beds are inclined at steep angles and locally wrinkled into tight folds. The thin layers of darker rock that separate the chert layers are shale, probably laid down from the farthest edges of the clouds of muddy sediment that deposited graded beds closer to shore.

The great block of the San Francisco Mint, on Market St. northeast of Twin Peaks, rests squarely on a big mass of green serpentinite. Watch for it along the sidewalk. More serpentinite is exposed on Potrero Hill and along the axis of Hunters Point. Most of the other hills in the city are Franciscan sandstone.

Sand dunes are still alive and well in San Francisco you can still see them near the San Francisco Zoo at Ocean Beach blowing across the Great Highway. Most of the dunes are now covered with buildings, excerpt fro some along the beach and some near the zoo. Some can also be seen here and there in Golden Gate Park.

The sand originally came from the Sacramento River during the ice ages, when the sea level was low and the great sand trap of San Francisco Bay did not exist. Waves coming form the north swept the sand south, down the beach. Then the strong sea breeze blew it off the upper beach when the tide was out and into the dunes. Now that the sea level is high, the river dumps its sand into the inland reaches of the bay, mostly into the advancing edge of the Sacramento Delta.

Fort Baker area watch for the splendid exposures of Franciscan rocks in roadcuts immediately north of the Golden Gate Bridge, between the Marin abutment and the Sausalito interchange. The road cuts include basalt flows, originally black but now streaked with shades of dull green, and numerous layers of muddy sandstone. Layers and occasional globs of red are chert. All of the layers tilt steeply down to the east and show obvious signs of having been torn, sheared, and crumpled. That happened as they were scraped off the descending seafloor and stuffed into the Franciscan trench, about 100 million years ago.

Large masses of serpentinite that include beautiful chunks of dark blue blueschist and dark green eclogite make the backbone of the Tiburon Peninsula, where houses now cover the best rocks. These same rocks are found on Angel Island, where they are easy to find; but are protected.

Information respectfully stolen from Roadside Geology of Northern and Central California written by David Alt & Donald W. Hyndman 2002.

5. Point Reyes National Park

Pt. Reyes is characterized by rugged wind blown rolling hills, beaches, and seacliffs. Here, the San Andreas Fault has left a major fault scar.

Point Reyes is located approximately 22 miles north of San Francisco on Highway 1 along the west coast of California. Travelers may approach the park from the winding scenic Highway 1, either northbound or southbound. You can also reach the park via Sir Francis Drake Boulevard or Point Reyes/Petaluma Road.

Predominantly Point Reyes can be recognized by the presence of the San Andreas Fault that bisects the peninsula, known as Point Reyes, from the rest of mainland California. The San Andreas Fault is a strike slip fault. Other features that can be seen on the sides of the peninsula are beaches, sea cliffs, and intertidal zones. The peninsula moved to the Northwest at an average of 1 to 2 inches per year, but has moved as far as 20 feet. In fact the rock that make up Point Reyes match up to those found 300 miles South in the Tehachapi Mountain. Point Reyes is composed of granitic bedrock and outcrops, marine sedimentary rocks, and sandstones. There is a trail called “The Earthquake Trail”, near Bear Valley Visitor Center that is supposedly extraordinary.

6. Ring Mountain Open Space Preserve

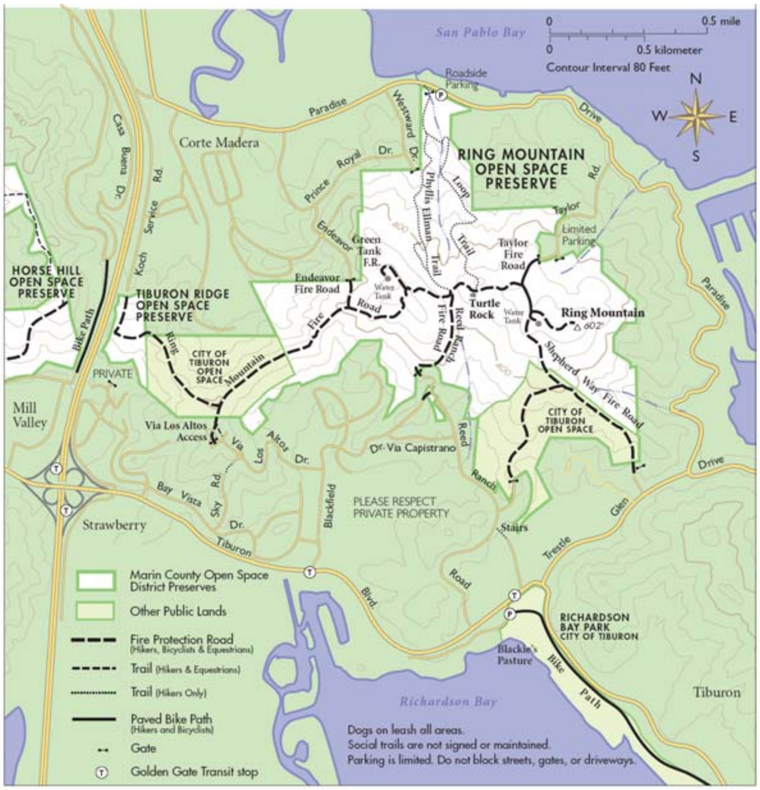
The hills at Ring Mountain provide great views of the Tiburon Penninsula, Alcatraz and San Francisco. Exposed here are a number of different rock units (volcanics, sediments, serpentinites, blueschists, etc.), all part of a Franciscan melange.

From US 101 in Marin County, exit Paradise Drive/Tamalpais Drive. Drive east on Tamalpais, and turn right onto San Clemente (before The Village shopping center). After a few blocks, San Clemente dumps into Paradise Drive. Continue on Paradise, past Westward Drive, to the preserve gate on the right side of the road. It's about 1.5 miles from 101.

Ring Mountain Open Space Preserve contains some of the most unusual natural landscape in Marin County. Named for George E. Ring, county supervisor from 1895 until 1903, this rock-strewn site is a mélange resulting from dramatic earth movements. Rocks such as blue schist and green schist, together with abundant serpentine, create soils, which are toxic to most plant life.

Plant communities, which are able to survive this harsh environment, however, thrive in the absence of competition. For this reason, Ring Mountain harbors an unusual number of rare and endangered plant species. In some instances, the entire known population of a species is contained within the preserve. In 1982, the Ring Mountain Preserve was established by the Nature Conservancy with the help of generous contributions from its donors and members. The property was transferred to Marin County Open Space District in 1995.

Although there are some maps of Ring Mtn, they are difficult to use because most of the terrane has no significant features. So, the best plan is just to walk around and look at



Map of Ring Mountain Preserve. Eclogites, blueschists and metagraywacke can be seen at Turtle Rock.

what is there. In some places along the Coast Ranges, the serpentinites have been melted and intruded along cracks and faults but the serpentinites at Ring Mountain are of the cold variety intrusions. There are a couple of theories as to how these cold intrusions may have gotten to where they are now exposed. The first of which is that they form in anticlinal arches and are forced as massive elongate plugs, another thought is that stray masses of serpentinites managed to squeeze through the compacting mass of Franciscan sediments. Either way the serpentinite (cold intrusions) forced their way upward with continued movement of earth's plates and erosion of the easily eroded mélange that surrounds them.

View from atop Ring Mountain: most or the rocks are serpentinites

Unlike rocks of the earth's crust, serpentinite contains almost no aluminum. Lacking aluminum, its weathered sediments are unable to form clay, an essential ingredient of fertile soils. The weathering rocks do not form insoluble residues that accumulate and transform into soils, but slowly dissolve and run off in both surface and subsurface waters. Not surprisingly, the serpentinite soils of the upper slopes of Ring Mountain (locally called the "Henneke" soils) are bare and thin between rocky outcroppings of rock. As a final challenge to plants trying to live here, serpentinite is almost devoid of potassium, sodium, calcium and phosphorus, all-important fertilizers, AND it is unusually rich in magnesium, chromium and cobalt, heavy metals that are toxic to most plants.

Recent article: Saha, Basu, Wakabayashi, and Wortman (2005) Geochemical evidence for a subducted infant arc in Franciscan High-grade-metamorphic tectonic blocks. GSA Bulletin, v 117, 1318-1335.

7. Xenoliths of Anderson-Coyote Reservoir, California

The Anderson-Coyote Reservoir sits in Santa Clara Valley, which is part of the broad fault system known as Old Woman Springs. Silver Creek Fault, part of the Old Woman Springs Fault system is about 1.5km east of the Anderson-Coyote Reservoir system. The reservoir system is located by the towns of Morgan Hill and Gilroy. The area is characterized by olivine basalt flows. There is a road cut at the intersection of Coyote Fault and Thomas Drive (Old East Dunne Ave) where a 3 meter serpentinized peridotite block in shear serpentinite can be seen. An overturned basalt flow interbedded with the Santa Clara Formation of Plio-Pleistocene Age consisting of clay silt sand and gravel is found along East Dunne Ave, 1.4 km from the intersection of Thomas Drive and East Dunne Ave. The alluvium covering the valley floor is an important water-bearing unit and the basin itself is part of the Coastal Basins, of which the Santa Clara subbasin is an important water source.

Our interest in the area is xenolith locations of which there are many, but only two notable ones. The xenoliths found in this area are predominantly spinel peridotites. The first location is a vent adjacent to the Coyote Reservoir and the second is a float of basalt flow approximately 3.2 km N of the locality adjacent to the Reservoir.

8. Walking tour of San Andreas Fault (Calaveras Fault) in Downtown Hollister, California

Hollister, California has a very interesting role in the grand scheme of the San Andreas Fault. Hollister is a town that is on a section of the Calaveras fault that continuously slips. In some of the older sections of town, you can walk around and actually see where the sidewalk is cracking, buckling and sections moving away. In other areas, you can see curbs and driveways with cracks. Geologists know that the fault started creeping approximately 1930, at a rate of 0.3 inch per year, accelerated to 0.6 during 1961-1967, and then slowed to an average of 0.25 inch per year (Alt & Hyndman, 2002). It is interesting that less than two miles northwest out of town, the fault is moving twice as fast as in town. We know that the fault is not stuck since it is still moving, so no strain is building up. This is not protection against earthquakes on other segments of the Calaveras fault, or on other faults (Alt & Hyndman, 2002).

The walking tour shown on the map is fun, but a bit underwhelming. At a couple of places the offset due to the fault is clear to see. But, in general what you see is just a lot of very cracked up pavement and road.

Site A: push-up ridge and distorted house
Sites B and C: cracked streets and offset curbs
Site D: 25 years of fault creep
Site E and F: fault creep after only 5 years

Displaced sidewalk at site F. The three students are standing on the race of the fault.

9. Pacheco Pass

A wide variety of Franciscan rocks is exposed in Pacheco Pass, along Hwy 152, east of Gilroy, California.

A stratigraphically coherent section of Franciscan metasedimentary rock is well exposed in the Diablo Range at Pacheco Pass east of Gilroy. This section was exhumed from depths of 20 to 30 km in a Mesozoic subduction zone.

There are many outcrops scattered across the hills at Pacheco Pass. They are separated by lots of grassy hillside. Lithologies vary, and to really see what is there, and to find specific rock types, may take some time.

The Diablo Range is part of the California's Coast Range. The Franciscan represents the trench complex of a Mesozoic, east-dipping subduction zone. Coeval with the formation of the subduction complex was the development of a volcanic arc, whose roots are the Sierra Nevada batholith. The Central Valley represents the fore-arc basin of the subduction system.

The Franciscan Complex is a package of rocks formed in an upper Mesozoic subduction zone. It consists of sediments deposited in an accretionary prism (imbricated ocean trench deposits) as well as the sections of the underlying oceanic crust and mantle. Ages range from uppermost Jurassic through Cretaceous. The sediments of the accretionary prism are medium- to fine-grained detrital rocks (graywackes, micrograywackes, and dark shales) that were sourced from the Sierran volcanic-plutonic arc, and they were deposited into the trench as turbidites. In the subduction process, they have been metamorphosed into metagraywackes. Radiolarian chert, pillow basalts and pillow breccia, and peridotite (oceanic mantle) represent the ocean floor rocks. These have been metamorphosed into metachert, greenstone, and serpentine, respectively.

Topography in the Diablo Range

The terrene of the central Diablo Range consists predominantly of Franciscan metagraywackes and finer grained metaclastic rocks. The Franciscan is divided into 4-5 packages separated by a series of subhorizontal bedding-pane thrusts. The thrust detachment at the base of each tectonic unit is mapped below a zone of mafic blueschist with overlying metachert. Some researchers have interpreted each package as a thin thrust slice dipping to the east. The packages are interpreted as getting older to the east. The “Coast Range Thrust” represented here by the Ortigalita fault binds the oldest package on the east side. East of the fault lies the Great Valley Series.

One of the best techniques to determine the depth of burial is by examining the petrology and geochemistry of the minerals in the metagraywackes. The albite present in the original sedimentary and igneous rock has been converted into jadeitic pyroxene plus quartz. This reaction can only occur in a high pressure, low temperature environment. Laboratory experiments indicate temperatures of about 200 degrees C and pressures of about 6-7 kilobars. This corresponds to depths of about 20 to 30 km in a subduction zone.

The process for getting the subducted oceanic crust back to the surface (exhumation) is not well understood. Whatever the process, it must be rapid on order to preserve the high-pressure, low temperature minerals. Some researchers have proposed a process propelled by buoyancy. Jadeitic pyroxene is less dense and more viscous than olivine that occurs in the mantle. This difference in buoyancy allows the subducted crust to rise. More remarkable is the fact that these tectonic blocks, some at least 10 km, have been returned to the surface from such depths relatively intact (stratigraphically coherent). This however, does not explain the rise of eclogite blocks, which are denser than upper mantel peridotite. Most people invoke a channel flow model to get eclogite to the surface.

Things to look for:

1) Knobs of greenstone (formerly weathered pillow basalt). Greenstone is weathered basalt and everyone could see outlines of good pillow structures. The basalts are only slightly metamorphosed (epidote and chlorite facies). These blocks represent weakly recrystallized oceanic crust, possibly a seamount that was subducted into the trench.
2) Outcrops of weathered metagraywacke containing jadeitic pyroxene. Under a hand lens, the jadeite here is tan- to flesh-colored with a pearly luster. Grains appeared as fibrous radiating sprays and prismatic clusters.

Two views of graywacke boulders

3) Dinosaur Point parking lot overlooking the San Luis Reservoir where a metagabbro that intruded into the metagraywacke can be seen. Topic for discussion: how could a mafic magma is injected into a turbiditic accretionary prism prior to subduction-zone metamorphism and subsequent exhumation? Beats me, but I bet one of these Stanford guys has an idea.

4) The Ortigalita fault. The fault is the so-called Coast Range thrust, and marks the boundary between the Franciscan Complex and the upper Cretaceous Great Valley Series. Here the Great Valley Series is steeply east-dipping, weakly metamorphosed conglomeratic sandstones and siltstones. This material was derived from the Sierran arc located to the east. Mineral assemblages indicate the Great Valley was buried to only about 10 km versus the Franciscan burial depth of about 20 to 30 km. These different burial depths are found all along the Coast Range thrust.

5) Franciscan outcrops west of the Ortigalita fault. The trace of the fault can be seen across the countryside. It is marked by a change in vegetation, style of erosion, and drainage pattern on either side of the fault zone. The Franciscan here consists of metagraywacke along with siltstones and tuffaceous units.

Metagraywacke

Metagraywacke

Respectfully stolen from:
NCGS Field Trip to the Franciscan Metasedimentary Section at Pacheco Pass. Reported by Richard Cardwell. Photos by Mark Detterman and Keil Albert.
http://www.ncgeolsoc.org/FieldTripInfo/Pacheco%20Pass%20Field%20Trip.htm

10. Pinnacles National Monument

Pinnacles National Monument is located south of Salinas, near Soledad. Access is from the east (Hwy 25) or the west (US 101); there is no connecting road that crosses through the monument.

The Monument is located near the San Andreas Fault which had a hand in creating the unique formations the Monument protects. The Pinnacles are part of the Neenach Volcano which erupted 23 million years ago near what is Lancaster, California today.

Pinnacles National Monument stands as a testament to the awesome power of nature. Wind, water, and time have taken its toll on this area of the world just east of central California's Salinas Valley. Pinnacles offer some unique geology as well as challenging rock climbing.

Standing as a counterpart to Yosemite, Pinnacles National Monument exhibits large extrusive rock formations and is consequently made up of mostly rhyolite. It is believed that 23 million years ago, a large volcano named Neenach formed the rocks now found in Pinnacles National Monument. Since then, erosion and the San Andreas Fault have split the volcano, sending Pinnacles northwest. Rolling hills and huge spires are all that is left of this once massive volcano system.

Although the huge spires often take center stage at Pinnacles National Monument, there are many caves to explore that have been punched out by volcanic activity and falling boulders. Pinnacles National Monument would also be a great place to collect volcanic tuff and andesitic rock and mineral samples as well as many forms of breccia.

Map showing location of Panoche Pass, Pinnacles National Monument, the New Idria serpentinite body, and the San Andreas Fault outcrop.

11. Panoche Pass

Blueschists, garnet amphibolites, retrogressed eclogites and a variety of other rocks can be found in the stream valley adjacent to highway J1 west of Panoche Pass.

This is a classic location! For more details, see the article by Ernst in the Appendix to this guidebook.

The geology at Panoche Pass is similar to that at Pacheco Pass. In both places, scattered outcrops and boulders on the hillsides and in stream valleys expose various units that make up the Franciscan melange.

This best outcrops are in the Tres Pinos Creek valley several miles (7?) west of the actual pass. They can be approached from Pacines (14-15 miles to the northwest) or from the town of Panoche (to the east).

The best rocks are in the stream bed where the road is several hundred feet above the creek with a steep hillside between. Unfortunately, in March 2006, the land was posted with many intimidating signs, and the land owner was quite hostile toward geologists.

Alternatively, you can find a pile of fresh blueschist boulders (many, huge, put there by the highway department) near a landslide, just a mile or so west of the main stream valley, on the south side of the road. Serpentinite is exposed in the road outcrop. Photos below.

Historic reference: Ernst, W.G. (1965) Mineral Parageneses in Franciscan Metamorphic Rocks, Panoche Pass, California. GSA Bull. 76, 879-914.

Blueschist boulders near Panoche Pass

Serpentinite outcrop near Panoche Pass

12. New Idria Serpentinites

(For more information, see guidebook in Appendix)

Idria is located in Central California about 140 miles southeast of San Francisco. The old mining town is located in a canyon on the San Carlos Creek, on the north side of the range where the serpentinite body is found.

To approach from the north. Take either California State Highway 25 at Paicines or catch Little Panoche Road from US Interstate 5. New Idria Road is the one paved road to Idria. It leaves the Panoche Valley and winds a slow twenty miles through Griswold Canyon and Vallecitos to the old mining ghost town of Idria. If you continue on the dirt road (high clearance and four-wheel drive recommended) past the town, you will climb steeply and reach the Clear Creek Management Area, and paved roads. The road is very rough and impassible when wet.

New Idria is one of the historic mining districts of California. Mercury and a number of rare gems have been produced here.

The serpentinite body lies atop rugged topography just north of the Los Gatos Rd. between Coalinga and Bitterwater.. Access is easiest from the south but more exciting from the north.

Be warned: access is impossible when the roads are wet.

Alternatively, you can approach from the south on Los Gatos Creek Rd between Coalinga and Bitterwater. This approach means you do not have to climb up and over the mountains.

Geology

The New Idria serpentinite covers a large area in the New Idria District of San Benito County in California. The New Idria District is well known for being one of the most highly mineralized areas in California. It is the only place in the world where gem quality bentoite is found. However, the serpentinite is the dominant geologic feature in the area. Indeed, the serpentinite helped shape the area with the major tectonic forces that it produced during its emplacement. The New Idria serpentinite body is elliptical and approximately 12 miles long by 4 miles wide. Its emplacement was the result of hydrothermal alteration of deep-seated mafic rocks and its subsequent volume change producing upward movement through weaker sedimentary rocks of the Franciscan Formation.

Naturally, the intrusion caused varying degrees of metamorphism in the Franciscan sandstones and shale beds. Highly metamorphosed and extensively folded beds are found along the southern margin of the body. These beds consist of a mixture of graywackes, sandstones, conglomerates, and shales that have locally been metamorphosed into blueschists and shales that contain intruded serpentinite bodies. The bodies have been fractured by localized faulting creating channel ways for mineral rich hydrothermal solutions. This allowed the occurrence of jadeitite, the more valuable type of jade, which is restricted to primary occurrences in bodies of subduction-related serpentinite along fault zones. A small but well documented occurrence of jadeitite is found along Clear Creek in the New Idria serpentinite. The beds on the northern edge of the body are Franciscan and Panoche sandstones and shales, that contain the large mercury deposits contained in cinnabar that were of interest to the New Idria Quicksilver mines. These mines were once one of the major mercury producers in California, but the mines were closed in 1972.

13. Exposure of San Andreas Fault near Priest Valley California

The San Andreas Fault is exposed in a nice sandstone road cut on Hwy 198, east of San Lucas and just a few miles west of Priest Valley, California.

Folded, brecciated, and mylonitized sandstone and serpentinite mark the San Andreas fault in this area. This is one of the few places where a cross section of the fault can be seen in road cut. There are several shear zones, all within several hundred yards of each other.

These photos show deformed rocks associated with the San Andreas Fault near Priest Valley CA.

14. Geology of Coast from Monterey to San Simeon

"Even the rocks are seductive and hypnotic." —noted former Big Sur resident Henry Miller.

Long stretches of California 1 cling to the steep slopes of the rugged Santa Lucia Range, between the road cuts on the east and long drops of fresh air on the west. Other long stretches cross flat marine terraces that emerged from the sea with the rising Santa Lucia Range. Beaches, many of them nearly inaccessible, softly line the coves. Rocky headlands resist the crashing surf. The few small towns and many visitors hardly diminish the sense of abiding wildness. Soil and brush cover most of the bedrock, except for along the coast.

Beach at Pt. Lobos

Franciscan rocks is somber shades of gray appear along the southern two-thirds of the route. They are west of the Sur-Nacimiento fault, part of the

The Big Sur Coast

Conglomerate at Pt. Lobos

Western Franciscan complex. Farther north, the Sur-Nacimiento fault, the western boundary of the Salinian block, plays hide-and-seek with the coastline. Pale outcrops of Salinian granite dominate where the fault lies just off shore; dark Franciscan rocks appear where it lies onshore. Other outstanding rocks include the towering volcanic monolith of Morro Rock and the beautiful sandstones at Point Lobos.

Hobnail Granite underlies much of Monterey and a broad area to the south. The best exposures are in the coastal outcrops of the Monterey Peninsula and at Carmel River State Beach, south of Carmel. It is a distinctive rock full of blocky crystals of orthoclase feldspar that resist weathering better than other minerals, and so tend to stand out in relief on weathered outcrops.

Big Sur is a section of the central California coast and adjacent mountains, typically considered to run for 90 miles (145km) between Carmel and San Simeon. It is characterized by the abrupt rise of coastal mountains, locally named the Santa Lucia Range, from the Pacific Ocean. This geology produces stunning views and has become a magnet for global tourism.

Granulite outcrop near Big Sur

Granulites are exposed just south of the town of Big Sur, but most rocks here are lower grade.

Big Sur has the steepest coastal elevation increase in the lower 48 states, where Cone Peak rises nearly a mile (5,155 feet/1.6km) above sea level, only three miles (4.8 km) from the ocean. The mountains trap most of the moisture out of the clouds, often in the form of morning fogs, creating a favorable environment for forests, including the southernmost habitat of the coast redwood. Farther inland, in the rain shadow, the conifer forests disappear and the vegetation becomes open oak woodland, and then transitions into the more familiar fire-tolerant California chaparral scrub. This paragraph compliments of Wixpedia.com.

Point Lobos State Reserve about eight miles south of Monterey has a great sequence of muddy sandstones and shales in the Carmelo formation, which may correlate with the conglomerate at the seaward end of Point Reyes.

The Carmelo formation probably accumulated within a narrow submarine canyon eroded into granite of the Salinian block. Turbidity currents, dense mixtures of debris and water, eroded the canyon that holds the Carmelo formation and deposited it. Look for the graded beds, coarse at the base and grading upward into finer sediment. They formed as particles settled from clouds of muddy water, the larger particles first, the smaller ones last. Look also for fossil burrows and strange marks or tracks on bedding surfaces. Those are probable traces of animals with soft bodies that did not become fossils, phantoms of the rocks.

Sur-Nacimiento can be spotted by watching for the dramatic change between pale granite of the Salinian block to the east and the dark Franciscan rocks to the west. The Sur-Nacimiento fault lies a short distance offshore along the north half of the drive between Monterey and Point Sur, and along the 24 miles between Big Sur and Lucia. White granite and streaky gneiss of the Salinian block appear in the coastal outcrops and road cuts in both areas.

Point Lobos Geology

The "modern" geological history of Point Lobos begins about 100 million years ago when dinosaurs still roamed the earth. Miles below the earth's surface a molten mass of rock deep inside a prehistoric chain of active volcanoes slowly cooled into what geologists call Santa Lucia Granodiorite. Over the next 40 million years this hard, granite-like rock slowly rose to the surface and now comprises one of the four types of rocks at Point Lobos. Resting on top of the granodiorite is an ancient deposit of sand and gravel that formed about 60 million years ago and has since hardened into a sandstone called the Carmelo Formation. Lying on top of the Carmelo Formation, like frosting on a cake, is the third geologically significant type of rock found at the reserve: sedimentary rocks that were deposited on ancient marine terraces. These terraces were formed as ocean waves created wide platforms when the sea level was higher than it is today. The sediments that were eroded from the old shoreline and deposited on the marine terraces consist of clay, silt, sand and gravel up to two million years of old. The fourth type of rock at Point Lobos is found along the shoreline where you can see how wave action has worn away the Carmelo Formation and granodiorite to form deposits of gravel and white sand beaches.

Franciscan rocks can be seen from the spectacular sea cliffs and rugged headlands along most of the coast between Point Sur and Morro Bay. Point Sur in a large sea stack of Franciscan volcanic rocks that are on magnificent display in the sea cliffs.

A few miles south of Big Sur, California 1 crosses several miles of grungy granite and associated metamorphic rocks of eh Salinian block. Farther south are more Franciscan rocks. The McWay thrust fault moved the Salinian rocks over the Franciscan rocks. The Salinian rocks resist erosion more successfully that the Franciscan rocks beneath them, so the fault makes a cliff. McWay Creek tumbles 70 feet over it to reach the ocean at McWay Cove.

Watch in the Franciscan complex for muddy sandstones in dark shades of gray and greenish gray, their original sedimentary layering sheared almost beyond recognition. Reaction with water altered the dark mineral in most of the basalts to the greenish mineral chlorite, which makes the basalt blackish green. A few basalts still show the distinctive pillows typical of lava flows that erupted on the ocean floor. Occasional outcrops of crumples ribbon cherts in shades of red, green and white brighten up the somber Franciscan scene. Serpentinites makes outcrops of broken rocks with slick surfaces in various shades of green.

Along several parts of the route, the highway follows smooth marine terraces that slope gently seaward about 100 feet above the beaches. The best are between Point Lobos and Point Sur, and north of Cambria.

The beaches north along the coast of San Simeon will have pretty pebbles. Look for beautifully rounded and smooth pebbles in all possible translucent shades of green, as well as gray, brown and red. Most of those lovely pebbles are Franciscan ribbon chert. A few are other Franciscan rocks, such as blueschist or eclogite.

Elephant seals (big!) can be seen on the beach near San Simeon.


Elephant seals on the beach

Information respectfully stolen from Roadside Geology of Northern and Central California written by David Alt & Donald W. Hyndman 2002.

View of Morro Rock from the north

15. Morro Rock and Port St. Luis

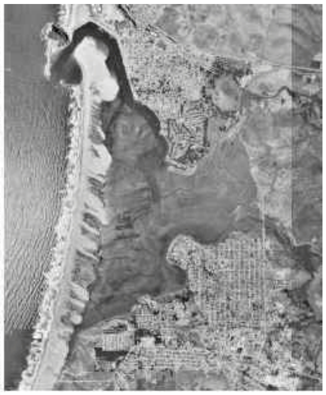
Near Morro Bay, there is a well exposed chain of extinct volcanic necks. Morro Rock is the most obvious, sitting as it does right on the ocean shore.

Spectacular Pillow basalts are exposed just north and west from the main peer at Pt. San Luis. Be prepared to get your feet wet.

Discovered in 1542 by Portuguese Explorer Juan Rodriguez Cabrillo, Morro Rock is one of a chain of nine extinct volcanic necks that stretch approximately 12 miles from Morro Bay to San Luis Obospo. The Chain actually known by two names (The Seven Sisters, or the Nine Morros/Sisters) depending on how many of the peaks are counted. It is theorized that the 22-28 million year old chain originally erupted along an old fault line, south of where they are now located with there remnants (the extinct necks) moving along the San Andreas fault to their present day locations.

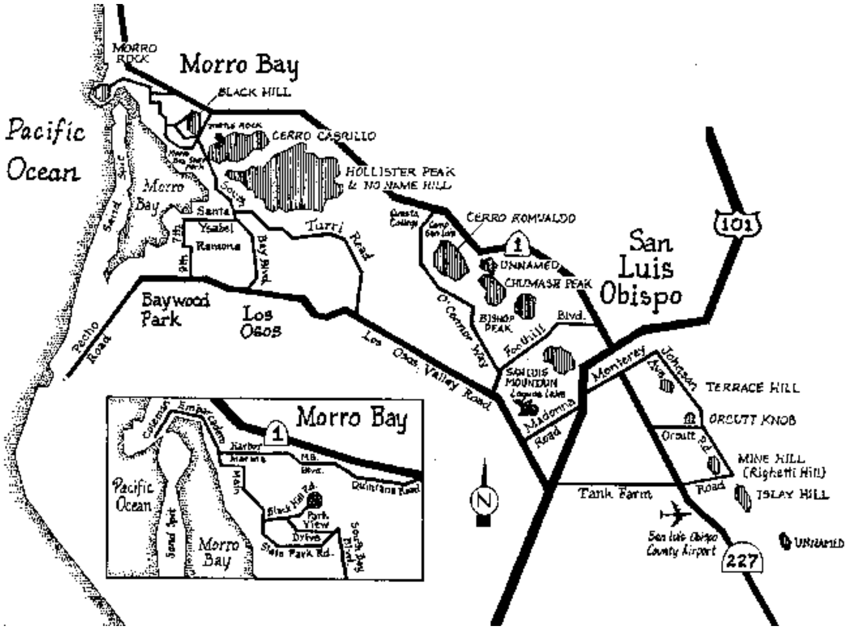
Morro Rock itself is the youngest of the chain (excluding Davidson Seamount, submerged 2.5 miles offshore of Morro Rock), is also the most eastern of the chain, located along the California coast. It is the most well known peak in the chain and is called “The Gibraltar of the Pacific”. Morro Rocks position concerning the coast has changed throughout the years. Originally it was an off coast peak, and today it has become part of the coastline. The changes are depicted in the figures below.

Pillow basalt near the pier at Pt. San Luis



1897 Topographic map   1981 Topographic map 1994 Satellite Photograph

Morro Rock itself was mined on and off until 1963. Morro Rock provided material for the breakwater of Morro Bay and Port San Luis Harbor. In 1966 a bill was introduced which transferred the full title to the State of California. Later the San Luis Obispo County Historical Society and the City of Morro Bay succeeded in getting the Morro Rock declared as California Registered Historical Landmark #821. Morro Rock also became State Landmark #801 in 1968, and is now a protected home for the endangered peregrine Falcon.



Map of Morro Bay

Just a short way south of Morro Bay, spectacular pillow basalts can be seen in beach cliffs near the commercial fishing pier at Port San. Luis.

16. San Andreas Fault near Palmdale

Located 60 miles northeast of downtown Los Angeles, Palmdale CA is home to one of the fastest growing communities in the country. Over 130,000 residents call Palmdale home, living together harmoniously in a “family oriented community.” However, we really could not care less.

These outcrops are interesting but hard to visit because they are on a busy highway and pulling over on the shoulder is generally not a good option. Best would be too find some way to access the outcrops from local roads – especially from the west.

What makes Palmdale interesting to us, and a popular geology field trip stop, is the impressive and complicated outcrops of San Andreas Fault features. Road cuts, about 5 miles south of Palmdale along highway 14, cut through highly folded and faulted segments of the San Andreas Fault system.

These outcrops at the western edge of the Mojave Desert are comprised mostly of highly deformed Tertiary lakebed sediments. The deformation here occurred as a direct result of moment within the fault zone. Many small faults developed in conjunction with the folds, and they bear the same orientation as the rest of the fault system.

Since the San Andreas Fault Zone is the boundary between the Pacific and North American plates, at the Palmdale outcrop, it is possible to walk from one continental plate to another in just a few minutes.

Picture of the Palmdale Road cut, with illustration of one of the many minor faults.

References:
Myers, Joshua and Morris, Ron Merritt, 1999. “Welcome to the San Andreas Fault Zone: Exposed at Palmdale,” Center For Los Angeles Basin Subsurface Geology (CLABSG), at California State University, Long Beach.

Map of the Palmdale area, courtesy of mapquest.com

http://seis.natsci.csulb.edu/VIRTUAL_FIELD/Palmdale/paltext.htm
Weber, F. Harold, Jr. 1998. “Right-Lateral Displacement of Pleistocene Sedimentary Deposits along the San Andreas Fault, Palmdale to Cajon Pass, Southern California” USGS Award No. 1434-HQ-97-GR-03168. http://erp-web.er.usgs.gov/reports/annsum/vol39/sc/g3168.htm/ annsum/vol39

Another view of the road cut on Highway 14

17. Joshua Tree National Park


Walkers and granite at Joshua Tree

With elevations ranging from 900 to 5000 feet above sea level, Joshua Tree shows the effects of plate tectonics, volcanism, mountain building, and stark erosion within the 800,000-acre park. Joshua Tree National Park is in southern California on the eastern end of the broad mountainous belt called the Transverse Ranges. The park consists of six main ranges: the Little San Bernardino Mountain, the Cottonwood Mountains, the Hexie Mountains, the Pinto Mountains, the Eagle Mountains, and the Coxcomb Mountains.


Students on field trip at Joshua Tree

The distinct rocks of Joshua Tree are a result of plutonic intrusions of a granitic rock called monzogranite. The monzogranite developed a system of rectangular joints. One set, oriented roughly horizontally, resulted from the removal—by erosion—of the miles of overlying rock, called gneiss. Another set of joints is oriented vertically, roughly paralleling the contact of the monzogranite with its surrounding rocks. The third set is also vertical but cuts the second set at high angles. The resulting system of joints tended to develop rectangular blocks. Ground water percolated down through the monzogranite joint fractures and transformed some hard mineral grains along its path into soft clay, while it loosened and freed grains resistant to solution. Rectangular stones slowly weathered to spheres of hard rock surrounded by soft clay containing loose mineral grains.

After the arrival of the arid climate of recent times, flash floods began washing away the protective ground surface. As they were exposed, the huge eroded boulders settled one on top of another, creating those impressive rock piles we see today.

FIGURE 1

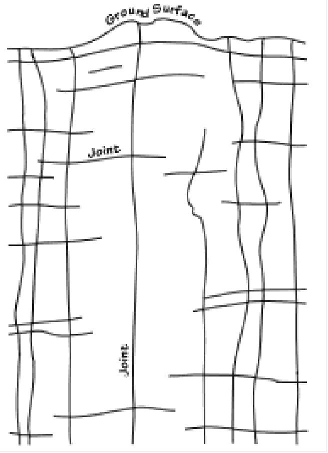


FIGURE 2

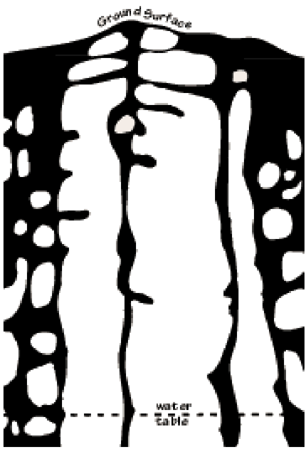
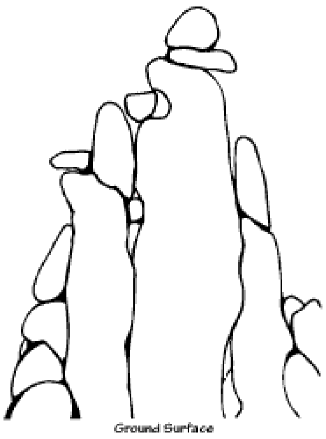


FIGURE 3



The three views above show how weathering produced the outcrops and spires we see today.

Faults regularly intersect each other and expose many rocks and features resulting from the earthquakes of tectonic activity. This activity can be attributed to the westward movement of the North American Plate as it moves over the Pacific Plate at a rate of one or two inches a year.

Throughout the park, there are many hiking trails available, along with rock climbing, horseback riding, and even a geology tour!

18. Xenoliths of Malapai Hill, Joshua Tree National Park

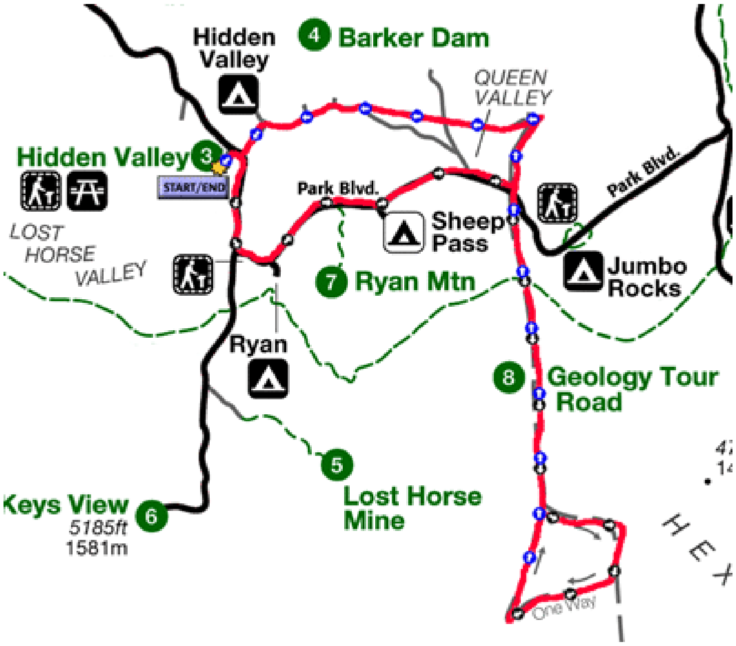
Malapai Hill is located in Joshua Tree National Park in southern California. It is characterized by an alkali olivine basalt of late Cenozoic age that has intruded into the Cretaceous White Tank Monzonite.

Malapai Hill is found along the Geology Tour route through the park, brochures can be picked up at the park office.

To get there you must hike about 3/4 of a mile across desert.

Malapai Hill contains ultramafic nodules, primarily lherzolites, commonly found in the basalts of the Mojave Desert. A lherzolite xenolith or nodule has a primary mineral composition of olivine, clinopyroxene, and orthopyroxene and may contain the accessory mineral of spinel. The Malapai lherzolites are uniform in composition, with a chemical composition indicating a source of extremely depleted mantle. Several theories have been put forth concerning the origins of ultramafic xenoliths. One is that lherzolites may be cognate material formed by fractional crystallization of the basalt.

View of Malapai Hill, from the Geology Tour route



Map depicting Geology Tour Road, Malapai is located near Ryan Mountain.

An alternative theory is that ultramafic xenoliths may be primary or depleted mantle from the site of partial melting or shallower levels cut through by ascending magma. The origination of Malapai Hill xenoliths is probably from the site of melting or depleted mantle accidentally incorporated into the basalt. This is based on the chemical and mineral composition of the xenoliths, which have extremely low amounts of Ti, Al, Ca, Na and K. Furthermore, pyroxene crystals of the xenoliths show exsolution lamellae as well as olivine kink bands, both of which indicate a metamorphic history preceding the xenoliths incorporation into the basalt.

19. Xenoliths at Deadman Lake Volcanic Field, California

Deadman Lake Volcanic Field is the result of a Late Pliocene basalt flow. Of interest to us is a composite maar-cinder cone where lherzolite xenoliths have been found. It is a somewhat poor cousin to Dish Hill, which is located north of Deadman Lake Volcanic Field, and contains lherzolite xenoliths. Amphibole is abundant at Deadman Lake Volcanic Field as veins that have formed along planes of weakness where the peridotite fractured as it was incorporated in the basalt.

Work done has suggested that these lherzolites represent residual liquids derived from more complex silicate melts that formed pyroxenite dikes. Essentially, the lherzolites are not deep mantle samples, but rather are upper mantle cognate pieces torn from the sides of lava tubes as the magma ascended to the surface. Evidence from the xenoliths shows metasomatism and slight alteration of the peridotite.

Directions

Dish Hill is about 17 miles east of Ludlow on the north side of the National Trails Highway (Historic Route 66). Deadman Lake Volcanic Field is located south of Dish Hill.

20. Yosemite National Park

Yosemite National Park has some of the best geological features in the United States. Nestled near the border of Nevada, Yosemite is a natural tourist attraction. The park is open year round with different things to see during all seasons. Hiking, fishing and skiing are some of the activities one can enjoy here. The Merced and Tuolumne rivers also cut through Yosemite, adding to the beauty and geology of the park.

Of course we are most interested in the geologic features of Yosemite above all else. Yosemite formed from the Sierra Nevada batholith being cut into by the Merced and gouged by glaciers. Yosemite National Park has some of the largest granite plutons in the U.S. Most of this granite is made up of only five minerals; Quartz, K-feldspar, plagioclase, biotite, and hornblende. All but Quartz contain Aluminum. It is fascinating to see these huge granitic plutons like Half-Dome or Glacier Point standing tall above the valley floor. Huge Sequoia trees and large waterfalls line the background in Yosemite National Park.

While Yosemite boasts large amounts of intrusive rocks, there is a fair amount of high and low grade metamorphic rocks surrounding the river bottoms and the park’s edge. Volcanic activity over millions of years has left us clues about the landscape and environment of the Sierra Nevada Mountains and the regions that surround it. Yosemite is definitely worth the trip for fantastic geology and awesome views.