Field Trip to Lexington Reservoir and Loma Prieta Peak Areas

This field trip examines faults, landslides, rocks, and geologic features in the vicinity of the San Andreas Fault and other faults in the central Santa Cruz Mountains in the vicinity of both Lexington Reservoir and Loma Prieta Peak. The field trip begins at Lexington Reservoir Dam at the boat dock parking area.

To get to Lexington Reservoir Dam, take Highway 17 south (toward Santa Cruz). Highway 17 enters Los Gatos Creek Canyon about 3 miles south of the intersection of highways 85 and 17. Exit at Bear Creek Road (5.2 miles south of Highway 85). Cross the overpass and turn left back onto Highway 17 going north. Stay in the right lane and exit onto Alma Bridge Road. Follow Alma Bridge Road across Lexington Reservoir Dam and turn right into the boat dock parking area (about 0.6 mile from the exit on Highway 17 north). A Santa Clara County Parks day-use parking pass is required to park in the paved lot. The park day use pass is $4 (2004). Vehicles can be left here for the day to allow car pooling (the park is patrolled, but as always, take valuables with you). **Reset your trip mileage odometer** to zero.

Detailed geologic maps, cross sections, and descriptions featuring bedrock geology, faults, and landslide information useful for this field trip area are available on-line via the USGS San Francisco Bay Region Geology website, on-line at http://sfgeo.wr.usgs.gov. McLaughlin and others (2001) have produced geologic maps of the Los Gatos, Laurel, and Loma Prieta 7.5 minute quadrangles that encompass this area. These maps are also consolidated within a research volume on the 1989 Loma Prieta Earthquake edited by Wells (2004). Wentworth and others (1998) is a regional geologic map of the San Jose 30'X60' quadrangle, and Brabb and others (1997) is a map of Santa Cruz County [see the reference list below].

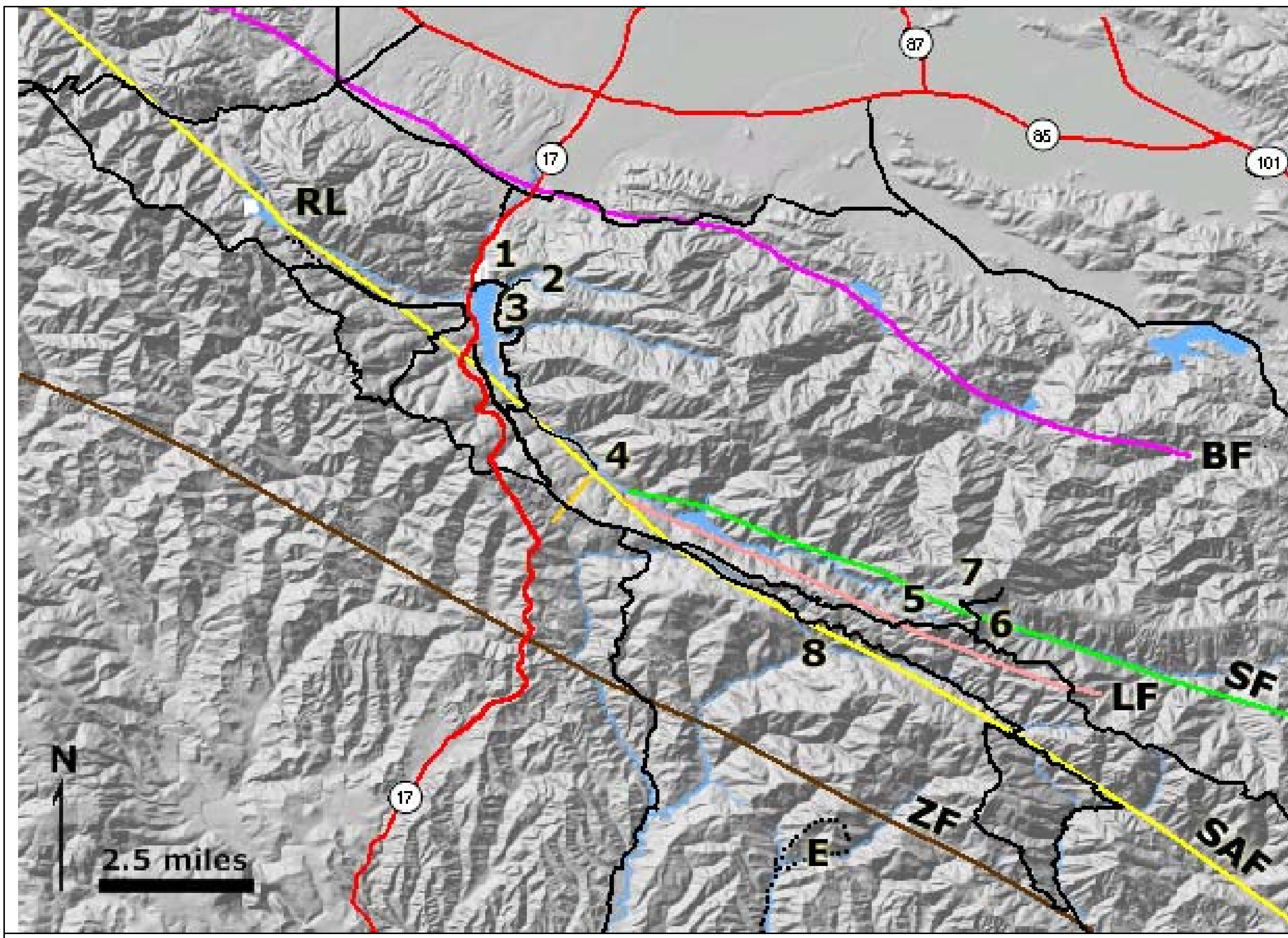

Figure 3-1. Map of the Santa Cruz Mountains between San Jose and Santa Cruz. Numbered stops (1-8) are part of this field trip. Faults shown in colors include the San Andreas Fault (SAF), the Lomitas Fault (LF), the Sargent Fault (SF), the Berrocal Fault (BF), and the Zayente Fault (ZF). Wrights Tunnel is shown in orange (at Stop 4). This map also shows other field trip options in the vicinity that involve hiking. These include the Big Slump Trail to the epicenter of the 1989 Loma Prieta Earthquake in the Forest of Nisene Marks State Park (E), and a trail to Ranch Lake (RL) in Sanborn County Park. The location of Wrights Tunnel is shown in orange at Stop 4.

The Santa Cruz Mountains segment of the San Andreas Fault extends from the San Juan Bautista area northward to Black Mountain. To the south of San Juan Bautista is a creeping segment that extends southward to the Parkfield area in central California. North of Black Mountain is the Peninsula segment that has remained essentially locked since the 1906 earthquake. The Santa Cruz Mountains segment, which experienced between one and two meters of offset during the 1906 earthquake, was the locus of nearly a dozen M-4 to -5 range earthquakes in the two decades preceding the M=~7.0 1989 Loma Prieta earthquake. These earthquakes occurred on the main trace of the San Andreas Fault and on other local faults that splay from the main trace.

Bedrock to the northeast of the San Andreas Fault in this region includes massive slivers or blocks of complexly faulted and folded terranes of the Franciscan Complex and Great Valley Complex. The Sierra Azul Block is a 4 to 5 km wide belt of Great Valley Sequence (Mesozoic and early Tertiary sedimentary rocks) wedged between the San Andreas Fault and a system of ancient faults that roughly parallel the eastern side of the crest of the Sierra Azul Ridge. The northern extent of the Sierra Azul Block is near Wrights Tunnel south of Lexington Reservoir. The New Almaden Block is on the east side of the Sierra Azul Block and consists of Mesozoic age Franciscan Complex (chert, mudrocks, limestone, and basalt volcanics) and Coast Range Ophiolite (Jurassic-age serpentinized ultramafic rocks) that crop out in a belt extending from Gilroy northward through the the Los Gatos-Lexington Reservoir area. Serpentinite exposures at the summit of both Mt. Umunhum and Loma Prieta are part of the New Almaden Block. The New Almaden Block is also host to the cinnabar-bearing silica-carbonate deposits [the largest mercury production district in North America].

Bedrock west of the San Andreas Fault is part of the Santa Cruz Block that consist of late Tertiary marine sedimentary rocks that overlie Salinian crystalline basement rocks (granitoid, diorite, and gabbro that intruded older Paleozoic and Mesozoic metamorphic rocks). These crystalline basement rocks are exposed to the south in the Watsonville-Aromas area and to the northwest on Ben Lomond Mountain.

Mileage	**Description**
0.0	**STOP 1 - Lexington Reservoir Dam boat dock parking area** (see description below). Restrooms are available here, albeit primitive. After the stop, turn right when you leave the parking area and continue south on Alma Bridge Road.
0.4	The entrance to Lexington Quarry is on the left. A large quarry in the Franciscan Complex exposed along the Limekiln Creek valley produces crushed sandstone for construction aggregate.
0.6	**STOP 2 - The Limekiln Trail** (see description below). Parking for about 10 vehicles is available here at the trail head. After the stop, continue south on Alma Bridge Road.
1.6	**STOP 3 - Douglas B. Miller Picnic Area** (see description below). This is both a field-trip stop and lunch stop. Restrooms are available, albeit primitive. After the stop, continue south on Alma Bridge Road.
2.4	Alma Bridge Road winds into and out of Soda Springs Creek canyon. Soda Springs road intersects Alma Bridge Road on the left (east). This road winds upward to the summit of Mount Thayer (mostly private land). A significant fire burned much of the hillsides along the east side of Lexington Reservoir in 1985 and threatened or damaged homes in the hills. The mostly chaparral-covered hills were more forested before the fire. The new vegetation is now a significant fire hazard during the dry summer-fall fire season.
4.1	Intersection of Alma Bridge Road with Aldercroft Heights Road. Turn right (west) on Aldercroft Heights Road. The bridge over Los Gatos Creek is labeled Alma Bridge 1952. **STOP 4 - Wrights Tunnel (Optional):** (see discussion below): Wrights Tunnel is a historic railroad tunnel that is now abandoned and sealed shut. It was severely damaged by the 1906 earthquake. The tunnel entrance is accessible via a trail between Aldercroft Road and Wright Station Road (to the south) and is downstream of Austrian Dam/Lake Elsman in the upper Los Gatos Creek drainage. Field trips can have had access to this area with permission from the San Jose Water Company.
4.6	An outcrop of serpentinite is visible along the left side of the Aldercroft Road indicating that this area is east of the San Andreas Fault. As you continue along the road look for geomorphic features that might reveal the location of the San Andreas Fault.
4.7	Intersection of Aldercroft Heights Road with the Old Santa Cruz Highway, turn left (south).

5.2	Along this section of the Old Santa Cruz Highway the soil along the road cuts changes consistency, becoming increasingly sandy, and redwood groves thrive (regrowth of the older lumbered forest). The change in soil reflects the transition of bedrock, soil, and vegetation across the San Andreas Fault Zone. However, the trace of the fault in not apparent along the highway.
6.4	Mountain Charlie Road is on the right. This is a remnant of an early trail that crossed the Santa Cruz Mountains in the late Eighteenth Century connecting Mission Santa Clara with Mission Santa Cruz (probably following existing Indian trails). The trail, and the road system that followed, utilized a low divide along the ridge crest called Patchen Pass. As mining, lumbering, and other regional commerce grew, the need for a road across the mountains led to the establishment of the Santa Cruz Turnpike Company which, in turn, awarded a road-building contract in 1858 to one of the early white settlers in the area, Mountain Charlie McKiernan. This road roughly ran parallel to the modern Highway 17, and still exists as part of Mountain Charlie Road (which intersects Summit Road east of Highway 17). The name Patchen comes from an original settlement located near the summit.
8.4	Intersection of Old Santa Cruz Highway and Summit Road. Turn left (east) onto Summit Road.
10.2	Walkway overpass crosses Summit Road at school. This area experience extensive damage to property with numerous surface ruptures from the 1989 earthquake. Most of the surface ruptures were a result of the gravitatational collapse of the mountaintop area during the shaking caused by the earthquake. This combined effect of earthquake tectonic forces and shaking, and the gravitational pull-apart of the mountain, is called *ridge-top spreading*. All of the visible damage has been repaired and is no longer obvious today. However, the surface rupture effects of the 1989 earthquake are still visible in remote sections of the Forest of Nisene Marks State Park (see discussion below).
10.8	Old School Vineyards are on Right. Summit Road straddles the San Andreas Fault Zone for the next quarter mile, but landscape features do not make the transition apparent.
11.0	Summit Center Market is on the left. (Groceries are available here.)
11.2	Soquel-San Jose Road is on the right. To the east of this intersection, Summit Road enters a straight wooded canyon of Laurel Creek that defines the rift valley of the San Andreas Fault. Look for geomorphic features along the road that reveal the trace of the fault.
12.2	Summit Road ascends into a flat area where a number of sag ponds can be seen along the right side of the road.
12.9	Intersection of Highland Way and Mount Bache Road. Continue strait onto Mt. Bache Road. Highland Way descends into headwaters region of Soquel Creek which drains a straight valley along the San Andreas Fault (see STOP 8 below). **Be cautious driving on Mt. Bache Road**. Although the road is paved, it is windy, narrow, and uneven due to slumping in many places. Vehicles traveling downhill may have more difficulty stopping that those traveling uphill.
13.9	Mt. Bache Road ends where Loma Prieta Avenue comes in from the left and continues uphill. Proceed straight onto Loma Prieta Avenue (continuing south).
14.4	Outcrops of steeply dipping and contorted sandstone and shale beds start to appear in cuts along Loma Prieta Avenue (continuing uphill). These are discussed in stops 4 and 5.
16.2-16.3	**STOP 5 - Loma Prieta Avenue** (see description below). A parking area is on the right surrounded by large boulders and a gate (do not block the gate - the steep dirt road is used for back country patrols by open space rangers). Additional pull offs are ahead on either side of the road where Loma Prieta Avenue crosses a narrow divide between the headwaters canyon of Los Gatos Creek on the left (north) and Soquel Creek in the San Andreas Rift Zone on the right (south). After the stop, continue south on Loma Prieta Avenue. The pavement eventually ends, but the graded road is maintained and is suitable for any passenger vehicle.
17.1	**STOP 6 - Intersection of Loma Prieta Avenue with Mt. Madonna-Summit Road.** A road to Loma Prieta Peak area is on the left. (See description below.) After the stop, turn left on the road leading to Loma Prieta Peak. (The "no trespassing" sign is not enforced in this lower section of the road, however farther above, gates indicate where private property begins). The road is rough, but is passable up to a large dirt parking area near the intersection of three private roads.
17.3-17.5	Along the route uphill toward Loma Prieta Peak, roadside outcrops of interbedded Late Cretaceous

	sandstone and shale give way to conglomerate. This, in turn, gives way to exposures of serpentinite of Jurassic age. This transition marks the location of the fault zone for the Sargent Fault (also visible at STOP 7). Intermittent views of the southern Santa Clara Valley are on the right.
17.5	**STOP 7 - Loma Prieta summit area** (see description below). A relatively large parking area is located on the left near the intersection of a gated road to Loma Prieta Peak and another unpaved road that leads downhill toward private residences built on the east side of Loma Prieta Peak. A third road (with a gate) leads north along the ridge line of Summit Road. Do not attempt to proceed into these areas without permission. After the stop, return down Loma Prieta Avenue to Mt. Bache Road.
23.0	At the Intersection of Mt. Bache Road and Highland Way, turn left (south). Highland Way descends into the upper valley of Soquel Creek that is also the rift valley of the San Andreas Fault. Highland Way is a road destined for trouble: for much of the next six miles the road crosses as Quaternary landslide deposits. The San Andreas Fault follows the west side of the valley near creek level.
26.0	**STOP 8 - Landslide on Highland Way** (see description below).
26.3	**END OF FIELD TRIP**. A trail head for the Soquel Demonstration Forest and the Forest of Nisene Marks is on the right (farther south) along Highland Way. Parking is available here for paths that lead to the epicenter area for the Loma Prieta Earthquake of 1989. Turn around here and return to Highway 17 via Summit Road. Alternatively, continue south along Highland Way and Buzzard Lagoon roads to get to Santa Cruz-Watsonville area and to Highway 1.

STOP 1 - Lexington Reservoir Dam boat dock parking area

Stop highlights: View of the San Andreas Fault rift valley, a range-front thrust fault, Franciscan Complex, graywacke

Lexington Reservoir Dam is located about 1.5 miles above the mouth of Los Gatos Creek Canyon (at the town of Los Gatos). The dam was renamed the James J. Lenihan Dam in 1997 to honor a former director of the Santa Clara Valley Water District. Two small communities, Lexington and Alma, existed in the upper, broad valley of Los Gatos Creek before the reservoir was constructed. The dam and reservoir were completed in 1952. The dam was built for flood control and to moderate the flow of water to Vasona Reservoir and groundwater-recharge percolation ponds farther downstream in the Campbell area.

Below the dam, Los Gatos Creek Canyon separates El Sereno (the mountain on the west side of the canyon) and St. Joseph's Hill (to the east; it is part of the Sierra Azul Open Space Preserve). A trail system between Los Gatos and the reservoir traverses the canyon and the eastern hillsides. Rocks exposed in the canyon and along the trails include sandstone, conglomerate, chert, and basaltic volcanic rocks, serpentinite and greenstone. The rocks are fragmented into car- to building-sized blocks and mixed together. Where these materials are too small to be differentiated into map units they are collectively assigned to a unit called a *mélange* (meaning "mix of rocks"). In some areas, belts of similar rock types can be mapped over the distance of many miles. The large blocks are bounded by faults that predate or are concurrent with the local development of the San Andreas Fault System in late Tertiary time. One large block of sandstone and mudrock of Cretaceous age is partially exposed in the cut across the road and in the hillsides below the boat dock parking area.

The view to the southwest across Lexington Reservoir reveals the trace of San Andreas Fault (fig. 3-2). It forms a side-hill bench (a break in the slope) across the hillside on Castle Rock Ridge in the distance. Conifers grow on the uphill, steeper slope on the west side of the fault. The trace of the fault continues north into Lyndon Canyon that separates El Sereno Ridge (on the right) and Castle Rock Ridge (on the left). To the south, the trace of the San Andreas Fault follows upper Los Gatos Creek before ascending over the ridge along Summit Road along the crest of the Santa Cruz Mountains.

In this region of the Santa Cruz Mountains, the rocks east of the San Andreas Fault consist of three groups: the *Coast Range Ophiolite*, the *Franciscan Complex*, and the *Great Valley Sequence*. The Coast Range Ophiolite is comprised of rocks that formed in the ocean's crust during the Jurassic and Cretaceous periods. These rocks have traveled great distances from their place of origin and consist mostly of serpentinitized ultramafic rocks and greenstone. The Franciscan Complex contains of a mix of oceanic sedimentary and volcanic rocks of Jurassic to Cretaceous age; this rock assemblage includes pillowed basaltic volcanic rocks, radiolarian chert, mudrocks, sandstone, limestone, and conglomerate. The basalts represent lava flows that formed at a mid-ocean ridge. These were overlain by open-ocean and continental margin sediments before being accreted onto the edge of the continent through plate tectonic motion. The Great Valley Sequence consists mostly of sandstone and shale of Cretaceous age deposited in a "fore-arc basin" developed between an Andean-style volcanic arc and the associated subduction zone to the west. Marine sedimentary formations of Miocene age (Temblor Sandstone and Monterey Formation) occur in the Cupertino basin, a great sediment-filled crustal downwarp located beneath the alluvial plain extending eastward from the foothills in the Los Gatos and Saratoga region and extending to San Jose and southern San Francisco Bay).

Rocks on the Santa Cruz (west) side of the San Andreas Fault are part of the Santa Cruz Block, an expansive geologic terrane that consists mostly of sedimentary rocks overlying older Salinian crystalline basement rocks. In the headwaters region of Los Gatos Creek, these rocks consist entirely of marine sedimentary rocks of early Tertiary age (Butano Sandstone of Eocene age, and San Lorenzo and Vaqueros Formation mostly of Oligocene age).

In this region, rocks younger than the San Andreas Fault include the Santa Clara Formation of Pliocene to Quaternary age. The Santa Clara Formation consists of stream cobbles, gravel, sandstone, siltstone, and mudstone, and bears freshwater gastropods, pelecypods, and terrestrial plant and vertebrate fossils); ~3.6 to 0.4 million years old. Younger terrace gravels along stream valleys incorporate a mix of all the above rock-types mentioned.

A walk down to the shore near the boat dock provides a view of Franciscan rocks (to the east) thrust-faulted over steeply-dipping gravels of the Quaternary Santa Clara Formation (to the west). The faulted contact is also visible on the far side of the bay of Limekiln Creek, however both outcrop area may not be exposed at high water levels. The thrust fault is part of the Lexington Fault zone that runs roughly parallel to the mountain front along the east side of the reservoir. The fault system extends from the park's boat dock parking area southward to where it merges with the San Andreas Fault in the vicinity of Wright's Tunnel (see below). Uplift along the thrust fault and other faults are responsible for the high, rugged topography of the Sierra Azul uplands (for more information, see McLaughlin and others, 2000). Likewise, the broad valley flooded by Lexington Reservoir may be partly due to tectonic downwarping in addition to the erosional downcutting by Los Gatos Creek.

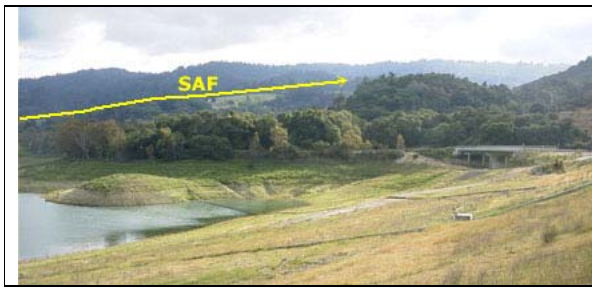

Figure 3-2. Northwest view from the boat dock parking area showing Lexington Dam and the location of the San Andreas Fault trace on the distant hillside west of Highway 17. The fault trace follows a side-hill bench below the upper steep slopes of Castle Rock Ridge on the horizon. The fault continues northward into the valley of Lyndon Canyon.

STOP 2 - The Limekiln Trail

Stop highlights: an active slump, a fault, serpentinite, sepentinite soil, vegetation contrasts, greywacke and other rocks

The Limekiln Trail climbs to the summit area of El Sombroso, a high point at the north end of the Sierra Azul Ridge. The destination of this stop is a landslide about 0.25 mile uphill from the trail head (fig. 3-3). The trail climbs a moderate grade before leveling out near the slide area. Do not go on the trail if the park police have closed it (park patrol officers will issue tickets).

The lower part of the trail ascends past outcrops of metabasalt, and sandstone and mudrock (also called graywacke) similar to rocks at Stop 1. The landslide occurs along the east side of a fault separating bedrock consisting of sandstone bedrock and serpentinite. The slump provides an excellent observatory of landslide processes, weathering of serpentinite, stream erosion, and vegetation characteristics associated with serpentinite and sandstone bedrock terranes. The stream also yields boulders of chert, slate, and rounded stream cobbles derived from sources higher on the mountainside.

Across the valley, belt of barren, gray limestone outcrops. A manzanita grove reveals the presence of serpentinite bedrock along the skyline. Approximately a mile south of the landslide on the opposite side of the valley is the Lexington Quarry, a large active quarry where rock (mostly metasandstone) is mined and processed into aggregate for construction. Geologic maps of the area show a system of southeast-trending faults through the area. One large fault mapped in this area, the Limekiln Fault, basically follows the trace of the stream valley. The fault exposed along the side of the landslide is only a part of the larger fault system. Be sure to examine outcrops in the creek to the right of the landslide. Note shearing features in the faulted bedrock, and observe the chaotic character of debris flow deposits along the stream banks.

Figure 3-3. An active landslide along the Limekiln Trail causes trail closure during wet seasons. In recent winters the road has been offset by several meters. During dry months the slide area is relatively safe to examine but be aware that rocks and soil in steep slopes may be unstable from recent movement. The landslide formed in deeply weathered serpentinite, but fresh blocks of rock material have accumulated in the stream at the toe of the slump.

STOP 3 - Douglas B. Miller Picnic Area

Stop highlights: an unconformity between weathered Quaternary gravels and Franciscan Complex sandstone

The Miller Point Picnic Area is located on a small peninsula in Lexington Reservoir. Besides being an excellent place for a picnic, the park offers an opportunity to examine rocks exposed along the reservoir shoreline. Large blocks of graywacke sandstone stand out on the shore (during low water). Wave erosion at the high water line has exposed an ancient stream terrace deposit consisting of a mix of gravel derived from upland localities (fig. 3-4). At some places along the shore it is possible to see the gravel resting unconformably on an eroded surface of the older greywacke bedrock. The gravel was deposited along the ancestral Los Gatos Creek. The stream has carved about 20 meters deeper into the valley since the time the terrace was formed.

The terrace gravel contains an assortment of different rock types, with sandstone being the most abundant. Rock types not at the Limekiln Trail stop include conglomerate and volcanic cobbles (clasts) (fig. 3-5). The volcanic clasts are dominantly andesite and possibly dacite -- these volcanic rocks are "intermediate" in composition between more felsic rock (rhyolite) and mafic rock (basalt). The volcanic cobbles display an abundance of phenocrysts (visible crystal mineral grains) surrounded by a finer ground mass. Some of the cobbles may be the intrusive igneous equivalent, granodiorite, which has the same mineral composition of its volcanic form, andesite. Some of the clasts contain xenoliths (pieces of the original host rock that was intruded by the volcanic material). The occurrences of these clasts in the terrace gravels demonstrate how earth materials are recycled (formed, eroded, deposited, exposed, eroded, and deposited again, etc.).

The volcanic cobbles are derived from outcrops of Cretaceous-age conglomerate throughout the upper hillsides of the Sierra Azul. It also forms part of the resistant ridge crest on the southwest side of Mt. Umunhum and along the ridge south of Loma Prieta peak, and probably elsewhere under the forest cover. Similar gravel deposits can be found around the parking area at Los Trancos, nearly 14 miles (20 km) to the northwest. The offset of these gravels by the San Andreas Fault help to determine the rate of slip along the fault over time.

Many of the volcanic clasts in the terrace deposit are "rotten" -- they practically crumble in your hands (fig. 3-5). This is due to chemical weathering of the rocks in the shallow surface environment (processes associated with soil development). The relationship between deposition of the terrace gravels and the motion along faults affecting stream drainages is unclear. However, the occurrence of terrace deposits in upland valleys elsewhere in the Santa Cruz Mountains and in the region is related to erosional "valley broadening" periods during the Pleistocene. This is opposed to "valley deepening" periods when streams carve downward into their flood plains. During times of high-standing sea level (during interglacial periods), the rise in stream base level tends to allow streams to backfill their channels with sediment. During wetter periods in the West (associated with glaciation), the combined influence of increased stream flow, reduction in sediment supply (due to increased vegetation), and lowered sea level (due to the formation of continental glaciers) induces streams to carve into their flood plains. Incising streams locally leave bench-like, gravel-covered terraces along the valley sides.

Figure 3-4. Stream boulders and gravel of Quaternary-age deposits overlie Cretaceous-age sandstone bedrock along the shore of Lexington Reservoir at Miller Point Picnic Area.

Figure 3-5. A "rotten" (partial weathered) cobble a mafic volcanic porphyry has an inclusion of gray metasandstone. This cobble was probably derived from the Late Cretaceous-age conglomerate found on Mt. Umunhum and Loma Prieta peaks. That conglomerate originally accumulated in the ocean, possibly at the mouth of a deep ocean canyon offshore of what is today southern California or Mexico. The sediments were consolidated into conglomerate before being transported northward by plate tectonic motion along the San Andreas Fault and fault systems that predate the San Andreas Fault. Similar blocks of conglomerate bearing clasts of a mafic volcanic porphyry occur in gravels of the *Corte Madera facies* of the Santa Clara Formation exposed at the Monte Bello and Los Trancos preserves nearly 25 kilometers to the north along Skyline Ridge. The measurable offset of the Corte Madera facies provides information about the timing and rate of movement along the San Andreas Fault.

STOP 4: Wrights Tunnel

Stop Highlights: a historic railroad tunnel built through the San Andreas Fault Zone

Wrights Tunnel was constructed by the Southern Pacific Railroad over (and through) the Santa Cruz Mountains. The tunnel took 3 years to build. During construction in 1879, Chinese laborers excavating the tunnel encountered a source of natural gas that exploded and burned, killing 31 people. The completed tunnel was 6,000 feet long and ran between two historic mountain communities (Wrights Station on the east, and Laurel on the west). The tunnel passes beneath Summit Road east of Highway 17. The primary income of the railroad was from tourism between the Bay Area and Santa Cruz resorts and recreation. The peak in use of the train line through the Santa Cruz Mountains in the 1910s and 1920s before fading as improvements to the highway system through the mountains provided access to the coast by automobile. The tunnel was dynamited shut in 1942 by the US Army out of fear that it might be used by a Japanese invasion force.

Wrights Tunnel was damaged by the 1906 earthquake. The fault rupture offset the tunnel about 400 feet inside the Wrights Station entrance. It took two years to rebuild the tunnel. Between 3.5 and 5 feet of right-lateral offset were reported on a strand of the San Andreas Fault in the tunnel. Some early reports suggest as much as 4 feet of vertical offset may have occurred. However, modern re-evaluation suggests that the fault zone is about 1/4 mile wide and that a total of 6 feet of offset occurred in the vicinity of Wrights Tunnel. The geologic map of Los Gatos quadrangle (USGS MF 2373) shows the main trace of the San Andreas Fault is inferred to cross Los Gatos Creek several hundred feet northeast of the east tunnel entrance. Most of the mapped cracks that were recorded from the 1989 earthquake occurred outside of the zone of faulting that occurred in 1906 in Wrights Tunnel.

Please note that there is limited parking and trail access to Wrights Tunnel, and poison ivy is abundant everywhere. The tunnel is closed, and permission for group access to the area is required from the San Jose Water Company.

Figure 3-6. View looking out of the west end of Wrights Tunnel toward Los Gatos Creek. The tunnel is now full of leaking cracks that are feeding a small stream flowing from the mouth of the passage.

Figure 3-7. Damage to the railroad track between Wrights Station (near the tunnel) and Alma caused by the 1906 earthquake. Both historic settlements and the rail line no longer exist. The gravel road now follows the rail path. The photograph is from the Lawson Report.

STOP 5 - Loma Prieta Avenue

Stop highlights: views of the San Andreas Rift Valley and Monterey Bay, Cretaceous fossils, conglomerate, turbidites

A parking area is on the right surrounded by large boulders and a gate (do not block the gate - the steep dirt road is used for back country patrols by open space rangers). Additional pull offs are ahead on either side of the road where Loma Prieta Avenue crosses a narrow divide between the headwaters canyon of Los Gatos Creek on the left (north) and Soquel Creek canyon in the San Andreas Rift Zone on the right (south). This stop involves a short walk along Loma Prieta Avenue to examine roadside outcrops and the regional landscape.

Loma Prieta Peak (covered with radio antenna) is visible on the north side of the road across the headwaters valley of Los Gatos Creek.

On the south side of the road the slope descends steeply into the linear valley of the headwaters region of Soquel Creek (fig. 3-8). The linear character of Soquel Creek canyon reflects the location of the San Andreas Fault. The forested ridge on the opposite side of the canyon is part of the Forest of Nisene Marks (the location of the epicenter of the 1989 earthquake). The more distant views along the saddle area include a sweeping view to the south of all of Monterey Bay and Monterey Peninsula, and the Santa Cruz urban coastal corridor.

Other than a few scattered homes and some radio towers, the upland area around Loma Prieta Peak is relatively wild country. The isolated country is prime mountain lion habitat. The west- and south-facing slopes tend to have chaparral to mixed shrub-deciduous forest (particularly bay laurel), whereas the wetter, cooler north- and east- facing slopes are forested with mixed evergreen (spruce-pine-redwoods). However, the character of the bedrock and derivative soil plays an important role in supporting different types of vegetation. Loma Prieta receives the greatest amount of rainfall annually in the South Bay region (on average, mixed precipitation is equivalent to about 60 inches of rainfall).

Vegetation and topography reveal the trace of the Lomitas Fault along the hillside about 200 meters below the south side of the road (fig 3-9). On the north side of the road, the Sargent Fault follows the valley of Los Gatos Creek (see Stop 6 discussion). Both faults merge with the San Andreas Fault in the vicinity between Wrights Tunnel and Austrian Dam in the upper Los Gatos Creek canyon.

Road cuts along Loma Prieta Avenue expose Late Cretaceous age marine sedimentary rocks. The alternating sandstone and shale beds are called turbidites. Turbidites form from sediment-bearing underwater landslides (turbidity currents) that roll down the continental slope and spread out on the deep ocean floor. The heavier sand is deposited first (forming sandstone) and the finer silt and clay settle out later (forming mudstone and shale). Turbidites are characterized by graded bedding, moderate sorting, and well-developed primary structures (including traces that reveal current orientation, bedding lamination, and bioturbation features from organisms that fed or lived in the sediment). These deep ocean sediments are now exposed in many areas throughout the Santa Cruz Mountains. The turbidite sandstone and mudstone cut by the construction of Loma Prieta Avenue near the parking area display exceptional examples of spheroidal weathering (the early stages of chemical weathering of freshly fractured rock).

In the middle of the saddle area are outcrops bearing massive sandstone, conglomerate and fossiliferous marl (bearing oysters, corals, calcisponges, and other invertebrates and trace fossils) (figs. 3-10 and 3-11). The conglomerate bears mafic-mineral bearing volcanic clasts (andesite and dacite) in a fine sandy matrix. These conglomerate beds are likely the source of the deposits seen at the Miller Point Picnic Area (Stop 3). The occurrence of the oyster-bearing beds is unusual. Modern oysters live in brackish, shallow water environments probably as they did in Cretaceous time. How this deposit arrived at its location amongst deep water deposits can only be speculated (perhaps carried down slope as a great submarine landslide, perhaps after an earthquake, massive storm, or giant tsunami impacted the coast). Elder (1991) provides more information about the paleontology of this site.

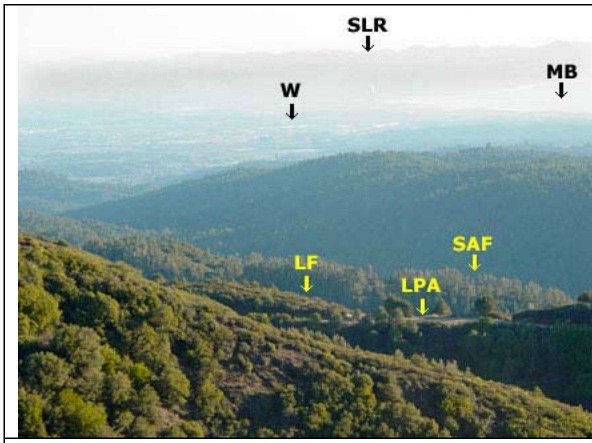

Figure 3-8. View looking south at the Loma Prieta Road (LPA) saddle area. The rift valley of the San Andreas Fault (SAF) is developed in the headwaters of Soquel Creek (which flows to the right). To the south of a divide in the rift valley is Corralitos Creek that flows south into the Watsonville area (W). A linear ridge and a change in vegetation mark the location of the Lomitas Fault (LF). Seen in the distance are Monterey Bay (MB), and the Santa Lucia Range (SLR), which at the northern end becomes the Monterey Peninsula.

Figure 3-9. Vegetation changes and topography reveal the trace of Lomitas Fault below the saddle area along Loma Prieta Avenue. Raised relief on the south side of the fault suggests that the Loma Prieta Peak side of the fault dropped relative to the opposite side. However, the fault probably shares the right-lateral motion of the San Andreas and other fault in the region. The valley of Soquel Creek is on the upper right. The stream drains into the ocean in the Capitola neighborhood of Santa Cruz.

Figure 3-10. A layer of conglomerate between beds of sandstone. The largest clasts of volcanic rock and sandstone are at the base of the graded bed, suggesting that rock pick hammer handle is in the direction of the top of the unit. Much more massive beds of conglomerate occur throughout the area along Loma Prieta Avenue and Mt. Madonna Summit Road. They also occur in the western Mt. Umunhum summit area.

Figure 3-11. Small oysters and calcisponges in a fine mudrock groundmass occur in an outcrop area near the center of the saddle area along Loma Prieta Avenue. Like the conglomerate beds., the oyster shells and other fossil material were probably deposited in a submarine fan channel far offshore (in a setting perhaps similar to the the bottom of submarine Monterey Canyon today). Today, oysters thrive in brackish estuary and nearshore waters, but cannot tolerate predation or environmental conditions typical of open-ocean marine waters.

STOP 6 - Intersection of Loma Prieta Avenue with Mt. Madonna-Summit Road

Stop highlights: Cretaceous turbidites, conglomerate, views of the southern Santa Cruz Mountains region

A parking area near the intersection of Loma Prieta Avenue and Mt. Madonna-Summit Road is the best place to examine the turbidite beds (alternating sandstone and shale layers). An optional walk (or drive) is to continue along Mt. Madonna-Summit Road to examine folds in the sandstone and shale and conglomerate (fig. 3-12). A view of the straight valley of Uvas Creek Canyon and the more distant Santa Clara Valley in the vicinity of Morgan Hill (near El Toro Peak) is approximate 0.2 miles south of the intersection. **Warning:** Be cautious of traffic while walking, especially near blind bends in the road.

Figure 3-12. Sandstone and shale beds (turbidites) and conglomerate crop out along Mt. Madonna-Summit Road. This roadcut is about 0.1 miles south of the intersection and displays both folds and minor fault offset.

STOP 7 - Loma Prieta Summit Area

Stop highlights: views of the Sargent Fault zone, Sierra Azul Ridge, Mt. Umunhum, serpentinite

Stop 7 is along the road to the Loma Prieta Peak summit area (fig. 3-13). An old sign near the intersection of Loma Prieta Avenue and Mt. Madonna-Summit Road warns travelers to “keep out.” However, the road is passable to the intersection of three gated roads farther along the route. Proceed up the road for 0.6 miles to a large circular parking area. Along the way, pay attention to the scenery and bedrock changes in the road cuts. Drivers should pay attention for potholes, but the road is passable for any vehicle. Unfortunately, much of the summit area of Loma Prieta and the passage along Sierra Azul Ridge to Mt. Umunhum are closed to the public, although field trips have been granted permission to enter in the past.

Along the route, the road crosses the Sargent Fault (fig. 3-14). The fault is indicated by the transition from conglomerate, sandstone and shale (turbidites), to serpentinite, as is visible in roadside outcrops. Small pull outs along the route provide scenic vistas to the south and east of the Santa Clara Valley and the foothill country and canyons east of the crest of the Santa Cruz Mountains. The Sargent Fault is considered an earthquake fault -- showing active recent seismicity and having association with damaging earthquakes in historic times in the Gilroy and Hollister region. The fault intersects the San Andreas Fault near Elsman Reservoir (upstream of Wrights Tunnel) and connects with the Calaveras Fault in the vicinity of Hollister. Like all major faults in the area, it displays evidence of right-lateral (dextral) offset. However, evidence of some vertical component offset is suggested by exposures of the fault scarp along the Los Gatos Creek canyon. The west side of the fault (toward the creek) appears to be raised as much as 200 feet relative to the Loma Prieta and Sierra Azul Ridge side of the fault. This perspective is best seen from the Stop 6 parking area (fig. 3-15).

The Stop 7 parking area also provides an opportunity to view the crest of the Santa Cruz Mountains extending north to the Mt. Umunhum summit area and beyond (fig 3-16). It also is an excellent location to examine serpentinite outcrops (fig. 3-17).

Figure 3-13. Serpentinite forms the core of Loma Prieta Peak. The chaparral- and manzanita-covered mountain top is privately owned, and space is leased for radio towers. The area is closed to public access. This view is from along the road to Stop 7.

Figure 3-14. This view is looking south along the straight canyon of upper Uvas Creek from along the road to Stop 7. The valley follows the trace of the Sargent Fault southward to the Gilroy area and on to Hollister where it joins the Calaveras Fault. Mt. Madonna-Summit Road follows the ridge on the right.

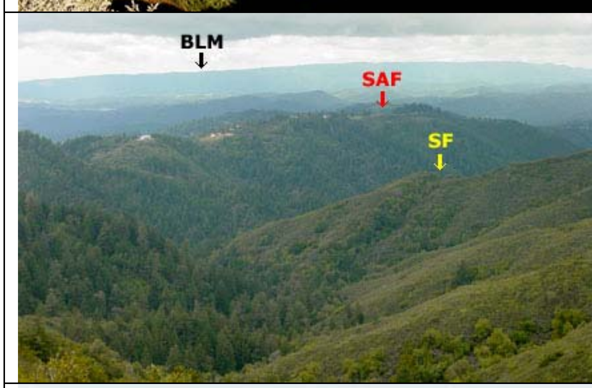

Figure 3-15. View looking west from the Stop 7 parking area. The linear scarp of the Sargent Fault (SF) is highlighted by a line of coniferous forest on its northwest-facing slope. The location where the trace of the San Andreas Fault (SAF) crosses the ridge along Summit Road is visible on the opposite side of Los Gatos Creek Canyon. Ben Lomond Mountain (BLM) is the long, gentle ridge on the western horizon.

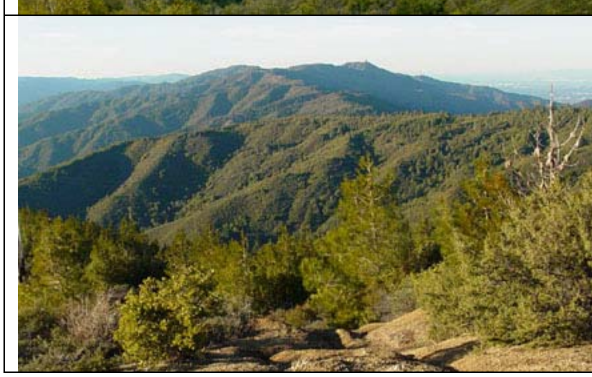

Figure 3-16. View looking north toward Sierra Azul Ridge and Mt. Umunhum. The low section along the ridge is underlain by early Tertiary carbonaceous shale and sandstone (containing land plant material). The higher section of the ridge consists of Cretaceous conglomerate. The eastern peak of Mt. Umunhum (near the large cement block-shaped structure of an abandoned military radar facility) consists of a complex mix of rocks, mostly serpentinite, associated with the Coast Range Ophiolite.

Figure 3-17. This view shows part of a large serpentinite block near the Stop 6 parking area. The rock reveals aspects of how mantle rock is converted to serpentinite. Pink crystalline masses are relatively unaltered ultramafic rock (harzburgite and peridotite). These are surrounded by black serpentinized material (resulting in the loss of crystalline texture). The blue veins are asbestoid minerals (mostly crysotile) and magnesium hydroxide-rich minerals. Surficial weathering converts these minerals to magnesium-rich clay soil.

STOP 8 - Landslide on Highland Way

Stop highlights: landslides, Tertiary sandstone and shale, San Andreas Rift Valley

Along Highland Way, about three miles west of the intersection of Summit Road, are a series of landslides that have frequently closed the road to through traffic. The road was most recently closed by massive landslides that occurred during the wet fall/winter of 1998 (fig. 3-18). The road has since been repaired, but the "fresh" landslide escarpments are still visible (even after construction repairs have smoothed out the typically chaotic landscape of a slide area). The steep, forested landscape throughout this area displays abundant evidence of landslide activity -- both active slides and other more ancient slides that are probably dormant.

A combination of factors makes this area prone to landslides, including:

* long, steep slopes;
* bedrock consisting of sedimentary rock (mostly shale and highly fractured sandstone);
* a seasonally wet period;
* mountain climatic conditions that promotes organic activity and associated weathering;
* rapidly down-cutting streams that undermine slopes;
* human activity - particularly their preponderance to cut slopes to build roads;
* frequent landslide trigger mechanisms, including earthquakes and major storms.

The bedrock exposed in the slide area is interbedded quartz-rich to arkosic sandstone, and shale of early Tertiary age (Eocene Mt. Madonna Sandstone; deposited between 34 to 56 million years ago). On the west side of Soquel Creek valley the bedrock is a mudstone of late Tertiary age (Purisima Formation; of Pliocene age, about 3 million years). Marine fossils in the Purisima Formation demonstrate that the Santa Cruz Mountains have risen from below sea level to over a kilometer in roughly 3 million years. In addition, another 3 to 4 kilometers of rock has probably been eroded from the crest of the Santa Cruz Mountains in the past 5 million years (McLaughlin and others, 2001).

Many trees in the Soquel State Demonstration Forest (across the valley) were damaged or fell in the 1989 Loma Prieta Earthquake. The magnitude ~7.0 earthquake occurred on Tuesday, 17 October, 1989 at 5:04 p.m. PDT. The epicenter of that quake was approximately four miles south of the slide area in the heart of the Forest of Nisene Marks State Park (37°02'N, 120°53'W). The depth of the main shock was approximately 11.5 miles below the surface. The fault plane is not vertical, but rather, it dips steeply at a high angle toward the southwest (NcNutt and Toppozada, 1990). The earthquake produced little physical evidence of right lateral offset on the surface, however the earthquake initiated numerous slope failures and slump-related ground ruptures throughout the Santa Cruz Mountains, particularly along the Summit Road corridor. Near the epicenter, uplift of about 55 cm resulted, whereas east of the fault subsidence occurred in the order of about 15 cm for the area around Loma Prieta peak. Within several miles distance from these areas, the measurable elevation offset diminishes to being negligible.

Figure 3-18. The Highland Way slide. Extensive work was conducted to remove dead trees and loose rock before the road could be repaired. This looser material is derived from Tertiary rock which consists of dark, hard, siliceous marine shale with interbedded arkosic sandstone. This sequence of marine strata forms a belt along the eastern side of the San Andreas Rift Valley for many miles extending to the south.

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