The Calaveras and San Andreas Faults In and Around Hollister

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Introduction

The focus of this trip is to view the surface expression of active strike-slip faults in both manmade and natural settings. We will visit the Calaveras Fault in downtown Hollister, a small city about 90 km (55 mi) southeast of Menlo Park, and the San Andreas Fault about 15 kilometers (9 miles) southwest of Hollister. Because both faults are actively creeping in this area (Wallace, 1990), we will be able to see recently offset human structures along both fault traces. At Hollister Hills State Vehicular Recreation Area (SVRA) and along the Cienega Valley, we will also have the opportunity to see superb examples of geomorphic features created along the San Andreas Fault.

Road Log

The first portion of this excursion guide consists of a road log, with directions and mileage checked in 2001. Discussions, maps, and figures are included with the appropriate field-trip stop materials, all of which follow the road log. Figure 6.1 provides the regional setting for the route and the field-trip stops. Please note that the road log begins at the intersection of U.S.Highway 101 and Interstate 280, approximately 22 miles south of Menlo Park, and is given in miles.

Mileage/Notes

0.0 Intersection of Interstate 280 and Highway 101 (marked at the Tully Road sign on southbound 101). Our journey to Hollister takes us south through the Santa Clara Valley. South of San José, Highway 101 runs generally upstream along the alluvial valley of Coyote Creek to Morgan Hill. The Santa Teresa Hills are on the west and the Edenvale and Coyote Hills on the east.

2.0 Coyote Hills visible on left. The bedrock here is mainly serpentinized ultramafic rocks (harzburgite and dunite) of the Coast Range Ophiolite, together with melange of the central-belt Franciscan Complex (Wentworth and others, 1999).

7.2 Junction of Highway 101 and Interstate 85. Coyote Peak (1155 feet) in the Santa Teresa Hills is on the right.

11.0 Gravel and finer grained sediments crop out on the left. Pliocene to Pleistocene sediments east of the southern Santa Clara Valley can be broadly assigned to the Santa Clara Formation, which is also exposed along the San Francisco Peninsula east of the San Andreas Fault and along the western foothills of the northern Santa Clara Valley. The Santa Clara Formation is thought to be correlative in age and depositional environment with the Livermore gravels east of San Francisco Bay.

The coarse-grained fluvial gravels of Pliocene to Pleistocene age are found parallel to, but significantly elevated above, the eastern edge of the modern Santa Clara Valley. Their general distribution suggests that the valley axis has shifted westward to its modern position, probably as a result of the compression and shortening documented by recent thrust faults in the area.

In the southern Santa Clara Valley, various workers have differentiated individual gravel units, including the Packwood Gravels, mapped east of Morgan Hill by Tolman (1934). Recent mapping by Wentworth and others (1999) differentiated fault-bounded packages of Pliocene to Pleistocene sediments on the basis of distinctive source lithologies. The gravels are in thrust-fault contact with serpentinized ophiolite and melange of the Franciscan Complex.

The Silver Creek Gravels, named by Jones and others (1994) for the valley east of the Coyote Hills, are found along the foothills on the east side of the Santa Clara Valley. A tuff interbedded with the older portion of the Silver Creek gravels was mapped Wills (1995) and identified by Sarna-Wojcicki and Meyer as the Huichica Tuff. The Huichica Tuff was erupted from the Sonoma volcanic field and has been recently dated by Ar/Ar isotopic methods at 4.71 million years old (A. Sarna-Wojcicki, oral commun., 2001).

12.0 Coyote Golf Course exit. Along this portion of Highway 101, prominent white, fine-grained beds, which appear very white because of the presence of magnesite, in the median of the highway here are of probable lacustrine origin. These beds are a part of the Scheller Gravels of Wills (1995). A tephra unit identified as the Rockland Ash by Sarna-Wojcicki and others (1985) was formerly exposed along the median strip in this vicinity. The Rockland Ash, an important marker tephra throughout northern California, was erupted from the vicinity of present-day Mount Lassen. It is between 450,000 and 620,000 years old and cannot be more precisely dated at this time. It is also unknown whether the ash is interbedded with the Scheller gravels or unconformably overlying them.

14.6 Cross Coyote Creek. Anderson Dam can be seen in the hills on the left. Anderson Dam was built in 1950 and reconstructed in 1987-88. Anderson Reservoir and Coyote Reservoir, built in 1936 and located further upstream on Coyote Creek, store water imported from the Central Valley Project. Both are along the Calaveras Fault, which runs along the foothills on the eastern side of Anderson Reservoir.

16.7 El Toro Peak (1420 feet) on right overlooking Morgan Hill. While camped at "21-mile house," 21 miles south of San Jose, in August, 1861, William Brewer glowingly wrote (Brewer, 1966):

> The Santa Clara Valley (San Jose Valley of the map) is the most fertile and lovely of California. At the point where we came into it, it is about six miles wide, its bottom level, a fine belt of scattered oaks four or five miles wide covering the middle. It is here all covered with Spanish grants, so is not cultivated, but near San Jose, where it is divided into farms, it is in high cultivation; farmhouses have sprung up and rich fields of grain and growing orchards everywhere abound. But near our camp it lies in a state of nature, and only supports a few cattle. One ranch there covers twenty-two thousand acres of the best land in the valley—all valuable… We camped under some beautiful oaks, near a house, where we got hay and water. Two days were spent examining the hills to the east of the valley, from the summits of which (near two thousand feet above the valley) are to be had most magnificent views. One sharp peak rose near camp, on the west, conspicuous from every direction.

El Toro, the "sharp peak" mentioned, was in Brewer's time called "Ojo de Agua de la Coche", which on the 1:100,000-scale topographic map is the name of the land grant rancho in the area including El Toro.

18.4 East Dunne Avenue exit. In this vicinity, young terrace surfaces and gravel deposits can be seen. We are leaving the drainage basin of north-flowing Coyote Creek and entering the basin of Llagas Creek, a south-flowing tributary of the Pajaro River. East Dunne Avenue provides access to the southern end of Anderson Reservoir and Henry Coe State Park (California's largest state park). The nearby town of Gilroy is probably best known as the "garlic capital" of the world and home to the annual Garlic Festival. Garlic growing began here after World War I. However, during the 1870's, Gilroy had a brief reign as the Nation's tobacco capital and was home to our largest cigar factory. For more information see the World Wide Web at http://www.ci.gilroy.ca.us/historydoc2.html.

27.9 Junction with State Highway 152 East to Los Banos.

31.0 Exit Highway 101 onto Route 25 (Hollister-Pinnacles exit). **WARNING! This is a dangerous exit; watch for confused drivers. Route 25 is a 2-way road and has had a number of disastrous head-on collisions in recent years—be alert.**

Our route into Hollister takes us through some very productive farmland. Local crops along today's routes include garlic, strawberries, tomatoes, salad greens, and seed nurseries for flowers.

33.8 San Benito County Line (on Route 25). As happened in Santa Clara County, agriculture in San Benito County is giving way to residential development. Nevertheless, for more than 50 consecutive years, California has been the leading agricultural producer in the United States. California's agricultural output is nearly $25 billion per year, and the state grows more than half the nation's fruit, nuts, and vegetables. Agriculture still accounts for almost 1 in 10 jobs in California.

39.5 Traffic light at intersection of Route 156. Continue on Route 25 South. The low hills on either side of the road are pressure ridges along the Calaveras Fault. For further discussion of the Calaveras Fault northwest of Hollister, please see the discussion included with Stop 1 materials.

42.0 The water tank on hilltop on the right is astride a pressure ridge along the Calaveras Fault.

Hollister, with a population of 34,413, is an agricultural center undergoing a rapid transition to a suburban bedroom community. The old part of the town retains much of its Victorian architecture, and we will see many fine homes built in the late 1800's. Large tracts of new homes are concentrated south of Hollister along Route 25. The exponential growth in and around Hollister was partly fueled by the delivery of imported water from the Central Valley Project's San Felipe Project in the late 1980's; prior to that time, growth was limited by the availability of local groundwater resources. At present, imported water supplies about one third of San Benito County's need (more information at San Benito County Water District's website at http://www.sbcwd.com/).

Both the 1906 San Francisco earthquake (Rogers, 1980) and the 1989 Loma Prieta earthquake caused substantial damage in Hollister. After the 1989 quake, some buildings in the downtown area were torn down. Many chimneys were toppled, and several older wood-frame residences were either knocked from their foundations or suffered severe damage to cripple walls.

42.5 Junction of Routes 156 and 25. Continue south on Route 25 into Hollister (the road becomes San Benito Avenue). Prepare to turn right onto 6th Street. Turn west and proceed two blocks to Dunne Park at 6th Street and West Street.

43.3 **Stop 1—Dunne Park.** We will leave the vehicles here and make a walking tour along the trace of the Calaveras Fault to observe evidence of creep. The total walking distance will be about 5 blocks round-trip. Refer to Stop 1 materials for discussion. Restrooms available at this stop.

Return to vehicles and proceed back (east) on 6th to San Benito Ave. intersection.

Reset mileage at corner of 6th Street and San Benito Avenue.

0.5 Downtown Hollister.

0.7 San Benito Avenue becomes Nash Road; continue straight at the light following signs to the Hollister Hills State Vehicular Recreation Area (HHSVRA).

1.6 Turn right at stop sign (Union Road). Cross the bridge over the San Benito River. The San Benito River has a drainage area of 586 mi^2 above the bridge. It heads in the Clear Creek area and flows northwest to join the Pajaro River near San Juan Bautista. The San Benito River is reportedly a source of placer benitoite [$BaTiSi_3O_9$], our state gemstone, derived from Franciscan terranes in the headwaters. During the El Niño winter of 1997-98, the bridge was temporarily closed when scour around the pilings almost undermined the structure. The peak discharge on February 3, 1998, was 34,500 cubic feet per second, more than twice as high as any previously recorded flood peaks. For more information, see the website at http://water.usgs.gov/ca/nwis/peak.

1.7 Immediately after crossing the bridge, turn left (south) on Cienega Road. Continue following the signs to HHSVRA.

3.2 Stop sign, right turn. As we travel up the steep and winding road, we will pass road cuts on the left that expose late Tertiary sedimentary rocks to be discussed at Stop 2. On the right are some excellent views of active slump-earthflows in these sedimentary rocks. Near the summit of the Cienega Road, headward migration of one scarp has reached the road, which has been relocated at least once due to active slumping.

6.5 Cross Bird Creek.

7.0 Turn right at Hollister Hills State Vehicular Recreation Area. The San Andreas Fault runs along the valley on our left.

7.1 Pass the ranger station. Proceed on the unpaved road into the Hollister Hills SVRA. Note the erosion control structures, including sediment retention basin on right.

7.8 Turn a very sharp left and preceed uphill to the picnic tables on the south end of Radio Ridge.

7.8 **Stop 2—Radio Ridge, Hollister Hills SVRA.** Radio Ridge is a linear ridge within the San Andreas Fault Zone, and its accessible summit provides one of the best ground-level opportunities to view the geomorphic expression of the fault. The geologic and geomorphic setting of the area, as well as the SVRA itself, are discussed in the materials covering Stops 2 and 3. Pit toilet available here (multiple flush toilets available at the campground at Stop 3).

8.0 Return to intersection with main access road. Make a sharp left downhill to the campground. Park at restroom facilities.

8.2 **Stop 3—Bird Creek Campground.** This will be a brief stop to examine the strain gauge across the San Andreas Fault. Data are sent from this gauge to the U.S. Geological Survey in Menlo Park by way of the Geostationary Operational Environmental Satellite. We will also have an opportunity to view the mapped fault trace and the exposure of Bird Creek sediments along the west bank of the creek. **WARNING!**: Watch for poison oak near the creek!

Depart Bird Creek campground and continue southeast parallel to Bird Creek. We will drive by an offset weir in the Bird Creek channel. Note the dramatic change in Bird Creek as we leave the canyon and emerge onto a very flat valley at the ranger station—this is an almost-defeated stream!

9.1 Ranger Station.

9.2 Stop sign at SVRA entrance, right turn on Cienega Road. Watch for flocks of wild turkeys that frequently visit this area. The 4-wheel-drive part of the SVRA lies to the right, southwest of Cienega Road, in this area. Note the actively eroding gullies. Park housing straddles the San Andreas Fault. Park personnel frequently report maintenance nuisances due to the ongoing fault creep.

10.3 Vineyard School, built on the trace of the San Andreas Fault.

11.0 Sag pond along the San Andreas Fault. According to oral tradition passed down in the 1980's from an elderly area resident to a former ranger at the SVRA, the pond drained during the 1906 earthquake.

11.2 **Stop 4—DeRose Winery.** Park along the main winery building and watch for oncoming traffic! This historic winery, a destination of geology field trips since the 1960's, is situated directly on the San Andreas Fault. At this stop we will view the effects of creep on the winery buildings and other structures. The history of the winery and results of fault monitoring are included with the Stop 4 materials.

This is the official end of our trip. Return to Menlo Park using the route below.

Reset mileage to 0.0 at the DeRose Winery. Drive north on Cienega Road.

1.2 For the next mile, keep a forward view of the road through the breaks in the trees. There are exceptional views of the San Andreas rift valley along this stretch.

6.0 Bear left at "Y" intersection and continue on Cienega Road.

7.5 Turn left onto Union Road.

11.1 Turn left onto Route 156. Pass the turnoff to San Juan Bautista. The mission at San Juan Bautista, one of California's 21 Franciscan missions, was founded in 1797. Its location placed it a day's walk from Mission Santa Clara. The church has been in continuous use since 1803, despite damage suffered during the 1906 earthquake, when one wall collapsed. San Juan Bautista marks the boundary between the Santa Cruz Mountains segment and the central creeping segment of the San Andreas Fault (Wallace, 1990; Working Group on California Earthquake Probabilities, 1999). Today, San Juan Bautista is a popular spot for tourists seeking history, good restaurants, and shops.

18.3 Turn right onto Highway 101 North to return to Menlo Park.

Field-Trip Stop Explanatory Materials

Stop 1—The Southern Calaveras Fault In Downtown Hollister

As defined by the U.S. Geological Survey's Working Group on California Earthquake Probabilities (1996, 1999), the southern Calaveras Fault extends for approximately 26 km (16 miles) south of Coyote Reservoir and includes the portion of the fault seen at Stop 1 in Hollister. The Calaveras and San Andreas Faults merge near the town of Tres Piños (fig. 6.1; Jennings, 1994). The Working Group (1999) estimated a slip rate of 15±3 mm/yr for this segment, with approximately 60 percent accommodated by fault creep. The Working Group (1996) also considered that the 1984 Morgan Hill earthquake, M_w 6.2, is a reasonable maximum magnitude event to occur on the southern Calaveras segment.

Walking tour: At Stop 1, we will conduct a short walking tour to examine the Calaveras Fault in downtown Hollister. Because the fault is creeping at about 0.5 inch (13 mm) per year, we will be able to see its effect on human structures, including sidewalks, curbs, and buildings. Both the grid layout of the streets and lots and the historic age of many of the houses and curbs make this a particularly good place to view the surface trace of the fault (fig. 6.2). The sites visited during this trip are also described by Rogers (1969). At sites that have remained relatively unchanged since 1969, it is interesting to compare his observations of offset with those seen 32 years later.

Dunne Park, south of 6th Street, reportedly occupies the site of a former cienega, or marshy area. Two low scarps run through the park, and Rogers (1969) reported a 13-cm right-lateral offset of a fence, built in the mid-1950's, in the barbecue area. Looking west along 6th Street, note the substantial dip marking the fault trace, a particularly anomalous feature when one considers its location in the middle of an alluvial plain. The retaining curb along the north side of 6th Street is markedly offset (fig. 6.3), as are the lower and more recent curbs and sidewalks. From 6th Street, we will walk north on Powell to 4th Street. If time permits, we will also look for evidence of offset features on 5th Street.

At the intersection of Powell and 4th Street, note that Powell changes its name to Locust. **PLEASE USE CAUTION when crossing 4th Street—this is a very busy road!** After crossing the road, we will proceed east on 4th Street, examining the evidence for offset along curbs and sidewalks. The large blue house on the corner also reveals some interesting structural effects of residing on a creeping fault for more than a century.

Continue on Locust (the continuation of Powell) to the alley behind the blue house. The foundation and siding of the old garage are an excellent testimonial to the different responses of concrete and wood to fault creep. Although time does not permit us to continue our walking tour south along the fault, other dramatic evidence of fault creep can be seen near Nash Road (fig. 6.2)

Supplement to Stop 1: Paleoseismic Studies Along the Southern Calaveras Fault

Bertuccio Ranch

During 1999 and 2000, seven trenches were excavated at two sites across the southern Calaveras Fault north of Hollister (Stenner, 2000). The southern site, Bertuccio Ranch, is located 5 km northwest of Hollister (fig. 6.1), on the northern end of a 30-m-high pressure ridge. Here an east-side-up scarp delineates the fault zone and is continuous for approximately 2 km. Two creepmeters within 0.5 km of the trenches recorded creep of 14 mm per year during the period of 1971 to 1979.

Two trenches were excavated at Bertuccio Ranch. Trench 1 crosses a human-modified, ~1-m-high fault scarp at the base of a 30-m-high, fault-bounded hill. Excavated to a depth of 2 to 3 meters, this trench revealed faulting which juxtaposed colluvium from the adjacent hillslope on the east side of the fault zone against fluvial overbank deposits capped by colluvium on the west side. Evidence of faulting occurs over a 9-m-wide zone and is distributed between one main trace and numerous vertically discontinuous traces. The main trace and some of the secondary traces can be followed to the surface through fill from the early to mid 20th century, and are interpreted to be actively creeping traces.

Trench 2 (fig. 6.4) was excavated about 300 m to the north of trench 1 across a 1.8-m-high fault scarp with moderate human disturbance. Fluvial sand, overbank silt, and standing-water clay dominate the lower meter of the western half of the 2-m-deep trench. The fluvial deposits are buried by colluvium and alluvium eroded from the scarp and transported from the hill slope adjacent to Trench 1. None of the colluvial/alluvial units appear as distinct colluvial wedges, and no buried free faces were observed in the trench. Instead, the colluvium is interpreted as the result of erosion over a broad topographic scarp—either from distributed coseismic faulting across the 5-m-wide zone of deformation or from continuous creep across the zone leading to erosion of a slowly forming scarp.

Fault slip is accommodated by four major traces and numerous minor traces in trench 2. The main faults have slipped obliquely, with an approximate displacement of more than 2.5 m up-to-the-east and an unknown lateral component across the exposed zone. The fault zone has juxtaposed different facies of varying thickness, complicating measurements of vertical slip across the zone. Each fault can be traced nearly to the surface, where recognition is difficult in the massive, bioturbated, and disturbed sediments. Radiocarbon dates suggest the fluvial deposits are about 1,700 to 3,000 years old (fig. 6.4). At the current creep rate, a ~1,700-year-old fluvial sand may have experienced as much as 25 m of right-lateral slip, with perhaps one-tenth resulting in vertical slip. The upper contact of the sand is displaced ~2.4 m although the unit thins dramatically across the fault zone.

All faulting in both trenches at Bertuccio Ranch may be attributed to creep, as no fissures or consistent upward terminations were found. Coseismic rupture may have occurred at this site, but evidence for it is lacking. The absence of such features could be attributed to the likelihood that faults formed during a coseismic rupture would subsequently accommodate creep, eliminating upward terminations. The possibility that coseismic rupture was small at the surface because of attenuation caused by continuous creep may also have the effect of making event identification difficult.

Costa Ranch

Five trenches were excavated at the Costa Ranch, 9 km northwest of Hollister (fig. 6.1). During 1971-79, a creepmeter at the site recorded 15 mm of creep during one year. Another creepmeter at Shore Road, less than 2 km to the north, recorded 6.5 to 12 mm per year, depending on the averaging technique (Schulz and others, 1979; Schulz and others, 1982). The fault here makes a right step of 25 to 30 m at the southern end of the site, and north of the site the fault bends to the east, producing sag ponds in the resulting extensional zones (fig. 6.5). Trenches 1 and 2 crossed the large stepover; trenches 3, 4, and 5 crossed the fault scarp and sag pond to the north (fig. 6.5).

Trenches 1 and 2 exposed 1 to 2.5 m of overbank sediments (silt, sand, and clay), upon which a moderately to very heavily bioturbated organic horizon has developed. One dominant fault is centered approximately in the middle of the two trench exposures and strikes northward, acting as a linking fault (fig. 6.5) that transfers slip between the main faults striking northwest on either side of the stepover. Those main strands on either side of the stepover occur as secondary structures in the trench exposures. Slip is oblique here, as the fluvial units are displaced down-to-the-east approximately 50 cm across the dominant fault and ~10 cm across the secondary faults. The formation of the sag pond also suggests an extensional component of slip. The dominant fault is a 1-m-wide zone of faulting. Units on the western side have retained their original near-zero dip, but within 1.5 m of the fault zone on the eastern side, fluvial units are tilted into the fault (westward) about 15 to 30 degrees. This is probably accommodating additional extension at the main fault zone. No evidence for distinct colluvial wedge packages, fissures, or consistent upward terminations was observed. Most of the faults are traced to the surface because of continuous creep, and the other strands die out upward in the bioturbated soil horizon. These upwardly discontinuous strands may be (1) creeping, but at a rate insufficient to be detected in the youngest sediments, (2) creeping, but with most creep concentrated along the other strands near the surface, (3) currently inactive, but formerly creeping traces, or (4) formed during coseismic rupture and subsequently not creeping.

Trenches 3 and 4 exposed stratigraphy similar to that in trenches 1 and 2: fluvially deposited silt, sand, and clay overlain by an organic horizon (fig. 6.6). Three radiocarbon dates within the upper fluvial sediments yielded a range of 1,800 to 2,700 uncalibrated years BP, a comparably aged sequence to that exposed at Bertuccio Ranch. In trenches 3 and 4, an additional unit interpreted as a deposit from the sag pond is present in the fault zone. Faulting at trench 3 is localized on a 1-m-wide zone and vertically displaces a silty sand unit ~1.5 m down-to-the-east. The amount of lateral slip is unknown. On the west side of the fault zone the strata remain subhorizontal. On the east side, within 2 to 2.5 m of the fault zone, the strata are warped down into the fault as much as 10 degrees (southwest). This warping is likely accommodating extension and is the location where a silty clay (sag pond deposit) is deposited in a wedge 4 m long and more than 2 m thick against the fault scarp.

Below the sag pond deposit is a similar unit bounded on both sides by faults (labeled "fault-bounded sag pond deposits" on figure 6.6). A possible explanation for why that unit is distinct from the upper sag pond unit is that initially the continuous extension at the fault was accommodated by the down dropping of a distinct block and the subsequent filling in with fine-grained organic sediment on top of the block. As extension continued through time, an increasing percentage of it was accommodated by tilting of the sediments into the fault in addition to brittle faulting of the block, allowing broader deposition of the sag pond material across the down dropping block. The faults bounding the block continue to creep (but with only a percentage of the total slip) and have propagated into the overlying sag pond and soil deposits (see trench 4, fig. 6.6). Another possibility is that the "fault-bounded sag pond deposits" represent fill of a large fissure following coseismic rupture, but the size and shape of the unit are inconsistent with this interpretation.

Although trenches 3 and 4 are only 4 m apart, the style of deformation is different. Sediments at trench 4 are faulted over a wider zone (5m) and have been tilted more than those at trench 3, where faulting is more brittle. On the west side of the fault, fluvial units are warped up as much as 25 degrees into the fault zone, and on the east side of the zone, the fluvial strata are tilted up to 30 degrees into the fault zone. Water saturation may play a part in the deformation of the sediment by tilting rather than by brittle faulting. In both trenches 3 and 4, some faults extend to the surface as obviously creeping faults, and many others likely are creeping but have not experienced enough creep to demarcate their location through the young, upper soil horizon. The upwardly discontinuous faults in trench 3 were difficult to trace upward through the sag pond sediments, but did not appear to terminate at a particular horizon. All deformation observed in trenches 3 and 4 can be explained solely by creep processes, but coseismic rupture cannot be excluded.

Trench 5 was excavated across the northern sag pond (fig. 6.5), revealing the structures accommodating the extension. The sag is bounded on both eastern and western sides by obliquely slipping faults (units change thickness across the structures) that let the area between them subside. The main fault zone, accommodating both normal and lateral slip, is just west of the middle of the pond. Faulting occurs throughout the area covered by the sag pond, but the main zone is ~1 m wide. As exposed in the trench, the faults either reach the surface or, as within the fairly massive sag pond clay, are difficult to trace.

Trench 5 exposed the youngest section at Costa Ranch, with approximately 2.5 m of sag pond sediment carbon dated by one sample at younger than 1,000 uncalibrated years B.P. Two dated shells suggest an even younger deposit of 300 years B.P. The sag pond strata are progressively warped down into the sag and also thicken toward the center. The uppermost unit, likely historical, also thickens into the center of the sag, and is faulted (vertical component ~1 cm each) by at least two strands that are creeping.

The deepest part of the exposure below the sag pond revealed a unit adjacent to the fault zone (and possibly crossing it) composed of both moderately organic silty clay and material comparable in appearance to the adjacent fluvial deposits. This deposit could be (1) a bioturbated mixture of scarp colluvium derived from a continuously forming scarp developed in the fluvial sediments before sag pond deposition began, (2) scarp colluvium derived from a coseismic rupture before sag pond deposition began, or (3) bioturbated pond sediment mixed with fluvial material after deposition. No fissure fills or consistent upward terminations were observed.

To date, no evidence for coseismic rupture of significant size has been found in late Holocene sediment in the 14 exposures of the southern Calaveras Fault. Creep and seismicity of micro-to-moderate magnitude may accommodate all of the fault slip, resulting in a low probability of future large earthquakes rupturing the southern part of the fault. The lack of evidence cannot preclude the possibility, however, that the fault has ruptured in a large earthquake. Coseismic rupture may have occurred at depth and did not reach the surface, or the rupture may have been severely attenuated toward the surface, with subsequent creep obscuring evidence of minor surface rupture. Future work is planned to add insight into this issue.

Stop 2 and 3—Hollister Hills State Vehicular Recreation Area

Hollister Hills

The Hollister Hills State Vehicular Recreation Area (HHSVRA) is a 6,627-acre facility operated by the California Department of Parks and Recreation. It is one of seven state-operated off-road vehicle facilities within the Department's Off-Highway Division. Approximately 4 million Californians participate in some form of off-road vehicular recreation each year (see the Division's web site at http://ohv.parks.ca.gov/html/ohvhome.htm), and the SVRAs were designed to provide safe, legal, and managed facilities to help meet this demand. Funding for staffing and maintaining the State's SVRAs comes partly from gas taxes and registration fees for off-road vehicles.

The Hollister Hills SVRA consists of two separate facilities. The portion including Radio Ridge (Stop 2) and the campground (Stop 3) is for use by off-road motorcycles, and another holding to the south (off Cienega Road en route to Stop 4) is for 4-wheel-drive vehicles (fig. 6.7). The motorcycle area includes 64 miles of trail, some of which can be seen from Radio Ridge. From Radio Ridge and while traveling through the SVRA, one can observe sediment-catchment basins, gabion baskets, and trail revegetation projects, all of which are designed to reduce and (or) mitigate erosion and sediment production.

Geologic Setting

On the southwestern side of the ridge, the linear valley of Bird Creek contains the mapped traces of the San Andreas Fault. From Radio Ridge, tall, wide-canopied sycamore trees mark the valley floor. The very steep, chaparral-covered slopes southwest of the Bird Creek valley are underlain by crystalline rocks of the Salinian block. In the area of the field trip, these rocks include substantial blocks of dolomitic marble as well as Mesozoic granitoids. Aggregate quarried from the marble blocks has been used as road base at Radio Ridge, and large blocks have been used as decoration near the park entrance. Graniterock Company excavates marble from the hills above Stop 4.

Northeast of Radio Ridge, grass-covered and lower lying hills are underlain by Pliocene sedimentary rocks. These consist of mudstone and sandstone of both marine and nonmarine origin. Beds of lignite which today lie within the SVRA were prospected in the early 1900’s, and shell fossils occur within some sandstone units. Taliaferro (1949) and Rogers (1980) mapped this unit as Purisima Formation, but other workers have assigned it to the Etchegoin Formation (Perkins, 1987). Because most workers restrict the use of Purisima Formation for units on the Pacific Plate, this unit may be more properly correlated with the lower part of the Etchegoin Formation, but Jennings and Strand (1958) have mapped it as Purisima Formation. Sandstone beds within the unit are typically vegetated with brushy chemise, whereas mudstone units are vegetated by grasses.

Soils developed on the sedimentary units northeast of the fault are fine grained and impermeable. Because they are impassable to vehicles when water saturated, this portion of the SVRA is closed during stormy weather. Hillslopes underlain by the Purisima Formation are very susceptible to failure by deep-seated slump/earthflows such as those viewed from Cienega Road en route to this stop. In contrast, soils developed on the granitic rocks southwest of the fault are coarse textured and permeable. They are highly susceptible to gullying, and several enormous gullies have formed during major storms on steep trails in the SVRA.

San Andreas Fault

Radio Ridge provides public access to one of the best places to view the geomorphic expression of the San Andreas Fault system in northern California. From the summit of the ridge, we can see examples of almost every geomorphic indicator of active strike-slip faults (fig. 6.8). The ridge itself is a topographically distinct uplift within the fault zone and may be either a compressional ridge or a laterally displaced hill. It is underlain by fossiliferous sandstone of the Purisima Formation. Northwest of Radio Ridge, a water tank marks the crest of a similarly anomalous ridge. Radio Ridge serves as a shutter ridge, deflecting Bird Creek as discussed below.

Northwest-trending linear valleys are present on both sides of Radio Ridge; the valley on the northeast side of the ridge may be a former trace of the Bird Creek channel. Sarna-Wojcicki and others (1975) mapped two traces of the fault in this area: one along the northeastern edge of the Bird Creek valley and a second along Radio Ridge. As we will see at Stop 3, the major San Andreas Fault trace, instrumented by the U.S. Geological Survey (USGS), runs along the flood-plain of Bird Creek in the approximate position of the sycamore trees. Looking southwest of Radio Ridge, one can follow the fault trace along Cienega Valley to a prominent notch in the divide seen on the skyline (fig. 6.9).

Bird Creek

Bird Creek is an excellent example of an offset stream, showing about the same amount of right lateral displacement as the length of Radio Ridge (fig. 6.7). From its headwaters, fed by perennial springs in the crystalline rocks of the Salinian block, the stream flows generally northeast to the San Andreas Fault Zone. This upper portion of the channel can be seen northwest of Stop 2—it is the valley separating the densely vegetated hillslopes from those marked by motorcycle trails and less mature chaparral, the result of a fire approximately 10 years ago. (Note: Because the park’s holdings do not include the slope directly southwest of Radio Ridge, the motorcycle park itself appears to be offset along the San Andreas Fault!).

When it reaches the southeast-trending fault zone, Bird Creek, joined by its major tributary, follows the fault zone on the southwest side of Radio Ridge (fig. 6.7) for about 2000 feet (613 m) until it again turns northeast and crosses to the other side of the fault, where it has deeply incised the sedimentary rocks northeast of the fault zone. Bird Creek’s gradient is dramatically flattened within the fault zone. The gradient is significantly higher in its headwater reaches, which is expected, but it is also higher downstream of the fault zone. We will have an opportunity to view low terraces and the channel of Bird Creek at Stop 3 and on our return to the ranger station.

The low terrace along the eastern bank of Bird Creek at Stop 3 contains the active trace of the San Andreas Fault. The fault is continuously creeping at this site, showing approximately 0.5 inch (12 mm) of right-lateral motion per year. A group of very large riparian sycamores and small scarp in the surface mark the fault within the campground area. An excavation along the right bank of Bird Creek, made in 1994 by Imogene Blatz, exposes a section of recent deposits of Bird Creek, including some distinctive flood deposits and calcic soil horizons. Downstream of this site, similar deposits and terraces of Bird Creek can be seen at lower elevations above the modern channel. Unfortunately, all of the low surfaces adjacent to Bird Creek have been extensively modified by motorcycles, road-building, and grazing animals. These activities have greatly hampered any definitive correlation of terraces and deposits or determination of offset across the fault.

Stop 3 also provides an opportunity to view the USGS creep-monitoring instrumentation across the main San Andreas Fault trace. The creepmeter at this site, USGS station xhr2, provides a continuous record of direct fault movement. A creepmeter is a length of wire stretched across the fault and anchored by piers on either end of the fault. When the fault moves, the wire is pulled through a measuring device, which then sends an electronic signal to the GOES satellite. The satellite antenna can be seen at Stop 3. At this particular site, vertical culverts mark the creepmeter anchors; the USGS technician services the creepmeter by descending a ladder in the culvert. Data from this station and from two instruments at Stop 4 can be accessed on the internet at http://quake.usgs.gov/research/deformation/measurements/index.html. This station showed an interesting creep event, with 5.18 mm of right-lateral slip, immediately after the 1989 Loma Prieta earthquake (fig. 6.10).

Stop 4—DeRose Winery

In the early 1850’s, a Frenchman named Theophile Vache planted the first grapevines in the Cienega Valley from cuttings brought over from Europe (Williams, 1965). Vache made wine and hauled it by oxcart to San Juan Bautista, which was then a stage stop along El Camino Real, the road from Los Angeles to San Francisco. You will have the opportunity to imagine this trip when we return at the field trip’s end.

The Vache vineyard was bought in 1883 by William Palmtag, who produced prize-winning wines under the labels of Palmtag Vineyard and San Benito Vineyard. In 1906, the property was sold to a group who changed its name to San Benito Vineyards Company. Vineyards in the region expanded until Prohibition, when all San Benito County wineries closed. In 1935, the vineyards reopened, and in 1943 they were acquired by W.A. Taylor and Company. (In many geological field reports, the winery is referred to as the Taylor Winery.) In 1948, San Benito County had 1,765 acres planted in grapes.

In 1953, Almaden Vineyards purchased the Cienega property and greatly expanded the capacity of the facility. At the time of Williams’ (1965) report, Almaden owned 3,500 acres planted in grapes. Operations at the winery then dwindled, and the property was sold to Hueblein, Inc., in 1987, at which time it lay dormant. Pat DeRose, the current owner, began operations at the Cienega property in 1988. The vineyard currently has 100 acres in grapes, 40 of which are vines planted before 1900 (see the website at www.derosewine.com).

The San Andreas Fault Zone

As originally mapped by Taliaferro (1949), the trace of the Calaveras Fault runs through the winery buildings (fig. 6.11). On the northwestern side of the buildings, a driveway running across the fault accentuates a prominent scarp. During the 1906 earthquake, the winery buildings in the Cienega Valley were substantially damaged. The Lawson report (Lawson and others, 1908) states that “At Palmtag’s winery, in the hills southwest of Tres Piños, the shock seems to have been more severe than elsewhere in the vicinity of that village. Furniture was moved, water was thrown from troughs, and an adobe building was badly cracked. One low brick winery was unharmed.”

The DeRose winery is the location where fault creep was first recognized (Steinbrugge and Zacher, 1960). The main winery building was constructed by then-owners W.A. Taylor Winery in 1948. In 1956, Zacher noticed displaced concrete slabs and fractures in concrete walls during a building inspection. Using the distorted buildings, Steinbrugge and Zacher (1960) began systematic creep measurements in 1956, and reported an average rate of about 0.5 inch (12mm) of right-lateral displacement per year for the period 1948-60. They also noted a coseismic slip of 3 mm at the time of a local M 5.0 earthquake in 1960. In 1957, creepmeters were installed within and around the winery buildings (Tocher, 1960), and monitoring continues at the site today (see the website at http://quake.usgs.gov/research/deformation/measurements/index.html). Damage within the winery buildings necessitated substantial reconstruction in the mid-1990’s, but continued creep already has created new cracks in the walls and floors of the main building.

On the southern side of the winery, the fault has displaced a concrete-lined drainage ditch, which in 2001 had apparently not been repaired since its construction. It is interesting to compare the amount of right-lateral offset documented in 1961 (fig. 6.12) with conditions seen on the field trip today.

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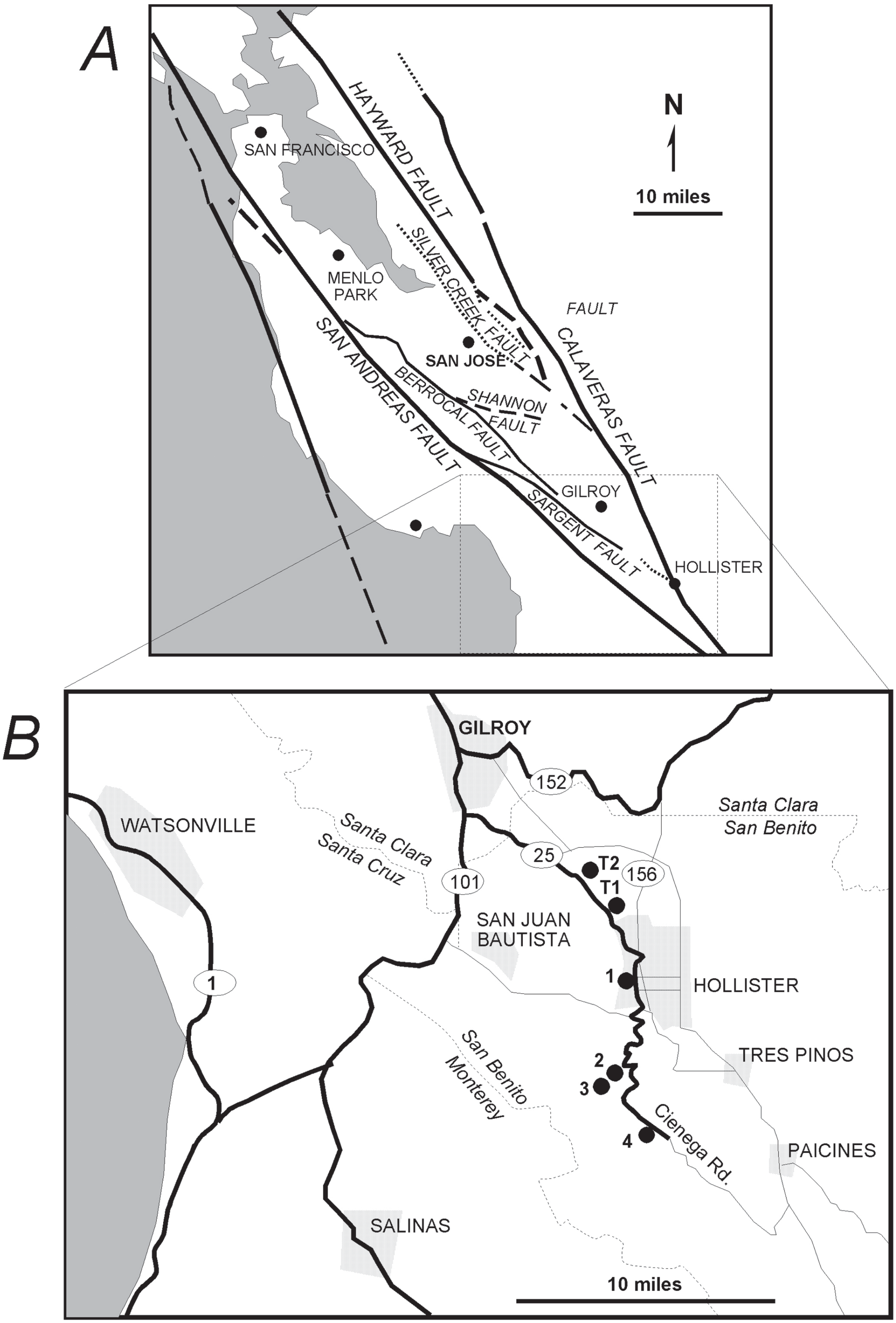

Figure 6.1. Location maps for field trip: ***A***, Major earthquake faults in the Bay area. ***B***, Field trip stops (1-4) and trench localities (T1, T2) discussed in text.

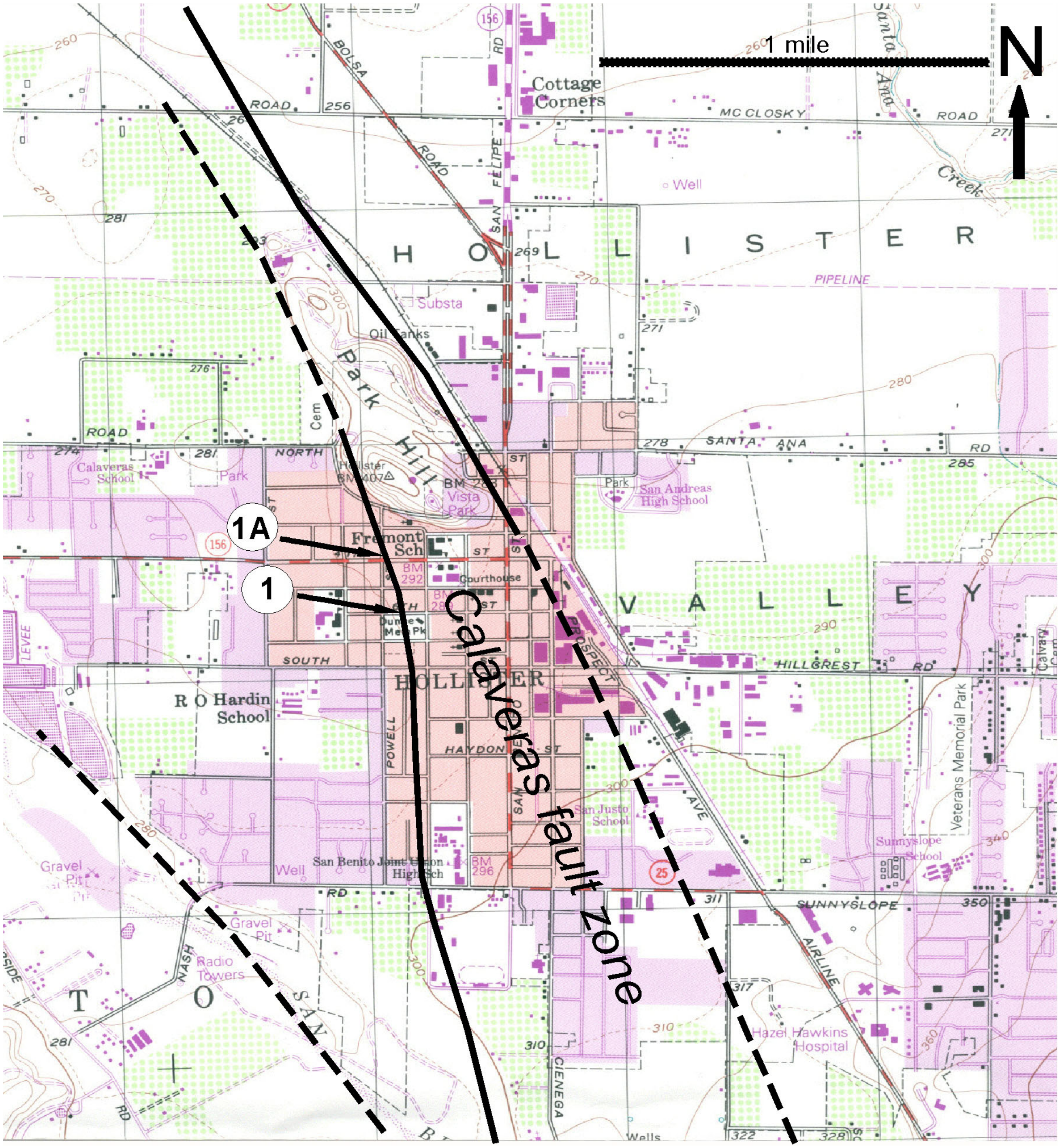

Figure 6.2. The Calaveras Fault in downtown Hollister (modified from Rogers, 1969); base map is the Hollister U.S. Geological Survey quadrangle map, scale 1:24,000.

Figure 6.3. Warped retaining wall with right lateral offset across the Calaveras Fault. View is west of 6th Street. Note rise in elevation across the fault. (Photo by Phil Stoffer, U.S. Geological Survey, 2001).

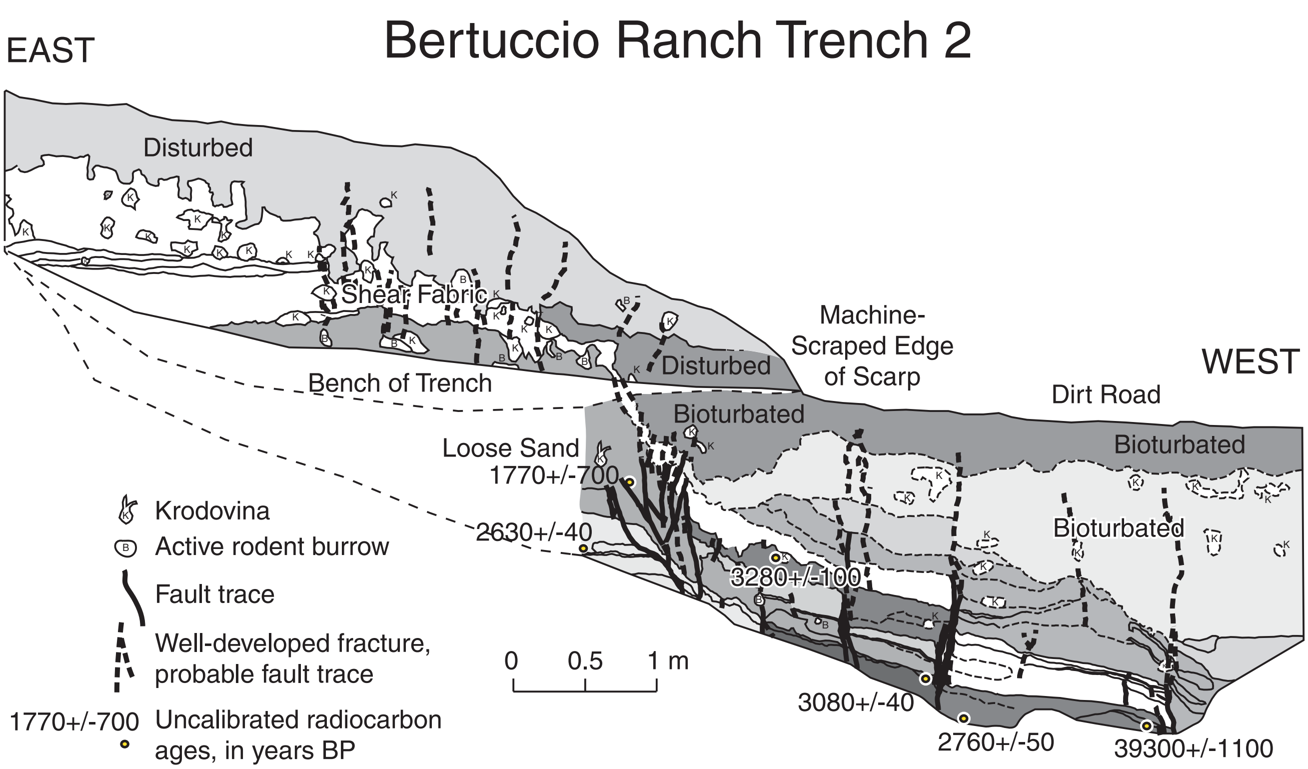

Figure 6.4. Trench log of Bertuccio Ranch trench 2. Fluvial and overbank sediments are overlain by colluvial and alluvial deposits (uppermost 3 units). Faults offset all units, and all appear to be creeping.

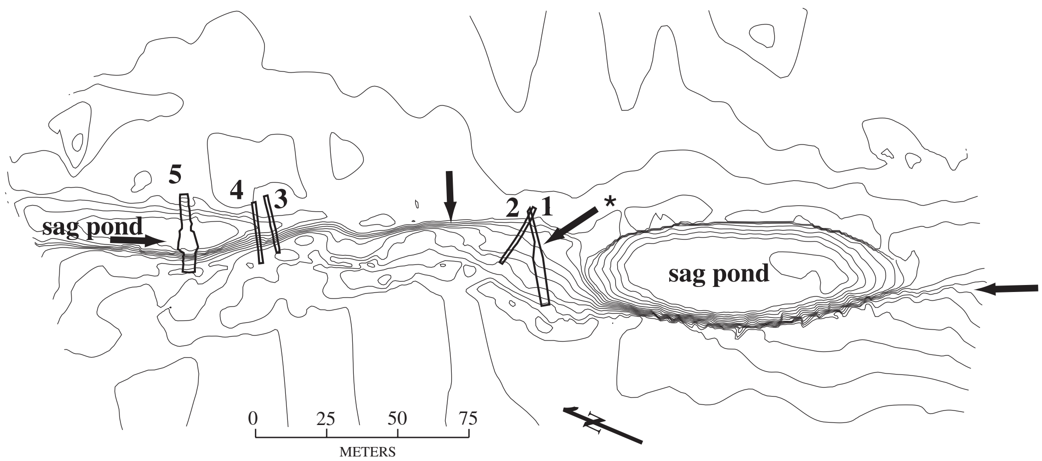

Figure 6.5. Topographic map of the Costa Ranch site. Trenches are numbered 1 through 5, arrows point at main fault, where a down-to-the-east scarp is commonly formed. Arrow labeled with asterisk marks position of linking fault. Contour interval is 15 cm.

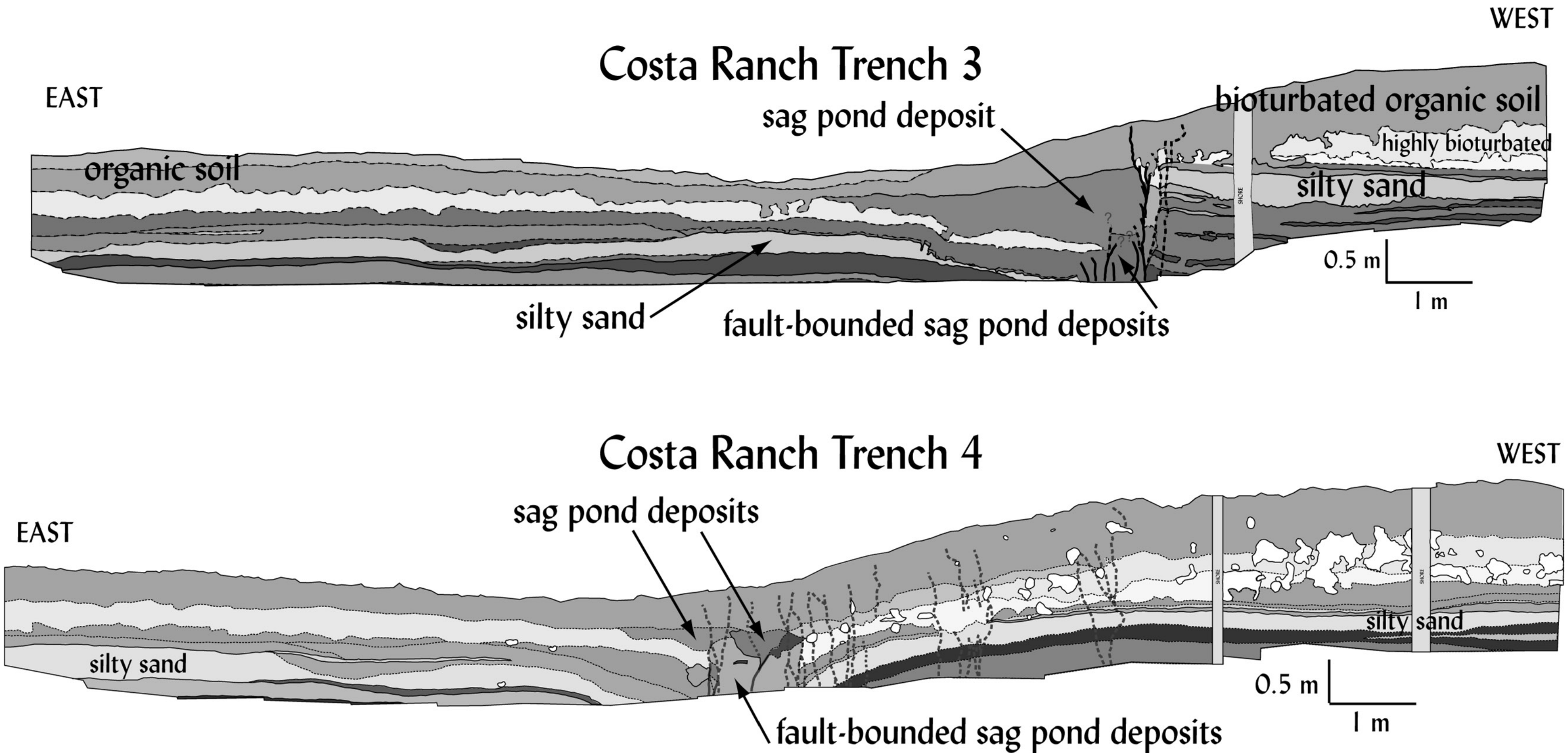

Figure 6.6. Trench logs of Costa Ranch trenches 3 and 4. Fluvial sediments, sag pond sediments, and the organic soil horizon are faulted and tilted into the fault zone to accommodate the right lateral and extensional component of slip. Although the two trenches are only 4 m apart, the styles of deformation are different.

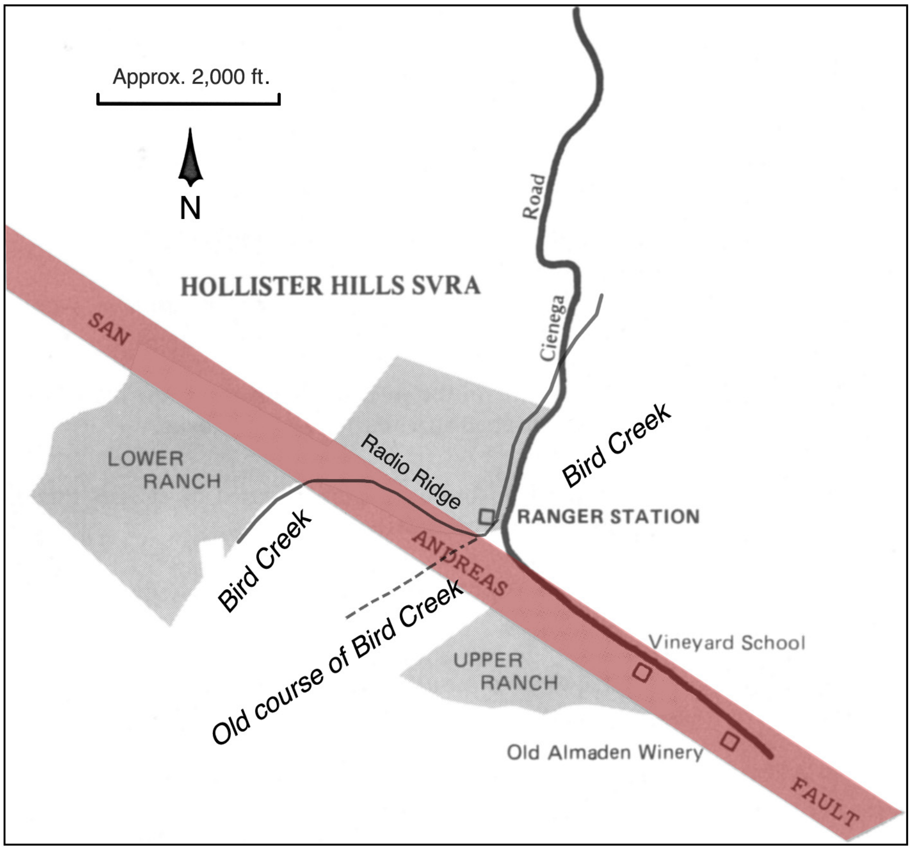

Figure 6.7. Map of Hollister Hills State Vehicular Recreation Area, showing offset of Bird Creek (modified from California Department of Parks and Recreation, 1989).

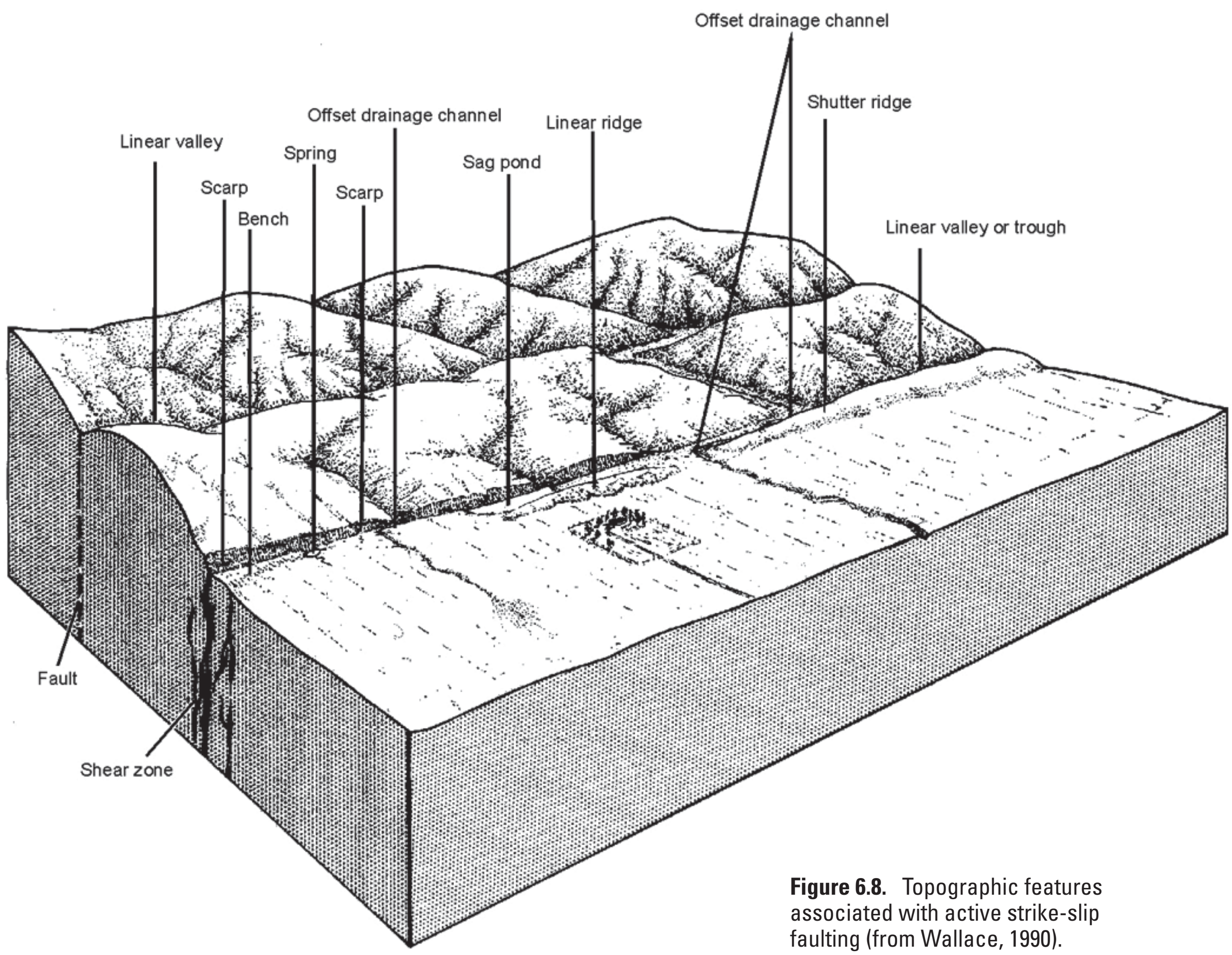

Figure 6.8. Topographic features associated with active strike-slip faulting (from Wallace, 1990).

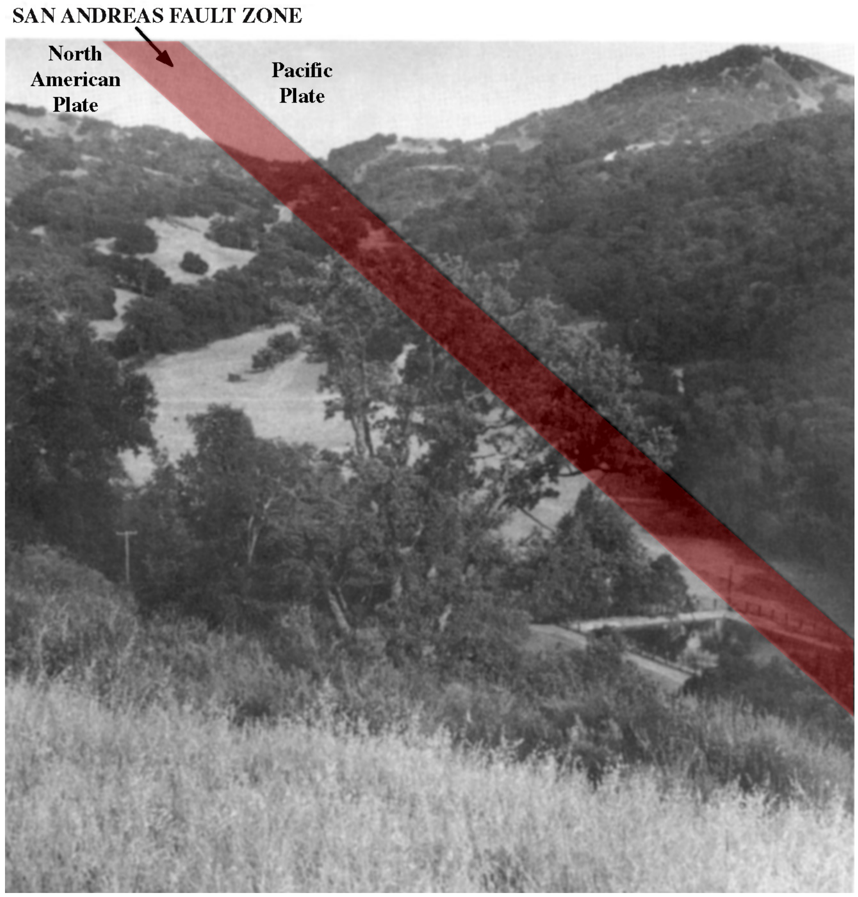

Figure 6.9. View of the San Andreas Fault from Radio Ridge looking southwest (modified from California Department of Parks and Recreation, 1989).

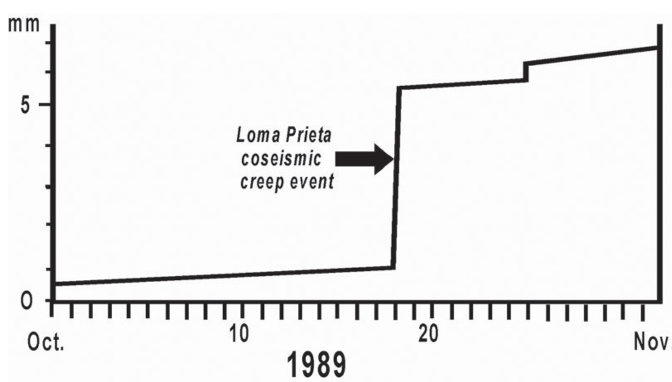

Figure 6.10. Creepmeter data for October 1989 from Hollister Hills State Vehicular Recreation Area campground (modified after a U.S. Geological Survey, 1990, unpub. manuscript).

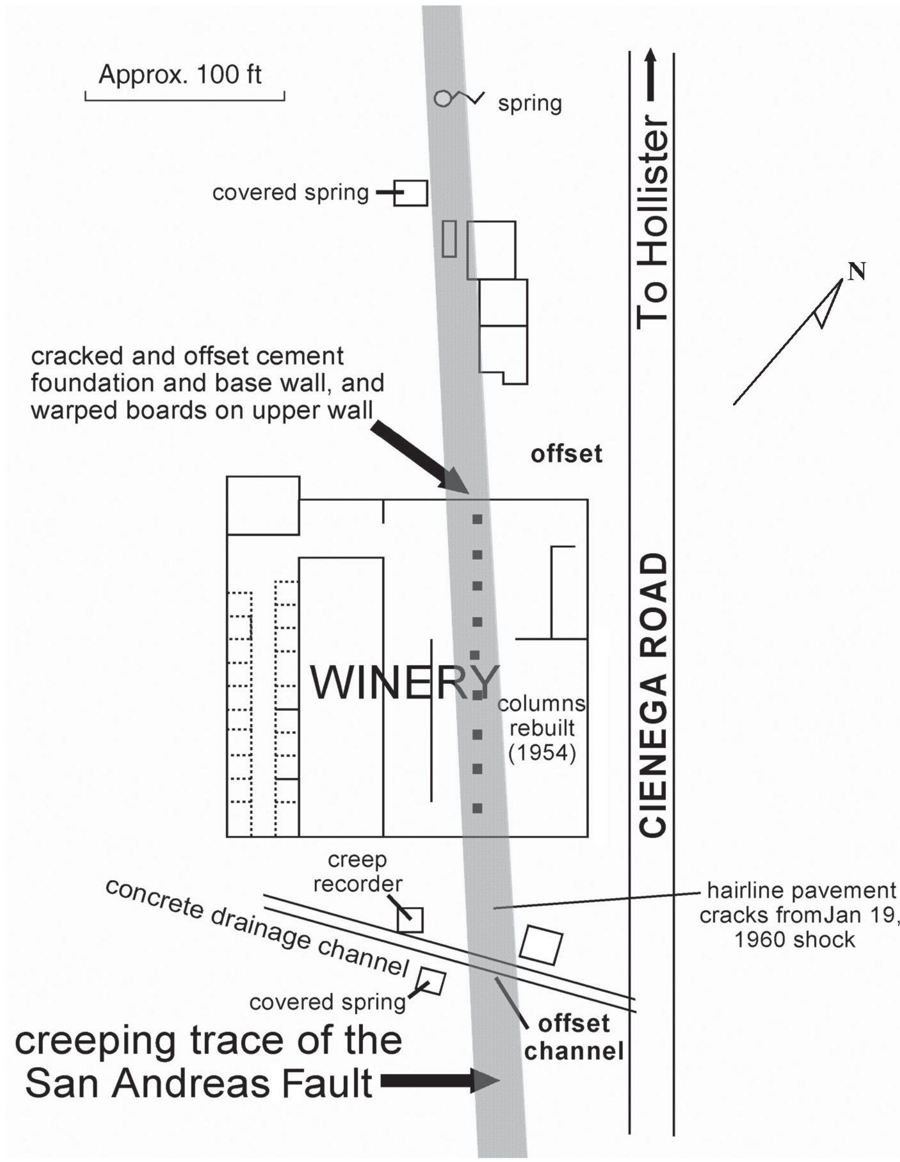

Figure 6.11. San Andreas Fault at DeRose Winery (modified from Tocher, 1960).

Figure 6.12. View northwest across San Andreas Fault trace at southern edge of DeRose Winery. Photo taken in April, 1961, by Stanley Skapinski, San José State University.