Use of Tephrochronology in Correlation and Dating of Some Late Neogene Sedimentary Sections, East San Francisco Bay Area, & Sediment Provenance in the Shell Ridge and Los Medanos Hills Areas, West of Mount Diablo

By

Andrei M. Sarna-Wojcicki and James P. Walker

This is an informal field trip guide and not an official publication of the U.S. Geological Survey
TEPHRA LOCALITIES OF THE GREATER EASTBAY

TEPHRA LOCALITIES 1-29-99
△ 738-339CR
△ BE-26
△ HUICHICA
△ KIRKER
△ LAWROR
△ NOMLAKI?
△ NONE
△ OLDER NOMLAKI
△ POINT OF ROCKS TUFF
△ PUTAH
△ ROBLAR

10 Kilometers

N
Northern California Geological Society Field Trip, Oct 16, 1999,

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&

Sediment Provenance in the Shell Ridge and Los Medanos Hills Areas, West of Mount Diablo

By

Andrei M. Sarna-Wojcicki and James P. Walker

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Introduction

We are going to take a field trip to four sites within the east San Francisco Bay area to look at exposures of upper Neogene (upper Tertiary and Quaternary) sedimentary rock units, and to a fifth site, where upper Neogene volcanic rocks are exposed. At four of the sites, we will see tephra layers (tuff beds or volcanic ash beds). One of the main themes will be the identification, correlation, and isotopic dating of tephra layers, and their use in providing chronostratigraphic information for the solution of geologic problems. We will look at the sedimentary features at these sites, to get some idea of the environments of deposition where the tuffs are found. We will consider the criteria used in the correlation of tephra layers, and the evidence for determining the eruptive sources from which the tephra layers were derived.

We will also look at two upper Miocene to Pliocene sections, and discuss the provenance of the sediments, as determined from clast compositions and flow directions, as well as their age, as determined from tephrochronology and other evidence.

Starting from the meeting place in San Ramon, we will drive south to Stop 1 near Del Valle Regional Park, south of Livermore (see map on cover of field trip guide). From Stop 1 we will proceed north to Stops 2 through 5. Stop 2 will be in the foothills south of Mount Diablo, in the Tassajara Valley. Stop 3 will be in the Shell Ridge Recreational Area west of Mountain Diablo. Stop 4 will be in the Los Medanos Hills to the North of Mount Diablo, south of Suisun Bay near Bay Point (West Pittsburgh). As time permits, we may go on to Stop 5, which is across Carquinez Strait, west of Suisun Bay, to see the southeastern part of the Sonoma Volcanics, near the source area from which one of the tephra layers was erupted, ~4.8 million years ago.

Field Trip Log

Directions to Meeting Place; Meeting Time: 8:00AM

Field trip starts at the Bishop Ranch 2 Parking Lot off Sunset Road, north of Bollinger Canyon Road, in San Ramon, on Saturday, Oct. 16, at 8:00. Most people will be coming to this site on U.S. Hwy 680. Take the Bollinger Canyon Road east from the freeway to Bishop Ranch, turn left (north) on Sunset (opposite Chevron Park), and first right at traffic light into parking lot. Drive around to the right, to end of parking lot, then turn left and continue to south half way down the length of the lot. The field trip group will meet here; we will have a short meeting to distribute field trip guides, talk about directions, and provide a short introduction to the field trip.

We consolidate into two vans and a “follow” car with drinks and lunches. We may have an additional car or two, but will want to limit the number of cars in order to meet new and old friends, socialize en route, maneuver better in tight places, conserve energy, and minimize pollution (as Chevron ads inform us, “Do people do this? Yes,
Simplified geologic map of the study region.

From Unruh and Sawyer, 1997

figure 1
From Unruh and Sawyer, 1997
Principal structural features of the Mt. Diablo fold-and-thrust belt: L—Livermore fault; ML—Mount Lewis seismogenic trend; T—Tassajara fault.
people do." They're probably watching us from just across the road!). The field trip
group departs from the lot at 8:30 A.M. en route to Stop 1. Drive to the parking lot
entrance, set mileage to zero at Sunset and entrance to parking lot. Turn left onto
Sunset, then right onto Bolliger Canyon Rd. Stay in right lane. Go over Hwy 680
overpass.

The field trip log provides distances between stops and landmarks, but not a
continuous running total. It is a good idea to have a navigator/narrator in the
"shotgun" seat of each vehicle. The front cover of the field trip guide has an overview
geologic map of the area that we will be visiting, with the stops numbered (Stops 1-5).

The inside of the front cover of the guide has a shaded digital relief map of the area
we will be in, with locations of tephra layers found in this area.

Directions to Stop 1
(Between Arroyo Mocho and Arroyo Del Valle)

0.4 Mi. Enter Hwy 680 onramp going South (toward San Jose).

5.2 Mi. Take exit to Hwy 580 East (toward Livermore).

12.1 Mi. On Hwy 580 east. The hills to the north (left) are the poorly exposed Pliocene
Tassajara and upper Miocene Sycamore Formations, composed of non-marine alluvial
deposits. We will be going through these hills later.

13.6 Mi. Take the North Livermore Avenue exit toward Livermore, going south. As
you cross the bridge over Las Positas Creek, on your right you can see the river
channel is incised into a late Pleistocene terrace, with a poorly developed soil horizon.
Unruh and Sawyer (1997) have been studying the stream terraces in this area, and
point out that where they are well developed, they have convex profiles above
bedrock anticlines, indicating recent and continuing (?) deformation on these
structures.

1.3 Mi. Pass under railroad bridge. Pass intersection with Railroad Ave. We continue
on N. Livermore Ave. through the center of old Livermore. N. Livermore Ave. turns
to S. Livermore Ave. at intersection with First Street.

2.9 Mi. South Livermore Ave., which trends SE, now curves to the east and becomes
Tesla Road. Continue east on Tesla Road.

0.5 Mi. Turn south onto Mines road. Proceed south. We drive along a broad late
Pleistocene alluvial fan. A few hundred meters south of this intersection, we cross the
trace of the Las Positas Fault, which trends NE to SW, bounds the front of the low hills
to the NE and SW, and is a boundary between the Livermore Gravels, to the SE, and
Quaternary alluvium, to the NW. This sinistral fault extends to the dextral Greenville
Fault, on the NE, and to the Williams and Verona thrust faults, on the SW (see front
cover and figs. 1 and 2).
We pass into an incised canyon, with late Quaternary stream terraces exposed on both sides, and higher ridges underlain by older fan alluvium composed of what was originally mapped as the "Livermore Gravels" of Clarke (1930), but was subsequently divided into the older Sycamore Formation of mostly latest Miocene age, and the overlying Livermore Gravels, of Pliocene and Pleistocene (?) age (Graymer and others, 1994).

3.2Mi. Cross bridge over Arroyo Mocho.

0.3Mi. Intersection. Mines road turns left (Green Road Sign: toward Mt. Hamilton and San Jose), and Del Valle Road continues on straight ahead (same green sign: toward Del Valle Regional Park; 4 Mi). Proceed straight on Del Valle road toward the park.

As we drive up Del Valle Road, we can see stream terrace surfaces, modified by erosion, on both sides of Arroyo Mocho. These are stream terraces uplifted along the north end of the Diablo Range, which is south of us (see front cover).

1.0 Mi. We pass upwards into "Livermore Gravels" (Sycamore Fm.), sporadically exposed in the road cuts. These are mostly muds or poorly indurated silts and sandstones, with much caliche developed in the surface soils, and as soil horizons within this alluvial unit.

0.7Mi. Intersection of Del Valle Rd. and Mendenhall Rd. Good outcrop (used to be, anyway) of what was previously mapped as the Livermore Gravels of Clark (1930), but is now remapped variously as the Tassajara or Sycamore Formations; also as the Contra Costa Fm). The sediments exposed here are mostly stream and fan alluvium, fine to medium grained, poorly sorted, with gravel lenses (channels). The rolling hills in the foreground are underlain by the Tassajara or Sycamore Formation, while the more rugged topography of the hills in the distance and skyline to the south is underlain by the Franciscan Formation.

STOP 1. Figure 3.

1.1Mi. On Del Valle Road, pull over to the shoulder, next to the "No Parking" signs. (We have notified the Park Ranger that we will be stopping here for the field trip). WATCH FOR TRAFFIC; STAY TO THE SIDE OF THE ROAD.
STOP 1) DEL VALLE ROAD
HUICHICA (4.71 Ma) AND LAWLOR TUFFS (4.83 Ma)

After Wagner et. al., 1991

Qo - Older Quaternary alluvium
QT - Plio-Pleistocene nonmarine (Livermore Gravels)
Mcc - Miocene Contra Costa nonmarine (previously, Livermore Gravels; also mapped as Sycamore Fm.)
Kp - Cretaceous Panoche Formation marine
Kjf - Cretaceous-Jurassic Franciscan Complex

1 mi.
Figure 4. These histograms represent chemical “fingerprints” by means of which individual tephra layers can be identified. Each of the bar diagrams represents the amounts of different elements (Sc = scandium; Mn = manganese; Fe = iron, etc.) that are present in volcanic glass shards of three different tephra layers (volcanic ash beds and tuff beds). The amounts shown are ratios to a chemical rock standard, U.S.G.S. G-1; this allows us to show all the elements on one scale. The chemical analyses were done by three different methods: INAA = instrumental neutron activation analysis; XRF = X-ray fluorescence spectrometric analysis; EMA = Electron-microprobe analysis. These histograms show that not only is it possible to chemically identify individual ash beds, but that we can also use the chemical composition of the volcanic glasses of ash beds to identify the volcanic source from which the ash was erupted. For example, the Lawlor and Huichica Tuffs were both erupted from the Sonoma Volcanics; the Rockland ash bed (~0.40-0.6 Ma) was erupted from the southern Cascade Range in northeast California. Replicate analyses are shown for the Huichica and Rockland ash bed.
Outcrop of two superposed tuffs are exposed here in a road cut. The tuffs are ~3 m and ~1.8 m thick, respectively. The stratigraphic separation between the tuffs is about 7.6 m. The tuffs are water-lain: they are well stratified to laminated, have normal graded bedding, and soft-sediment deformation structures. They are fine grained (sand- to clay-size). A lower, massive portion of both beds, up to about 30 cm thick, may be airfall ash, or possibly ash that fell into standing water (though we would expect the grading in the latter case to be reversed). A K-Ar age of 4.46 ±0.45 million years was determined on plagioclase crystals on this tuff from this site (Garniss H. Curtis, U.C., Berkeley, in Sarna-Wojcicki, 1971, 1976).

We have correlated these tuffs to other exposures of tuffs that have been found in the San Francisco Bay area, using a combination of petrographic characteristics and chemical composition of the volcanic glass and primary minerals (fig. 4). By this technique (referred to as tephrochronology) we have been able to correlate a number of ash beds and tuffs in the S.F. Bay area. Also, during the course of the last 30 years, we have extended this technique regionally, to correlate Neogene tephra layers (tephra=volcanic ash layers, tuffs, and other associated pyroclastic rocks) in the western U.S. and the Pacific borderland, including correlations between onland sections and sediments in the ocean floor, obtained from the Deep-Sea Drilling and Ocean Drilling Projects (Sarna-Wojcicki and others, 1991 a and b).

In the Bay Area, the lower tuff correlates with the Lawlor Tuff of Weaver (1949), found further to the north in the Los Medanos Hills south of Suisun Bay. There, a K-Ar date on a plagioclase separate yielded an age of 4.1 ±0.16, a date with a smaller analytical error. Because the sample at this latter site was “better” (coarser grained, air-fall pumice and ash-flow pumice-vitric tuff), and because of the better precision, this date was preferred over the older date. The older date was suspected of being contaminated with detrital material that might have yielded too old a date (Sarna-Wojcicki, 1971, 1976).

Subsequently over the years, new techniques have been developed that improve on the old K-Ar dating technique. In particular, variations of the 40Ar/39Ar technique using a laser to fuse mineral grains have made it possible to obtain dates on individual crystals, and evaluate the dates for possible detrital or “xenocrystic” contamination. Thus, obviously older “outlier” dates can be rejected. Moreover, the new techniques have shown that in some experiments using the old K-Ar technique, often not all the radiogenic argon in the minerals was extracted during fusion, so that some of the old radiometric dates were actually too young, rather than too old. New 40Ar/39Ar dates on the Lawlor Tuff by Al Deino and colleagues at the Berkeley Geochronology Center have yielded new single-crystal dates on plagioclase from the type section of the Lawlor Tuff that yield an age of 4.83 Ma, with a small analytical error (A. Deino, unpublished data).

The Lawlor Tuff was erupted from the Sonoma Volcanic field in the northern S.F. Bay area. Evidence for this is the following: the tuff increases in grain size toward that field, has been found at two sites within the Sonoma Volcanic field where it is coarse and thus presumed to be close to its eruptive source, and it has chemical characteristics that are similar to tuffs within the Sonoma Volcanic field. In the
Sonoma Volcanic field it is intercalated with flows and coarse pyroclastic deposits that are close to their eruptive sources. In addition to having been identified at numerous sites in the S.F. Bay area, the Lawlor Tuff has also been found in (1) the Kettleman Hills, where it is present at the top of the marine Ecogoin Formation, (2) in the marine Malaga Formation in western Los Angeles Basin, (3) in alluvial deposits of the Horned Toad Hills of the Mojave Desert, where it is present in non-marine alluvial deposits associated with a late hemphillian vertebrate fauna, and (4) in the Crowder Flat section near Alturas, in northeastern California, where it is present in alluvial deposits (Sarna-Wojicki and others, 1991). This tuff is also present in deformed alluvium on the east side of the Diablo Range, near Patterson.

The upper of these two tuffs is correlated by its chemical and petrographic characteristics with the Huichica Tuff. This tuff is also derived from the Sonoma Volcanics, and its type locality is in the Huichica Formation of Weaver (1949), south of the Sonoma Range north of San Pablo Bay. We also find this tuff in the Paso Robles Formation, further south in the Coast Ranges. Alan Deino of the Berkeley Geochronology Center has dated the Huichica Tuff by the iset fusion 40Ar/39Ar technique and obtains an age of 4.71 Ma (A. Deino, unpublished data).

The sediments below, between, and above the tuffs at this location are derived from the Franciscan Complex, as determined by the mineralogy of the sediments. Heavy mineral separates from the sediments contain typical Franciscan minerals: jadeite-omphacite, glaucophane, lawsonite, actinolite, epidote, rutile and sphene. The sediments containing these tuffs were derived from the Mount Diablo Mountain Range, to the south.

The sediments containing these two tuffs rest unconformably on rocks of the Franciscan complex and the Great Valley sequence. The sedimentary unit containing these tuffs was originally mapped as the Livermore Gravels by Clark (1930), and later by Huey (1948). Several geologists mapping in this area since have noted that the Livermore gravels are quite variable from site to site, and within stratigraphic sections. In particular, the lower part of the Livermore Gravels appears to be much more fine-grained than the overlying upper part, and several geologists have proposed that the Livermore Gravels actually may contain at least two separate formations that are separated by unconformities. These observations have lead to the subdivision of the Livermore Gravels into a lower, older unit that has been variously named as the Contra Costa Formation (or Group) or as the Sycamore Formation. The former is present in the Berkeley Hills block to the northwest of the Calaveras fault, the Sycamore Formation is present north of Livermore, in the gently rolling hills south of Mount Diablo.

These observations combined suggest that during the early Pliocene, at the time of deposition of the Lawlor and Huichica Tuffs, the Diablo Range was lower and less rugged than it is at present. Uplift of the Diablo Range after deposition of the “Sycamore” formation in later Pliocene and Quaternary time in this area uplifted these sediments, and coarser Livermore Gravels (in the revised sense of the term) prograded and deposited further north and above the “Sycamore” Formation in this area.
We will walk down the road toward Del Valle Regional Park, and downsection, to see the "Sycamore" Fm. in fault contact with the Franciscan, along a north-trending fault.

Directions to Stop 2
(Tassajara Valley south of mt. Diablo)

We will retrace our route back through Livermore. Turn around and drive back along the way we came.

1.3Mi. We get a good view of the Quaternary (?) terraces that are inset into the "Sycamore" Formation and the Livermore Gravels. In the distance slightly to the right of straight ahead, you can see Mount Diablo. As we return to the intersection of Mines and Tesla Roads, you can see the hills to the east (right) bounded by the dextral Greenville Fault; ahead of us, the Tassajara Hills and Mount Diablo in the distance, and the Berkeley Hills block, bounded on the east by the dextral Calaveras Fault, to the west (see figs. 1 and 2).

7.5Mi. Cross Railroad Ave., continue to Hwy 580. Proceed on N. Livermore, under the RR overpass, under the Hwy. 580 overpass.

1.3Mi. Enter Hwy. 580 heading west, to the Collier Canyon Road exit. Stay right.

1.9Mi. Take the Collier Canyon Road exit, and turn north on Collier Canyon Road (Airway Blvd.).

0.7Mi. Turn right at intersection.

0.4Mi. Turn left (north) and continue on Collier Canyon Rd. We are driving through the Tassajara Formation and into the Sycamore Formation (see map, front cover, and fig. 6).

3.6Mi. Two tuffs are exposed on the south limb of the Rasmussen anticline (Tassajara anticline). The section here is folded, in some places into tight synclines and anticlines, and is probably cut by thrust faults as well, but the surface expression and exposures are poor (fig.2).

0.8Mi. Intersection with Carneal Rd. Continue on Collier Canyon Road.

1.0Mi. Sharp curve in road; road goes down steeply. Ridge ahead crossing the road is the Highland Syncline (Sycamore Valley Syncline), and contains a sequence of tuffs ranging in age from about 5.4 Ma, the Pinole Tuff and is roughly on trend with the 6.25 Ma Roblar Tuff. These are not very well exposed. The sequence of tuffs is repeated in reverse order on the other side of the ridge, thus this is a true syncline, though the axial region may be offset by a fault. Some loss of section in the axial region may also be possible. The bedding here is nearly vertical.
STOP 2: CAMINO TASSAJARA RD.
ROBLAR TUFF 6.25 Ma

After Wagner et. al., 1991

QT - Plio-Pleistocene Livermore Gravels
Pta - Tassajara Fm., nonmarine
Mcc - Miocene Contra Costa Formation, nonmarine
Msp - Miocene San Pablo Group, marine

1 mi.

figure 6
0.5Mi. Intersection of Collier Canyon Rd. with Highland Rd. Turn left (west) onto Highland Road. As we proceed along this road, we are roughly on trend and parallel with the Highland Syncline and the sequence of tuffs present near its axial region. The Highland Syncline has been renamed the Sycamore Valley Syncline, and the Rasmussen Anticline has been renamed the Tassajara Anticline in some recent works, including Unruh and Sawyer (1997).

A simplified geologic map of the East Bay area taken from Unruh and Sawyer (1997) is shown in fig. 1, and the principal structural elements in this region are shown in fig. 2.

0.8Mi. Cross Highland Syncline again. Tephra bed exposed in road cut on the right.

0.8Mi. Intersection of Highland Rd. and Camino Tassajara. Turn right (north) onto Camino Tassajara. Proceed north.

STOP 2. Fugure 6.

0.4Mi. On your left (west) you will see a large gray building. Turn left into the parking lot. This is the San Ramon Valley Fire Protection District’s Station #36, at 6100, Camino Tassajara. PARK BY THE SIDE OF THE LARGE GRAY BUILDING, NOT IN FRONT, SO AS NOT TO BLOCK THE FRONT DOORS TO THE FIRE ENGINES, AND SO AS NOT TO BLOCK THE DRIVEWAY THAT GOES BACK INTO THE STATION SERVICE YARD.

Walk around to the south of the station, on the west side of Camino Tassajara, and walk through the cattle gate, along San Ramon Valley Fire Trail 36-5, a few hundred yards to the exposure of a white rock (tuff) behind the station. Close cattle gate after entering and leaving. PLEASE, NO SMOKING WHILE ON THIS PROPERTY.

The tuff is situated in the upper part of the Sycamore Formation, stratigraphically below the overlying Tassajara Formation. The tuff we are looking at here is nearly vertical in attitude. The tuff is water-deposited and water-worked, as indicated by its texture, sorting, and rounding of the pumice lapilli, as well as by its bedding characteristics.

This is an exposure of a tuff that we correlate on the basis of its chemical fingerprints with the Roblar Tuff. The latter tuff is present in the marine Wilson Grove Formation in Sonoma County, to the northwest of here, near Petaluma and Sebastopol. We have also identified the same tuff in (1) the Petaluma Formation, north of San Pablo Bay, (2) in the Contra Costa Formation south of San Pablo Bay, (3) in the eastern Berkeley Hills Block near Lafayette, as well as (4) here in the Sycamore Formation south of Mount Diablo. Subsequently, we have also identified this tuff in deep-sea sediments of DSDP core 34, in the Delgada submarine fan west of Cape Mendocino. The tuff there is associated with the a biostratigraphic datum the age of which is independently estimated to be ~6.1 Ma (fig. 7).
Distribution of the Roblar Tuff, 6.25 Ma, in northern California

figure 7
Early K-Ar age determinations on this tuff yielded dates ranging from 5.7 to 6.1 Ma, on plagioclase separates. A subsequent date by 40Ar/39Ar on the tuff near Lafayette yielded a date of 6.25, with a much smaller analytical error (Robert Fleck, USGS, unpublished data). We accept the Ar/Ar date as a better approximation of the age of this tuff.

The exposures of the Roblar Tuff and the associated sediments in which we find it appear to form a natural progression that one would find within a single drainage system that drained roughly from east to west. Coarse- to medium-grained alluvium within the Sycamore Formation south of Mount Diablo progresses to medium-grained alluvium in the eastern Berkeley Hills near Lafayette. This, in turn, grades to finer-grained alluvial, lacustrine, and lagoonal deposits of the Contra Costa Formation in the northwestern part of the Berkeley Hills Block. Further to the northwest, at Sears point, we find the Roblar Tuff in estuarine and marine deposits, while further still to the northwest, near Petaluma and Sebastopol, the Roblar Tuff is found in fully marine, shallow shelf deposits. Lastly, the Roblar Tuff also occurs in deep submarine fan deposits off the Mendocino coast. The tuff provides a single timeline to correlate these sediments in time, while their sedimentary progression from subaerial to littoral to marine suggests the possibility that they were all once contiguous.

A possible palinspastic restoration for 6.25 million years ago is shown in fig. 8. The several offsets along faults within the San Andreas Fault System, combined with the age of the Roblar Tuff, provide a way of determining long term rates of displacement on these faults. By dividing the amount of apparent displacement by the age of the Roblar Tuff, we derive a long term average displacement rate for each of the strands in the San Andreas fault system. What we come up with are rates that are similar to rates calculated by other, independent lines of evidence. One complication is that we have to call upon the Tolay fault, or a similar fault, now inactive, to derive the entire amount of apparent displacement on the fault system. But maybe this is a positive complication, telling us something about the earlier history of displacement!

Directions to Stop 3
(Shell Ridge Rec. Area west of Mount Diablo)

From the Fire Station, turn left onto Camino Tassajara. Follow Camino Tassajara as it curves to the west. About 1/4 mi. north along C. Tassajara, there is a road to the right (east). About another 1/4 mi. to the east of this intersection, in the bottom of a small creek tributary to Tassajara Creek, is an exposure of the Lawlor Tuff. There may be an intervening structure between this exposure and that of the Roblar Tuff, that we just saw. The exposure is pretty poor, so we won’t stop to see it (see tephra distribution map, back of front cover, for tephra locations in the East Bay region).

3.6Mi. Entrance to Black Hawk Plaza (U.C. Vertebrate Paleo Display is here, and an auto museum as well). Continue on Camino Tassajara, however.

0.6Mi. Intersection of Blackhawk Rd. and Crow Canyon Rd. with Camino Tassajara. Keep on Camino Tassajara.
Palinspastic Restoration for 6.25 Ma BP
1.7Mi. Intersection of Sherbourne Hills Road with Camino Tassajara. Keep going west on Camino Tassajara. The hills to the south are the Sherbourne Hills, and are the westward extension of the Highland Syncline (a.k.a. the Sycamore Valley Syncline; figs. 2 and 3). The syncline plunges to the ESE. The “Sherbourne Tuff,” it appears, is actually a stratigraphic interval of some thickness that contains several tuffs, including the Roblar Tuff (6.25 Ma) near its base, and the Pinole Tuff (5.2-5.4 Ma), near its top. The younger dates are obtained by the old conventional K-Ar technique, and may turn out to be older, if our experience in reading these tuffs holds true.

1.2Mi. Continue west to Sycamore Valley Rd. Camino Tassajara turns off to the NW (right), but we keep going straight on Sycamore Valley Road. In the distance ahead of us you can see Las Trampas Ridge, part of the Berkeley Hills block, bounded on the east side by the Calaveras fault. The Lafayette Tuff (a.k.a. the Roblar Tuff) is found in the Contra Costa Fm. over in that area. (See figs. 1,2 and the inside cover).

1.5Mi. Cross over Hwy. 680 overpass, and find a convenient gas station for a pit stop on the other side of the highway. There are several gas stations here.

Reassemble, get in the vans, and cross back over the freeway and get on Hwy 680 going north toward Walnut Creek.

6.3Mi. Stay in middle lane (don’t go off on 2 left lanes; they go to Hwy. 24).

1.5Mi. Take Ygnacio Valley Rd. exit, heading east (right). We have driven around from south of Mount Diablo to the west side.

1.4Mi. Turn right (SE) on Homestead Rd.

0.2Mi. Turn left onto Marshall Rd. Continue on this winding road and follow it to the end. Shell Ridge is to our left (north).

STOP 3. Figure 9.

1.1Mi. Park as near as you can to the cattle gate at the entrance of the Shell Ridge Recreational Area. It may be hard to find a place. Indian Valley School is the school just south of Marshall Rd.

TAKE YOUR LUNCHES AND DRINKS WITH YOU. Also hats, sun block, etc. We will go for a short hike (1/2 Mi) and lunch. As we hike down the trail, to the southeast, Shell Ridge is to the left (north). It is underlain by the lower part of the Cierbo Fm. We are walking along Indian Valley between Shell Ridge on the north and another ridge to the south. We are walking in the middle to upper part of the Cierbo Fm., and the Neroly Formation makes up the ridge to the south.

The Shell Ridge Open Space contains units from the Eocene to the Pliocene (fig.10). Bedding here is very steeply dipping to overturned. Shell Ridge and the ridge to the south are composed of the San Pablo Group (fig. 11). Shell Ridge, and Indian Valley to the south, are occupied by the Cierbo Formation. The Ridge
STOP 3: SHELL RIDGE OPEN SPACE
CIERBO AND NEROLY FMS.

After Wagner et. al., 1991

Mcc - Miocene Contra Costa Fm., nonmarine
Msp - Miocene San Pablo Group, marine
(includes the Cierbo and Neroly)
Mmy - Miocene Monterey Fm., marine
Ed - Eocene Domengine Sandstone, marine

1 mi
Composite columnar section of the Neogene at Diablo Foothills
Contra Costa County, California

<table>
<thead>
<tr>
<th>Unit</th>
<th>Age</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sycamore</td>
<td>4.33 Ma</td>
<td>Sycamore Formation – Siltstone. Light tan in outcrop. Unidentified razor clams and plant material (rushes?) present.</td>
</tr>
<tr>
<td>exposed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>370 m</td>
<td></td>
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<tr>
<td>Neroly</td>
<td>11.3 Ma</td>
<td>Clerbo Formation – Fine- to coarse-grained lithic-rich quartzofeldspathic sandstone. Yellow-gray in outcrop. ~140 m above base are coalescing shell hash lenses several less extensive shell hashes unstratified. Shell hash contains: heavy-shelled pelecypods to 6 cm long, oysters approximately 20 cm long, Natica sp., Astrodapias sp., Astrodapias cestoides. Conglomerate lenses are common.</td>
</tr>
<tr>
<td></td>
<td>792 m</td>
<td>Clerbo Fm. – Poorly cemented siltstone in limited exposures. Contains clams of the genus Tastetula.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clerbo Fm – Very fine- to medium-grained lithic-rich quartzofeldspathic sandstone. Buff to light gray in outcrop. Lenses of conglomerate, carbonate, and shell hash. Fossilized wood (branches with bark?). Shell hash contains gastropods 15-20 mm long, heavy-shelled, and nodal pelecypods 2-3 cm long. Conglomerate lenses are internally cross-bedded and cross-bedded with the surrounding sand.</td>
</tr>
<tr>
<td></td>
<td>52 m</td>
<td></td>
</tr>
<tr>
<td>Rose</td>
<td>Not</td>
<td></td>
</tr>
<tr>
<td>exposed</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Key:
- Siltstone
- Sandstone
- Trough cross-bedded Sandstone
- Tuff
- Carbonate
- Conglomerate
- Shell hash
- Fossil
- Wood
- Leaves

Scale: 200 m
to the south of Indian Valley is composed of the Neroly Formation (Graymer, et al., 1994). Sedimentologic and Provenance data is taken from ongoing San Jose State University thesis work (J.P. Walker).

Sedimentology: The Cierbo is composed of feldspatholithic sands commonly deposited in 1-meter thick beds. Some beds show no internal structures, others show parallel laminae, cross beds and trace fossils. Characteristic of the Cierbo Formation is the presence of shell hashes, composed of disarticulated valves and pebbles. These bed forms vary from approximately 20 cm thick and a couple of meters long to approximately a meter thick and up to a kilometer long in outcrop, the largest shell hashes can be found holding up Shell Ridge itself. The faunal assemblage found in the shell hashes varies along strike and stratigraphic position but always contains heavy-shelled pelecypods including Saxodamis sp. and Ostrea (titan?) in the lower shell hashes. Gastropods of the genus Natica and echinoderms of the genus Astrodapsis sp. are found at various stratigraphic locations and positions along strike. Restricted to the upper shell hashes is Astrodapsis cierboensis. In general the assemblages suggest an environment just below the surf zone (J. W. Durham, pers. Comm., 1994).

The Neroly Formation is composed of volcanolithic sands. These are in meter to 2-meter-thick beds often showing cross beds or laminae. The uppermost portion of the unit is composed of mudstones in centimeter scale laminae. The Lower portion of the Neroly (not present at field trip stop) is organized into large meter scale trough cross beds, with decimeter scale interbeds of mudstone often containing leaf imprints. The environmental interpretation for the lower section is fluvial.

The upper half of the Neroly Formation contains shell hashes and conglomerates. The faunal assemblage in the shell hashes contain; Glycimeris septenalis (?), Prothaca paphe, Cardium sp., Ostrea titan (?). This assemblage is composed of disarticulated valves and suggests an environment just below the surf zone (J. W. Durham, pers. Comm., 1994), or an estuarine environment.

Provenance: The Cierbo and the Neroly at this location both have a Sierran provenance in the sand size fraction, dissected volcanic arc for the Cierbo and active volcanic arc for the Neroly. Counts of gravel size clast of 400 clasts were done here and near stop 4 (fig. 12). The Cierbo in the Diablo Foothills shows a high degree of variability with volcanics making up from about 20 percent to over 60 percent. The Neroly gravel size clast counts show the unit to be composed of between 50 to over 95 percent volcanic clasts. The most common volcanic type in the Neroly is andesite (>50%) with basalt and dacite as sub-populations. The volcanic fraction of the Cierbo shows a much greater heterogeneity than does the Neroly.

The dominant populations in the Cierbo are metamorphic clasts making up from 40 to 80 percent of the total population. Conspicuously absent from the metamorphic clasts are graywacke and blueschist, suggesting that the Franciscan is not the provenance of the Cierbo on this side of the Calaveras Fault. The more likely source for the metamorphic clasts is the Sierran foothills/roof pendant.
The Volcanic suites in the Neroly appear to vary with their latitude (fig 13), the northern most sites seem to indicate a provenance from the northern Sierras, which is also consistent with paleocurrent data collected from those sites. The mid-latitude sites (stop 3) show a provenance similar to that of the volcanics found at the Mehrten type locality near Lodi. The southern most sites have a provenance that best matches the volcanics found along Route 108 in the Sierras further south. It is interesting to note that the southern most sites have paleocurrent data that show flow to the north-northwest and the metamorphic assemblage contains graywacke and blueschist, suggesting that the Diablo Ranges deflected the fluvial system that originated in the Sierras.

Directions to Stop 4  
(Alves Construction Co. Quarry)

Return to cars and retrace our route back to Ygnacio Valley Rd. (Marshall to Homestead, right at Homestead, to Ygnacio). Pass Cierbo Fm. in road cuts to north and south. At Tampico, we cross top of Shell ridge.

~1.3Mi. Ygnacio Valley Rd. Turn right (NE) on Ygnacio.

1.1Mi. Chevron gas station on our right. We will have a pit stop here, if necessary. After stop, continue NE on Ygnacio Valley Rd. toward Clayton Rd.

1.9Mi. Quarries in Domengine(?) (Eocene) sandstone in hills ahead.

0.2Mi. Cross Lime Ridge. Eocene. Large landslides in Eocene.

1.5Mi. Quarry in Eocene rocks.

0.6Mi. Domengine sandstone exposed in road cut. To the south, in the distance, you can see a quarry cut into a sheeted dyke complex in the ophiolite sequence on the north flank of Mount Diablo (Zion Peak).

1.4Mi. Turn left (NW) onto Clayton Rd. Proceed toward Bailey Rd.

1.5Mi. Turn right onto Bailey Rd. Proceed on Bailey Rd. across Los Medanos Hills. The Los Medanos Hills are a structurally asymmetrical anticline, bounded in part on the southwest by the Clayton and other faults, which may be a fold associated with a detachment fault (figs. 1, 2). We will cross a thick section of Tertiary sedimentary rocks here. From SW to NE they are the Eocene Markeley Fm., the Oligocene (?) Or Miocene) Kirker Fm., mostly to the SE of Bailey Rd., the Miocene Cirbo and Neroly Formations, the 4.8-Ma Lawlor Tuff, and the Los Meganos Gravels (a.k.a. the Wolfskill gravels, or the Tehama Fm., depending on which reference one uses), ca. 3.5 Ma to upper (?) Quaternary.
1.6Mi. But first, we cross RR tracks. This is part of the concord naval Weapons Station. See bunkers up the hill to the right.

0.4Mi. Boulders of Concord basalt. Ray Sullivan has obtained an age roughly equivalent to that of the Lawlor Tuff on these, ~5 Ma. This unit may represent basaltic magma leaked up along the Concord and related faults. The structural and depositional relationships between this unit and the rest of the section are not clear (to us!). We continue up across the Los Medanos Hills, and the section described above.

2.3Mi. Lawlor Tuff is exposed in the road cut on the left (west) side of the road, just before entrance to the dump, on the right. We are now in Lawlor Canyon, at the type locality of the Lawlor Tuff. We may pull over to the right side of the road and look at the exposure.

PLEASE DO NOT GET OUT OF THE VEHICLES. The road is narrow here with little visibility because of the curve up the road behind us. There is very little room on the other side of the road, not enough for a large group this size to look at the outcrop safely. The Lawlor lies here on top of the Neroly Fm., and dips to the NE at about 40-45 degrees. The lower, white part of the tuff is pumice lapilli air-fall tuff; the upper, rusty-to-pink part of the unit is an ash-flow tuff. We will get a chance to look at the textures more closely at the next stop, Alves’ Quarry.

Proceed further north, downhill along Bailey Rd.

0.5Mi. Leland Rd. Turn left onto Leland Rd., just south of new BART Station, in West Pittsburgh (a.k.a., Bay Point).

0.6Mi. Continue straight as road narrows.

0.1Mi. Turn left onto dirt road at sign (Curbertson; sign points right, but you turn left).

0.1Mi. We’ll stop by the office of Alves Construction Co. We’ll check in and let them know we’re here. Then we’ll continue south on dirt road, up the hill.

Mr. Alves and his son tell me that they killed about:

...SEVEN RATTLESNAKES HERE ABOUT A WEEK OR TWO AGO WHILE WORKING ON FIXING A FENCE. SO, I’D BE CAREFUL WHERE I STEPPED AND WHAT I STEPPED ON...

0.5Mi. Gate. Lawlor Tuff to the left (east), across the creek bed. Proceed along dirt road, bearing left. Neroly Fm. outcrops to our right.

STOP 4: Figure 14.

0.3Mi. Turn right on dirt road. Proceed to quarry (fenced in to "..."Keep the kids out," says Mr. Alves). This is STOP 4, (Figure 14). Alves Construction Co. Quarry. Leave vans/cars near quarry, and walk up road. We are walking near the contact
STOP 4: ALVES QUARRY
LAWLOR (4.83 Ma) AND BE25 (11.5 Ma) TUFFS

After Strand and Koenig, 1965; and Wagner et. al., 1991

Pt - Pliocene (& Quaternary?) Tehama Fm., nonmarine
Plt - Pliocene Lawlor Tuff, 4.8 Ma
Msp - Miocene San Pablo Group (includes the Neroly and Cierbo Formations, marine)
Φk - Oligocene (Miocene?) Kirker Fm., marine
Emk- Eocene markeley Fm., marine
between the Neroly Fm., to our right (north) and the Cierbo Fm., to our left (south). The marine Cierbo Formation is rich in fossils at this locality. Many macrofossil pelecypods and gastropods are present in the upper part of the Cierbo (e.g., Saxidomus conradii, a large, oval clam with prominent concentric ridges. We have found such clams here with articulated valves). The Neroly Fm. here is dominantly alluvial, with large scale cross-bedding. It contains abundant petrified wood fragments. Mr. Alves’ son found a chunk the size of a softball here the other day.

...AS WELL AS RATTLESNAKES.

Deviating a bit to the right off the dirt road as we go uphill, we can look through the disturbed ground (now overgrown with grass) to look for some of these fossils. Heading up the road for about 1/4 mi., we pass from the dominantly andesitic sands of the Neroly and Cierbo Formations (derived from the Sierra Nevada), downsection into the lower Cierbo (also referred to as the Briones Fm. by some mappers). Here the unit is finer. The tuff exposed in the road here is the “BE25” tuff, the same tuff that we find on the southwestern side of the Diablo anticlinorium at Stop 3 and to the SE of there (table 1).

We will now go cross country (or via the dirt road if you should prefer) toward the prominent ridge of Hill 566 (ft.) to the NW of the quarry. We will see both the Neroly Fm. and the Lawlor Tuff.

The Lawlor Tuff here rests unconformably on the Neroly Fm. Our tephrochronologic correlations bracket the age of the Neroly Fm. in this area between about 9.8 and 11.1 Ma, though the formation may encompass a broader time frame than that, particularly at the younger end. As one goes to the ESE along the strike of these units toward Markeley Canyon, there is a formation that intervenes between the top of the Neroly and the base of the Lawlor. Lithologically it resembles the Neroly Fm., but contains clasts of Neroly sandstone, and is less massive and poorly indurated. This formation probably represents locally reworked Neroly. This Fm. pinches out to the WNW. As we go up Hill 566 and look at the contact between the Neroly and Lawlor, we see that it is offset by multiple faults, with apparent downdropping to the ESE.

The Neroly Fm. here is derived mainly or exclusively of andesitic and other volcanic clasts derived from the upper Tertiary volcanic and volcaniclastic rocks of the Sierra Nevada. The “Cierbo and Neroly Sea,” judging from the distribution of the Neroly Formation in the Coast Ranges and from subsurface information in the western Great Valley, made a fairly broad incursion across this region in upper Miocene time.

Looking at the texture of the lower, white part of the Lawlor Tuff, we can see that the unit is composed of closely-packed, relatively well-sorted pumice lapilli clasts with minor, smaller lithic fragments, with little fine-grained interstitial material. This is a “clast supported” texture typical of air-fall tephra. This tells us that the Lawlor was deposited directly as an air-fall layer on top of the erosional surface of the Neroly Fm. Going upsection in the Lawlor Tuff to the brown- to reddish-brown upper part, we see that the texture here is different. Pumice lapilli and lithic fragments “float” in a finer-grained matrix of ash and lithic grains. This is a texture typical of ash-flow tuffs. Pumice lapilli in such a deposit are often rounded by being tumbled in the ash-flow.
Table 1. Chemical composition of volcanic glass shards determined by electron-microprobe analysis of Neogene tuffs from Shell Ridge, and correlated reference samples. Values given are in weight-percent oxide, recalculated to 100 percent. About 15 individual glass shards were analyzed for each sample. S.C. - similarity coefficient for comparison of samples 1, 6, 8, and 9, with similar reference samples; a value of 1 represents a perfect match. Average values of analyses of a homogenous glass standard are given to provide estimate of precision. C. E. Meyer, U.S.G.S., Mealo Park, analyst.

<table>
<thead>
<tr>
<th>Sample</th>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>Fe₂O₃</th>
<th>MgO</th>
<th>MnO</th>
<th>CaO</th>
<th>TiO₂</th>
<th>Na₂O</th>
<th>K₂O</th>
<th>S.C.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lawlor Tuff (4.1 Ma); Sycamore Fm., Shell Ridge, this study (1), Isaacson and Anderson (1992) (2), and Lawlor Tuff exposed on north flank of Los Medanos Hills, north of Mount Diablo and the study area (3-5); sample (5) is from the type locality in Lawlor Canyon. (Sarna-Wojcicki and others, 1991)</td>
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</tr>
<tr>
<td>1. MRT-2</td>
<td>73.4</td>
<td>14.3</td>
<td>2.16</td>
<td>0.09</td>
<td>0.03</td>
<td>0.87</td>
<td>0.16</td>
<td>4.31</td>
<td>4.60</td>
<td>1.000</td>
</tr>
<tr>
<td>2. WC-33B</td>
<td>73.8</td>
<td>13.9</td>
<td>2.17</td>
<td>0.09</td>
<td>0.07</td>
<td>0.93</td>
<td>0.17</td>
<td>4.30</td>
<td>4.55</td>
<td>0.973</td>
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<tr>
<td>3. 758-141A(2)</td>
<td>73.4</td>
<td>14.3</td>
<td>2.15</td>
<td>0.09</td>
<td>0.04</td>
<td>0.88</td>
<td>0.17</td>
<td>4.31</td>
<td>4.55</td>
<td>0.973</td>
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<tr>
<td>4. 758-156A</td>
<td>73.6</td>
<td>14.3</td>
<td>2.16</td>
<td>0.08</td>
<td>0.04</td>
<td>0.89</td>
<td>0.16</td>
<td>4.41</td>
<td>4.11</td>
<td>0.976</td>
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<td>5. LAWLOR-1</td>
<td>73.2</td>
<td>14.3</td>
<td>2.15</td>
<td>0.09</td>
<td>0.04</td>
<td>0.84</td>
<td>0.18</td>
<td>4.83</td>
<td>4.37</td>
<td>0.974</td>
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<tr>
<td>Tuff near the base of the Sycamore Fm. (&gt;6.25 Ma), Macedo Ranch (Isaacson and Anderson, 1992) (6); and near the base of the Sycamore Fm., 2 miles east of Tassajara, south of Mt. Diablo (7) (Sarna-Wojcicki, 1971)</td>
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<tr>
<td>6. SIMP-3</td>
<td>77.2</td>
<td>13.5</td>
<td>1.59</td>
<td>0.17</td>
<td>0.04</td>
<td>0.85</td>
<td>0.20</td>
<td>3.19</td>
<td>4.49</td>
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<td>7. 758-339CR</td>
<td>75.8</td>
<td>13.9</td>
<td>1.61</td>
<td>0.19</td>
<td>0.04</td>
<td>0.83</td>
<td>0.20</td>
<td>3.90</td>
<td>4.39</td>
<td>0.768</td>
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<td>Tuff in the Briones (?) Fm. (~11.5 Ma), Shell Ridge, this study (8, 9), tuff in the Briones (?) Fm., Los Medanos Hills north of Mt. Diablo (10), and tuff near the top of the Aldrich Station Fm., west of Walker Lake, Nev. (11); the latter tuff is underlain and overlain by two tephra layers that are correlated to the Trapper Creek section, Ida.; the two tephra layers at the latter locality are dated directly by the 40Ar/39Ar method (Perkins and others, 1995).</td>
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<td>8. MRT-3A</td>
<td>78.7</td>
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<td>0.09</td>
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<td>4.02</td>
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<tr>
<td>9. MRT-3B</td>
<td>78.7</td>
<td>13.6</td>
<td>0.58</td>
<td>0.08</td>
<td>0.07</td>
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<td>10. 920692-2</td>
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<td>11. BE-25</td>
<td>77.1</td>
<td>12.7</td>
<td>0.56</td>
<td>0.07</td>
<td>0.07</td>
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<td>0.10</td>
<td>1.40</td>
<td>7.44</td>
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<tr>
<td>Natural glass standard used as monitor in analysis (electron-microprobe analysis)</td>
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<tr>
<td>RLS 132 (n=18)</td>
<td>75.4</td>
<td>11.3</td>
<td>2.12</td>
<td>0.06</td>
<td>0.16</td>
<td>0.11</td>
<td>0.19</td>
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<td>4.4</td>
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<tr>
<td>± 1 s:</td>
<td>0.1</td>
<td>0.2</td>
<td>0.04</td>
<td>0.01</td>
<td>0.01</td>
<td>0.1</td>
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<tr>
<td>% s:</td>
<td>0.2</td>
<td>1.9</td>
<td>17</td>
<td>6.3</td>
<td>9</td>
<td>5.3</td>
<td>2.7</td>
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<td>Natural glass standard used as monitor in analysis (wet-chemical analysis)</td>
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<tr>
<td>RLS 132</td>
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<td>2.12</td>
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<td>0.12</td>
<td>0.21</td>
<td>5.3</td>
<td>4.5</td>
<td></td>
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</tbody>
</table>

1 Iron reported as FeO for the standard. Table from Walker and others, 1996.
Such units are sometimes difficult to distinguish from lahars (hot mud flows) or cold reworked volcanic debris and mud flows. The former tend to be largely monolithologic, while the latter may incorporate a variety of lithologies. The only sure way to tell them apart is to measure the paleomagnetic orientations of pumices clasts in the deposit. Because ash flows are emplaced at high temperatures above the Curie points of magnetic minerals, they acquire uniform orientations in the ambient magnetic field, and have the same orientations—while colder deposits will yield random pumice clast magnetic orientations.

At the top of Hill 566, we get a good view (most days, anyway) of Suisun Bay and the surrounding countryside. Upsection from the Lawlor (downhill to the north), we see the gently rolling foothills underlain by the Los Medanos Gravels of Patten, 1947; (a.k.a., the Wolfskill Fm. of Weaver, 1949; the Tehama Fm. of Sims and others, 1975). Sarna-Wojcicki has found the Putah Tuff (3.4 Ma; Miller, 1966) in the basal part of this formation, a tuff present near the base of the Tehama Formation further north, near Putah Creek. Hence the recommended change to Tehama Fm. for these sediments. The age of the top of the Tehama here is unknown but is probably early Quaternary.

The Lawlor Tuff must have been deposited on a surface of low relief, judging from its lithology and that of the associated sedimentary units. The tephra layer and associated units are now deformed—tilted to high angles, and in places folded and faulted. The Lawlor Tuff was erupted from the Sonoma Volcanic field, based on grain size gradients and the presence of the coarse, proximal Lawlor Tuff interbedded with volcanic flows and other pyroclastic deposits in the Sonoma Volcanics.

Sarna-Wojcicki's (1971) early and crude interpretations of the stratigraphy and structure in this region suggested that Mt. Diablo was not in existence at the time of the eruption and deposition of the Lawlor Tuff, and neither was Suisun Bay, if the ash-flow tuff was to travel across this area to the south and southeast. If an upland existed at the site of Mt. Diablo, it certainly would have had to be very subdued. Subsequent work by others, including Unruh and Sawyer (1997) support this case in a general way (see figs. 15 and 16; these figures show the inferred post - and pre-deformation cross sections across the Mount Diablo antiform and related structures). These authors have used the dated tephra layers as chronostratigraphic and structural markers in constructing "retrodeformable" cross-section, and deriving strain rates for the East Bay region. These authors will be dismayed to hear, however, that these tephra layers have now been redated and that they will have to recalculate their strain rates all over again! The changes, however, will be small and well within the limits of their estimated errors.

Sarna-Wojcicki's (1971) early interpretations will probabluy also have to be modified in other respects: ash-flows may be able to travel over water, and Sarna's earlier interpretation of ash-flow textures in the Lalwor Tuff south of Mount Diablo are also probably in error, but a dip restoration and smoothing-out of the faults and faults still leaves little room for a high mountain before about 4.8 Ma (fig. 16).

Assuming we still have time to go on to another stop: the last stop will be to the northwest of Hill 566 and Stop 4, across the Martinez Bridge, and a few miles up Hwy 680, at the southeastern edge of the Sonoma Volcanics.
Restored cross-section B-B'.
From Unruh and Sawyer, 1997
Directions to Stop 5
(North of Bahia, former Goodyear Station; distances are approximate)

Retrace our route back to Bailey Rd. via Leland Rd.

2.6Mi. Intersection of Leland and Bailey Rd. Turn left on Bailey. Go under Highway 4 underpass.

0.3Mi. Turn left onto Hwy. 4 heading west. Continue west on Hwy. 4 to Hwy 680. Turn north on Hwy 680, and across the Martinez Bridge. Continue on Hwy 680 north.

~4.0Mi. From the Toll House on the north side of the bridge, go about 4 miles. You will see a large quarry on the right (east side) of the road, in a hill sticking out of the marshy plain bordering the west part of Suisun Bay.

~0.5Mi. Go another 0.5 miles beyond the hill to an exit marked either Nimz or Parish Rd. Cross over the overpass, and turn to the south along the frontage road, back the way you came. Go about 0.75 mi. south, until you come to a long curve in the frontage road, a long road cut. Park on the right side of the road on the shoulder, at the north end of the road cut.

STOP 5. Figure 17.

BE CAREFUL HERE; BLIND CURVE; STAY ON WEST SHOULDER OF ROAD.

This locality is called “Goodyear Station,” after a Southern Pacific Railroad stop to the south of this locality. The small town built around this stop is now called “Bahia.” There used to be a large “mothball” fleet of Liberty ships and other Navy ships that were retired after the Second World War, and later, anchored just to the east in Suisun Bay. Most of this fleet has been scrapped, but some ships are still anchored here.

A section of pumice-lapilli-lithic ash-flow tuffs, about 160 m thick, is exposed in the road cut. The tuffs are massive and dip moderately to the north. Bedding is indistinct, marked by abrupt grain size changes and concentrations of larger lithic fragments at the base of the flows. The mode of emplacement of the tuffs is again determined from the textural characteristics of the unit and its composition. Pumice lapilli and blocks are surrounded by a finer matrix (“matrix supported” texture). There is a progressive change in the color of the lapilli upward in the sequence of ash flows. Near the base, the pumice lapilli are lighter in color than the medium-gray matrix; higher up in the section the lapilli and matrix blend into a lighter gray, suggesting that a zoned magma was being emptied during the course of these eruptions. There is no evidence for erosion between emplacement of the ash-flows, suggesting that they were emplaced close in time.

The ash-flow tuffs at this locality are overlain by a jointed andesite flow about 15 m thick. The andesite appears to have “baked” and welded the top of the ash-flow tuff sequence.
STOP 5: GOODYEAR STATION: LAWLOR TUFF 4.83 Ma, AND RELATED VOLCANIC ROCKS

After Koenig, 1963

Pv - Pliocene Sonoma Volcanics
E - Eocene marine
Kl - Lower Cretaceous, marine

figure 17
The tephra here is chemically identical to that of the Lawlor Tuff. So, judging by its coarse grain size, the Lawlar Tuff was erupted from somewhere near this area. The air-fall pumice and ash blanketed the area to the south and east. The ash-flow tuff extended from here to at least the southeastern edge of the Los Medanos Hills, and possibly south of the present Mount Diablo. As we mentioned previously, Mount Diablo did not exist at the time, or was an area of very low relief at ~ 4.8 million years ago.

We find no localities of the Lawlor Tuff to the west in the Coast Ranges, or in Deep-Sea cores. This suggests that winds blew to the east, and furthermore, that a drainage divide was in existence here at that time (that is, there was no connection to the west and the ocean in this area) and the Great Valley was one large, integrated drainage basin that drained south and into a marine embayment that extended across the present Kettleman Hills and Temblor Range, and connected to an ancestral embayment near and north of Monteray Bay. As supporting evidence, we find the Lawlor Tuff at the top of the marine Etchegoin Fm. in the Kettleman Hills, to the south.

At Stop 5, we are at the southeastern edge of the Sonoma Volcanic field. Most of the field lies to the west and north of this locality. There is a strong indication of right-lateral offset of this part of the Sonoma Volcanics to the NW along the Green Valley Fault. To juxtapose the southeastern taf of the Sonoma Volcanics against the main body of the Sonoma Volcanics requires about 18 km of right-lateral shift (fig. 17). To match these silicic ash flows of the Lawlor Tuff with correlative exposures, we would have to go to the Monticello Road Section, along Hwy. 128, to the north. This is equivalent to a long-term displacement rate of about 0.3 to 0.4 cm/yr, similar but on the high side of other proposed strain rates for the Green Valley Fault.

End of the field trip. Thanks for your participation. Travel safely back to your homes.

References


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