Hart

NORTHERN CALIFORNIA GEOLOGICAL SOCIETY

Field Trip Guide Book

Spring 1979

GEOLOGY AND ENGINEERING IN THE LIVERMORE-HAYWARD REGION, CALIFORNIA

Contents

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David Drowley............................Chevron, U.S.A.
F. Mills.................................U.S.G.S.
D. Myren.................................U.S.G.S.
L. G. Peake..............................U.S.G.S.

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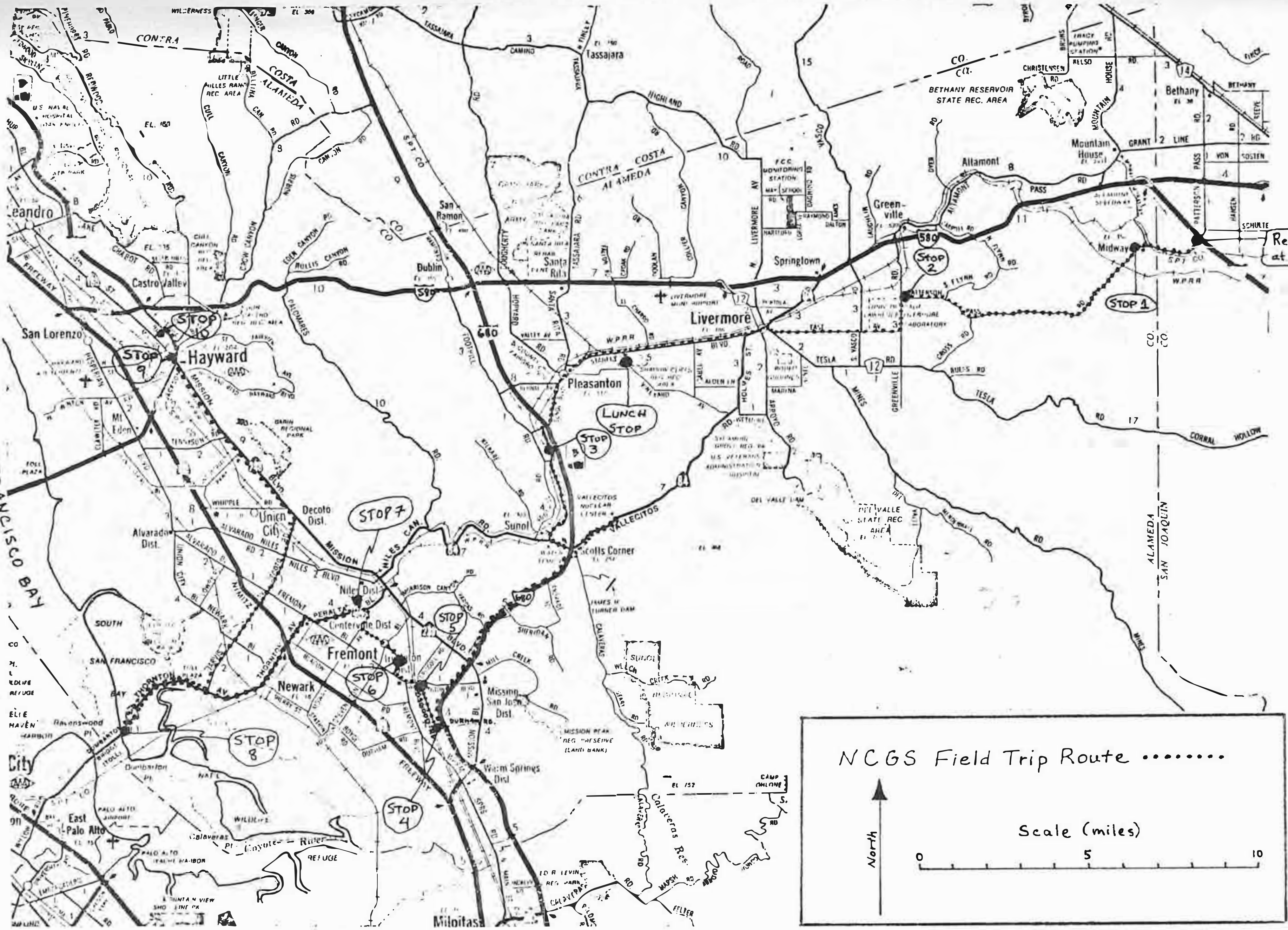
G. C. Jacob
Illustrations............................C. Clennon



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Northern California Geological Society

NCGS SPRING FIELD TRIP ROAD LOG

LEG ONE

Tesla Substation to Castlewood Country Club

MILEAGE: Total/From last checkpoint

0.0/0/0 Rendezvous at junction of Interstate 580 and Patterson Pass Road, 9:00 A.M. Saturday, May 5th. Begin by following Patterson Pass Road westward.

The Diablo Range lies to the west, the San Joaquin Valley to the east. Outcrops of Late Miocene clays, minor interbeds of brownish sands, gravels, and some blue sandstone, altogether approximately 2000 feet thick (Huey, 1948) represent the Upper Neroly Formation. The outcrops generally dip gently eastward along Patterson Pass Rd. as it traverses westward across the east limb of the Altamont anticline (See Fig. 1).

The Upper Neroly is conformably underlain by a 100-700 feet thick section of blue sandstone, andesite boulder conglomerate, and tuffaceous clay shale interbeds of the Lower Neroly which conformably overlies the Cierbo Sandstone, also believed to be upper Miocene. This unit is composed of quartzose detritus; poorly sorted white to buff colored sands and pebble conglomerates locally containing interbeds of tuffs and carbonaceous shales, altogether 500 feet thick (Huey, 1948).

The Neroly and Cierbo unconformably overly Cretaceous sandstone and shale of the Panoche Formation, which according to Huey accumulated in a shallow marine basin. In the vicinity of Patterson Pass, the Panoche is estimated to be 7500' thick.

All these units were subject to post-Miocene deformation and erosion. At that time, numerous W to NW trending folds and faults in this area were initiated, including the Midway Fault, Altamont Anticline,Patterson Fault, Greenville Fault, Carnegie Fault, Corral Hallow Fault, and the Tesla Fault. Subsequent to the deformation and erosion of the Cretaceous and Miocene units was the deposition of flood plain gravels, sands and clays of Plio-Pleistocene-age named the Livermore Gravels, which flank the southern portion of Livermore Valley (Huey, 1948).

1.5/1.5 Intersection of Patterson Pass Road and railroad tracks at Midway:

This is the approximate location of the NW trending Midway Fault. An apparent 100 foot vertical displacement of Cretaceous rocks along the fault to the northwest could be due in part to right-lateral strike-slip movement. Furrows, sag ponds, and springs mark the fault trace to the southeast. Locally, Quaternary alluvium is juxtaposed against the Upper Neroly. The age of the fault is post-Neroly.

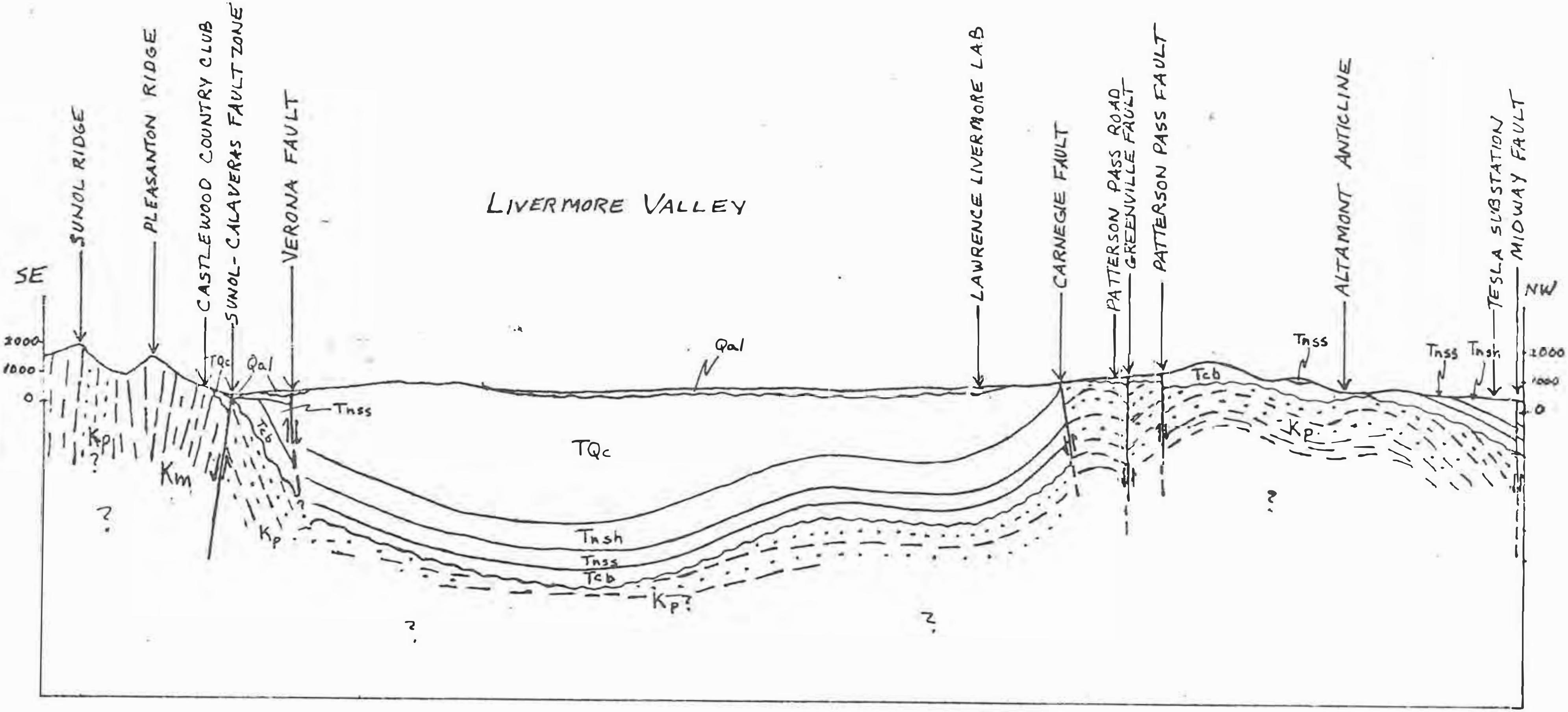

Figure 1). GENERALIZED STRUCTURE SECTION: LIVERMORE VALLEY

0 1 2 3 4 Miles

HORIZONTAL SCALE 1:137,500

VERTICAL SCALE 1:60,000

VERTICAL EXAGGERATION = 2.29X

Qal - Quaternary Alluvium
TQc - Livermore Gravels/Orinda Fm.
Tnsh - Neroly Fm. (upper shale)
Tnss - Neroly Fm. (lower sandstone)
Tcb - Cierbo Fm.
Kp - Panoche Fm./Del Valle Fm.
Km - Undivided Cretaceous marine

2.0/0.5 Stop 1 Western corner of P.G.E. - Tesla substation:

Larry Patzkowski will review engineering/geological considerations in transmission tower-line construction. Some geologic hazards affecting this area are soil creep, hillslope failure, soil erosion, and seismic disturbances.

Continue following Patterson Pass Road west. The Upper/Lower Neroly contact is approximately 0.5 miles from the Tesla substation, followed soon thereafter by the Cierbo Sandstone contact as the road traverses the east limb of the Altamont anticline.

4.0/2.0 Approximate location of Altamont anticline fold axis. Trend of fold is to the NW. Several lesser folds can be seen while traversing the west limb of the anticline before reaching Patterson Pass.

6.5/2.5 Look for the trace of the W-NW trending Patterson Fault, essentially a southeastward extension of the Greenville Fault. Numerous springs mark the fault trace near the road. A vertical displacement of 100-300 feet is estimated. The age of this fault, like the others, is regarded as post-Neroly.

South of Patterson Pass, other post-Miocene faults which together with the Patterson and Greenville faults form a W-NW trending shear zone are the Carnegie, Corral Hollow, and Tesla Faults.

On the west side of Patterson Pass the road cuts through the Cierbo Formation to the Quaternary alluvium forming the floor of Livermore Valley. Beneath the alluvium are the Livermore Gravels, estimated to reach 4000 feet in thickness (Huey, 1948). The Livermore Gravels were originally correlated with the Orinda Formation of Miocene/Pliocene age, but it is now thought that the two units are unconformably separated (Hall, 1958). These rocks together with the Miocene and Cretaceous sediments form a large synclinal trough comprising the Livermore Valley, now covered by surficial Quaternary deposits.

10.7/8.7 Stop 2 Intersection of Patterson Pass Road and Greenville Road:

Richard Darrow of Chevron will be discussing the geology of the Livermore Basin. Continue south along Greenville Road.

11.8/1.1 Intersection of Greenville Road and East Avenue, just past the Lawrence Livermore Lab: Turn right onto East Avenue, continue to Livermore. Livermore Gravels are exposed immediately SE of this intersection.

15.6/3.8 Junction of East Avenue and South Livermore Avenue in Livermore: Turn right onto S. Livermore Avenue.

15.8/0.2 Junction of S. Livermore Avenue and First Street (Highway 84 west): Turn left onto First St., following the signs to Pleasanton.

16.4/0.6 First St. becomes East Stanley Blvd: Continue westward following Hwy 84 to Pleasanton.

20.2/3.8 Lunch Stop: Shadow Cliffs Regional Recreation Area, on the left. Buses may park in the bus/trailer parking area. [Cars may attempt to follow the buses, but probably will be required to pay $2.00 admission fee.]

Here Quaternary sands and gravels overlie the Livermore Gravels. Numerous gravel deposits in the area are mined due to their economic value and proximity to nearby communities.

Continue after lunch westward through Pleasanton on Hwy 84.

21.6/1.4 E. Stanley Blvd. becomes First St. through Pleasanton: When in doubt, follow Hwy 84.

22.5/0.9 First St. becomes Sunol Blvd: Follow Sunol Blvd. under the freeway (Interstate 680) where upon it becomes Pleasanton-Sunol Blvd.

The Sunol-Calaveras fault zone runs NW along the valley bordering Pleasanton Ridge just west of Pleasanton. This fault is considered active; the last major earthquake occurred in 1861 and was of sufficient magnitude to cause ground breakage. Since then, creep has been monitored along this fault as it has along the Hayward fault (Greensfelder, 1972).

Tertiary units are juxtaposed against Cretaceous sediments at the fault zone. Locally the fault-zone plane dips to the southwest at angles between 31^{o} and 53^{o}. Pre-Miocene vertical displacement of at least 2,000 feet and post-Miocene right-lateral displacement of three miles or more is estimated (Hall, 1972).

According to Hall, Pleasanton Ridge is largely composed of 5500' of sandstone and sandy shale or siltstone with some interbedded conglomerate stringers, comprising the Niles Canyon Formation. Down-section this unit grades into the Oakland Conglomerate. Conformably overlying the Niles Canyon Formation is the Del Valle Formation which outcrops on the side of Sunol Ridge to the west of Pleasanton Ridge. Unconformably overlapping the Cretaceous sediments are the Cierbo Sandstone and Livermore Gravels.

The Del Valle Formation apparently correlates with the Panoche Formation of the Diablo Range, and thus is inferred to be of middle to upper-Cretaceous age. The underlying Niles Canyon and Oakland formations are thought to be Lower Cretaceous (Hall, 1958).

24.1/1.6 Pleasanton-Sunol Blvd./Castlewood Drive: continue along Pleasanton-Sunol Blvd. To the west is Pleasanton Ridge. Numerous old landslides form the topography along the base of the ridge. The Calaveras-Sunol fault zone follows the valley along Int. 680; immediately west of the fault are the Livermore Gravels while upthrown to the east are Miocene deposits beneath recent alluvial cover.

25.5/1.4 Stop 3 Along Pleasanton-Sunol Blvd:

Michael Dresen of Cal. State Hayward will discuss slope stability of the Pleasanton Ridge with emphases on the Castlewood Landslide.

Continue south along Pleasanton-Sunol Blvd.

LEG TWO

Pleasanton to Hayward via Dumbarton Bridge

27.6/2.1 EBMUD Water Temple-Intersection of Niles Canyon Road and Pleasanton-Sunol Blvd: Turn left (east) toward Hwy 680. Following signs to Highway 84 EAST, go under the freeway, loop around to the
28.3/0.7 right and onto the 680 north/84 east on-ramp. Immediately thereafter take 84-east exit [Vallecitos Road-Livermore.] Follow Vallecitos Road east to Vallecitos Nuclear Center.

About 1 mile from Hwy 680 Vallecitos Road crosses the Maguire Peaks Fault. This fault shows post-Miocene, pre-Pleistocene vertical displacement, the western block being upthrown. The fault trace parallels the Calaveras-Sunol fault but is concealed by the Livermore Gravel flood-plain deposits.

30.5/2.2 Vallecitos Nuclear Center: (No Stop). This nuclear center has been closed due to its proximity to the Maguire Peaks Fault.

Continue back to Int. 680 along Hwy. 84.

32.1/1.6 Junction Hwy. 84/Int. 680; follow 680 south towards Fremont to the Durham Road exit.

Along the way, 680 traverses the NW trending Mission Pass Syncline followed by the overturned Vargas Anticline. Near the core of the syncline, middle to lower Cretaceous marine sediments (Niles Canyon, Oakland Fm.) are exposed, followed by middle to upper Miocene rocks including the near-shore, transgressive Briones Fm. sandstone, the overlying Cierbo Fm. Above that are found fresh water sands and gravels of the Orinda Formation.

Decending into the Fremont area, 680 crosses the Mission Fault at the base of the hills immediately east of Fremont (near the Mission Blvd. exit). The fault is a vertical or high-angle reverse fault having approximately 1000 feet of dip-slip displacement, upthrown to the east. The trace of the fault parallels the base of the hills, and may represent the southern extension of an eastern branch of the Hayward fault (Hall, 1958) although no strike-slip evidence has been found. The fault locally separates middle and upper Miocene sediments from quaternary deposits of the S.F. Bay Area basin.

West of the Mission Fault lies the Hayward Fault Zone which is known to have produced large earthquakes in the past (eg. 7.0 ± 0.5 M in 1868) and is now actively creeping (Greensfelder, 1972). This fault zone trends NW, extending beyond Berkeley to south of San Jose. Recent movement along this fault is right-lateral and is responsible for many stream offsets and street offsets. Right lateral displacement has been at least 1200 feet since Late Pliocene/Early Pleistocene time.

39.6/7.5 Durham Road Exit off Hwy 680: Take Durham Road west to the first corner, where Durham Road stops and Osgood Road begins.

39.9/0.3 <u>Stop 4</u> Corner of Durham Road/Osgood Road:

Bob Nason of the USGS will discuss recent fault evidence near P.G.&E power lines.

Continue north on Osgood Rd. to old Gallapogos Winery ruins, just before the intersection of Osgood Road and Washington Blvd.

41.4/1.5 <u>Stop 5</u> Osgood Road just south of Washington Blvd:

Parking space available on the left, the Gallapogos Winery ruins are on the right. Bob Nason will continue discussion of recent Hayward Fault movement as evidenced by displacement of foundation pillars.

Continue west on Washington Blvd. to Fremont Blvd. (about 0.3 miles from last stop). Follow Fremont Blvd. by veering to the right. Proceed to Grimmer Blvd.

42.2/0.8 Intersection of Fremont Blvd. and Grimmer Blvd: Turn right onto Grimmer. Follow Grimmer north to Hetch Hetchy aqueduct, just before the T-intersection of Grimmer and Paseo Padre Parkway.

42.6/0.4 <u>Stop 6</u> Hetch Hetchy aqueduct near the intersection of Grimmer and Paseo Padre:

Parking space is limited. A suggestion would be to turn left on Paseo Padre and park on the first available side street if space isn't available at or just before the intersection.

More recent fault evidence can be seen here.

Continue west along Paseo Padre Pkwy. to Mowry Avenue.

44.2/1.6 Turn right onto Mowry Ave. Follow Mowry to Peralta Blvd.

44.9/0.7 Turn left onto Peralta, following signs to Dumbarton Bridge/Hwy. 84. Look for Shinn Ave. on right shortly (Approx. 0.1 miles).

50.0/0.1 Turn right onto Shinn Ave. Head north to end of street and park on right.

50.2/0.2 Stop 7 End of Shinn Ave: Recent fault evidence is present along the guard rail bordering the railroad tracks here.

Continue back to Peralta Blvd. and on to the Dumbarton Bridge.

51.9/1.7 Intersection of Peralta Blvd. and Fremont Ave:

Turn right onto Fremont Ave., follow Fremont to Thornton (first lighted intersection) whereupon make a left turn, following the signs to Dumbarton Bridge/Hwy 84.

56.8/4.6 Dumbarton Bridge Tollgate: Go through tollgate to the construction area at the eastern end of the bridge.

The hills here and to the north are composed of Franciscan sediments exposed immediately west of the concealed NW-trending Silver Creek Fault.

59.6/2.8 Stop 8 Dumbarton Bridge construction site: Parking area at equipment/supply yard on right just before bridge.

Adlai Goldschmidt of Caltrans will discuss problems and techniques of the Dumbarton Bridge construction in San Francisco Bay mud.

Continue on to Hayward by following Hwy 84 back through the toll plaza to Jarvis Ave., the first main intersection.

62.9/3.3 Intersection of Thornton Ave. (Hwy 84) and Jarvis Ave: Follow Jarvis eastward over Highway 17 (Nimitz Freeway) whereupon Jarvis Ave. becomes Decoto Road (approximately 2.9 miles from Thornton/Jarvis intersection). Continue east on Decoto to Mission Blvd. (Hwy 238).

68.6/5.7 Intersection of Decoto Rd. and Mission Blvd: Turn left onto Mission Blvd. and follow to Hayward.

The Hayward fault zone runs parallel to Mission Blvd. along the base of the hills immediately to the east. Here the fault zone separates Franciscan marine sandstones and shales of Jurassic (?) age forming the hills to the east from Cretaceous sediments to the west. Further north, Franciscan rocks are found on either side of the fault, and are locally intruded by the Pliocene Leona Rhyolite (Case, 1963).

The Franciscan unit east of the Hayward Fault zone is an upthrown block bordered on the east by the Chabot Fault, located in the Hayward-Fremont hills a few miles east of the Hayward fault zone. East of this fault Cretaceous marine sediments are seen.

The Chabot Fault parallels the Hayward Fault Zone and may be considered a southern extension of this zone from Hayward. At Hayward, the two faults become increasingly complex and essentially are part of one large shear zone.

Evidence of movement along the Hayward Fault Zone may be seen along Mission Blvd., where vegetation contrasts mark the fault trace because of groundwater seepage.

Continue along Mission Blvd. to downtown Hayward.

74.5/5.9 Intersection of Jackson St. (Hwy 92), Foothill Blvd (Hwy 238), and Mission Blvd. (becomes Hwy 185): Follow Mission Blvd.; to stay on Mission approach this intersection in the left lane. One block past this intersection is D Street, the next stop.

74.6/0.1 Stop 9 Intersection of D Street and Mission Blvd: Park either along Mission Blvd. or along D Street after turning right off of Mission.

Active right-lateral creep in the Hayward Fault Zone is indicated by curb-offsets, foundation cracks, etc. at two places along D Street in this block.

Continue up D Street. (or some other) to Foothill Blvd. which runs parallel to Mission Blvd. a few blocks to the east. Turn left onto Foothill Blvd. and follow it to Hazel Avenue which borders the parking lot north of Capwell's Department store.

75.4/0.8 Stop 10 Far northwest corner of Capwell's parking lot along Hazel Avenue.

More recent fault creep evidence in the Hayward fault zone can be seen in the foundation abutments of the Hazel Ave. Bridge which crosses the San Lorenzo Creek behind Capwell's. After a short walk to the west across the bridge, more creep effects can be observed on Sunset Blvd. and Rose St. a few blocks away between Mission Blvd. and Main Street. Here curbs and sidewalks dramatically show the effects of right-lateral movement.

End of trip: Follow Foothill Blvd. to Freeway 580. Signs will direct you to S.F. or Walnut Creek/Concord.

References

Case, James Edward (1963). Geology of a Portion of the San Leandro Hills, Calif. M.S. Thesis, U.C. Berkeley. (unpublished).

Hall, Clarence (1958) Geology and Paleotology of the Pleasanton Area, Alameda and Contra Costa Counties, California, University of Calif. Publications in Geological Sciences, vol. 34, p. 1-85.

Huey, Arthur (1948). Geology of the Tesla Quadrangle, California. Calif. State Div. of Mines, Bulletin 140, 75 pp.

Greensfelder, Roger (1972). Crustal Movement Investigations. Calif. Div. of Mines and Geology Special Publication 37, 25 pp.

ENGINEERING GEOLOGY CONSIDERATIONS IN TRANSMISSION LINE SITING STUDIES

By

RAYMOND L. BLUM

Senior Engineering Geologist

Siting Department

Pacific Gas and Electric Company

and

LARRY G. PATZKOWSKI

Engineering Geologist

Department of Engineering Research

Pacific Gas and Electric Company

INTRODUCTION

The geologic environment is but one of many factors considered in transmission line siting studies. This paper describes the role of engineering geology in the appraisal of high-voltage transmission line corridors. Such appraisals include specific route alignment and individual tower location siting studies. Potential geologic hazards are broadly considered throughout the siting process, but generally become a more critical factor once specific transmission line alignments and tower sites are preliminarily located using other siting parameters. Most potential geologic hazards can be avoided by prudent siting of towers.

This paper briefly reviews the transmission line siting process and provides examples as to where engineering geology considerations are brought to bear in that process. Several specific potential geologic hazards that often emerge in the siting of transmission lines are discussed. These include:

- Surface faulting
- Ground motion (shaking) effects of earthquakes
- Landsliding and slope stability
- Erosion and drainage considerations

Following the discussion of specific geologic hazards are a few comments on line undergrounding concepts as related to geologic conditions.

Geotechnical aspects of the Tesla-Lawrence Lab 230 kV Tower-line are briefly discussed in the appendix to this paper.* The appendix can also serve as a discussion guide for the May 5, 1979 field trip.

TRANSMISSION LINE SITING PROCESS

Pacific Gas and Electric currently utilizes a transmission line siting process consisting of five discrete phases or steps.** The first phase is project definition wherein project need, along with power plant and electric delivery points identification, serve to block out a geographical study region.

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*This particular example locationally fits the field trip agenda, but since there were few geotechnical problems the example is <u>not</u> a good representation of the geotechnical applications in the siting process described herein.

**See Figure 1, attached.

The second phase consists of a regional assessment, i.e., a study of the geographical region lying between the generating power plant and delivery "end" points or substation where the power is needed for redistribution.

The main product from the regional assessment is the identification of study corridors. Several alternate study corridors are often identified within a given region. These corridors are typically rather wide, extending as two- to three-mile-wide swaths through the region and connecting the terminal points mentioned above. Initially, the corridor concept follows a basically direct (often straight) line between those points, but in practice the final alignment is often altered ("jogged" or "dog-legged") by cultural and physical constraints such as state or national parks, large lakes, airports and urban centers. Generally, geologic constraints do not grossly affect study corridor selection for two reasons: (a) physical constraints to safe and reliable tower line construction are surprisingly few (discussed later herein), and (b) the study corridors are of sufficient width to accommodate route deviations to avoid most geological problems that might be identified in subsequent phases of more detailed study.

The third phase of study is comprised of fairly detailed corridor analysis. It is at this point in the siting process where important applications of engineering geology are most often first exercised. The primary purpose of corridor analysis is to identify or select a "preferred" corridor within which a specific or "optimum" alignment for the tower line would ultimately be mapped. Preferred corridor selection is based upon many land use and environmental considerations, but does include the concept of avoiding potential geological hazards that could result in unstable or unreliable tower foundations.

In the realm of engineering geology, constraints and potentially hazardous areas that are most often considered include zones of "active" or relatively recent faulting, areas of active landsliding, unstable slopes, problem foundation areas (e.g., marshes or other soft deposits), flood plains and areas prone to tower footing erosion. Literature, map and aerial photo studies are initiated at this point in the siting process in order to identify specific locations of potential geologic hazards or constraints. This is often supplemented with one or several reconnaissance fly-overs via helicopter or fixed-wing aircraft. Usually, within a given corridor, geologic hazards--once identified--can be mitigated by special engineering applications or be physically avoided by slightly altering the alignment of the proposed towerline within the preferred corridor. Thus, in the corridor analysis step, engineering geology assessments are used to alert the routing engineer as to the locations and range of potential severity of any geotechnically troublesome areas.

The fourth phase of the siting process identifies alternate routes within the corridor(s). The main goal is to select the single ("optimum") route that best meets all of the land use, economic, environmental and other siting parameters specified in the overall siting program. Trial route layouts require a rather close profiling of the topography in order to determine if ground clearance of the future overhead lines can be met. This in turn leads to individual tower site location considerations.

This step in the siting process lends itself well to direct field examinations wherein the engineering geologist and the routing engineer together walk over the route and field-check tentative tower locations. This also provides a first-order check on the areas previously identified as being potentially geotechnically troublesome. Individual tower sites are checked for topographic and geologic (usually foundation) suitability. The feasibility of possible mitigation measures-including slight locational shifts--are field-assessed. Practical and direct application of engineering geology is thus a key element of the siting process at this stage. Known or suspected fault traces previously identified are field-examined, as are landslide and questionable foundation areas. This provides some "feel" for the recency or severity of the problems and offers an "on the ground" opportunity to examine the feasibility of spanning, routing around or otherwise mitigating potential geological hazards. In case of shallow landsliding, slumping or soil creep, special deep footings are often more practical and economical than an alighment or tower location shift.

The fifth and final phase of the siting process is right-of-way acquisition and selective clearing of vegetation prior to construction. In some cases, clearing of dense vegetation reveals additional geological questions. The route or field engineer will in these instances call upon the engineering geologist for additional assessments.

This, then, briefly describes the transmission line siting process and the role that engineering geology plays in that process. Before going on to discuss some of the specific applications and methodology used to geotechnically appraise transmission corridors and routes, we would reiterate here one important, but often under-emphasized aspect of siting transmission lines: Geologic hazards do not constrain towerline locations to the extent that they do other structures. For example, faults very often occupy topographic lows while tower locations take advantage of topographic highs for purposes of overhead line ground clearances. As a consequence, towers are rarely sited on faults and the fault areas are simply spanned by the overhead lines. Likewise, small active landslide areas can be successfully spanned by judicious utilization of topographically high tower locations. Finally (as will be developed later in this paper), tower structures' configuration and physical flexibility provide a large inherent damage-resisting capability in terms of accommodating strong earthquake-induced ground motions.

SPECIFIC GEOLOGICAL HAZARDS CONSIDERATIONS

Given the background information developed in the preceding section, we will next discuss in more detail some of the specific methodology applied to both identify and mitigate potential geologic hazards.

Surface Faulting

PGandE's service territory is geographically very large, encompassing 48 counties in 94,000 square miles. Numerous fault strands of many fault systems of diverse degrees of "activity" are thus encountered during our overall siting studies. In the Bay Area we must deal with zones and individual strands of the San Andreas fault system. Many of these features have been historically active and some are undergoing fault creep. Industrial and residential development and the associated need for power do not totally "respect" fault locations; thus of necessity transmission lines must sometimes cross fault strands, zones and systems.

The first step of course is the identification and mapping of faults and fault-like features. Both office and field studies are applied. Initially, published and unpublished maps and reports are obtained and reviewed. Additionally, meetings are sought with geologists from other agencies (USGS, CDMG, universities, consultants) who have had experience in the region of study. Aerial photos and other available imagery are utilized to identify suspect lineaments and faults. This data is plotted, along with corridors, routes and tentative tower locations, onto topographic base maps at an appropriate scale. These working maps are then taken to the field where fly-over and walk-over reconnaissance serves to more precisely assess the locations and nature (severity) of surface faulting potential.

After potentially hazardous areas of surface faulting are fairly precisely located, the impact from future activity can be minimized by avoiding the direct placement of individual towers on identifiable fault traces and positioning the transmission line alignment to cross the fault at a wide, preferably right angle. This allows reasonably large ground displacements to be accommodated by the flexure capability of the line itself. Suspension insulators fitted to towers adjacent to fault zones can add further flexibility.

Ground Motion (Shaking) Effects of Earthquakes

Generally speaking, ground shaking effects of earthquakes have caused much (many times over) more damage to structures than has surface faulting. Transmission towers, however, are unique structures that have historically performed extremely well during earthquakes. Past damages to transmission towers have been to our knowledge exclusively limited to foundation, not structural failure.*

The reason that towers have an extremely low probability of seismic failure is that they are designed to withstand large lateral forces from wind and broken conductor loads.

In a report on the 1971 San Fernando earthquake, the City of Los Angeles Department of Water and Power attributed the lack of damage caused by ground acceleration alone to the high wind loading criteria used in the design of the towers and to the hinge effect of the suspension insulators which support the conductors.

Since the 1971 San Fernando earthquake there has been increased interest in the seismic resistance of all electric facilities, including transmission lines. As a result, dynamic analyses of various transmission towers have been performed.

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*In the San Fernando earthquake in 1971, damages were reported to more than 100 towers, but in nearly all cases, this stemmed from ground displacement or landsliding. Most repairs consisted of grading, backfilling and compacting the soils around the footings.

In a paper in the IEEE Transactions on Power Apparatus and Systems, L. W. Long of Duke Power Company presented results of dynamic analysis of typical 230 kV towers which demonstrated that ground shaking produces no overstress in transmission structures designed in conformity with the National Electric Safety Code. Towers used by PGandE are designed to the loading criteria of CPUC General Order 95, rather than the National Electric Safety Code. However, the loading conditions of the two codes are generally comparable.

In order to quantify the amount of ground shaking a typical PGandE tower might be expected to withstand, a pseudo-dynamic analysis of a 230 kV double-circuit tangent tower was performed recently, in connection with the New Melones-Warnerville line. As is our practice, this tower had been designed to withstand the lateral loading resulting from a 58 mph wind acting on the conductors and tower body, together with the unbalanced pull resulting from two broken conductors, with a safety factor against collapse of 1.5. Since neither extreme wind loading nor broken conductor loading would be expected to occur at the same time as an extreme earthquake, the full, ultimate lateral load carrying capacity of the tower was considered to be available to resist earthquake loading. Results of the study indicated that the tower would withstand a ground acceleration of about 0.9 g. In addition, it was found that the tower could undergo a differential footing displacement on the order of several inches and still be able to resist ground accelerations of over 0.5 g, demonstrating its ability to withstand substantial shaking even after being damaged by possible ground movements. The results of a dynamic analysis of a double circuit tubular structure designed for the same loading as the New Melones-Warnerville latticed tower indicate that the tubular structure can withstand a ground acceleration of about 1.0 g as compared to 0.9 g for the latticed tower.

In summary, ground shaking effects on tower structures are not considered to be a geologic hazard which would substantially constrain the location of a planned transmission line. Potential ground shaking effects on footing foundations, however, re-emphasizes the importance of siting towers on stable materials.

Landsliding and Slope Stability

Landsliding and slope stability considerations are of paramount importance in the siting of transmission towers.

As with surface faulting, the identification (location mapping) and assessment of "activity" or severity is followed by developing feasible mitigation measures.

As pointed out earlier, simple avoidance of active landslide areas is the most straight forward approach. Relatively long span capabilities allow placement of transmission lines through smaller slide areas in a manner where the slide itself is spanned and the supporting tower structures are sited away from the lateral slide boundaries.

Route alignment changes may be required in the case of larger active slides. Deviations in alignment can be costly, since heavier towers are needed at sharp angle points. Thus, some cost versus "risk" judgement is often necessary and in these cases more detailed field studies including exploratory drilling to define the depth of sliding are justifiable. Special deep-drilled footings can be effectively utilized in cases of shallow sliding or slope "creep" and ravelling.

In cases where it is necessary to locate a transmission line through extensive landslide areas, one approach is to attempt to sub-classify the sliding terrain into smaller, discrete slides that may range in activity from active through dormant. If realignment is adjudged unfeasible or cost-prohibitive, towers are sited in the dormant slide areas and the more active areas are spanned. There is some degree of risk in this approach, but successful examples can be cited. The Fulton-Lakeville line along the west slopes of the Sonoma Mountains near Santa Rosa crosses large unstable masses interspersed with naturally stabilized or dormant slides. Selective tower placement on these dormant bodies has resulted in a highly satisfactory towerline service history of many years. Other cases can be cited where lines cross Franciscan melange containing isolated resistant outcrops surrounded by slumping unstable groundmass. The same selective approach to siting individual towers has been successfully applied in this terrain.

Erosion and Drainage Considerations

Erosion and drainage considerations do not generally dictate choice of alignment during the siting process but do become important geologically related factors during and following construction. Construction access roads in steep terrain can cause significant environmental and visual impacts. Tower sites themselves generally do not require grading since lattice tower legs can be adjusted to fit the existing topography.

The engineering geologist can greatly aid the routing and construction engineers in assessing the severity potential and developing mitigation measures for access road construction impacts. The general approach is to minimize the extent of new grading and its concomitant disturbance of topsoil. Existing fire trails, ranch roads and access roads to parallel tower lines are utilized to the extent possible. Where applicable, ridge-top fire trails can be improved and temporary spur segments to tower locations are built to side-hill tower sites. After construction, these spurs are "put to bed" or restored to a near original condition by regrading and reseeding. In rare cases of extremely steep topography coupled with easily erodable materials (e.g., decomposed granite at high elevations), helicopters are employed to transport and position towers, thus, eliminating the need for new road construction. This is an expensive operation, however, and carries with it scheduling problems during stormy or windy weather.

Preconstruction planning of access road routes must include careful considerations of culvert placement, drainage bars, ditches and rock rip-rap to minimize erosion and siltation. Overly steep newly graded cut banks in unstable slope areas often present problems in terms of bank sloughing or sliding. One problem with cut slope flattening or benching to achieve more cut stability is that such a measure in steep country results in a much larger cut which causes a long-term scar on the hillside. This is especially true where exposure by grading presents a major color contrast between the underlying soils or rock and the naturally weathered or vegetated surface. There are thus "tradeoff" considerations involving environmental, aesthetic, engineering road design and road maintenance cost values.

It can be seen from the above that it is important to assess the general soils' environmental situation along proposed transmission lines and associated access roads. A first step towards such an assessment is to consult published maps and surveys by the Soil Conservation Service. These surveys provide useful classification categories that describe soil thickness, texture, fertility, permeability and erosion hazard index. Aerial photo based soils maps are useful tools that the geologist should have in hand during field reconnaissance of access road layout. Topsoils should be considered valuable commodities that have taken many years to develop. They should not be wasted by being allowed to uncontrollably wash into streams where the resultant silt load would have detrimental effects on the aquatic environment.

Headward gully erosion, either naturally occurring or man-induced (by altered drainage) can cause erosional damages to tower footings. Field experience in the vicinity of Petaluma has shown that the bedrock there - unconsolidated Petaluma formation - is so susceptible to gullying that several proposed tower sites required location shifting to avoid future undercutting of footings. In other cases, standard mitigation measures including rip-rap and interceptor ditches can be successfully applied. Long-term erosional effects of slope alteration by access road construction is in many cases difficult to judge; hence, it is not uncommon that the geologist is called back months or years later to advise on remedial measures for erosional problems, which may have developed.

Geologic Considerations Related to Transmission Line Undergrounding*

In cases of special aesthetic sensitivity (often urbanized areas) to new transmission lines, the utility is sometimes pressured to "underground" the line. There is a significant cost penalty for such an approach since both the methodology and the field transition installations from overhead to underground are extremely expensive. In addition, underground conduit is much more susceptible to earth movements that may occur in areas of landslide, slump, settlement or fault displacement and/or fault creep. The undergrounding approach is "through-going", thus, the opportunity to span unstable foundation areas is lost. Topographic constraints also are magnified by the undergrounding concept because of the difficulty in trenching and backfill operations on steep slopes. Access roads to provide for trenching/cable laying/ backfill machinery would be extensive, costly and would have many more direct physical impacts on the environment than would overhead lines.

The additional exposure to geotechnical hazards in the undergrounding approach requires much more detailed field investigations. Exploratory trenching, drilling and large scale mapping of slides and surface fault traces are essential elements of the preliminary field studies.

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*Not to be confused with distribution line undergrounding which is a relatively common practice.

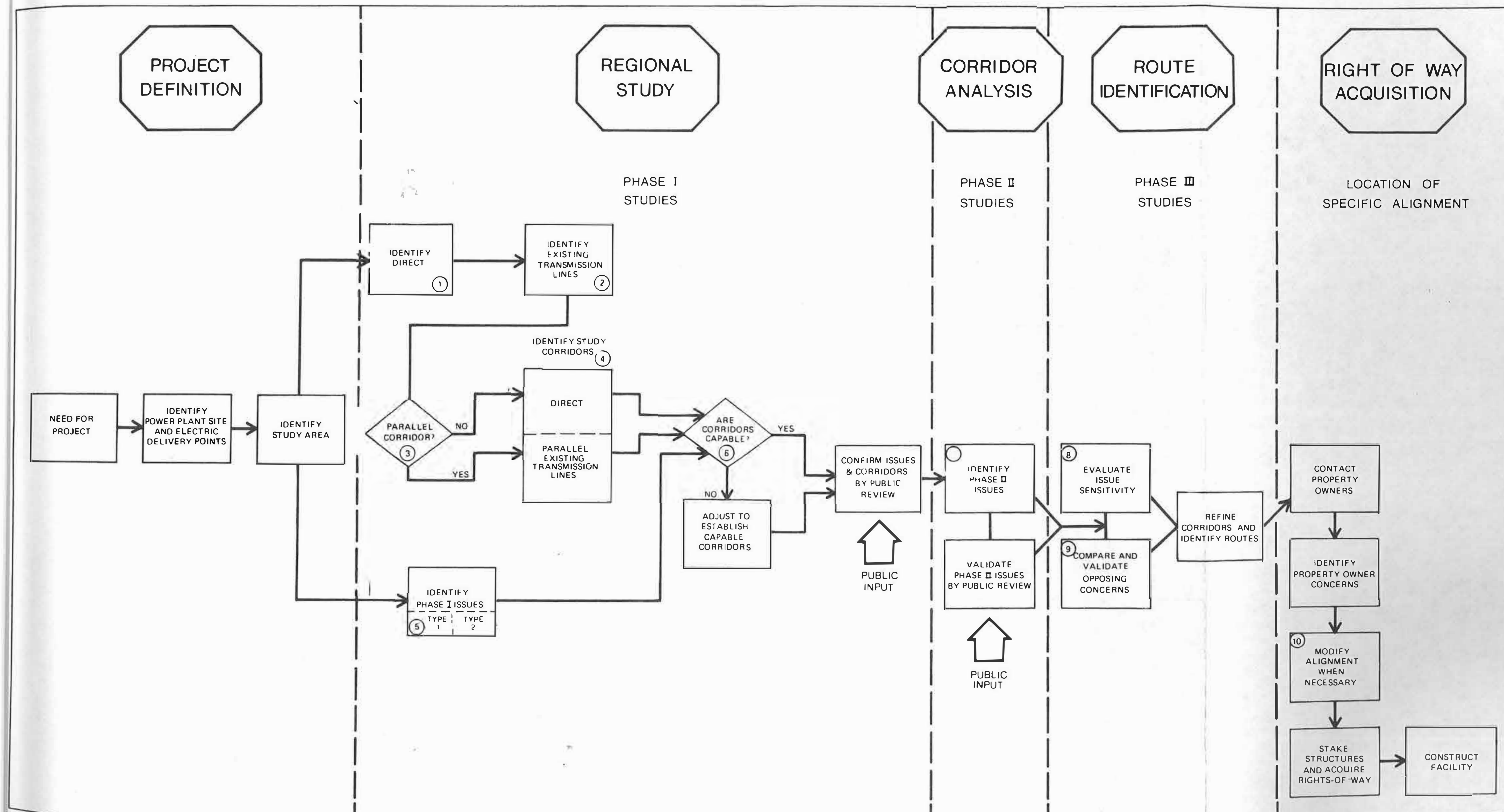
Summary

This paper has described the importance of engineering geology considerations in the transmission line siting process. We have attempted to show how early involvement of the engineering geologists can benefit both the utility and the public by the ultimate achievement of siting more reliable, economic and environmentally acceptable transmission lines.

In addition to the geological aspects of the siting process itself, there are many geotechnical requirements in the permitting and approval process of transmission line proposals. Environmental assessments, impact statements and other reports are prepared and submitted to regulatory bodies including the California Public Utilities Commission (CPUC), the California Energy Commission (CEC), and the Federal Energy Regulatory Commission (FERC). These data requirements call for descriptive and graphical representations of the projects' geology, potential geologic hazards, paleontological and mineralogical resources.

Finally, as stated earlier in the body of this paper, temporal changes in the geological environment can result in tower line maintenance problems which require even further services of the engineering geologist.

TRANSMISSION SELECTION PROCESS--SEQUENCE OF EVENTS



NOTES ○

1. Most direct may present the best opportunity resulting in fewer impacts and least cost
2. Existing transmission lines may present special opportunities for new transmission line locations
3. Decide whether to parallel an existing transmission line or to use the most direct route
4. Width may vary with length - a connection of only several miles would use narrower study corridor
5. Sensitive environmental and land use areas of regional or statewide significance which could influence the location of a wide corridor.
6. Corridors which will yield at least one suitable route by avoidance or mitigation of sensitive
7. Sensitive environmental and land use areas (including Phase 1 issues) within the corridor which influence the location of a transmission route
8. Evaluate sensitivity to determine if avoidance or mitigation is necessary
9. Public concerns for mitigation or routing adjustments
10. Weigh and balance environmental, land use, engineering and economic factors

FIGURE 1

APPENDIX

TESLA-LAWRENCE LAB 230 KV T/L

Environmental Setting

The study area is part of the Central Coast area of California. It is located in the east central portion of the Diablo Range and on the eastern edge of the Livermore Valley. This range is the driest of the central coast ranges and is typified by cattle ranching and the production of winter grains. The following descriptions highlight the primary elements in the environmental setting.

Topography

The topography varies from level grassland surrounded by low rolling hills at Tesla Substation to moderately steep, rolling foothills along the existing tower lines to an alluvial plain bordered by gently rolling terraces near Greenville Road.

Soil

The eastern end of the project area contains the Clear Lake-Synnyvale Association. Erosion hazard is slight.

The western part of the project area has the Rincon-San Ysidro and Positas-Perkins Associations. This association is susceptible to land slips on steeper slopes.

Regional Geology and Seismicity

The study area lies within the north central part of the Coast Ranges geologic province, which is characterized by a series of subparallel mountain ranges and inland valleys with general northwesterly trends.

Rock units exposed in the vicinity of the study area are from recent gravel and clays found in the Livermore Valley, late Pliocene Livermore Formation gravels on the Livermore Valley margins, early Pliocene Orinda Formation sandstones and siltstones in the Dougherty Hills to the north, and Cretaceous sandstones and shales of Pleasanton Ridge and the Altamont Pass areas. Older Franciscan formation rocks are exposed in the region at Mount Diablo and the highlands south of Livermore-Pleasanton.

The project is within the San Francisco Bay region which is characterized by both abundant and frequent earthquakes (Brown 1971). During historic times, damaging earthquakes have occured in the area, notably the 1906 San Francisco earthquake orginating on the San Andreas fault, magnitude 8.3 on the Richter Scale.

The San Andreas fault system , including its major branches, the Hayward and Calaveras faults, is most likely the source of possible future damaging earthquakes in the Bay Area. Greensfelder (1974) has estimated the maximum credible rock acceleration for areas of California. The project area lies within a zone of maximum credible rock acceleration of 0.3 to 0.4 g based upon proximity to known historic and Quaternary faults. A map prepared by Jennings (1975) indicates several Quaternary faults near the project area as well as the active branches of the San Andreas fault system. The following table gives relative location of these faults to the project area.

Several pre-Quaternary faults, including the Patterson Pass, Corral Hollows, Carnegie, and Greenville faults traverse the project area (DWR 1966).

None of the faults in the project alignment are known to be associated with historic surface rupture; therefore, this potential geologic hazard can be considered low. Moderate to strong ground shaking is anticipated during the life of the project.

Fault	Distance and Direction From Project Area Center
Active Faults[1]	
San Andreas	70 km SW
Hayward	38 km SW
Calaveras	30 km SW
Quaternary Faults[2]	
Tesla	4 km SW
Midway	4 km NE
Livermore	15 km SW
Verona	24 km SW
Pleasanton	27 km W

1. Active faults - recognized historic (last 200 years) movement as evidenced by surface rupture, fault creep, displaced survey lines.

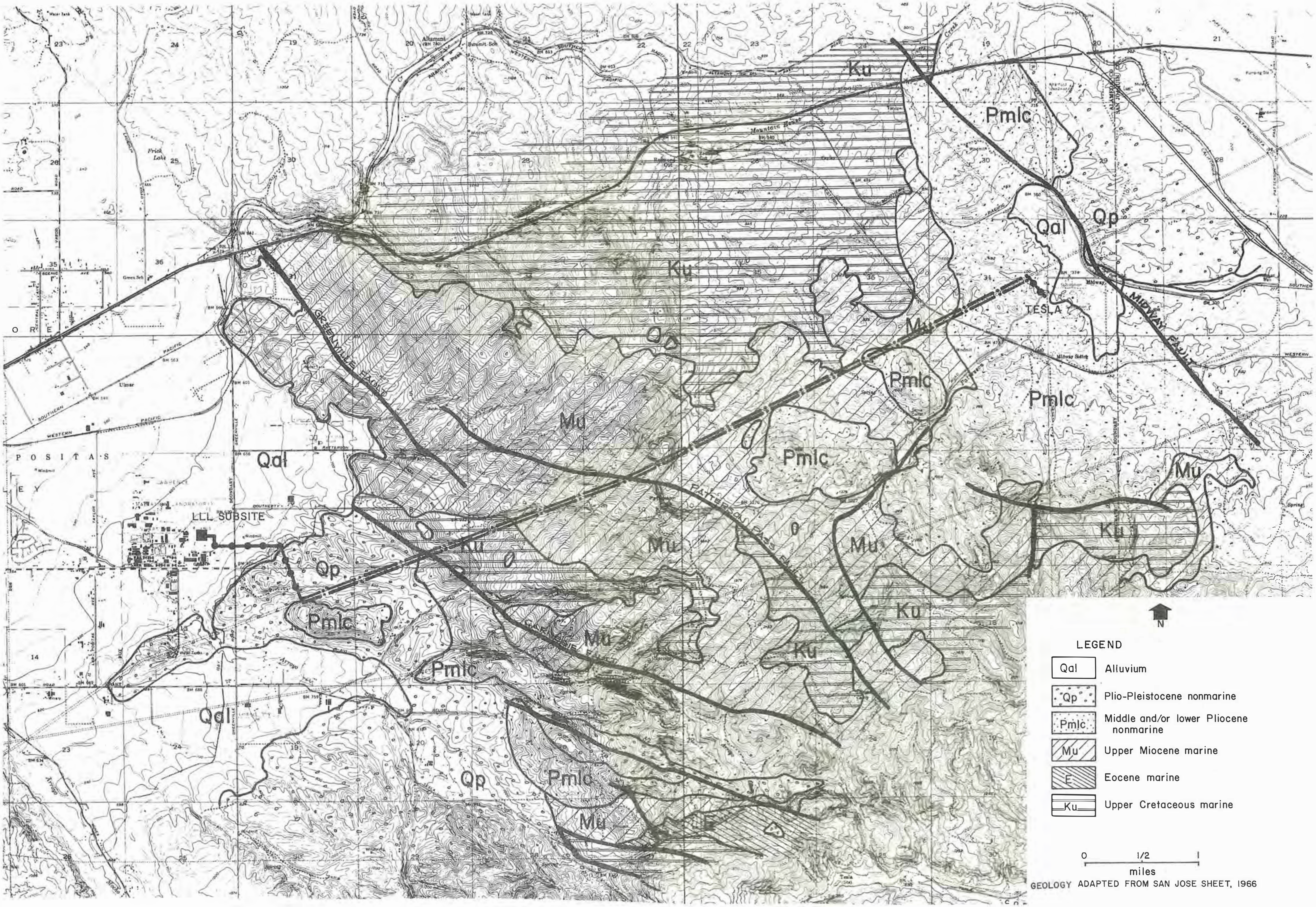
2. Quaternary faults - recognized movement during last two million years as evidenced by topographic features.

Slope Stability and Erosion Hazard Assessment

A field inspection of the proposed project was conducted in order to assess the present slope stability and erosion hazard along the alignment of the Tesla-LLL 230 kv T/L in the Livermore Hills, southeastern Alameda County. The proposed project involves setting wooden poles at Tesla Substation and in the vicinity of Lawrence Livermore Laboratory in order to tie-in and conductor an existing steel tower alignment. The bulk of the project has steel towers erected and an access road system constructed. Limited new access will be required at both ends of the project in gentle terrain.

The field inspection indicated that no areas of significant mass wasting will be involved at existing tower sites or proposed pole locations, although some areas of slope distress will be spanned by the alignment, especially along steeper draws, and areas shown on a map prepared by Nilsen (1972). Two towers in Section 2 and 10, T.3S., R3E., MDBM, located in an area mapped as landslide (Nilsen 1972) appear satisfactory. The large landslide area appears dormant.

Surface soils are generally clayey and expansive and are subject to some downslope creep. Present erosion appears to be confined to existing gullies and draws along intermittent water courses. Existing access roads in the project area show no undue signs of accelerated erosion. The hazard of soil erosion and landslides along the project alignment is slight.


Ku
Pmlc
Qal
Qp
Mu
E
TESLA
LLL SUBSITE
GREENVILLE FAULT
MIDWAY FAULT
LEGEND
Qal Alluvium
Qp Plio-Pleistocene nonmarine
Pmlc Middle and/or lower Pliocene nonmarine
Mu Upper Miocene marine
E Eocene marine
Ku Upper Cretaceous marine
N
0 1/2 1
miles
GEOLOGY ADAPTED FROM SAN JOSE SHEET, 1966

REFERENCES

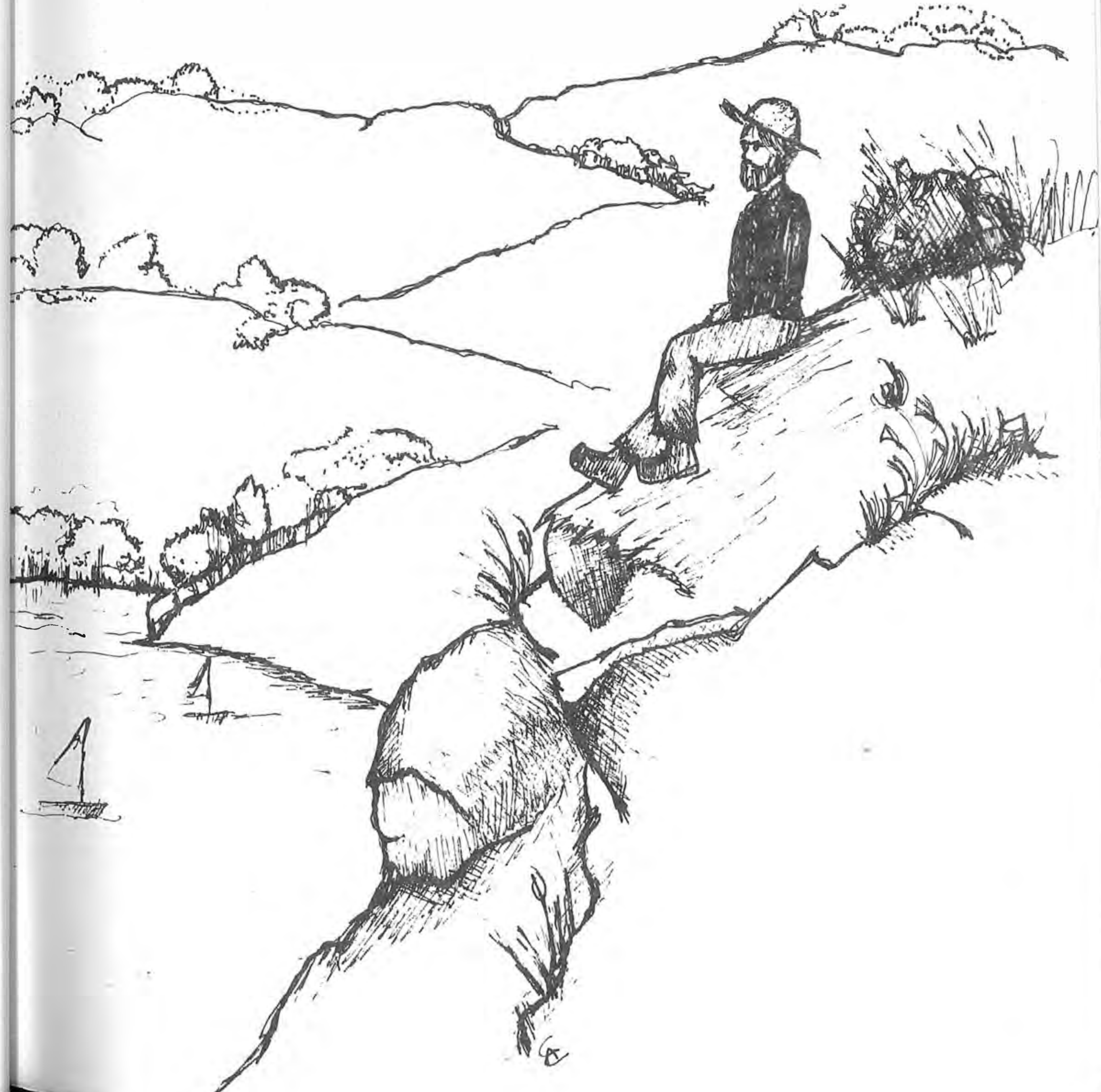
1. Brown, R. D., Jr. and Lee, W. H. K.. 1971. Active Faults and Preliminary Earthquakes Epicenters (1969-1970) in the Southern Part of the San Francisco Bay Region. Basic Data Contribution 30 U.S. Geological Survey.

2. Department of Water Resources. 1966. Livermore and Sunol Valleys Evaluation of Groundwater Resources. Appendix A: Geology, Bulletin No. 118-2.

3. Greensfelder, Roger W. 1974. Maximum Credible Rock Accelerations from Earthquakes in California. Map Sheet 23. California Division of Mines and Geology, San Francisco.

4. Jennings, C. W., and others. 1975. Fault Map of California with Locations of Volcanoes, Thermal Springs, and Thermal Wells: California Division of Mines and Geology, Data Map Series, Map No. 1.

5. Nilsen, T. H. 1972. Preliminary Photointerpretation Map of Landslides and Other Surficial Deposits of Parts of the Altamont and Carbona 15-Minute Quadrangles, Alameda County, California (Miscellaneous Field Studies Map MF-321) from San Francisco Bay Region Environment and Resources Planning Study, Basic Data Contribution 34, HUD.



THE LIVERMORE BASIN

DICK DARROW
CHEVRON U.S.A., SAN FRANCISCO

As the earth's American and Pacific Ocean crustal plates drift by one another, the prime break is the San Andreas fault. But because of the irregular boundaries of the plates, a zone of structural activity is formed, and sedimentation adjusts very quickly. The sediment cover, ever changing and responding to the stresses and strains beneath, is our visual reference.

The Livermore basin is one of several deep sedimentary troughs that formed within the influence of the San Andreas system. It is filled primarily with late Miocene and Pliocene sediments. It shows the results of tensional (rapid sedimentary fill) and compressional (long linear folds and faults) forces caused as the irregularities of the crustal blocks moved by each other.

The complex nature of the basin fill is confirmed by the results of a valiant attempt by Cities Service Oil Company in 1973 to prospect for Eocene and Cretaceous sediments. The exploratory hole was drilled in Section 7 of T2S R1E, and logged to 17,404 feet, apparently still in Miocene age strata with the bottom hole sediments tilted up to 80 degrees.

Our present view of the Livermore basin, as shown in Figure 1, is a triangular shaped area about 26 miles high and 14 miles wide at its base. It is bounded on the north-northeast by an intruded and uplifted block of Cretaceous sediments we know as Mount Diablo, on the west-southwest by the Sunol-Calveras branch of the San Andreas fault system, and on the Southeast by the portion of the California coast range referred to as the Hamilton Mountain Franciscan Complex.

The Livermore valley area, perhaps known more for its fine wines than its geology, has been of interest to seismologists and geologists since an 1868 earthquake when springs containing some hydrocarbons began flowing along faulted areas northeast of the town of Livermore.

The valley has had the exploratory and drilling attention of many independents as well as Buttes, Texaco, Hancock, McCulloch, Standard of California, Exxon, and most recently, Cities Service oil companies.

McCulloch Oil Company is credited with finding the only commercial oil accumulation to date. The field area lies just east of the town of Livermore, is about 125 acres in size, and was discovered in 1967. The oil is 28° API gravity and the ultimate recovery of the field is estimated at 1.7 million barrels.

General Geology

The Livermore Basin, like many "active" areas, has experienced almost continuous sedimentary and structural changes since its inception. In Cretaceous time, the area was part of an ocean basin.

Toward the end of the Cretaceous period, Mount Diablo had already experienced a great deal of uplift and erosion. By the Paleocene and Eocene epochs, the Livermore area was a broad shelf that gathered shallow marine and swampy sediments. The San Andreas fault system was soon to actively break and alter the edge of the American crustal block.

One of the large irregularities near the edge of the drifting American block caused the formation of a deep trough that continuously filled with Miocene and Pliocene sands and shales. As the irregularity either drifted past, or changed shape, the sediment filled trough, in attempting to re-close, began the long history of progressively folding and faulting the young sediments. Some even appear to have been forced out onto the surrounding surfaces.

A large diabase intrusive mass at Mount Diablo asymmetrically forced its way up through the Cretaceous and Tertiary sediments, stretching and tilting them to the extent that along that side of the basin, sedimentary layers were pushed to vertical and overturned positions. Good exposures of vertical and overturned Eocene, Miocene and Pliocene sediments are present along the south entrance road to Mount Diablo state park.

At the same time, the Coast Ranges were continuing their growth and the Sunol-Calveras branch of the San Andreas fault system alternately tore off and plastered on bits and pieces of sediment along the westerly side of the Livermore valley area.

The present status of the basin seems to be that of continued structural deformation. Even though we may believe we understand the mechanisms involved, our understanding of the subsurface sediments and geometry becomes progressively poorer with depth.

Stratigraphy

There may be as much as 22,000 feet of Eocene, Miocene and Pliocene sediments present in the deeper part of the Livermore Basin. Paleocene sediments are missing along the outcrop area because they were either stripped off earlier in the basin's history, or have been cut off by the Mount Diablo uplift partially overriding the basin's edge. A stratigraphic chart of the Tertiary formations is shown in the upper right hand portion of Figure 1.

Eocene

Capay and Domengine Formations.

A little over 2800 feet of marine to brackish water shales, thin bedded and massive sands are exposed just south of Mount Diablo that are equivalent in age to the Capay, Domengine, Nortonville and Markley formations of the western portion of the Sacramento Delta. They are important reservoir rocks for the Delta, Suisun and Concord gas fields, and will be prime exploratory targets for much of the Livermore basin once the structure of the Basin is better understood.

Tesla sand.

The Tesla sand of the Livermore field is the approximate time equivalent of the Domengine sand. It is a white sand exposed along Corral Hollow southeast of Livermore, and has been mined for glass manufacture.

Miocene

Sobrante Formation.

Overlying the Domengine sand unconformably, is 500 to 700 feet of mappable sand and pebbly conglomerate. The Sobrante sands, which contain shallow marine fossil remains, are well exposed and structurally overturned along the south entrance road to Mt. Diable state park.

Briones - Cierbo - Neroly

The Briones, Cierbo and Neroly units make up about 4500 feet of sands, pebbly conglomerates and tuffaceous sands and shales. All are shallow marine or brackish water sequences. Usual distinctions are made by contrasting typically thinner bedded Briones sands and minor pebbly conglomerates with the more massive bedded coarse sands and conglomerates of the Cierbo formation. The Neroly formation is typified by an opaline coating on the sand grains giving it a blue cast. The Cierbo sand section is the principal oil producer at the Livermore Field.

Pliocene

Orinda

The Orinda formation is a non-marine sequence of sands, conglomerates, shales and volcanics widespread through the Livermore basin. As indicated by the stratigraphic chart, the Orinda actually includes tuffs, the Livermore gravels and other volcanic sediments. The Orinda formation is the youngest unit mapped in the central portion of the basin. Its thickness varies considerably. Unless structurally repeated, there may be as much as 15,000 feet of Orinda sand, conglomerate, shale and tuff in the major synclinal areas of the basin. It's likely that a much greater thickness was originally deposited.

Structure

The Livermore Basin is bounded by large faults where the stresses have far exceeded the strength of the sediments. Though a number of large surface structural features can be mapped in the basin, it is quite possible that none extend to any great depth before becoming detached or complexly folded.

Although the basin appears quite complicated and difficult to assess, when we remember that there are a number of other sedimentary troughs genetically related to the San Andreas system, we can hardly expect the Livermore basin to be completely unique.

A number of California coastal basins are characterized by a thick young sedimentary section deposited in a trough, and then compressed into tight linear folds. In some cases the most incompetent young sediments have been squeezed out over the trough edge. When we carefully examine the edges of the hills just east of Highway 680 for several miles north of the town of Dublin, or the edge of the hills north of Highway 580 between the Livermore airfield and Camp Parks, we see recent uplift indicated by the stream drainages.

As a result, if one visualizes a trough filled with a thick young sedimentary section with overturned beds on one side, compressed beds in the center and overthrust or extended incompetent beds on the other, Figure 2, a diagrammatic cross section similar in part to other coastal California basins, could represent a reasonable model.

Cross Sections AA', BB', CC', and DD' are more conventional sections that are drawn primarily by extending surface and well data to depth. Starting from the north, Section AA' shows the basin to be a large compressed syncline bounded by the Sunol-Calveras fault, and the flank faults of Mount Diablo.

The region across which Section BB' is drawn appears to near the deepest portion of the basinal trough. The shape of the center of the basin is conjectural.

Sections CC' and DD' belong more to the Hamilton Mountain uplift area, and show typical coast range type structural features.

In looking for structural characteristics or qualities that can be used as a basis for further studies, at least two are apparent that appear to be consistent.

1) Where the young sediments are thick, they tend to form long linear structural folds paralleling the flank of the Mount Diablo uplift.

2) Where the young sediments are relatively thin, they display no structural strength and are folded, faulted and crushed, and reflect only the latest structural warps of the older beds beneath.

These two characteristics should help us determine the major structural influences, and the optimum areas for further studies.

Oil and Gas Exploration

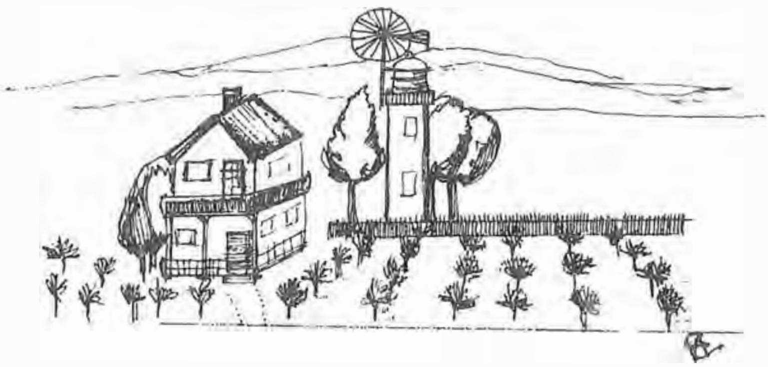
Oil seeps have been recognized in the eastern portion of the Livermore Valley since 1868. Though some pits were dug along seep areas to gather oil at that time, exploration by drilling did not really begin until the late '20s and '30s. To date, the 60 odd wells that have been drilled in the Livermore Basin can be fairly easily divided into three categories.

1) Those that have drilled following up surface seeps or similar areas in the Tertiary section where the rocks are faulted and crushed. The Livermore field belongs within this group. Figure 3 shows a simplified section and map of the field. Thirty some other wells have been drilled looking for this type of feature.

2) Wells drilled on large anticlinal features either for Tertiary or Cretaceous objectives. Six such wells were concentrated on what is called Hospital Nose, just south of the town of Livermore where Texaco found some non-commercial gas in Cretaceous sands in 1952. Nine wells have been drilled along the large surface exposed Tassajara anticline without success. Seven were in the shallower portion, and two in the deeper portion of the basin. Other scattered wells have been drilled on surface mapped structures. All unsuccessful.

3) Two attempts have been made to drill for deeper structures using seismic or gravity information for structural prediction. Standard of California drilled an 8081 foot test in Section 17, T2S R1E in 1964, and Cities Service drilled their 17,404 foot test nine years later one mile to the north in Section 7. Neither found any encouragement. Standards test drilled over steepened beds from the surface to total depth.

Because of the variations in surface terrain and rock types, and the complex surface folding and faulting, exploration through seismic and gravity definition has been and will continue to be very difficult. Tightly folded and overturned beds on the surface offer little predictability for the attitudes of older Tertiary or Cretaceous beds. The complexities will eventually be solved, however, and exploration of the Livermore Basin will resume.



<u>Selected References</u>

California Oil and Gas Fields, 1973, Volume 1, California Division of Oil and Gas, Sacramento, California.

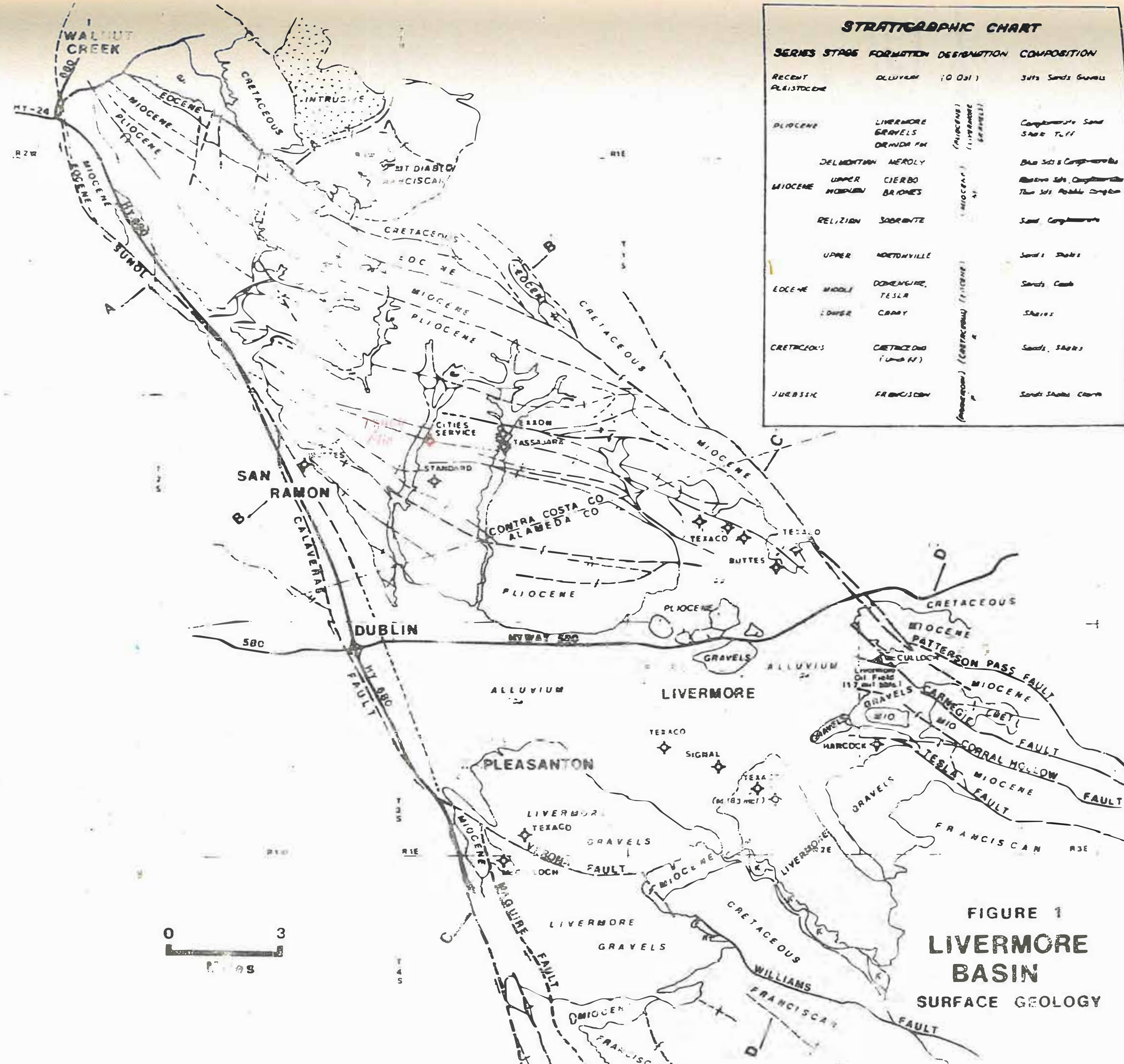
Ford, R.S. 1966, Ground Water Geology of Livermore Valley
Urban Environmental Geology in the San Francisco
Bay Region
California Department of Water Resources

Geologic Society of Sacramento, 1964, Guidebook to the Mount Diablo Field Trip, 1964:
Davis, Calif., Geol. Society of Sacramento.

Hall, C. A., 1958, Geology and Paleontology of the Pleasanton Area, Alameda and Contra Costa Counties, California:
University of Calif. Publ. in Geol. Sciences, v. 34, No. 1.

Huey, A.S., 1948, Geology of the Tesla Quadrangle, California:
California Div. of Mines Bulletin 140.

Lutz, George, 1951, The Sobrante Sandstone: University of Calif.
Publ. of the Department of Geologic Sciences, v. 28, 1951.



STRATIGRAPHIC CHART

SERIES	STAGE	FORMATION	DESIGNATION	COMPOSITION
RECENT PLEISTOCENE		ALLUVIUM	(Q Qal)	Silts Sands Gravels
PLIOCENE		LIVERMORE GRAVELS ORINDA FM	(PLIOCENE) (LIVERMORE GRAVELS)	Conglomerate Sand Shale Tuff
	DELMONTIAN	NEROLY	(MIOCENE)	Blue Ss & Conglomerates
MIOCENE	UPPER MOHNIAN	CIERBO BRIONES		Massive Ss, Conglomerate Thin Ss Pebble Conglom
	RELIZIAN	SOBRANTE		Sand Conglomerate
	UPPER	NORTONVILLE	(EOCENE)	Sands Shales
EOCENE	MIDDLE	DOMENGINE, TESLA		Sands Coals
	LOWER	CAPAY		Shales
CRETACEOUS		CRETACEOUS (undiff)	(CRETACEOUS)	Sands, Shales
JURASSIC		FRANCISCAN	(FRANCISCAN)	Sands Shales Cherts

FIGURE 1
LIVERMORE BASIN
SURFACE GEOLOGY

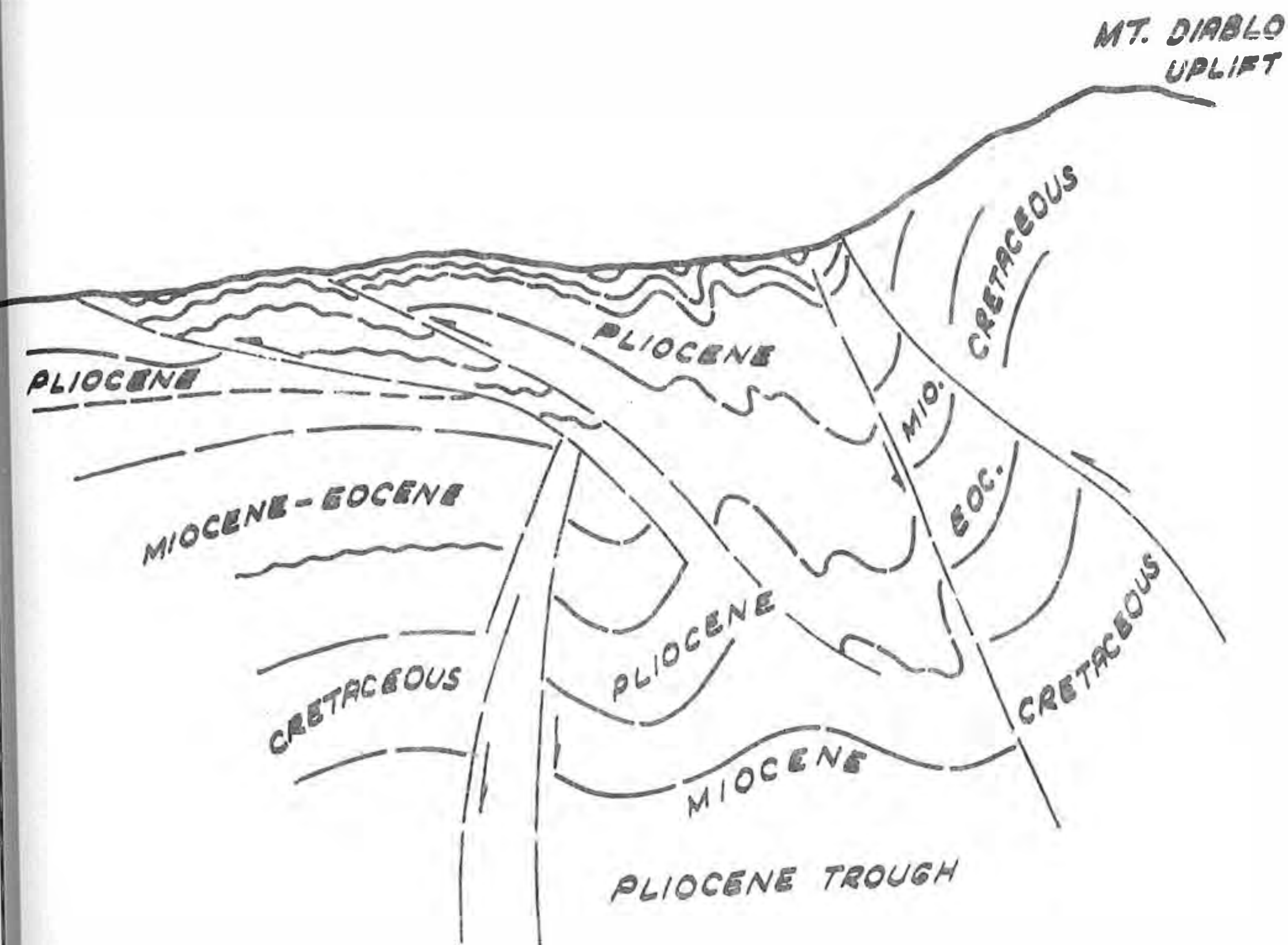
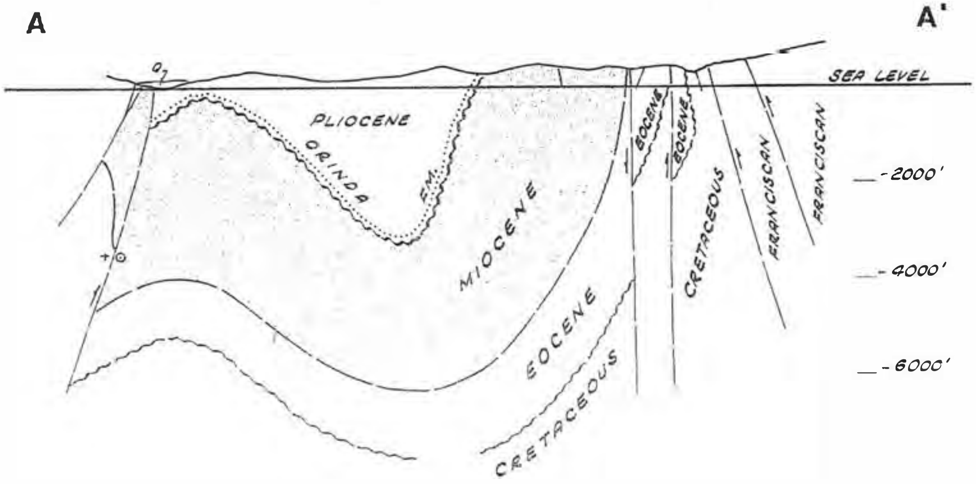
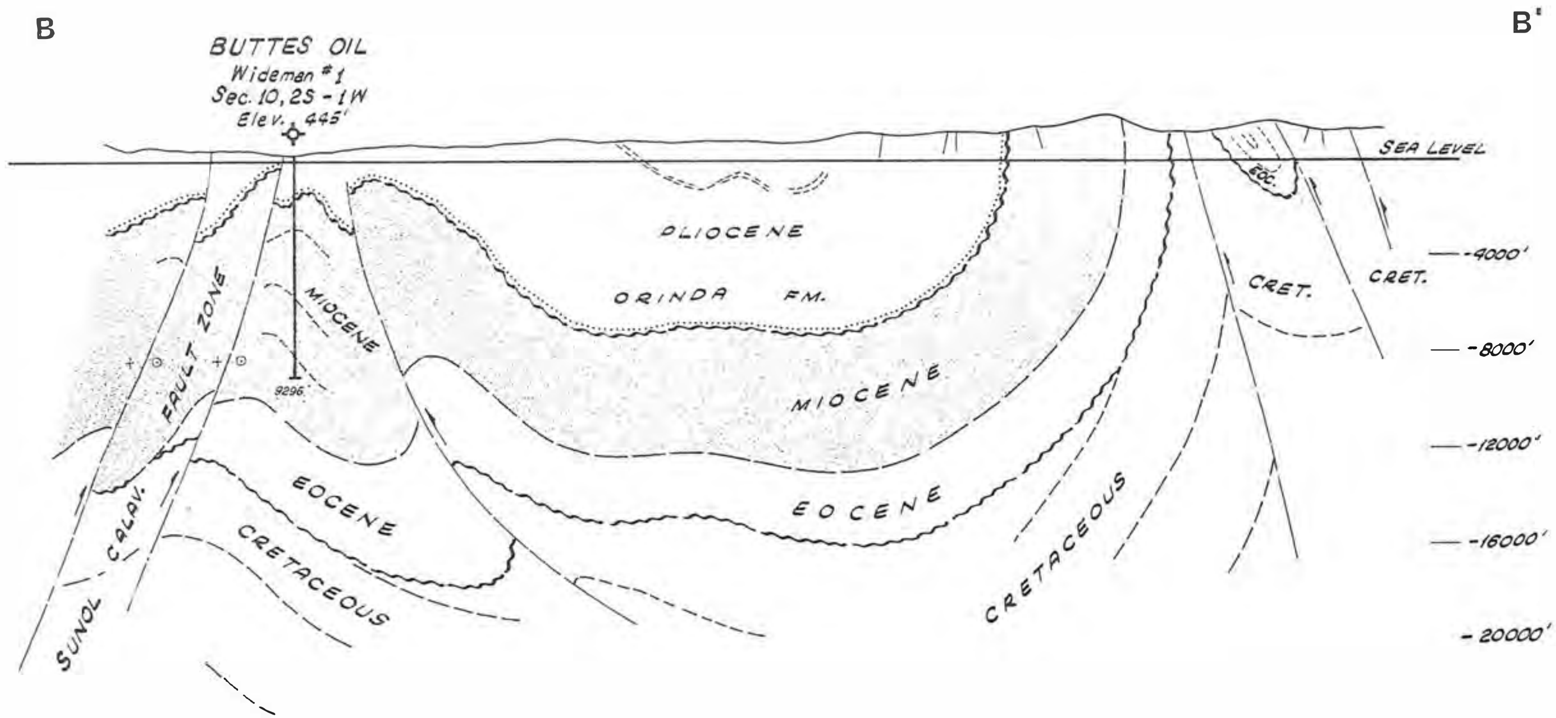
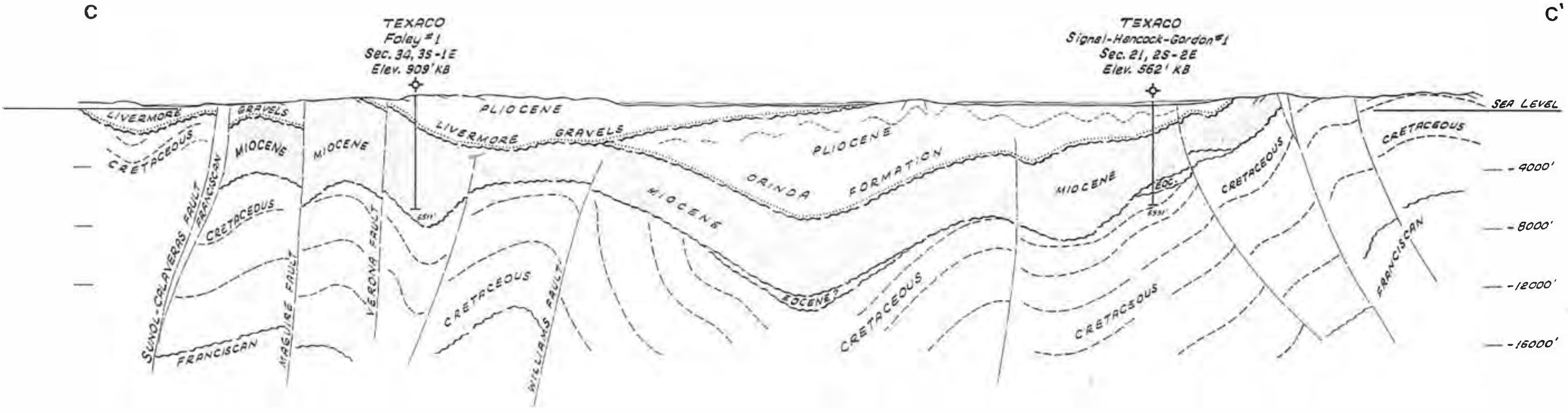


Figure 2

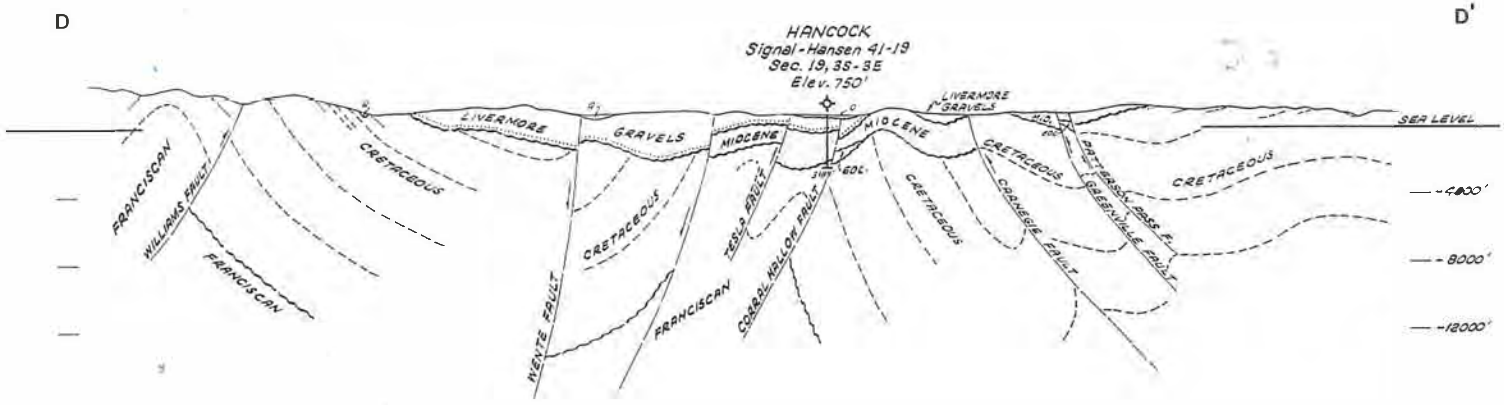
DIAGRAMMATIC CROSS SECTION
LIVERMORE BASIN


A
A'
SEA LEVEL
a
PLIOCENE
ORINDA
FM.
MIOCENE
EOCENE
CRETACEOUS
EOCENE
EOCENE
CRETACEOUS
FRANCISCAN
FRANCISCAN
-2000'
-4000'
-6000'


B
B'
BUTTES OIL
Wideman #1
Sec. 10, 2S - 1W
Elev. 445'
SEA LEVEL
9296'
PLIOCENE
ORINDA FM.
MIOCENE
MIOCENE
EOCENE
EOCENE
CRETACEOUS
CRETACEOUS
FAULT ZONE
SUNOL
CALAV.
EOC.
CRET.
CRET.
-4000'
-8000'
-12000'
-16000'
-20000'



C
C'
TEXACO
Foley #1
Sec. 34, 3S-1E
Elev. 909' KB
TEXACO
Signal-Hancock-Gordon #1
Sec. 21, 2S-2E
Elev. 562' KB
SEA LEVEL
-4000'
-8000'
-12000'
-16000'
LIVERMORE
GRAVELS
PLIOCENE
LIVERMORE GRAVELS
PLIOCENE
ORINDA FORMATION
MIOCENE
MIOCENE
MIOCENE
MIOCENE
CRETACEOUS
CRETACEOUS
CRETACEOUS
CRETACEOUS
CRETACEOUS
CRETACEOUS
CRETACEOUS
EOCENE?
EOC.
FRANCISCAN
FRANCISCAN
FRANCISCAN
SUNOL-CALAVERAS FAULT
MAGUIRE FAULT
VERONA FAULT
WILLIAMS FAULT



D
D'
HANCOCK
Signal-Hansen 41-19
Sec. 19, 3S-3E
Elev. 750'
SEA LEVEL
-4000'
-8000'
-12000'
LIVERMORE
GRAVELS
LIVERMORE GRAVELS
MIOCENE
MIOCENE
MIO.
EOC.
CRETACEOUS
CRETACEOUS
CRETACEOUS
CRETACEOUS
CRETACEOUS
FRANCISCAN
FRANCISCAN
FRANCISCAN
WILLIAMS FAULT
WENTE FAULT
TESLA FAULT
CORRAL HALLOW FAULT
CARNEGIE FAULT
PATTERSON PASS F.
GREENVILLE FAULT

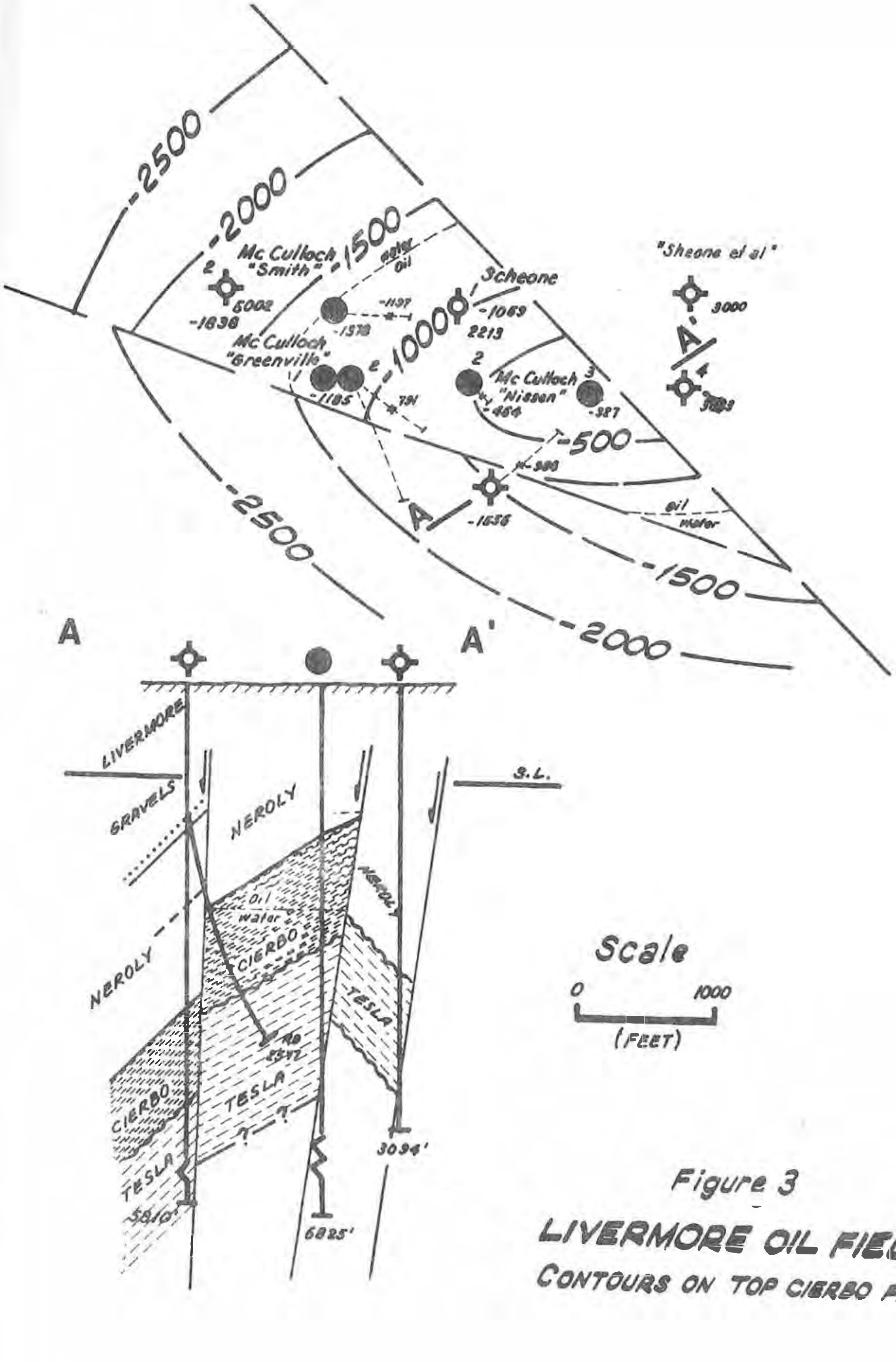


Figure 3

LIVERMORE OIL FIELD

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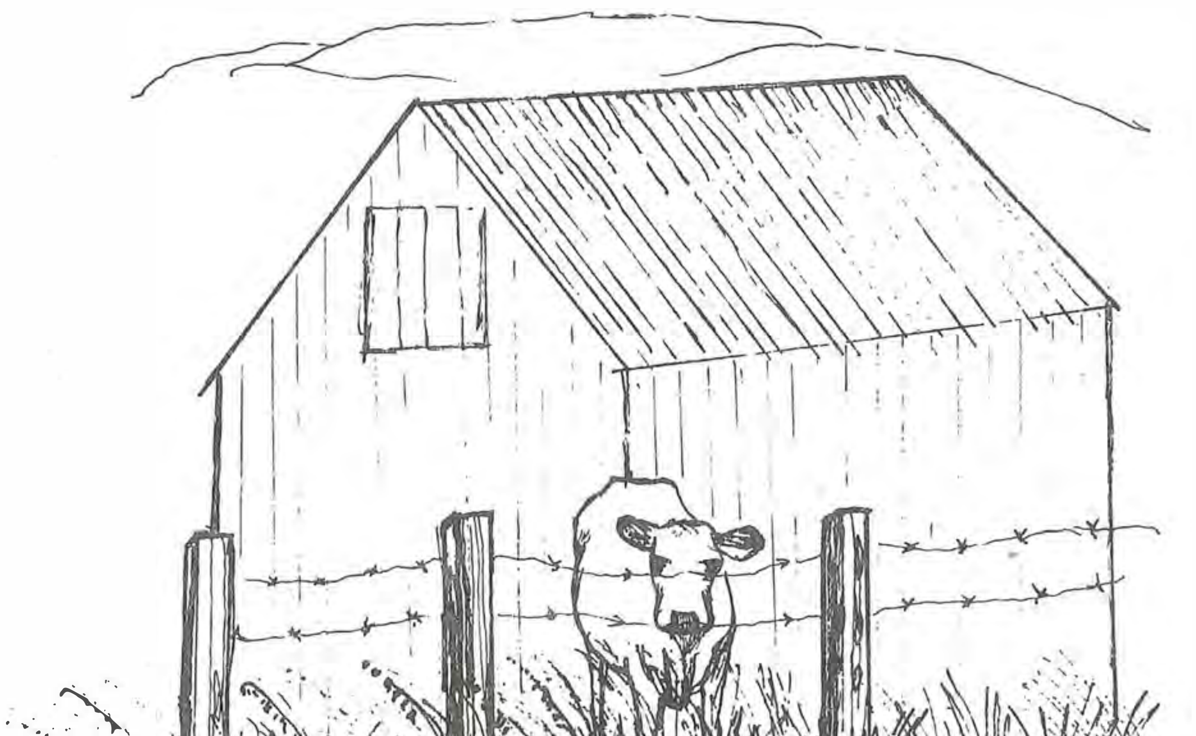

Geology and Slope Stability of Part of Pleasanton Ridge, Alameda County, California

by

Michael D. Dresen, California State University, Hayward

Introduction

Pleasanton Ridge is located approximately 2 miles southwest of the city of Pleasanton in central Alameda County, California. At present (1979), the Pleasanton area is growing rapidly, and pressure to develop the Pleasanton Ridge area is mounting. Damage to structures from landslides in Alameda County has been estimated at over $5,000,000 for the 1968-1969 rainy season (Nilsen and others, 1976). Greater losses can be expected in future years as land development is forced into hillside areas. It is important, therefore, to provide slope stability information to community planners so that such data can be incorporated into land-use policy decisions.

Geology

Stratigraphy

Pleasanton Ridge is situated on the western margin of the Amador Valley in the central Coast Ranges of California. The Pleasanton Ridge area is underlain by stratified sedimentary rocks which range in age from Lower Cretaceous to Plio-Pleistocene (see figure 1). The upper segment of the northeast slope of the ridge, the crest of the ridge, and the southwest slope of the ridge are underlain by Lower

Cretaceous Marine strata of the Great Valley Sequence. These rocks consist of conglomerate sandstone, siltstone, and shale of the Oakland Conglomerate (Ko) and sandstone, siltstone, and shale of the Niles Canyon Formation (Knc, Hall, 1958). In general, these beds comprise a homoclinal sequence on the northeast slope of Pleasanton Ridge which strikes N25-40^{o} west and dips 20-35^{o} southwest. However, overturned beds are found on the southwest slope of the ridge (see figures 2 and 3).

Rocks younger than Cretaceous are found only in the southern half of the study area on the northeast slope of Pleasanton Ridge. These include fossiliferous marine sandstone of the Upper Miocene Briones Formation (Tmb); marine sandstone, claystone, and limestone which are tentatively assigned to the Undifferentiated San Pablo Group (Tmsp); of Upper Miocene Age; conglomerate and claystone which are questionably assigned to the Upper Pliocene Orinda Formation (Tpor); and nonmarine conglomerate of the Plio-Pleistocene Livermore Gravels (Tplg). The Tertiary and Quaternary rocks are exposed in only limited areas since Holocene landslide deposits have largely covered them.

Calaveras Fault

The location of the Calaveras fault in the Pleasanton Ridge area is not well known because Holocene landslides have covered the trace (or traces) of the fault. Previous workers have placed the trace of the fault near Foothill Road; apparently at the break in slope formed by the intersection of Amador Valley with the northeast slope of Pleasanton Ridge. In this study, I have mapped a more westerly trace of the Calaveras fault (see figure 4). Existence of this trace is indicated by a notch in an east-west trending ridge, and an elongate, northwest-trending linear escarpment at the southern boundary of the study area. Further evidence consists of Upper Miocene Briones sandstone (Tmb) in juxtaposition against the Great Valley Sequence Conglomerate and sandstone (Kocg) in the vicinity of Castlewood Country Club (see figures 2 and 4). In my judgement, this westernmost trace of the Calaveras fault forms the fundamental boundary between the Great Valley Sequence to the west and the Cenozoic strata to the east. Furthermore, additional traces apparently exist which are obscured by landslides. One such trace has been mapped near the intersection of Foothill Road and Castlewood Drive by Judd Hull and Associates (1975, see figure 4).

Landslides

Types and Dimensions

Landslides in the Pleasanton Ridge area can be grouped into 3 general categories: earthflows, slumps, and complex landslides. (Complex landslides are characterized by a combination of types of movement (e.g. sliding and flowing) and/or types of materials (e.g. bedrock and soil)). The landslides range in size from relatively small earthflows and slumps measuring 10 feet long, 5 feet wide, and 2-3 feet deep to rather large complex landslides measuring 4500 feet long, 3500 feet wide, and 100-200 feet deep.

Landslide History

Three major periods of landsliding are recognized in the Pleasanton Ridge area. The most recent period of landslide activity has produced relatively small earthflows and slumps. The relative freshness of landslide morphology exhibited by those landslides indicates they have occurred within the last few hundred years. A second period of landsliding was characterized by the occurrence of large complex landslides. These landslides exhibit subdued morphologic features which suggest they were produced several thousand to a few tens of thousand years ago. The oldest period of landsliding appears to have been characterized by the occurrence of large earthflows and slumps. The highly subdued morphologic features exhibited by these landslides indicate that they occurred several tens of thousand years ago.

Distribution of Landslides

Nearly all of the landslides in the Pleasanton Ridge area are found on the northeast slope of the ridge; with only a few, relatively small landslides present on the southwest slope. This uneven distribution suggests that some factor (or factors) peculiar to the northeast slope of the ridge controls the distribution of landsliding. In large part, the presence of the Calaveras fault zone on the northeast slope appears to explain this distribution. Specifically, a set of joints of probable tectonic origin exists in the Oakland conglomerate on the northeast slope of the ridge. This set of joints strikes parallel to the trend of the ridge (northwest) and dips steeply to the northeast. It appears that these joints served as planes of weakness along which the large complex landslides began movement at the time of their formation. In addition, movement in the Calaveras fault zone has brought landslide-prone Tertiary strata (i.e. the Orinda Formation and the San Pablo Group) to the northeast slope of the ridge. Furthermore, rocks within the fault zone have probably been weakened by shearing and are thus more susceptible to landslides.

Causes of Landsliding

As stated above, the landslides produced during the most recent period of landsliding are much smaller than the landslides produced during the two earlier periods. This difference in size indicates that the conditions under which the very large complex landslides were produced must have been significantly different from present-day conditions, which have produced relatively small landslides. Stout (1977) has described large-scale landsliding in southern California which occurred 16,000 to 20,000 years ago. This large-scale landsliding occurred during a period of heavy precipitation which was partly contemporaneous with late Wisconsin (called the Tioga stage in California), glacial activity and greatly lowered sea level. The heavy precipitation resulted in highly saturated ground conditions and higher erosion rates. These conditions created oversteepened, saturated slopes and ultimately resulted in the production of large landslides. Similar conditions in the Pleasanton Ridge area (possibly in conjunction with seismic shaking) may have produced the large complex landslides during the second period of landsliding. Similar conditions contemporaneous with a pre-Tioga glacial period may have produced the oldest landslides.

Many of the landslides in the Pleasanton Ridge area produced during the most recent period of landsliding have been caused by the activities of man. Numerous landslides have developed in road cuts where slopes have been oversteepened and undercut by construction. In addition, one residence in the vicinity of Castlewood Country Club was completely destroyed and another was severely damaged by a slump which occurred in 1969. The slump was allegedly caused by increased pore-water pressures resulting from watering of the golf course upslope from the two residences (Daniel J. Rhoades and Associates, 1975). Such instances of man-induced slope instability emphasize the need for careful planning if development is considered in the Pleasanton Ridge area.

Relative Slope Stability

A map depicting my interpretation of the relative stability of slopes in the Pleasanton Ridge area is shown in figure 5. This map is similar to maps described by Hoexter and others (1978) for portrayal of relative slope stability in a manner which is meaningful to planners or other non-geologists involved in land-use planning. It is emphasized that this map is not intended to replace site-specific engineering geologic and soils investigations. Rather, the map is designed to convey general information concerning slope stability to planners thereby enabling them to incorporate slope stability considerations into their land-use policy decisions.

On the map, three broad categories are utilized to portray relative slope stability: (1) stable ground, (2) potentially unstable ground, and (3) unstable ground. These categories are subdivided on the basis of the depth and type of material involved, and according to the degree of slope. Assignment of areas to a particular category was made by consideration of the magnitude, type, and recency of past landslide activity, as well as the degree of slope and the nature and structure of the materials comprising the slope. Recommendations concerning development potential and types of further studies required are made for each category.

References Cited

Hall, C.A., 1958, Geology and Paleontology of the Pleasanton Area, Alameda and Contra Costa Counties, California: Univ. Cal. Publ. Geol. Sci., vol. 34, no. 1, pp. 1-90.

Hoexter, D.F., Soto, A.E., and Hozhausen, G.R., 1978, A method of evaluating relative stability of ground for hillside development: Engineering Geology, An International Journal, Elsevier Scientific Publishing Company (in press).

Hull, J.R. and Associates, 1975, Soil Investigation Phase II - Site suitability for old "pitch and putt" coure, Foothill Road, south of Castlewood Drive, Pleasanton Township, Alameda County (Sunol), California: Project no. 039-A68, unpublished report.

Nilsen, T.H., Taylor, F.A., and Brabb, E.E., 1976, Recent landslides in Alameda County, California (1940-1971), an estimate of economic losses and correlations with slope, rainfall, and ancient landslide deposits: U.S. Geological Survey Bulletin 1398, 21p.

Rhoades, D.J., and Associates, 1975, Design level recommendations for repair of landslides at 405 Oak Lane, Project no. 463-00, unpublished report.

Stratigraphic Column

AGE			FORMATION		Thickness in Feet	LITHOLOGY
CENOZOIC	Quaternary	Holocene	Landslides and Alluvium		?	Alluvium and Landslide Deposits.
		Pleistocene	Livermore Gravels		200+	Poorly consolidated conglomerate with pebbly sands and silty clay.
	Tertiary	Pliocene	Orinda (?) Formation		500+	Interbedded soft claystone and poorly sorted, friable conglomerate. Minor soft sandstone, some hard conglomeratic sandstone.
		Upper Miocene	San Pablo Group	Undifferentiated San Pablo Group	500+	Interbedded soft sandstone, limestone, and claystone. Minor conglomeratic sandstone.
				Briones Formation	300+	Well-indurated, fossiliferous, calcareous sandstone and conglomeratic sandstone.
MESOZOIC	Lower Cretaceous		Niles Canyon Formation		2000+	Upper Member - Interbedded siltstone and shale with minor fine-grained, thinly bedded sandstone. Lower Member - Well-indurated sandstone and conglomeratic sandstone.
			Oakland Conglomerate		2000+	Well-indurated, fractured and jointed conglomerate and sandstone. Minor siltstone and shale. Shale Member - Interbedded siltstone and shale with subordinate fine-grained, thinly bedded sandstone.

Michael D. Dresen

Figure 1

EXPLANATION FOR GEOLOGIC MAP

Quaternary	Qls	Undifferentiated landslide deposits
	Qal	Alluvium
Tertiary	Tplg	Livermore Gravels
	Tpor	Orinda Formation
	Tmsp	Undifferentiated San Pablo Group (Briones, Cierbo, & Neroly formations)
	Tmb	Briones Formation
Late Cretaceous	Knc / Kncsh / Kncss	Niles Canyon Formation: Kncsh - shale and siltstone member; Kncss - sandstone member; Knc - undifferentiated Niles Canyon Fm.
	Ko_{cg} / Ko_{sh}	Oakland Conglomerate: Ko_{cg} - conglomerate and sandstone facies; Ko_{sh} - siltstone and shale facies
		Contact - dashed where approximately located, dotted where concealed
	80	Strike and dip of bedding
	40	Strike and dip of overturned bedding
	30	Strike and dip of joint
	25	Dip of fault
	?·?·?·?	Fault - dashed where approximately located, dotted where concealed, querried where existence uncertain
	U D	Relative movement of fault
	A —— A'	Line of geologic section

GEOLOGIC MAP
of part of
PLEASANTON RIDGE

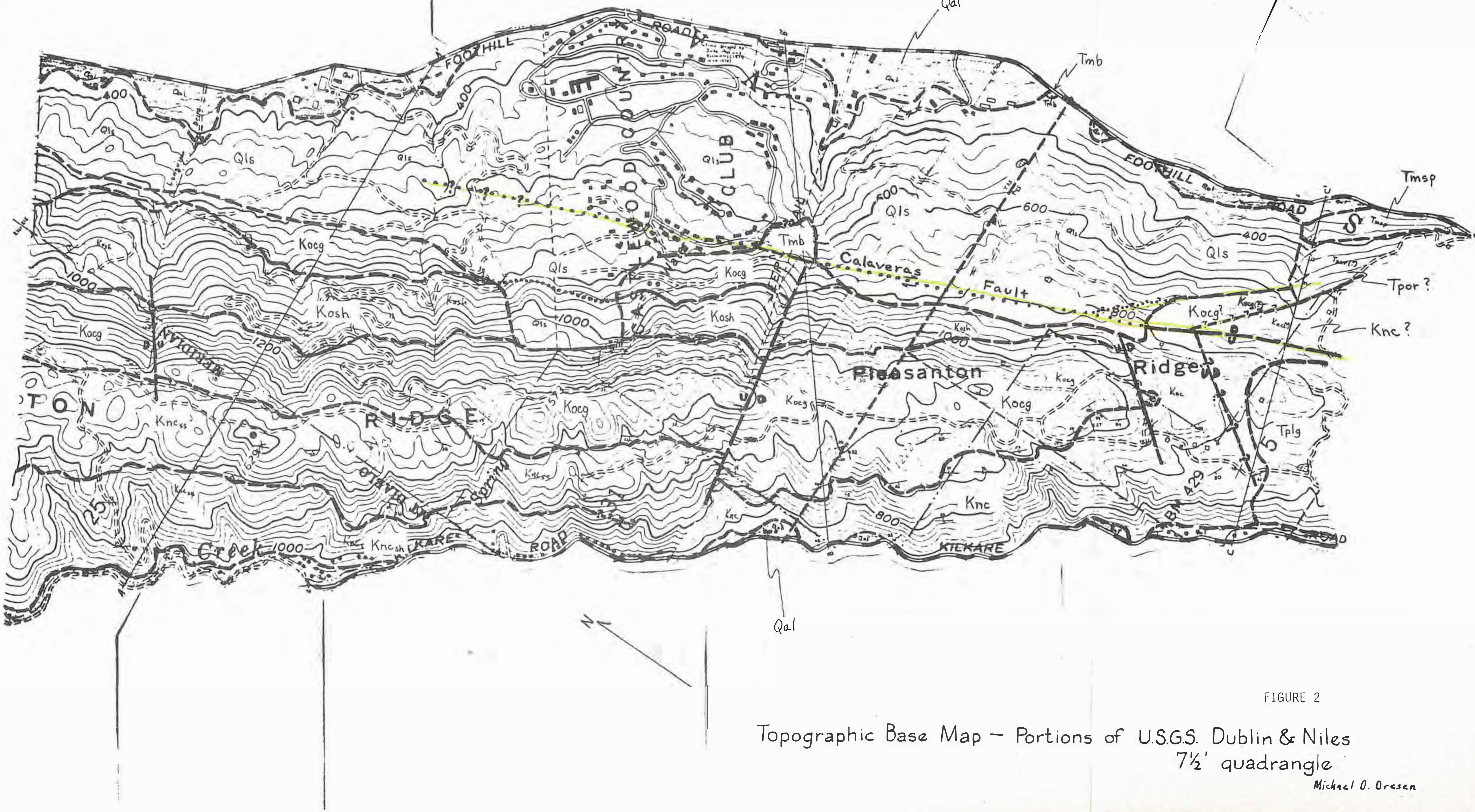

FIGURE 2

Topographic Base Map – Portions of U.S.G.S. Dublin & Niles 7½' quadrangle

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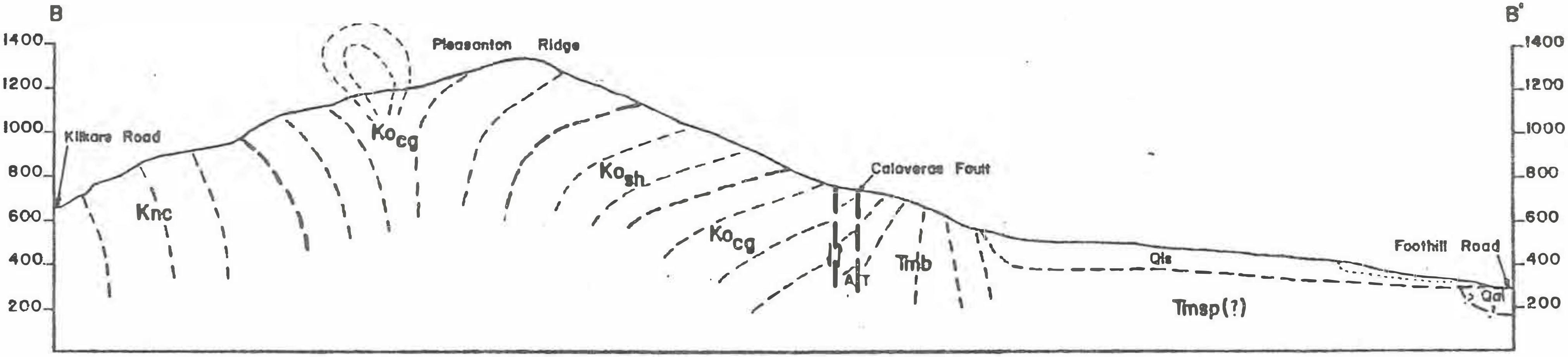
Geologic Section B-B' Across Pleasanton Ridge, Alameda County, California



Vertical and Horizontal Scales - 1: 6000

0 50 100
Meters
0 250 500
Feet

N48E →

Elevations in Feet Above Mean Sea Level

Figure 3

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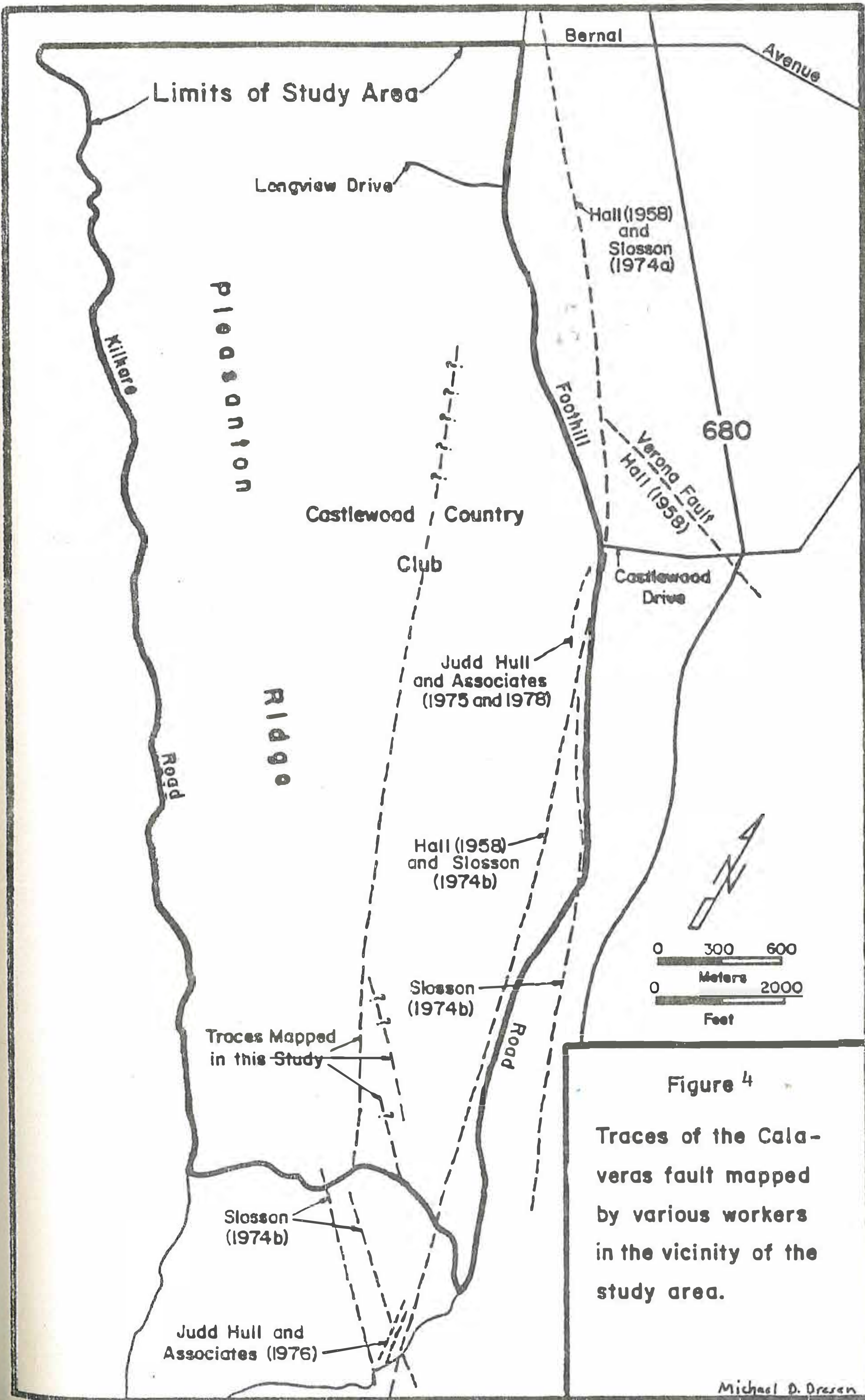

Figure 4

Traces of the Calaveras fault mapped by various workers in the vicinity of the study area.

EXPLANATION FOR RELATIVE SLOPE STABILITY MAP

UNSTABLE GROUND

Us	Active shallow landslides (less than 5 feet deep). Engineering geologist should be consulted as to the suitability of site for development.
Ud	Active deep landslides (greater than 5 feet deep). Not recommended for development.

POTENTIALLY UNSTABLE GROUND

Psm	Possible shallow landsliding (less than 5 feet deep) on 15-30% slopes. Consult engineering geologist about suitability of site for proposed development and location and design of cut slopes and foundations.
Pss	Possible shallow landsliding (less than 5 feet deep) on greater than 30% slopes. Not recommended for development.
Pdm	Possible deep landsliding (greater than 5 feet deep) on 15-30% slopes. Engineering geologist should perform site-specific investigation to assess landslide potential prior to development.
Pds	Possible deep landsliding (greater than 5 feet deep) on greater than 30% slopes. Not recommended for development.

STABLE GROUND

Sb	Competent bedrock within 3 feet of the surface. Slopes less than 15%. Consult soil engineer as to foundation design.
Sun	Unconsolidated material on less than 15% slopes. Consult soil engineer as to location and design of foundations.

RELATIVE SLOPE STABILITY MAP
of part of Pleasonton Ridge, ALAMEDA CO., CALIFORNIA

by Michael D. Dresen

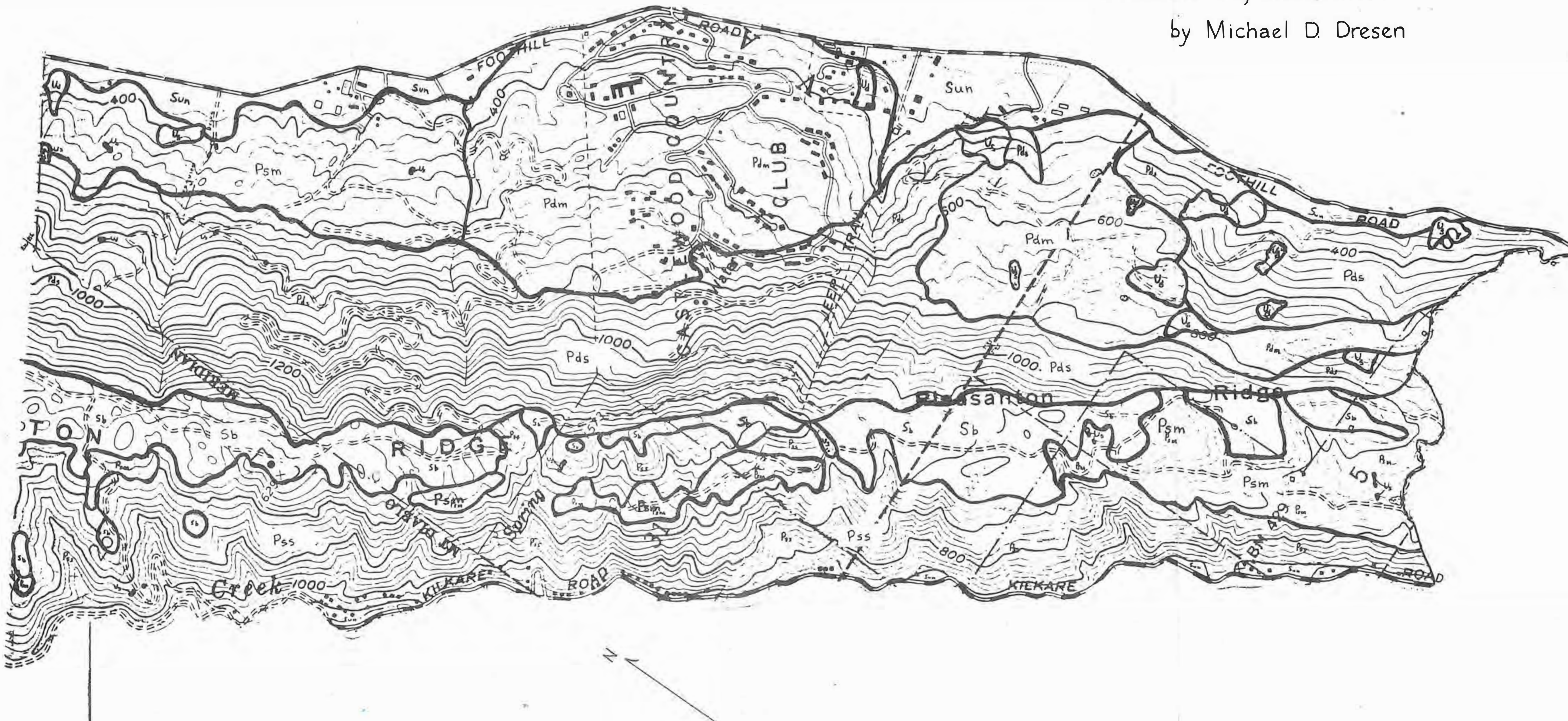

FIGURE 5

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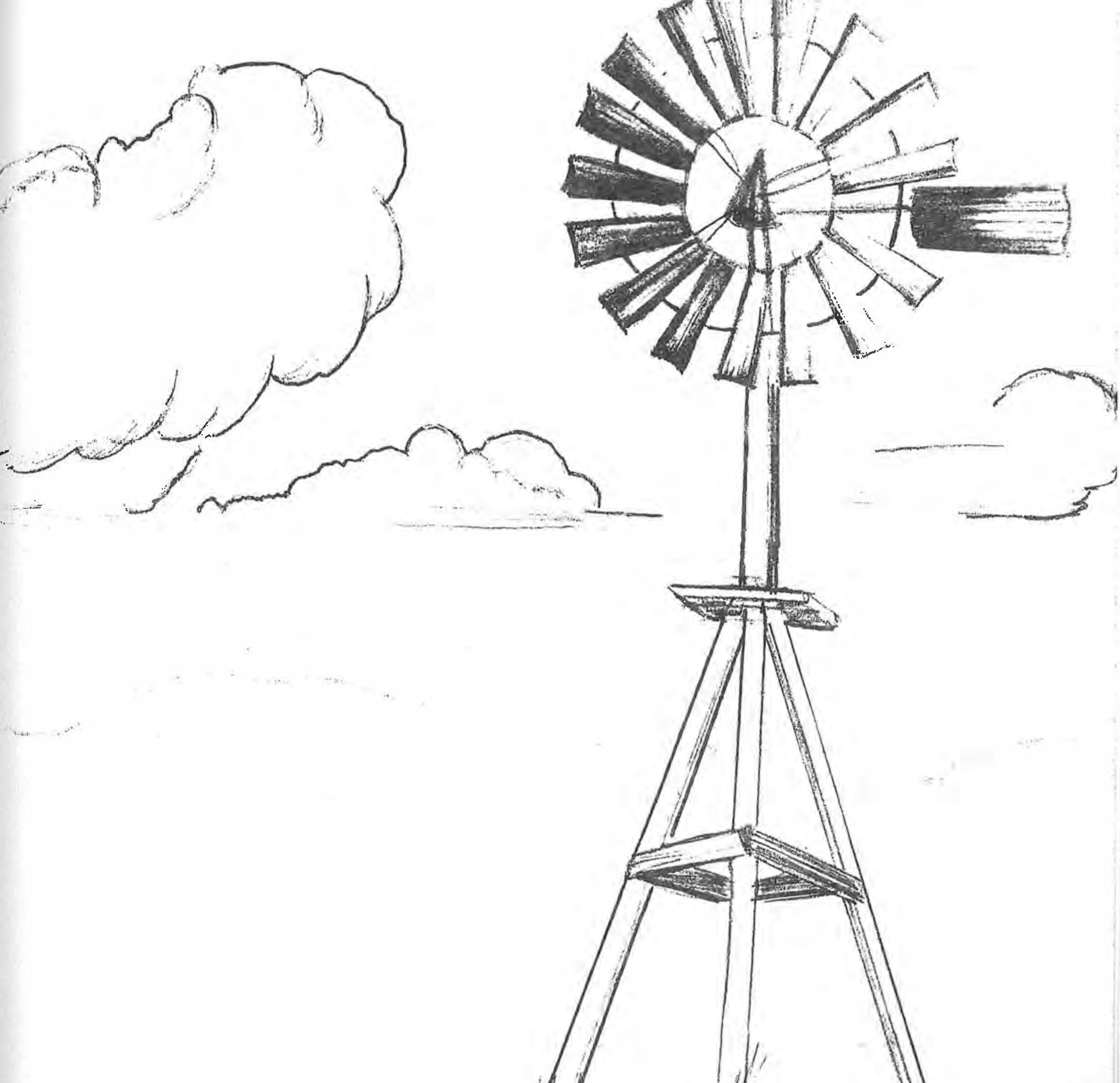

EVIDENCE OF ACTIVE SLIPPAGE ALONG THE HAYWARD FAULT

by
Dr. Robert Nason
United States Geological Survey
Menlo Park, California

Introduction

Active fault creep slippage is occurring along the Hayward, Calaveras, and San Andreas faults in central California. Measured fault slippage rates range up to 25mm/yr. The fault creep slippage is characterised by continuous slippage over many years, a slippage zone width of one to 10 metres, a correlation of creep slippage zones with fault gouge zones, and a distribution related to past earthquakes.

In 1960 evidence of active fault creep slippage on the Hayward fault was found in Fremont, California, by Cluff and Steinbrugge (1966). The active fault slippage had offset a warehouse, fences, pipelines, and railroad tracks. The offset of engineering structures, including underground tunnels, is discussed by Bonilla (1966), Blanchard and Laverty (1966), Radbruch and Lennert (1966), and Bolt and Marion (1966).

In 1966 and subsequent years evidence of active fault slippage has been found more widely on the Hayward fault (Radbruch, 1968).

Hayward Fault

The Hayward fault was examined for evidence of active slippage from Pinole Point (00 km) to Fremont, California (64 km). A special investigation was made within Hayward, California with the help of Joseph Carey (of the City of Hayward) and the City of Hayward survey crews.

Active slippage is found along all of the known part of the Hayward fault, from San Pablo to Fremont (figure 2). In San Pablo street and fence offsets indicate a fault slippage-rate of 0.5 cm/yr, and offset of a geodetic quadrilateral indicates the same rate at Berkeley (0.5 cm/yr). The slippage-rates at Hayward and Fremont are approximately 0.6-0.7 cm/yr. The slippage-rates appear to be uniform along the Hayward fault with a southward increase from San Pablo to Fremont.

Fault Gouge

A zone of "fault gouge" is found at the locality of fault creep slippage at many places. Fault gouge is a weak clayey material found along faults in vertical zones one to 10 or more metres thick. The clayey material is rich in montmorillonite and sheared serpentine at many sites. The similar widths and positions of creep slippage zones and fault gouge zones suggest a genetic relationship between them. That the fault gouge zones extend to at least several hundred metres depth is shown by occurrences in mines and tunnels. The fault gouge material is probably formed by the pulverizing of sediments and rocks in previous fault slippage; the fault gouge may then migrate along the slippage zone to its present position.

The active fault creep slippage occurring on the Hayward fault at Hayward, California, shows several unique and important features. The offset curbs and sidewalks resulting from the fault slippage were discovered in 1966 by Robert Pocan and Joseph Carey of the City of Hayward, and confirmed by Radbruch (1968).

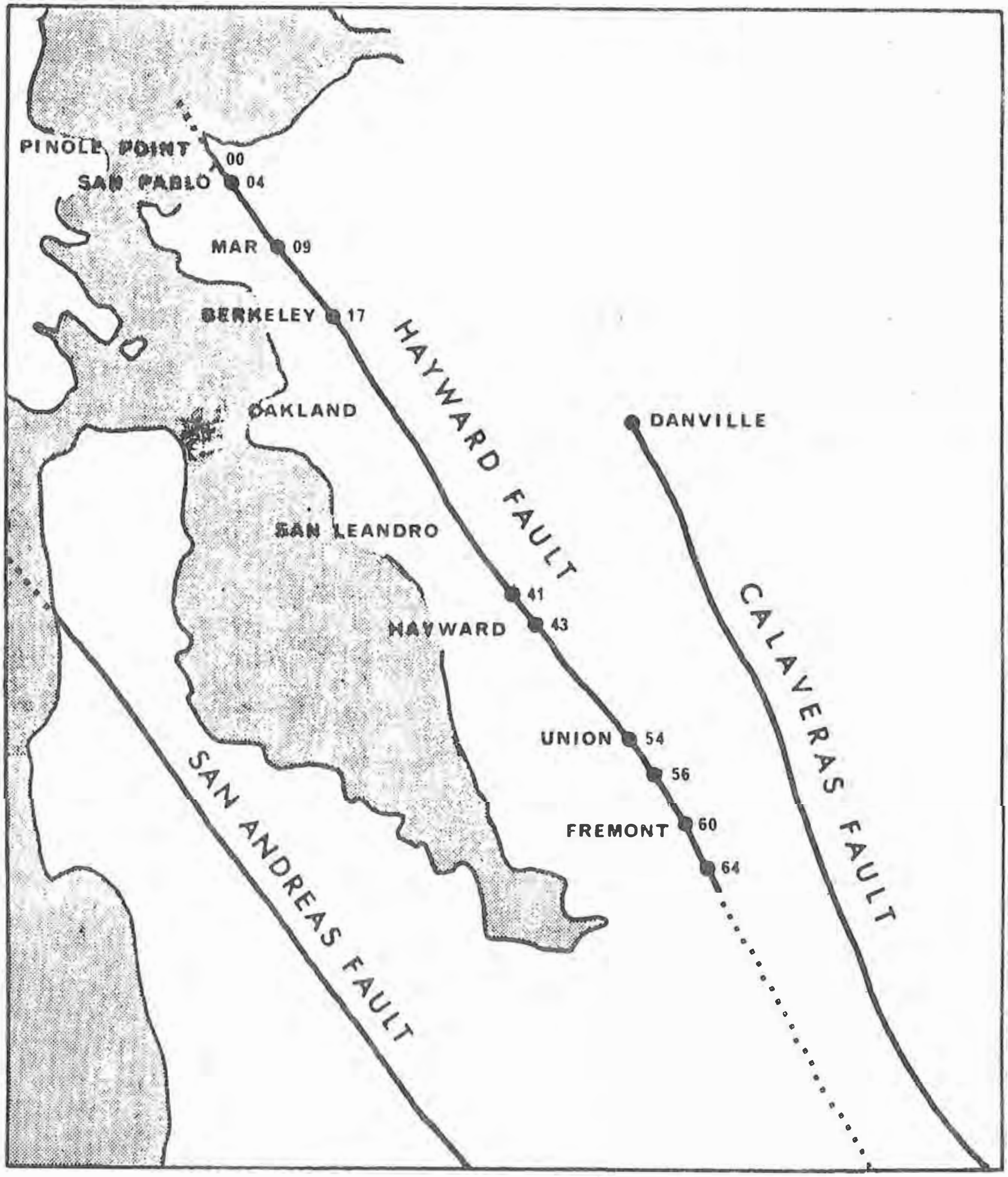

FIGURE 2. Map of Hayward fault showing place names and distances in kilometers southeast of Pinole Point.

A detailed investigation of the downtown Hayward area has shown several features of interest (Nason and Carey, in preparation). The fault creep slippage is occurring on not one but several distinct fault traces that overlap each other (map, figure 3). The reason for the multiple fault traces is not known.

In downtown Hayward (figure 3), four fault traces with active fault slippage have been located. These are the Mattox, Prospect and Veterans fault traces in one group and the Hazel fault trace to one side. The Mattox, Prospect and Veterans fault traces form a stepped-left en echelon pattern with the individual fault traces having a 3^{o} angle to the general fault strike. The Prospect and Veterans fault traces overlap each other very clearly at C Street and D Street where they are 50 meters apart. It is not clear how much overlap there is between the Prospect and Mattox fault traces.

The active fault slippage appears to transfer from one fault trace to another through a strained region between the fault traces. Figure 4 shows surveys of the old curbs on C Street and D Street. Two distinct curb offsets are evident about 50m apart on D Street. However, 150 M north at C Street the eastern fault trace is no longer evident. Instead the fault offset is spread out between the two fault traces in a region of strain.

Three hundred metres to the south of D Street there is a bulldozed east-west exposure that cuts at least 5m beneath the original ground surface. Two zones of greyish clayey gouge occur in the exposure about 50m apart. The two fault gouge zones correlate with the Prospect and Veterans faults traces at D Street in both position and spacing. This

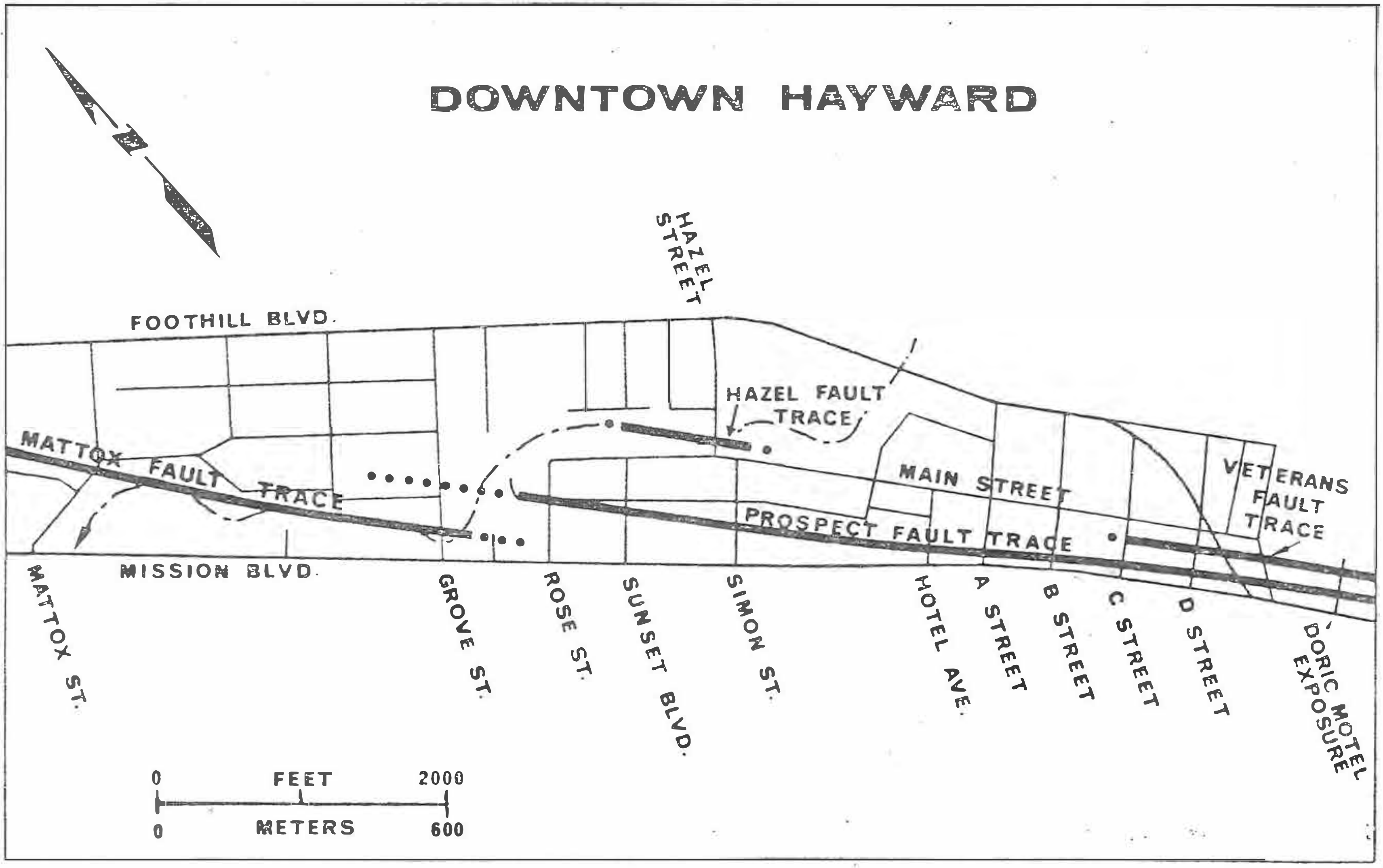

FIGURE 3. Map of Hayward fault traces in downtown Hayward, California.

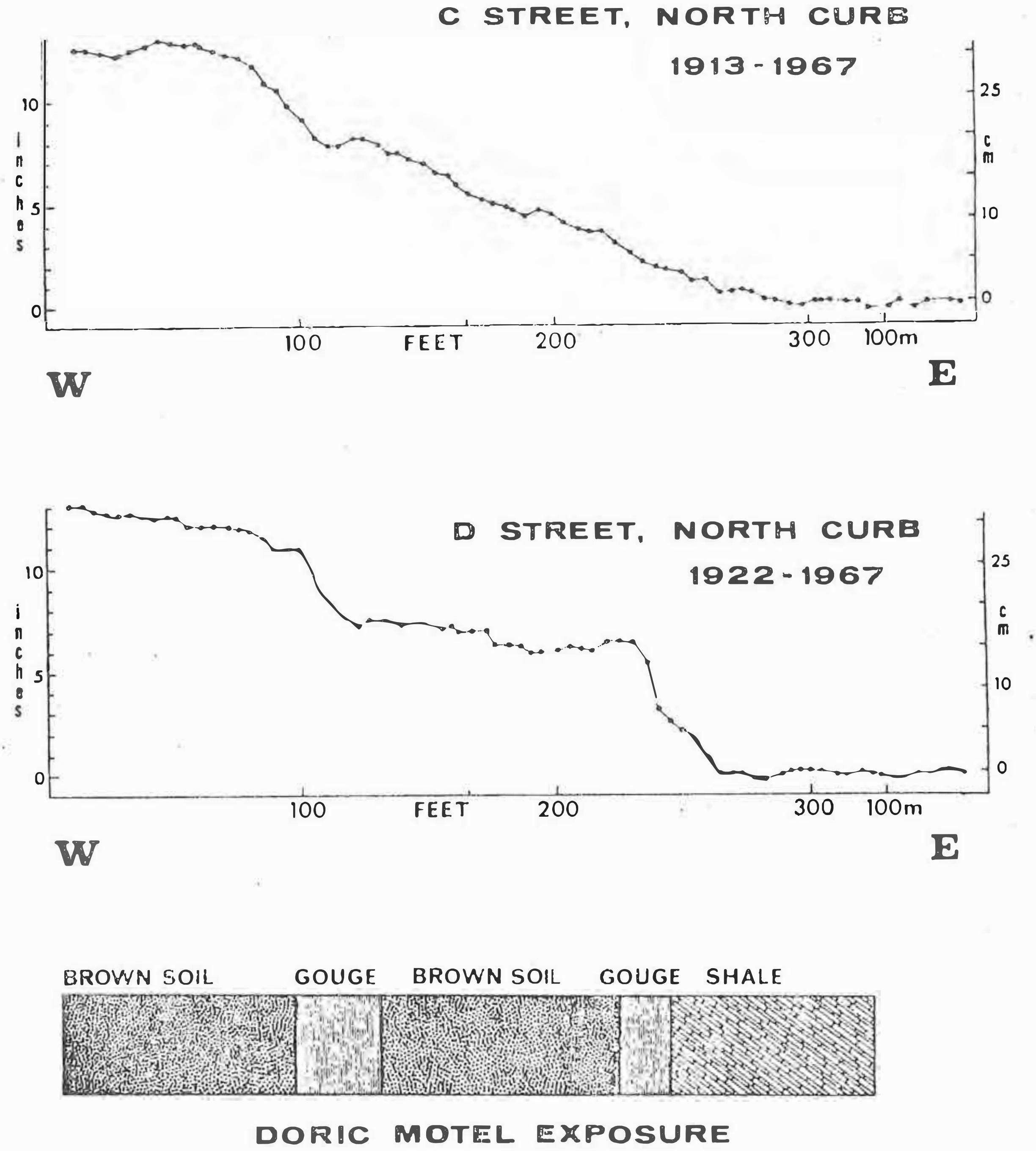

FIGURE 4. Surveys of offset curbs along C Street and D Street and profile of geologic exposure at Doric Motel, Hayward.

occurrence strengthens the apparent correlation of fault gouge zones and fault creep slippage zones as observed at other sites. This correlation is important for theorising about fault creep slippage.

The occurrence of active slippage on multiple fault traces is very significant, for fault creep slippage is a long-term process acting over many years. That the creep slippage occurs in the ground at the same place year after year indicates that something in the ground controls the location of the creep slippage (geologic control).

The trace of the surface fault breakage in the major 1868 Hayward fault earthquake has been studied by Radbruch (1968), who finds that the 1868 fault breakage was not along either the Veterans fault trace or the Prospect fault trace at C Street and D Street, but between them.

The fault creep slippage has apparently been continuous and approximately constant for the past 40 years in Hayward. At Simon Street, curbs constructed in 1980 were offset 20cm in 1967, indicating an average slippage rate of 5.5mm/yr. over 37 years. Survey marks installed in 1958 were offset 4.5cm in 1966, also indicating an average slippage rate of 5.5mm/yr. in eight years. New survey marks established in 1966 and 1967 have been offset at a rate of about 6mm/yr. also. The agreement of slippage rates over three time periods suggests that the fault creep slippage rate is more or less constant with time.

The fault slippage from 1958 to 1966 occurred at a time when little or no displacement was observed at triangulation marks distant from the fault (Pope <u>et al.,</u> 1966). Therefore the fault creep slippage from 1958 to 1966 probably represented partial elastic strain relief. That the fault creep slippage occurred during a period of no regional elastic strain accumulation indicates that a high level of elastic strain already existed, which is important to any theory.

The fault creep slippage at Hayward is especially significant because of the occurrence of multiple fault traces, the transfer of slippage from one fault trace to another, the correlation of multiple slippage zones with multiple fault gouge zones, and the continuity of slippage with time even when geodetic surveys show no displacement away from the fault in certain time periods.

Fremont, California

In Fremont older features are offset more than younger features, showing the continuity of fault slippage with time. The average slippage-rate is about 0.6 cm/yr. since 1930. The offset of Gallegos winery (Fig. 5) (48 cm since 1880) indicates a lesser slippage-rage (0.4 cm/yr) from 1880 to 1930. The railroad tracks at Shinn Station (constructed in 1909 and 1910) show an apparent offset of 20-25 cm, which is equivalent to offsets from the early 1930's. There was a damaging local earthquake in this area in May 1933. Possibly the railroad tracks were repaired after this earthquake and the 20-25 cm offset represents fault slippage since then. The evidence in Fremont indicates a relatively uniform rate of slippage except for the railroad tracks. This conclusion differs from that of Cluff and Steinbrugge (1966), who concluded from less data that most of the slippage occurred in the interval from 1951 to 1957. The evidence of different offsets with different age before and after the 1951 to 1957 interval shows the continuity of fault slippage-rate.

Extensions of the Hayward Fault

The path of the Hayward fault is not known north of Pinole Point; it may joint the Rodgers Creek-Healdsburg fault north of San Pablo Bay.

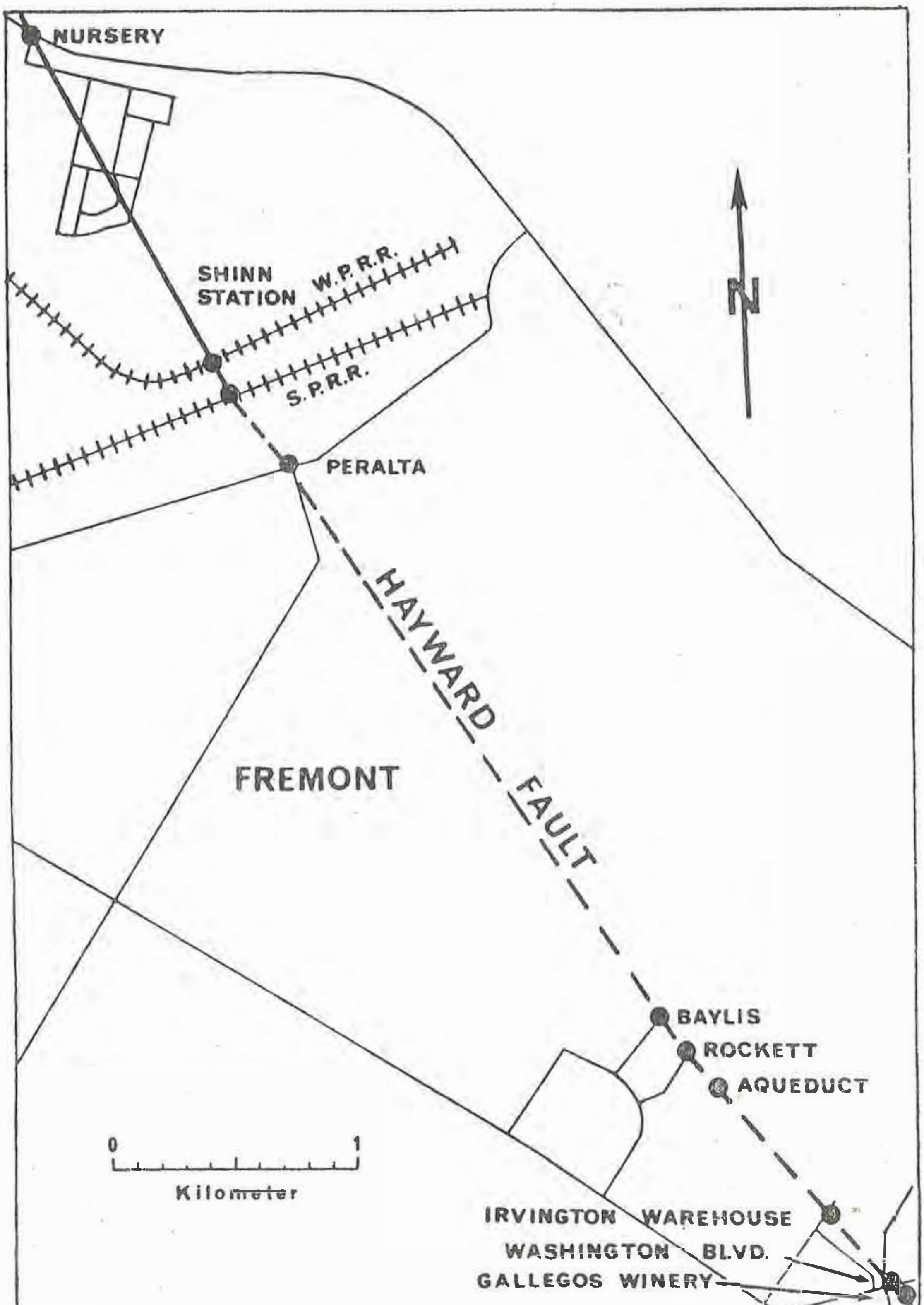

FIGURE 5. Map of Hayward fault sites in Fremont, California.

Similarly, the path of the Hayward fault is not known south of Fremont, and the fault may joint the Silver Creek fault southeast of San Jose. The Silver Creek fault is a major discontinuity in rock units south of San Jose and apparently joins the Calaveras fault at Anderson Reservoir (Rogers, 1966), so it is a reasonable continuation for the Hayward fault. This is apparently the path of the Hayward fault in the discussion of Louderback (1937).

Instrument Measurement

The instrument used to measure creep on the Hayward fault is the diagonal strainmeter. Diagonal strainmeters have been used by Nakamura and Tsuneishi (1967) at Matsushiro, Japan, and Smith and Wyss (1967) at Parkfield, California. The NOAA Earthquake Mechanism Laboratory design shown in Fig. 6 uses a 3mm invar rod inside a protective pipe buried 0.5m underground. Rod lengths are fastened together for a total length of 10 to 15m or more. The rods are anchored to a pier on one side of the fault and loosely tensioned by a spring on the other side. The spring ends of the rods are then sensed by instruments at the two instrument piers. Electronic transducer output is continuously recorded on a strip-chart recorder.

The rods are established across the fault along the 45° diagonals, so that fault movement causes one rod distance to lengthen and the other to shorten.

A Theory of Fault Creep Slippage and Earthquakes

As noted above, the distribution of currently active fault creep slippage appears related to the major earthquakes of 1857 and 1906. Fault creep slippage is actively occurring between the fault breaks of 1857 and 1906 but not occurring along the 1857 and 1906 fault breaks,

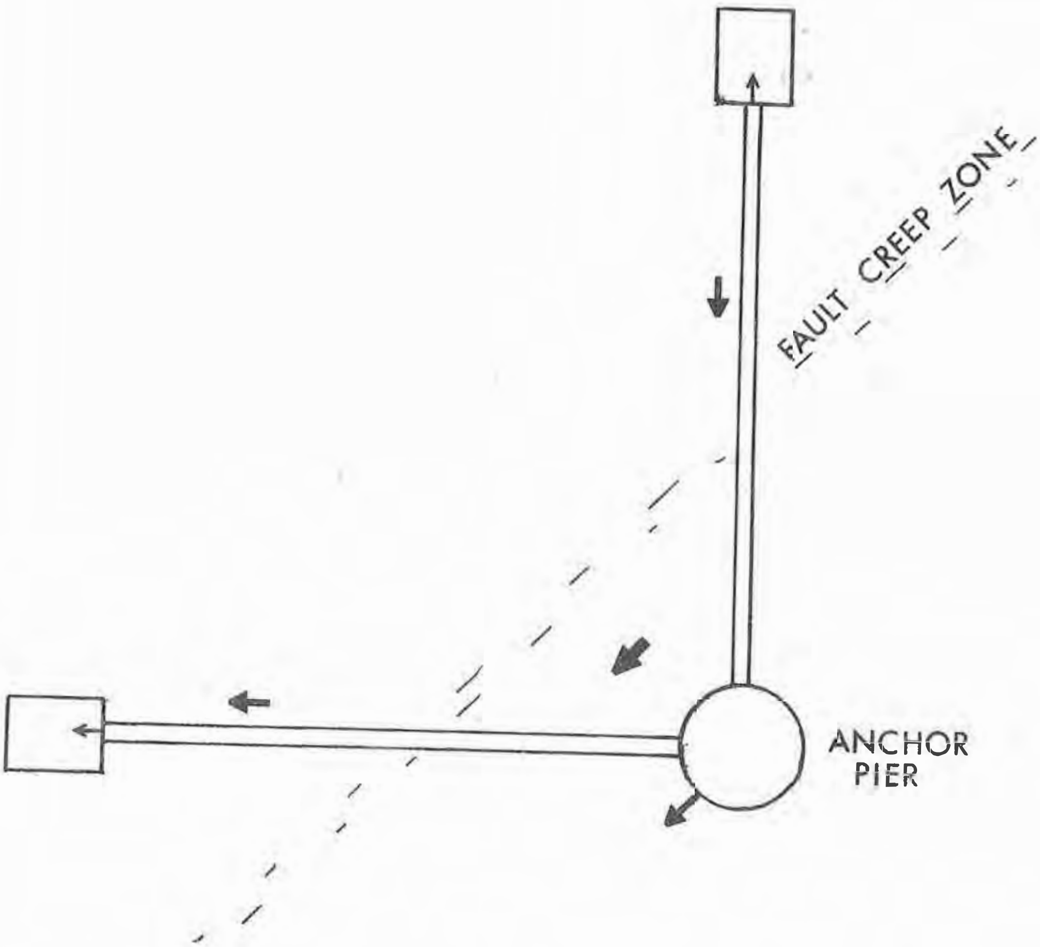

FIGURE 6. Layout of diagonal creepmeter using invar rods and spring tensioning, as installed by ESSA Earthquake Mechanism Laboratory.

except for the region of San Juan Bautista.

Allen (1968) has suggested that this distribution indicates different conditions along different parts of the fault. In his model, the 1857 and 1906 segments of the fault do not creep because they are "locked" in some manner. The elastic strain builds up without creep and results in major earthquakes instead. In the portion of the fault that is between the 1857 and 1906 fault breaks, however, the active fault creep keeps strain from building up to a great earthquake.

An alternative model is that the fault creep slippage is one phase in a time-history of elastic strain build-up and earthquakes. In this model, one starts with an essentially unstrained state immediately after a great earthquake, the great earthquake having relieved the previously stored-up elastic strain. Because of the lack of elastic stress after the great earthquake, there is a lack of fault creep.

Gradually, however, the condition of elastic strain and stress would be built up by the displacement of blocks or plates at a distance from the fault on either side. The plate displacement might be part of the New Global Tectonics pattern of Isacks et al. (1968). The plate displacement would gradually build up elastic strain and increased elastic stress in the fault region.

As the elastic strain gradually increases, the stress across the fault will also increase. At some point the elastic stress at the fault will exceed the small strength of the clayey fault gouge material in the fault zone. When that occurs, the clayey gouge will begin to "creep", just as any plastic material creeps under stress. The rate of creep will depend on the effective strength of the fault gouge material and the magnitude of the elastic stress, and at low-elastic stresses the creep rate will be low. The creep rate will increase, however, with increased elastic stress. The fault creep slippage is evidence of the presence of elastic stress. Since it is the fault gouge material that deforms by creep, the fault creep slippage will be located at the fault gouge zone, as observed.

The fault creep will start slowly, at a rate near zero, so the displacement of points away from the fault (the block or plate movement) will exceed the rate of slippage at the fault. Because the plate displacement exceeds the fault slip, the elastic strain and stress will continue to increase. And as the elastic stress increases, the creep rate increases. There would probably be a clear increase in minor and moderate seismicity as well.

The fault zone of course is not uniform in its mechanical properties either with depth or along its length. Therefore some parts of the fault zone will creep more easily than others, and some parts will act as blockages in the creep slippage. The observed variety of creep events and earthquakes may result from the sudeen breakage of such blockages.

With time the elastic strain will build up to a very high level. The creep slippage rate might be high, but still not enough to match the displacement of blocks away from the fault. As the elastic strain builds up, larger and larger earthquakes occur. Finally a very large earthquake occurs, one which relieves all of the elastic strain in the fault region, returning the fault to an unstressed state, completing the cycle.

The sequence of strain build-up, creep slip and earthquakes can be considered as an elastic strain cycle. The cycle might last for hundreds of years. The cycle might also be very complex in complex areas.

Such a cycle of increasing build-up of elastic stress and strain with more and more minor and moderate seismicity has been observed by Burridge and Knopoff (1968) in elastic models consisting of springs, masses and slip surfaces. The models of springs, masses and slip surfaces may be an excellent approximation to elastic rock properties in the real earth.

The possible application of this strain cycle theory to California would be as follows. The portions of the San Andreas fault that were offset in the 1857 and 1906 earthquakes are now seismically quiet in the early part of the strain cycle. The elastic strain build-up has been insufficient since the earthquake of 1906 to cause significant minor seismicity or creep. With time, however, the elastic strain will gradually increase. Then the fault creep slippage and moderate seismicity will also increase.

The active fault creep slippage and moderate seismicity on the central San Andreas fault south of Hollister represents a later stage in the strain cycle, with significant elastic strain and stress to drive the active fault slippage. This area may be nearer a great earthquake than the other areas. Or possibly the current fault creep slippage rate (2.5cm/yr.) is sufficient to relieve the elastic strain as rapidly as it accumulates. In any case, the fault creep slippage indicates significant elastic stress in the region at the present time.

It should be noted that the seismicity in northern California was much greater before the 1906 earthquake than after (Richter, 1958). This was true both along the San Andreas fault and in the surrounding areas. For instance, at Santa Rosa (80km north of San Francisco and 30km east of the San Andreas fault) there were four damaging earthquakes in the 50 years before 1906 but none in the 50 years after 1906 (see list in Tocher, 1957). The many earthquakes indicate an elastically more strained condition prior to 1906, in agreement with the strain cycle model.

According to the model, there should have been high seismicity active fault creep slippage on the San Andreas fault where none is evident today north of San Francisco in the years preceding 1906.

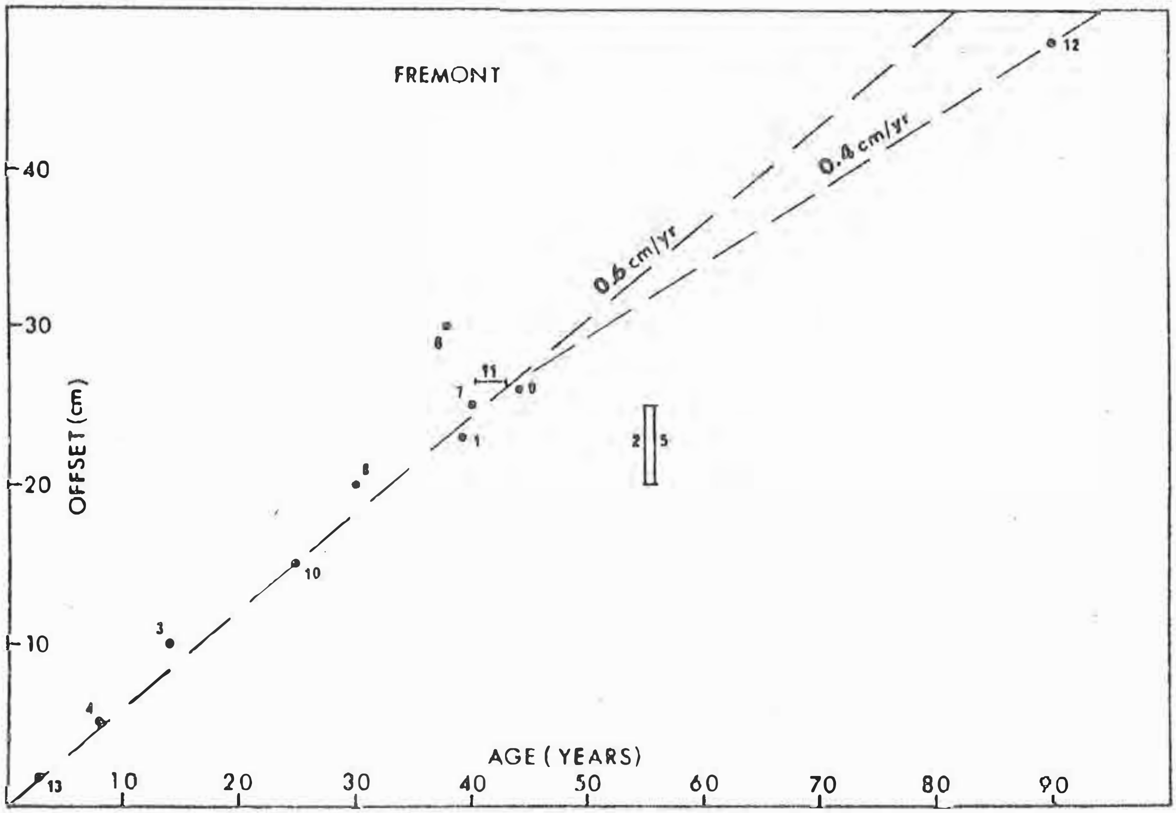

FIGURE 7. Plot of fault offsets of features of different age in Fremont, California. Features are 1) Mission Boulevard at Nursery Road, 2) Western Pacific Railroad tracks, 3) Guardrail at Shinn Station, 4) U.S. Gypsum Company fence, 5) Southern Pacific Railroad tracks, 6) Peralta Boulevard, 7) 1925 Hetch Hetchy aqueduct, 3) 1935 Hetch Hetchy aqueduct, 9) Irvington warehouse building, 10) Irvington warehouse fence, 11) Washington Boulevard, and 12) Gallegos Winery.

References

Allen, Clarence R., 1968. The tectonic environments of seismically active and inactive areas along the San Andreas fault system. Proceedings of Conference on Geologic Problems of San Andreas Fault System. XI: 70-82.

Blanchard, F.B.; Laverty, G.L., 1966. Displacements in the Claremont water tunnel at the intersection with the Hayward fault. Bull. Seism. Soc. Am. 56: 291-293.

Bolt, Bruce A.; Marion, Walter C., 1966. Instrumental measurement of slippage on the Hayward fault. Bull. Seism. Soc. Am. 56: 305-316.

Bonilla, M.G., 1966. Deformation of railroad tracks by slippage on the Hayward fault in the Niles district of Fremont, California. Bull. Seism. Soc. Am. 56: 281-289.

Brown, R.D. Jnr.; Wallace, R.E., 1968. Current and historic fault movement along the San Andreas fault between Paicines and Camp Dix, California, Stanford University Publications in Geological Sciences, XI:

Burridge, R.; Knopoff, L., 1967. Model and Theoretical Seismicity, Bull. Seism. Soc. Am. 57: 311-371.

Cluff, L.S.; Steinbrugge, K.V., 1966. Hayward fault slippage in the Irvington Niles districts of Fremont, California. Bull. Seism. Soc. Am. 56: 257-279.

Isacks, B.; Oliver, J.: Sykes, L.R., 1968. Seismology and the new global tectonics. J. Geophys. Research. 73: 5855-5899.

Koen, T.W., 1933. Analysis and effects of current movement on an active fault in Buena Vista Hills oilfield.

Nakamura, Kazuaki; Tsuneishi, Y., 1967. Ground cracks at Matsushiro probably of underlying strike-slip fault origin. II the Matsushiro earthquake fault. Bull. Earthquake Res. Inst. (Tokyo). 45: 417-471.

Nason, R.D., 1969. Preliminary instrumental measurements of fault creep slippage on the San Andreas fault, California. Earthquake Notes. XL: 6-10.

Nason, Robert D.; Carey, Joseph. Fault slippage on the Hayward fault at Hayward, California (in preparation).

Pope, A.J.; Stearn, J.L.; Whitten, C.A., 1966. Surveys for crustal movement along the Hayward fault. Bull. Seism. Soc. Am. 56: 317-323.

Radbruch, Dorothy H., 1968. New evidence of historic fault activity in Alameda, Contra Costa, and Santa Clara counties, California. Stanford University Publications in Geological Sciences, XI: 46-54.

Radbruch, Dorothy H.; Lennert, Ben J., 1966. Damage to culvert under Memorial Stadium, University of California, Berkeley, caused by slippage in the Hayward fault zone. Bull. Seism. Soc. Am. 56: 295-304.

Richter, Charles F., 1958. Elementary Seismology, W.H. Freeman and Co., San Francisco, California. 739 pp.

Smith, Stewart W.; Wyss, Max, 1968. Displacement on the San Andreas fault subsequent to the 1966 Parkfield earthquake. Bull. Seism. Soc. Am. 58: 1955-1973.

Steinbrugge, K.V.; Zacher, E.G., 1960. Creep on the San Andreas fault--fault creep and property damage. Bull. Seism. Soc. Am. 50: 389-396.

Tocher, Don, 1957. Seismic history of the San Francisco region. Calif. Div. Mines Spec. Report. 57: 39-48.

______ 1960. Creep on the San Andreas fault--creep rate and related measurements at Vineyard, California. Bull. Seism. Soc. Am. 50: 396-404.

Whitten, C.A., 1961. Measurement of small movement in the earth's crust. Acad. Sci. Fennicae Annales, Ser. A. III Geol. Geog. 61: 315-320.

Whitten, C.A.; Claire, C.N., 1960. Analysis of geodetic measurements along the San Andreas fault. Bull. Seism. Soc. Am. 50: 404-416.

Copies of:

NASON, R. D., (1971), Investigation of Fault Creep Slippage in Northern can Central California. Ph.D. Thesis, University of California, San Diego.

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Foundation Studies for the Dumbarton Bridge Replacement

By

Adlai F. Goldschmidt*

March, 1979

Abstract

Geotechnical studies conducted for the Dumbarton Bridge Replacement consisted of a drilling program, a seismicity study, a reflection seismic study and pile load tests. The foundation design for the bridge as well as many of its structural design aspects were based on these studies.

Introduction

The Dumbarton Bridge Replacement Project will improve State Highway 84 in San Mateo and Alameda Counties, California about 25 miles south of the City of San Francisco. The site of the most southerly highway crossing of San Francisco Bay is between the cities of Palo Alto and Newark (Figure 1). The project consists of three segments. The western approach with several alternate routes in San Mateo County, the overwater portion across San Francisco Bay and the eastern approach in Alameda County. This report will cover the engineering geology studies made for the overwater portion of the project.

*Engineering Geologist, Caltrans, Division of Project Development, Office of Structures Design, Engineering Geology Branch.

The existing bridge, named after Dumbarton Point near Newark (Alameda County), was built in 1927 for the Dumbarton Bridge Company at a cost of $2,250,000. It is located at the narrowest neck of San Francisco Bay where only 1.2 miles of overwater structure was required. The Dumbarton Bridge was the first highway bridge to be built across San Francisco Bay. It was operated as a private toll bridge until purchased by the State of California in 1951 for $2,500,000.

About 3/4 mile south of the Dumbarton Bridge are the Southern Pacific Railroad crossing opened in 1908 and the City of San Francisco's Hetch-Hetchy Aqueduct crossing which was placed in service in 1925. The aqueduct supplies water from the Sierra Nevadas to San Francisco.

The new Dumbarton Bridge

The existing low level bridge, which is over 50 years old, is inadequate. Its two narrow lanes are hazardous, passing slow vehicles is dangerous, and opening the lift span causes traffic delays. Because of the many problems with the existing bridge, Caltrans decided to build a new high level bridge. The new bridge located about 90 feet north of the old bridge, will make up for all of the inadequacies of the old bridge in keeping with todays needs and designs. The structure is being built in two contract segments. The low bidder for both contracts is the Guy F. Atkinson Company of South San Francisco. The first contract consists of the east and west approach spans. The main channel spans comprise the second contract.

The new high-level structure (Figure 2) will be 8800 feet long. It will have two vehicle lanes and an eight foot shoulder for each direction of traffic with an eight foot median and safety barrier. In addition, there will be a separate eight foot bicycle/pedestrian path along the south side of the bridge. The main shipping channel span will provide for navigational clearance of 85 feet vertically and 340 feet horizontally.

Prestressed concrete girders will be used for all but the longest spans of the new bridge. Steel girders will be used for the main channel spans. The substructure will consist of slender, double concrete piers on pile supported footings (Figure 3).

When construction of the new bridge is completed, the center spans of the old bridge will be removed. The remaining trestle portions will be rehabilitated for use by the public for fishing and birdwatching.

Geotechnical Investigations

The foundation study used for the design of the new Dumbarton Bridge was made by the Division of Bay Toll Crossing of the California Department of Public Works (now Caltrans-District 04). Field work was accomplished in 1970. Foundation drilling was done under contract. The Duncanson-Harrelson Company was the prime contractor and the Pitcher Drilling Company the subcontractor for the work. Bay Tolls engineers supervised the field investigation and were responsible for all its technical and engineering aspects.

Twenty-four borings were drilled at the site and numerous soil samples were obtained for laboratory testing. Five inch diameter test borings were drilled with rotary drilling equipment to a maximum depth of 205 feet (Figure 4).

"Undisturbed" soil samples were obtained in the cohesive material. Soil identification, unit weights, Torvane shear tests, and pocket penetrometer tests were made on samples at the time of drilling. Samples for further testing were forwarded to the Materials & Research Laboratory in Sacramento. The laboratory data obtained included Atterberg limits, gradation curves, unit weights, undrained shear strengths, and consolidation tests.

The Standard Penetration Test was used to sample granular materials. This test consists of driving a 2-inch outside diameter, 1 and 3/8-inch inside diameter, split barrel sampler with a 140 pound hammer, which has a drop of 30 inches. Blow counts were recorded and the soil samples obtained were identified by field inspection.

Plans for the structure were completed by the Bay Tolls staff and forwarded to the Caltrans Structures unit for final checking. The Engineering Geology Branch reviewed the foundation data and decided that additional information was required. As a result, in late 1977, additional borings were made on shore and in the shallow water-mud flat areas for the approach structures. Subsurface data for the main channel crossing was obtained from two borings drilled at pile load test sites. The Standard Penetration Test was used to test and sample subsurface soils in these borings. A reflection seismic study (Figure 4) was conducted across the "deep" water portion of the channel. Earth Science Associates of Palo Alto, California was the consultant for the seismic study.

Additional borings were drilled by the Engineering Geology Branch during 1978 and 1979 to verify subsurface conditions at each pier location. These borings were required because pile driving data and pile load test data did not agree with the soils data already obtained.

Geology

The site, on San Francisco Bay, is located in the Coast Range geomorphic province of California. The province is characterized by northwest trending mountain ranges and valleys. San Francisco Bay occupies a very large and complex valley, which has become drowned as a result of Pliocene and Pleistocene warping and faulting as well as Pleistocene glacial melt. Deposition of material during the Pleistocene and Holocene has resulted in a great thickness of sediments overlying Franciscan formation bedrock adjacent to and beneath San Francisco Bay. At the site, the depth to bedrock varies from about 600 feet on the west to about 500 feet on the east. The bridge will be supported by piles driven into the sediments.

The bridge site is situated almost equidistant between the major geologic structures of the area-the San Andreas fault zone to the west and the Hayward fault zone to the east.

The San Andreas fault is the principle active fault in California and is traceable for several hundred miles.

Large earthquakes have occurred on both the Hayward and San Andreas faults during historic time.

Four distinct marine and non-marine sedimentary units were encountered in the borings. These units are essentially flat lying throughout the site. They are in unconformable contact with each other and, as a result, have uneven boundaries. Details of the soils units are shown in the cross section (Figure 5) and on the "Logs of Test Borings" (Figures 6 and 7). Descriptions of the units are outlined below and are compared with the stratigraphy of others as shown on Table 1. Soil properties are shown on Table 2.

Geologic Data

1. Bay mud (Holocene) Very soft, estuarine organic clays and silt. This layer extends from the bay bottom down to elevation -35 ±5 feet.

2. Terrestrial basin deposits (Pleistocene) Soft to stiff layers of silty to sandy clay with interbeds of loose silt and fine sand. This layer underlies the "Bay Mud" and extends to elevation -50 ±5 feet.

3. Stream deposits (Pleistocene) Compact to dense, fine to coarse sand and gravelly sand with basal pebble gravel lenses. This layer extends to elevation -70 ±10 feet.

4. Older basin deposits: (Plio-Pleistocene) This unit consists of very stiff to stiff, silty to sandy clay with compact to dense, interbeds of silt and sands. The upper few feet of this layer is weathered. The unit was encountered below elevation -70±.

Seismic Study

The seismic study for the Dumbarton Bridge replacement was conducted during 1972 by Shannon and Wilson, Inc., Burlingame, California. The earthquake resistant design of the structure is based on their report. The information contained in the report includes earthquake engineering studies, a ground response analysis, and deformation and stability studies. Strong ground motions are based on a Richter magnitude 8.0+ earthquake occurring on the San Andreas fault scaled to a peak rock acceleration equal to 0.5 gravity. These motions would result in a horizontal ground motion of about 0.3 gravity on top of the sand layer at elevation -50. The fundamental period of the soil deposit will vary between two and four seconds depending on the earthquake magnitude. The report also indicates that liquefaction would not be a problem at the site.

Foundation Types

The Dumbarton Bridge replacement will traverse mud flats, salt evaporation ponds, tidelands, and the main channel of San Francisco Bay. Because of the soft, varying nature of these deposits, the varying depth of water, and structural considerations, three different pile types will be used for structure support. The structure will be essentially symmetrical around the channel section.

Driven vertical piles will be used for support of the entire structure. Piles are designed to be corrosion resistant, and have a safety factor of two. The abutments including an approach ramp will be supported by solid 20" square prestressed concrete piles each supporting a load of 90 tons. The approach span footings will be placed on the bottom of the bay and will be supported by 20" round steel piles (Figure 8) filled with concrete. These are also 90 ton design load piles.

Main span footings will be supported on 54 inch diameter piles (Figure 8) extending through the deeper water into the soil below. These hollow piles are jetted and driven into position prior to being filled with concrete. They were designed for loads of 250 tons each and are the most significant aspect of the foundation system for the structure.

Pile Load Tests

A pile load test program has been developed as a part of the construction contract to insure that all piles are adequate to support the loads for which they have been designed. Several designated control areas, which include one pile type each, have been established. The first piles to be driven in a control area are tested to double design load prior to driving the remaining piles. If the piles satisfy the design criteria for load and settlement, then the remaining piles in the control area are driven. If the piles do not satisfy the criteria, then their lengths are adjusted so that they will conform. Additional load tests (and piles) may be used if inadequacies develop.

References

Atwater, B. F., Hedel, C. W., & Helley, E. J., 1977, Late Quaternary depositional history, Holocene sea-level changes, and vertical crustal movement, southern San Francisco Bay, California, USGS PP-1014.

Caltrans,1973, Final environmental impact statement for the Dumbarton Bridge replacement project.

Earth Science Associates, 1978, High resolution seismic reflection study of the subsurface geology of San Francisco Bay adjacent to the Dumbarton Bridge.

Hazelwood, R. M., 1976, Contour map & section, bedrock surface South San Francisco Bay Region, USGS MF-796.

Nichols, D. R., & Wright N. A., 1971, Preliminary map of historic margins of marshland, San Francisco Bay, California, USGS open file map.

Shannon & Wilson, Inc., 1972, Dumbarton Bridge replacement seismic study.

Comparison of Stratagraphic Nomenclature at the Dumbarton Bridge

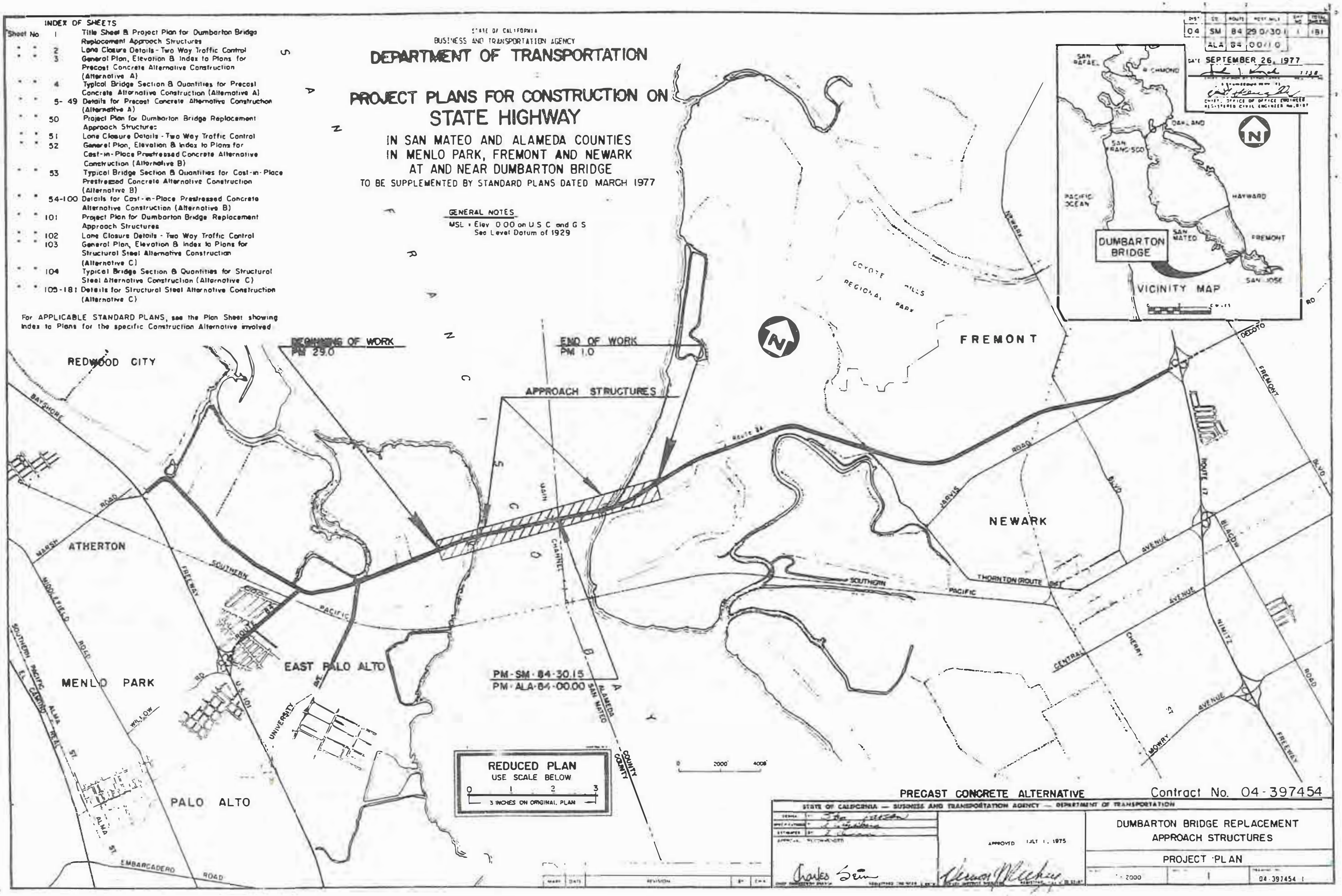
Caltrans	Atwater et. al. (age)	Trask & Ralston (from Atwater et. al.)
1. Bay mud	Estuarine deposits (Holocene)	Bay mud
2. Terrestrial basin deposits	Alluvial deposits (late Pleistocene and Holocene)	Posey Formation
3. Stream deposits (Newark Aquifer)	Estuarine deposits (late Pleistocene)	San Antonio Formation
4. Older basin deposits	Terrestrial and esturine deposits (Pliocene ? and Pleistocene)	Alameda Formation

Table 1

Soil Properties (average)

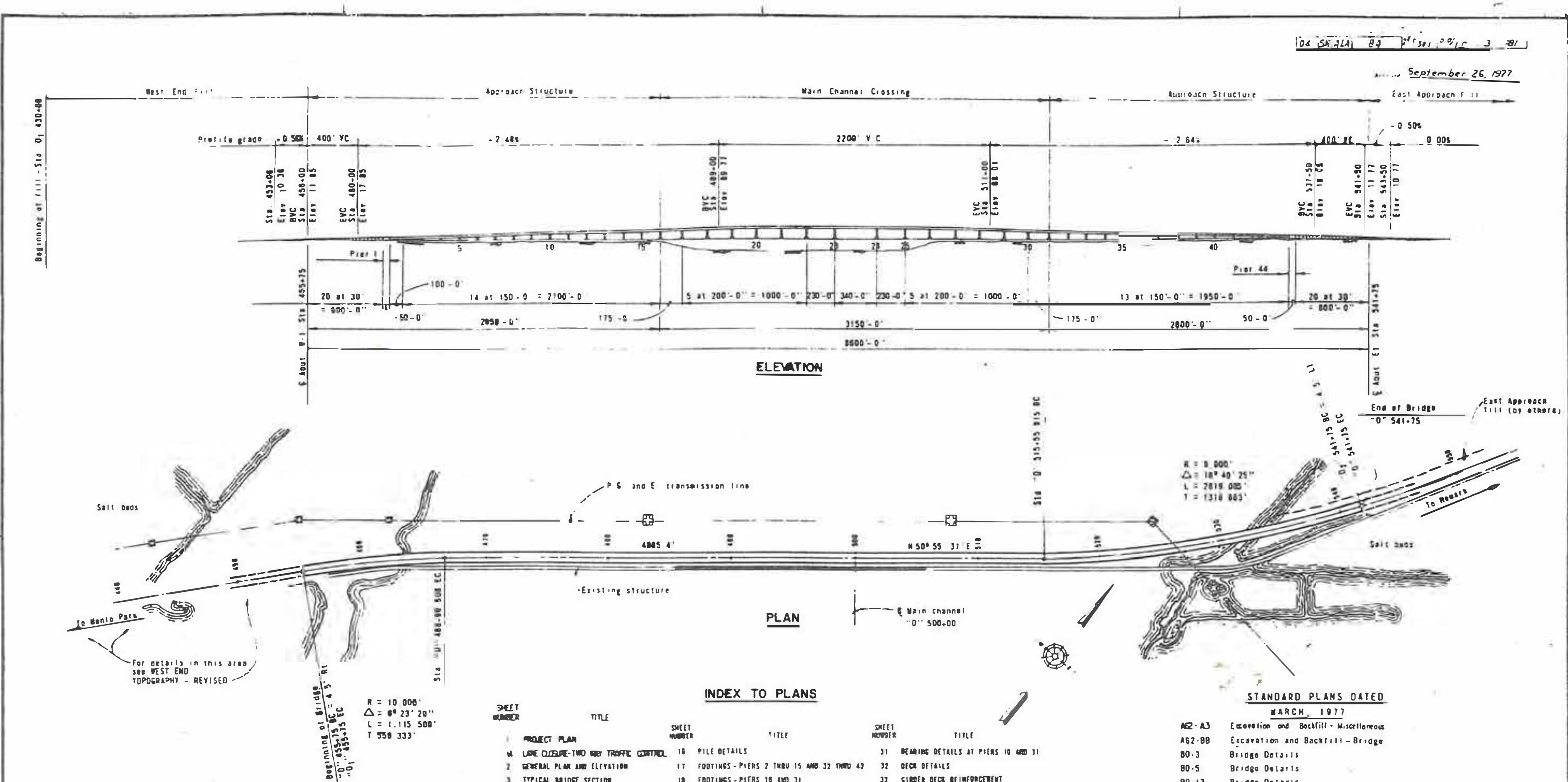
Unit	Unit Weight (lbs/ft^3)	Water Content (%)	Cohesion or Shear Strength (tons)	Penetration Index (blows/ft)	Angle of Shearing Resistance
1. Bay mud	95	100+	0.1-0.2	Push	-
2. Terrestrial basin deposits	125	30	0.75-1.0	10-15	-
3. Stream deposits	130	20	-	20-40	35^{o}-40^{o}
4. Older basin deposits	130	30	0.75-2.5	20-35	-

Table 2



INDEX OF SHEETS
Sheet No
1 Title Sheet & Project Plan for Dumbarton Bridge Replacement Approach Structures
2 Lane Closure Details - Two Way Traffic Control
3 General Plan, Elevation & Index to Plans for Precast Concrete Alternative Construction (Alternative A)
4 Typical Bridge Section & Quantities for Precast Concrete Alternative Construction (Alternative A)
5-49 Details for Precast Concrete Alternative Construction (Alternative A)
50 Project Plan for Dumbarton Bridge Replacement Approach Structures
51 Lane Closure Details - Two Way Traffic Control
52 General Plan, Elevation & Index to Plans for Cast-in-Place Prestressed Concrete Alternative Construction (Alternative B)
53 Typical Bridge Section & Quantities for Cast-in-Place Prestressed Concrete Alternative Construction (Alternative B)
54-100 Details for Cast-in-Place Prestressed Concrete Alternative Construction (Alternative B)
101 Project Plan for Dumbarton Bridge Replacement Approach Structures
102 Lane Closure Details - Two Way Traffic Control
103 General Plan, Elevation & Index to Plans for Structural Steel Alternative Construction (Alternative C)
104 Typical Bridge Section & Quantities for Structural Steel Alternative Construction (Alternative C)
105-181 Details for Structural Steel Alternative Construction (Alternative C)
For APPLICABLE STANDARD PLANS, see the Plan Sheet showing Index to Plans for the specific Construction Alternative involved
STATE OF CALIFORNIA
BUSINESS AND TRANSPORTATION AGENCY
DEPARTMENT OF TRANSPORTATION
PROJECT PLANS FOR CONSTRUCTION ON
STATE HIGHWAY
IN SAN MATEO AND ALAMEDA COUNTIES
IN MENLO PARK, FREMONT AND NEWARK
AT AND NEAR DUMBARTON BRIDGE
TO BE SUPPLEMENTED BY STANDARD PLANS DATED MARCH 1977
GENERAL NOTES
MSL = Elev 0.00 on U.S.C. and G.S. Sea Level Datum of 1929
SAN FRANCISCO BAY
BEGINNING OF WORK PM 29.0
END OF WORK PM 1.0
APPROACH STRUCTURES
PM-SM-84-30.15
PM-ALA-84-00.00
MAIN CHANNEL
SAN MATEO
ALAMEDA
COUNTY
COUNTY
REDWOOD CITY
ATHERTON
MENLO PARK
EAST PALO ALTO
PALO ALTO
FREMONT
NEWARK
COYOTE HILLS REGIONAL PARK
BAYSHORE
MARSH ROAD
MIDDLEFIELD ROAD
FREEWAY
SOUTHERN PACIFIC
ROUTE 84
U.S. 101
UNIVERSITY AVE
WILLOW RD
EL CAMINO REAL
ALMA ST
EMBARCADERO ROAD
JARVIS
NEWARK BLVD
THORNTON (ROUTE 84)
CENTRAL AVENUE
CHERRY
ROUTE 17
NIMITZ FREEWAY
MOWRY AVENUE
FREMONT BLVD
DECOTO RD
BLACOW ROAD
REDUCED PLAN
USE SCALE BELOW
0 1 2 3
3 INCHES ON ORIGINAL PLAN
0 2000' 4000'
DIST 04 CO SM ROUTE 84 POST MILE 29.0/30.1 SHT NO 1 TOTAL SHEETS 181
ALA 84 00/1.0
DATE SEPTEMBER 26, 1977
CHIEF, OFFICE OF OFFICE ENGINEER
REGISTERED CIVIL ENGINEER
SAN RAFAEL
RICHMOND
OAKLAND
SAN FRANCISCO
PACIFIC OCEAN
HAYWARD
SAN MATEO
FREMONT
SAN JOSE
DUMBARTON BRIDGE
VICINITY MAP
PRECAST CONCRETE ALTERNATIVE
Contract No. 04-397454
STATE OF CALIFORNIA — BUSINESS AND TRANSPORTATION AGENCY — DEPARTMENT OF TRANSPORTATION
APPROVED JULY 1, 1975
DUMBARTON BRIDGE REPLACEMENT
APPROACH STRUCTURES
PROJECT PLAN
1"=2000'
1
04-397454 1

FIGURE 1



INDEX TO PLANS

SHEET NUMBER	TITLE	SHEET NUMBER	TITLE	SHEET NUMBER	TITLE
1	PROJECT PLAN				
1A	LANE CLOSURE-TWO WAY TRAFFIC CONTROL	16	PILE DETAILS	31	BEARING DETAILS AT PIERS 16 AND 31
2	GENERAL PLAN AND ELEVATION	17	FOOTINGS - PIERS 2 THRU 15 AND 32 THRU 43	32	DECK DETAILS
3	TYPICAL BRIDGE SECTION	18	FOOTINGS - PIERS 16 AND 31	33	GIRDER DECK REINFORCEMENT
4	PLAN AND ELEVATION - 1	19	TOWER DETAILS - 1	34	DETAILS AT EXPANSION JOINTS
5	PLAN AND ELEVATION - 2	20	TOWER DETAILS - 2	35	CONCRETE BARRIERS
6	PLAN AND ELEVATION - 3	21	TOWER DETAILS - 3	36	CONDUIT INSTALLATIONS - BARRIER RAILING
7	PLAN AND ELEVATION - 4	22	TYPICAL SECTION	37	CONDUIT INSTALLATIONS - PIERS 13 TO 16
8	PLAN AND ELEVATION - 5	23	GIRDER LAYOUT	38	CONDUIT INSTALLATIONS - PIERS 1 AND 44
9	TRESTLE DETAILS - 1	24	PRESTRESSED GIRDERS	39	CONDUIT - BLOCK DIAGRAMS
10	TRESTLE DETAILS - 2	25	PRESTRESSED GIRDER DETAILS	40	WEST END TOPOGRAPHY - EXISTING
11	TRESTLE DETAILS - 3	26	GIRDER RESTRAINERS	41	WEST END REGRADING PLAN
12	PIERS 1 AND 44 - DETAILS - 1	27	PINNED GIRDER AND CAP CONNECTIONS	42	WEST END TOPOGRAPHY - REVISED
13	PIERS 1 AND 44 - DETAILS - 2	28	FIXED GIRDER AND CAP CONNECTIONS	43	EAST END TOPOGRAPHY
14	PIERS 1 AND 44 - DETAILS - 3	29	EXPANSION BEARINGS AT PIERS	44	EAST END FILL
15	PILE LAYOUT	30	BEARING DETAILS AT PIERS 1 AND 44	45 THRU 48	LOG OF TEST BORINGS

FOR APPROXIMATE QUANTITIES SEE SHEET 3

STANDARD PLANS DATED MARCH, 1977

A62-A3	Excavation and Backfill - Miscellaneous
A62-BB	Excavation and Backfill - Bridge
B0-3	Bridge Details
B0-5	Bridge Details
B0-13	Bridge Details
B7-1	Box Girder Details
B7-5	Deck Drains
ES-7A	Electrical Details, Structure Installations

REDUCED PLAN
USE SCALE BELOW
0 1 2 3
3 INCHES ON ORIGINAL PLAN

SCALE IN INCHES ON ORIGINAL

PRECAST CONCRETE ALTERNATIVE

STATE OF CALIFORNIA — BUSINESS AND TRANSPORTATION AGENCY — DEPARTMENT OF TRANSPORTATION

IN CHARGE OF DESIGN

APPROVED July 1, 1975

S. Larsen

DESIGN ENGINEER

W. Reichott

DUMBARTON BRIDGE REPLACEMENT
APPROACH STRUCTURE

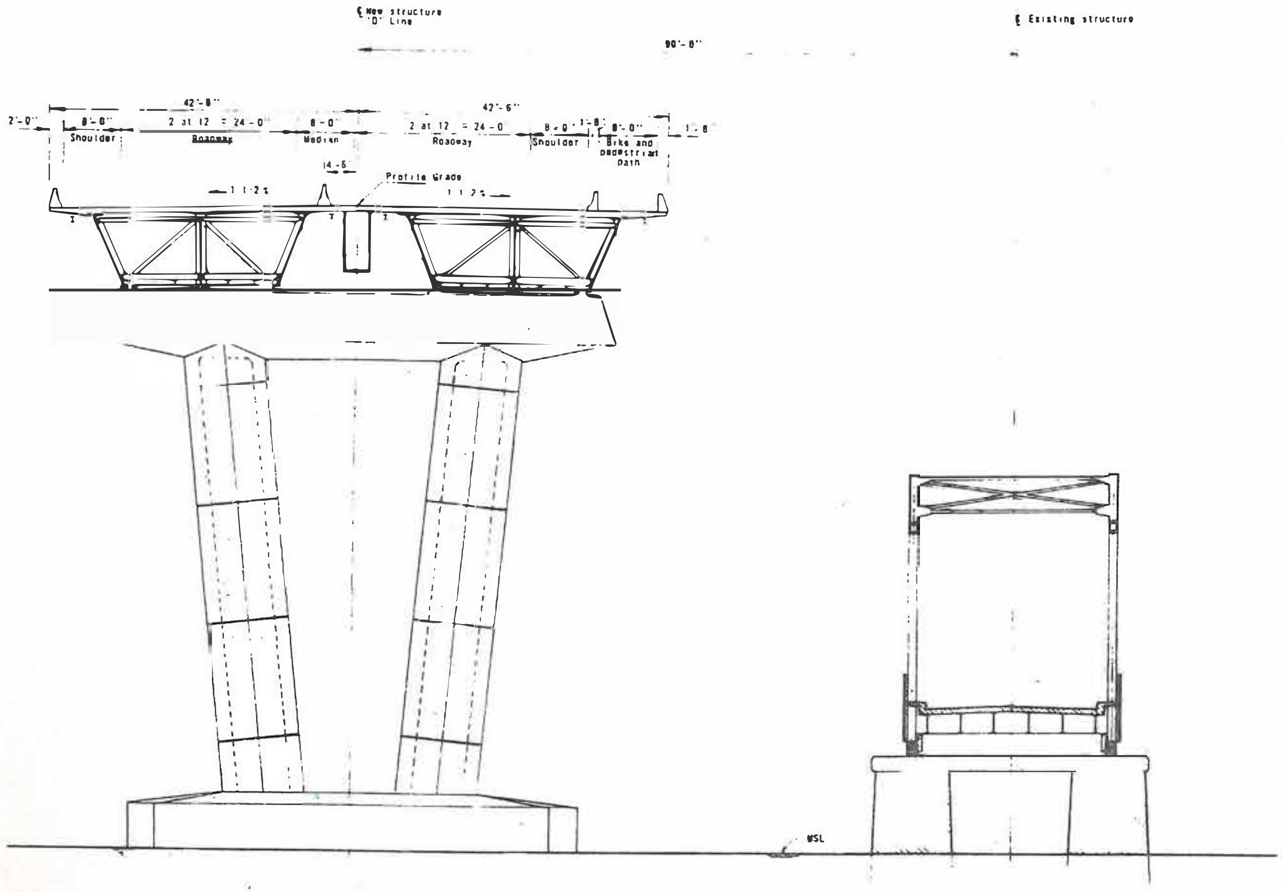
GENERAL PLAN AND ELEVATION

SCALE	SHEET NO.	DRAWING NO.
1" = 400	2	04 397454 2

MARK	DATE	REVISION	BY	CHK

FIGURE 2

January 30, 1978



NEW BRIDGE SECTION

EXISTING BRIDGE SECTION

DESIGN NOTES

SPECIFICATIONS - AASHTO 1973 Standard Specifications for Highway Bridges with revisions and the Bridge Planning and Design Manual of the Division of Structures, California Department of Transportation, except as modified below

LIVE LOAD - HS 20

PILING - For pile details see sheet 8

REINFORCED CONCRETE

1. f'c = 3500 psi, fc = 1400 psi, unless otherwise noted
2. f'c = 4000 psi, fc = 1600 psi, for tower legs and caps

LIGHTWEIGHT CONCRETE

1. Bridge Deck - f'c = 3500 psi, fc = 1200 psi

REINFORCING BAR STEEL

1. All reinforcing bar steel shall conform to ASTM A615 - Grade 60 or A706 except stirrups and ties shall conform to A615 Grade 40 or A706. The transverse reinforcing bars in the concrete deck and all bars in the barriers shall conform to either ASTM A615 - (Grade 40, Grade 50) or A706
2. Minimum cover for reinforcing steel, measured from the surface of concrete to the face of any bar, shall be 4" unless otherwise noted
3. Lap splices of reinforcing bars #11 or larger for the tower legs and cap will not be allowed unless otherwise shown

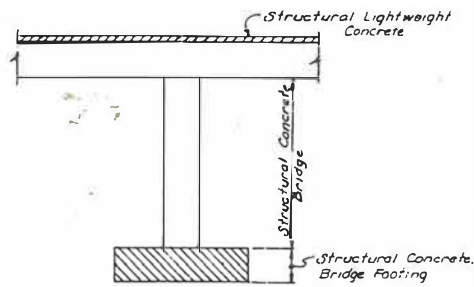
STRUCTURAL STEEL

A36 Fy = 36,000 psi

All steel shall be A36 unless otherwise noted

Low Alloy (LA)

Thickness	ASTM	Min Yield Point (Fy)
3/4" and Under	A441	50,000 psi
2" and Under	A572	50,000 psi
4" and Under	A588	50,000 psi



CONCRETE TYPE
No Scale

REDUCED PLAN
USE SCALE BELOW
0 1 2 3

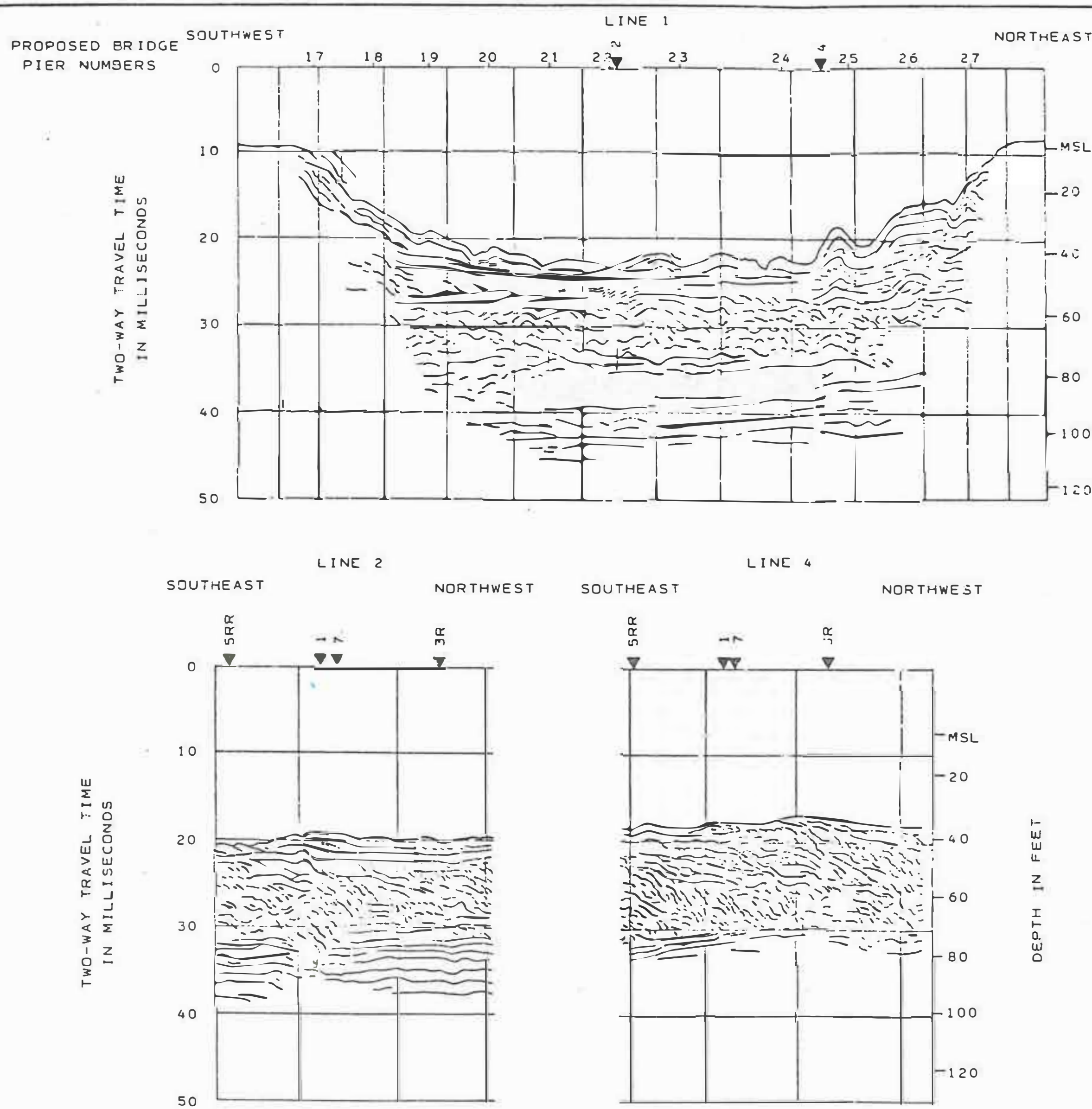
STATE OF CALIFORNIA — BUSINESS AND TRANSPORTATION AGENCY — DEPARTMENT OF TRANSPORTATION —

APPROVED Nov. 1, 1977

DUMBARTON BRIDGE REPLACEMENT
MAIN CHANNEL CROSSING
TYPICAL BRIDGE SECTION

04 39:484-3

FIGURE 3



LEGEND

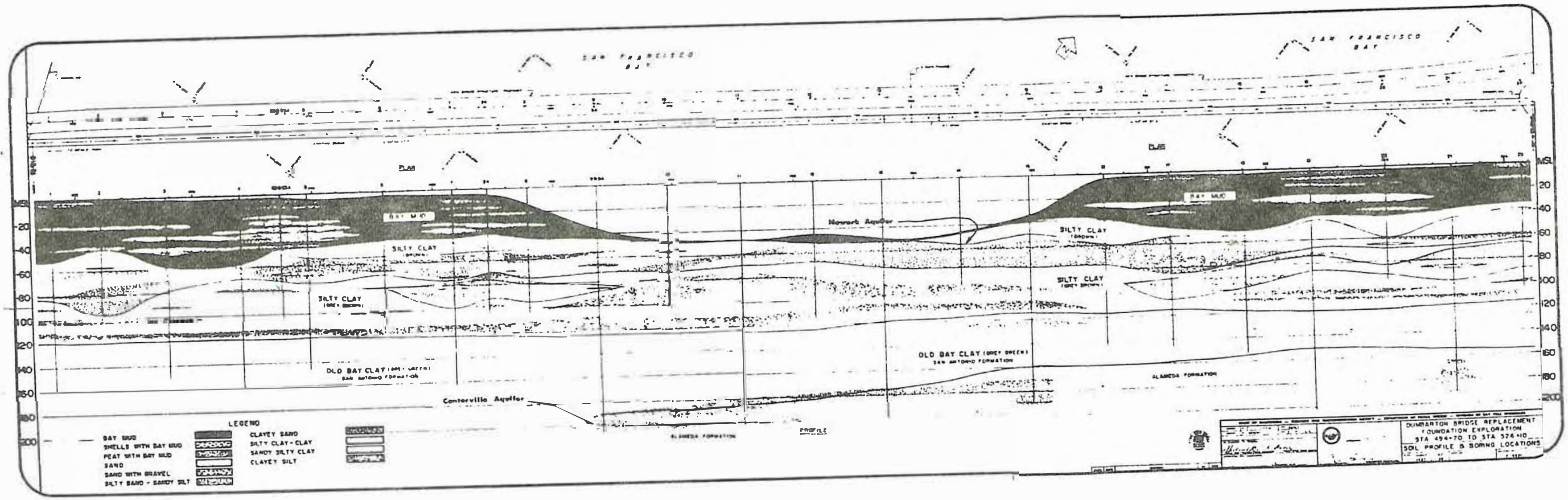
▼ LOCATION OF SEISMIC LINE CROSSING. THE NUMBER OF THE CROSSLINE IS INDICATED ABOVE THE LOCATION ARROW.

SEISMIC ENERGY INFERRED TO BE REFLECTED FROM SUBSURFACE STRATA.

FIGURE 4

INTERPRETIVE SEISMIC SECTIONS OF LINES 1,2 AND 4. INFERRED MULTIPLE AND DIFFRACTED SEISMIC RETURNS HAVE BEEN DELETED FROM THESE SECTIONS. THE DIFFERENT SEISMIC SIGNATURES INDICATING DIFFERENT LITHOLOGIC UNITS CAN BE CLEARLY DISCERNED ON THE SECTIONS. SHORT, WAVY AND GENERALLY CHAOTIC RETURNS ARE INTERPRETED TO REPRESENT SANDY AND CONGLOMERATIC MATERIAL. THE MORE EVENLY LAYERED SEISMIC RETURNS ARE INFERRED TO ORIGINATE FROM BAY MUDS AND CLAY AND SILT LITHOLOGIES.

FIGURE 4



GEOLOGIC CROSS SECTION

FIGURE 5

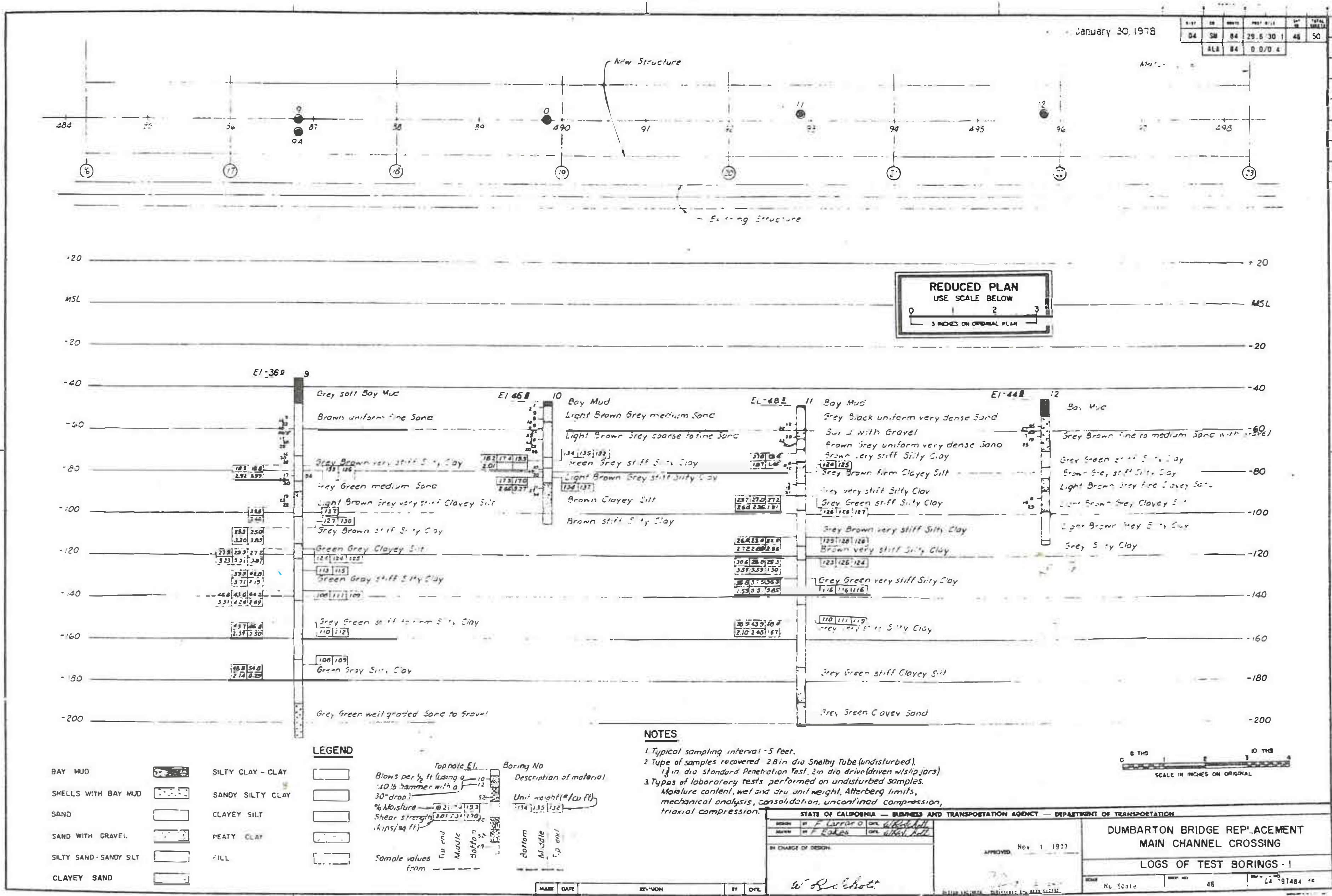
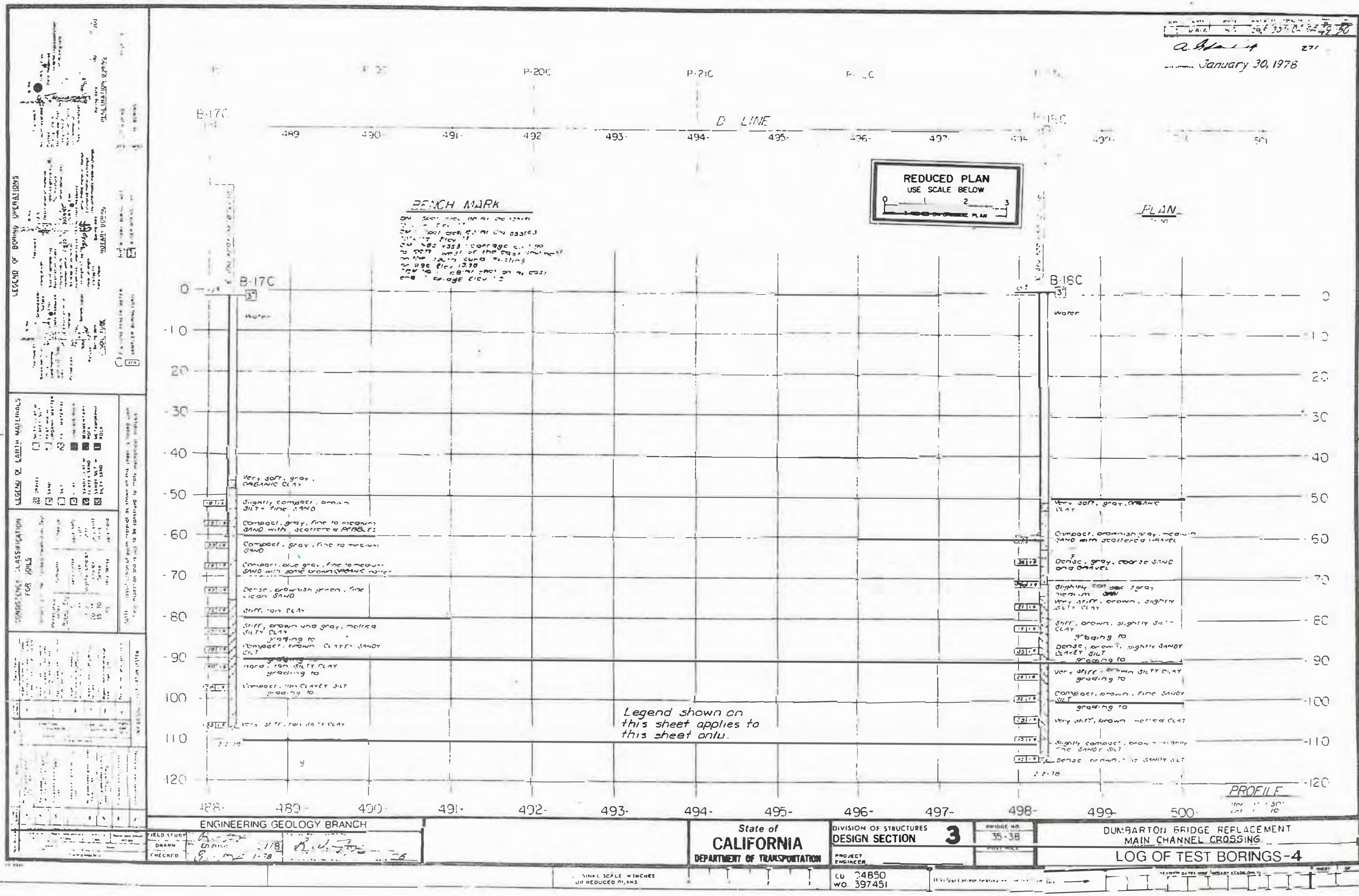
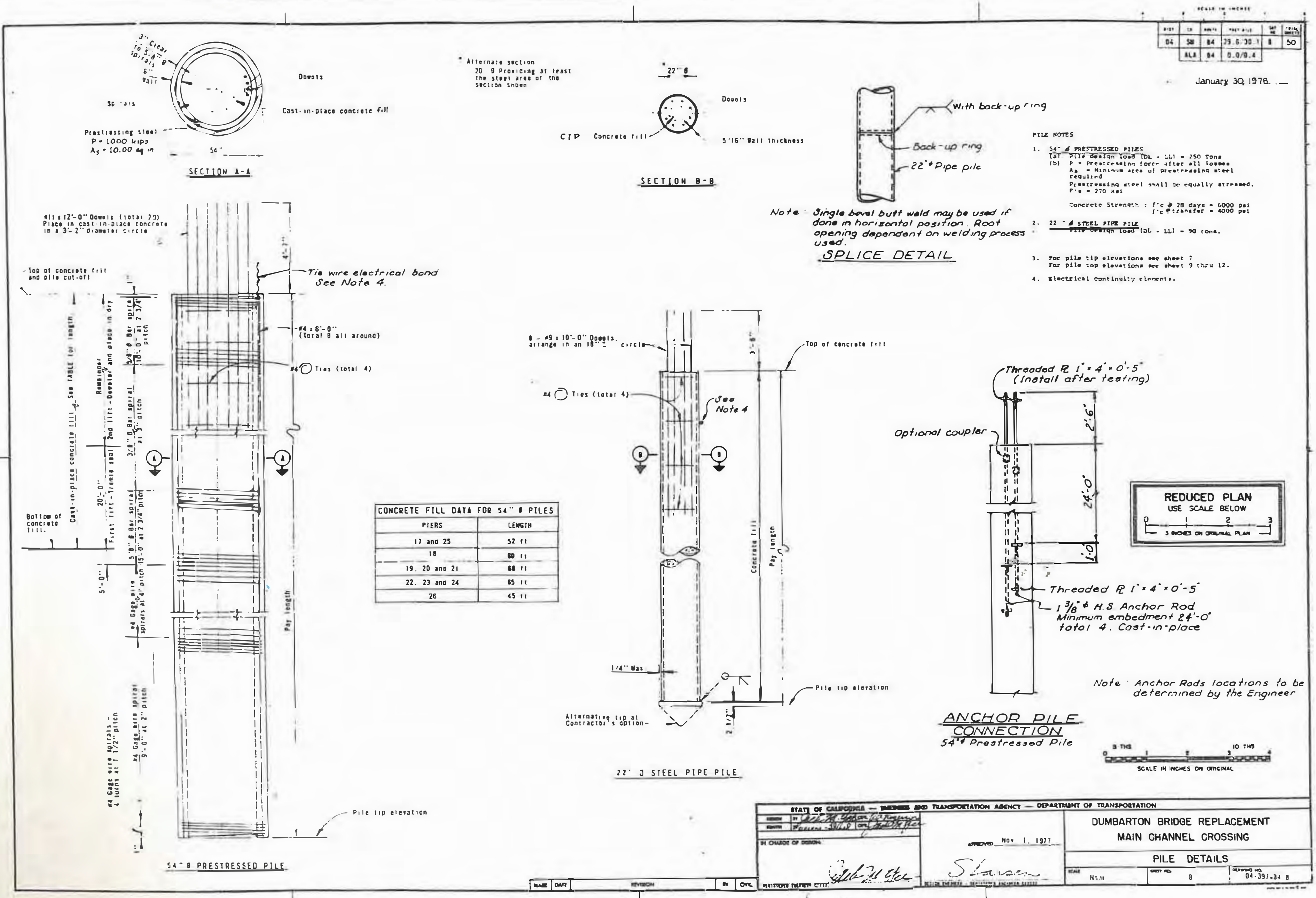

January 30, 1978
New Structure
Existing Structure
REDUCED PLAN
USE SCALE BELOW
3 INCHES ON ORIGINAL PLAN
Grey soft Bay Mud
Brown uniform fine Sand
Grey Brown very stiff Silty Clay
Grey Green medium Sand
Light Brown Grey very stiff Clayey Silt
Grey Brown stiff Silty Clay
Green Grey Clayey Silt
Green Gray stiff Silty Clay
Green Gray Silty Clay
Grey Green well graded Sand to Gravel
Bay Mud
Light Brown Grey medium Sand
Light Brown Grey coarse to fine Sand
Green Grey stiff Silty Clay
Light Brown Grey stiff Silty Clay
Brown Clayey Silt
Brown stiff Silty Clay
Grey Black uniform very dense Sand
Sand with Gravel
Brown Grey uniform very dense Sand
Brown very stiff Silty Clay
Grey Brown firm Clayey Silt
Grey Green stiff Silty Clay
Grey Brown very stiff Silty Clay
Brown very stiff Silty Clay
Grey Green very stiff Silty Clay
Grey Green stiff Clayey Silt
Grey Green Clayey Sand
Grey Brown fine to medium Sand with Gravel
Grey Silty Clay
LEGEND
BAY MUD
SHELLS WITH BAY MUD
SAND
SAND WITH GRAVEL
SILTY SAND - SANDY SILT
CLAYEY SAND
SILTY CLAY - CLAY
SANDY SILTY CLAY
CLAYEY SILT
PEATY CLAY
FILL
Top hole El.
Boring No
Blows per ½ ft (using a 140 lb hammer with a 30" drop)
Description of material
% Moisture
Shear strength (kips/sq ft)
Unit weight (#/cu ft)
Sample values from
Top end
Middle
Bottom
NOTES
1. Typical sampling interval - 5 feet.
2. Type of samples recovered: 2.8 in dia Shelby Tube (undisturbed), 1⅜ in dia Standard Penetration Test, 2 in dia drive (driven w/slip jars)
3. Types of laboratory tests performed on undisturbed samples. Moisture content, wet and dry unit weight, Atterberg limits, mechanical analysis, consolidation, unconfined compression, triaxial compression.
SCALE IN INCHES ON ORIGINAL
STATE OF CALIFORNIA — BUSINESS AND TRANSPORTATION AGENCY — DEPARTMENT OF TRANSPORTATION
DUMBARTON BRIDGE REPLACEMENT
MAIN CHANNEL CROSSING
LOGS OF TEST BORINGS - 1
Nov 1, 1977

FIGURE 6



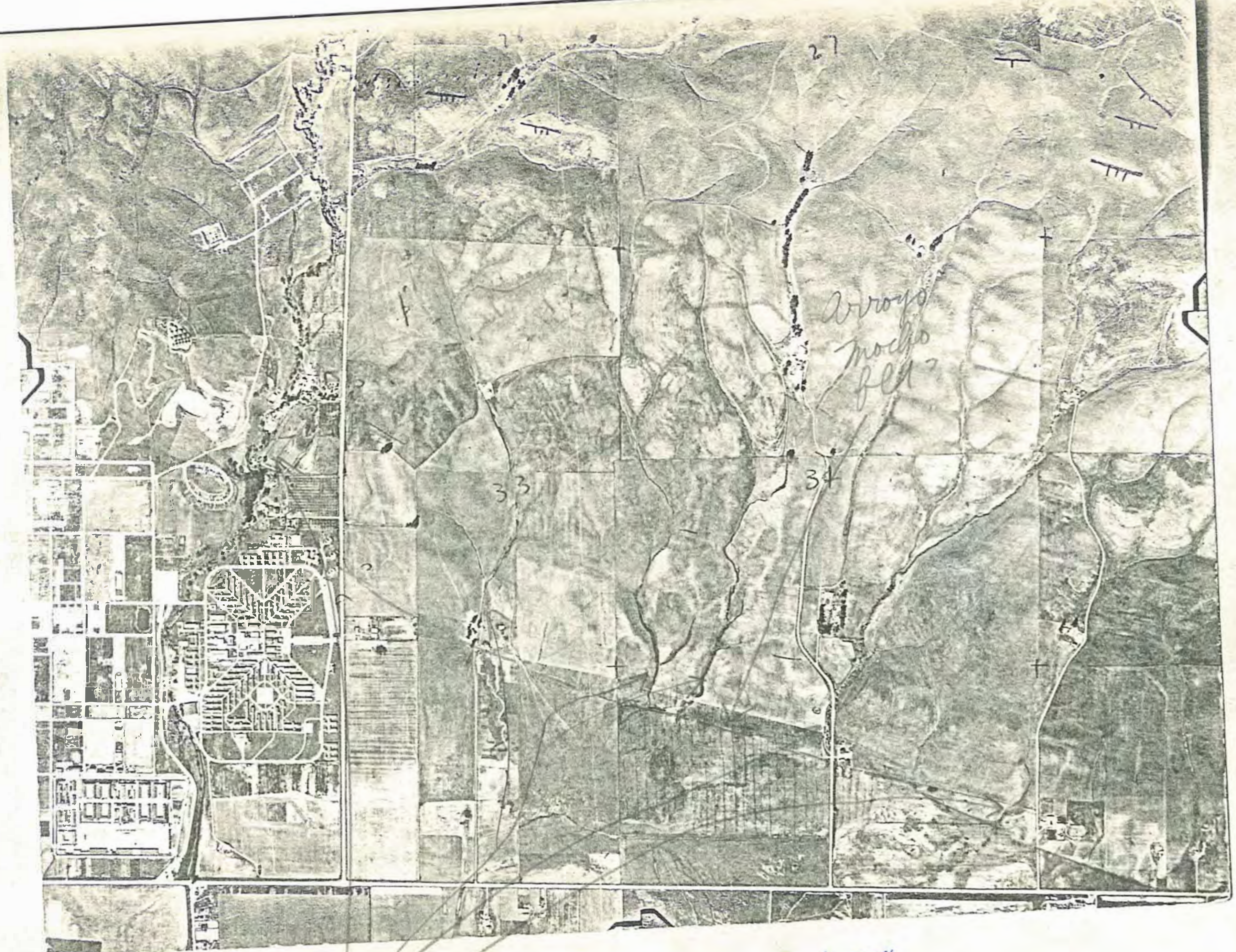
January 30, 1978
D LINE
REDUCED PLAN
USE SCALE BELOW
BENCH MARK
PLAN
B-17C
B-18C
Water
Very soft, gray, ORGANIC CLAY
Slightly compact, brown SILTY fine SAND
Compact, gray, fine to medium SAND with scattered PEBBLES
Compact, gray, fine to medium SAND
Dense, gray, coarse SAND and GRAVEL
Very stiff, brown, slightly SILTY CLAY
Stiff, brown and gray, mottled SILTY CLAY
grading to
Compact, brown, fine SANDY SILT
Legend shown on this sheet applies to this sheet only.
PROFILE
LEGEND OF BORING OPERATIONS
LEGEND OF EARTH MATERIALS
CONSISTENCY CLASSIFICATION FOR SOILS
ENGINEERING GEOLOGY BRANCH
State of CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF STRUCTURES
DESIGN SECTION 3
35-38
DUMBARTON BRIDGE REPLACEMENT
MAIN CHANNEL CROSSING
LOG OF TEST BORINGS-4
CU 04850
WO 397451

FIGURE 7



CONCRETE FILL DATA FOR 54" Ø PILES	
PIERS	LENGTH
17 and 25	52 ft
18	60 ft
19, 20 and 21	68 ft
22, 23 and 24	65 ft
26	45 ft

FIGURE 8



Incised streams possibly related to Diablo uplift.

Hand-out at 1979 NCGS field trip (Dick Darrow, Standard)