SOUTHERN CALIFORNIA CHAPTER

AEG SOUTHERN CALIFORNIA FIELD TRIP, JUNE 11, 2016, SANTA MONICA AND MALIBU FAULT ZONE.

Introduction

Shant Minas, PG, EG, PMP

Greetings, friends, colleagues, and fellow professionals,

And welcome to our second annual Field Trip along the Hollywood-Santa Monica-Malibu fault zones. Last year's trip was a tremendous success and we are happy to follow up with the westward continuation along this now famous (or infamous!) fault zone.

We would like to thank our co-sponsors of the event, Choice Drilling of Sylmar and Kehoe Testing and Engineering of Huntington Beach. Choice Drilling offers a wide range of drilling services for the geotechnical and environmental professional, including continuous core drilling often used in fault studies, with both full size and limited-access rigs. Kehoe Testing and Engineering specializes in Cone Penetrometer Testing and for seismic shear wave velocity and also have different size rigs for various applications. Please talk to our vendors and see how they can help you on your geotechnical and geologic projects.

The organization of this field trip took a considerable effort from our current Southern California Chapter Board, represented by Darrin Hasham, Vice Chair; Pedram Rahimikian, Treasurer; Matt Pendleton, Secretary, David Perry, Membership Chair, Ted Zeidan, Newsletter Editor, and myself, Shant Minas, current Chair. We are pleased to have you all here on this informative and fun field trip. Also like to thank our employers, namely Kleinfelder, GeoConcepts, Earth Consultants International, AMEC Foster Wheeler, and Applied Earth Sciences for contributing significant man-hours toward the organization of this trip. The Road Log and Field Map has been prepared for participants courtesy of Applied Earth Sciences.

Stay tuned for a Special Publication to be issued later this year by AEG Publications in which we will organize and highlight all of the presentations made for last year's and this year's field trips. Thanks for being with us and we hope you find this field trip informative and fun!

Shant Minas

AEG Southern California Chapter Chair

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STOP A: DISCUSSION OF MALCOLM FAULT STUDY, 2015-16,
BY SHANT MINAS, APPLIED EARTH SCIENCES

Applied Earth Sciences was commissioned to conduct a geologic fault rupture hazard study at 1754-51 Malcolm Avenue in Westwood, just north of the intersection with Santa Monica Boulevard, in 2015. The site is located one block west of the LDS Temple, famous in the geologic profession for being the location of the "best manicured" fault scarp in Los Angeles. Moreover, city maps (Navigate LA) and published maps by AMEC and Kenney all show the fault passing right through the area. The client was notified prior to commencing the work that the likelihood of finding a fault was relatively high.

Over the course of a period of six months, AES advanced a total of 20 CPTs and 3 continuous core borings along Malcolm Avenue in two north-south transects. A branch of the fault was encountered in each of two transects, crossing through the northern portion of the property. Soft, fine-grained deposits north of the fault were interpreted to be sag pond deposits. The two closely spaced transects allowed us to make a finding regarding the approximate orientation of the fault. We utilized prior published reports for Metro Red Line by AMEC, Parsons et. al. for soils age-dating information. The soils were characterized to be Holocene within the upper ten feet or so, with Pleistocene soils at approximately 10-12 feet below street grade.

A no-build zone was established ten feet from the fault location. A small portion of the proposed building is to extend into the no-build zone. This was accomplished by requiring the portion of the building extending across the no-build zone to be cantilevered. Moreover, the cantilevered portion needs to maintain a minimum of 12" clearance from local grade to accommodate vertical offset from a fault rupture, requiring minor grading of ground surface below the cantilevered portion.

Lastly, the entire building is to utilize a 24" mat foundation, as additional engineered mitigation. AES also conducted geotechnical investigation in a later phase. Our geologic and geotechnical reports were eventually approved by the City in early 2016 and the project is currently in the design finalization phase.

[SEE MAP AND SECTION ON NEXT PAGE]

Shant Minas

Engineering Geologist, PG, EG, PMP

Applied Earth Sciences

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Field Trip Stop 1: Veterans Administrations
Presentations: Miles Kenney PhD, PG, Kenney GeoScience, Oceanside, CA, Miles.kenney@yahoo.com

Quaternary Tectonic History of the "Santa Monica Fault Zone", northern Newport-Inglewood Fault, West Beverly Hills Lineament from the Pacific Ocean to the Cheviot Hills, California

Miles Kenney PhD, PG,

The Santa Monica Fault Zone is located within the Transverse Ranges Southern Boundary Fault System (TRSBFS), an active tectonic region understood to at least collectively, accommodate "oblique" left-lateral reverse stress. The question arises how this oblique stress is accommodated via strain (faulting) along the TRSBFS. For example, is it accommodated on separate fault systems that are dominantly left-lateral (strike-slip) and others that are reverse (compressional). Or across oblique motion fault zones. It is clear that at various times, some fault zones along the TRSBFS have accommodated oblique left-lateral reverse displacement, and that other fault zones have accommodated a dominantly left-lateral or reverse styles of displacement, which is discussed herein.

During the Miocene (20-12 million years ago) normal extensional faulting occurred but were reactivated or simply transitioned to oblique left-lateral reverse faults during the early Pliocene (~5 million years ago - Ma). These fault zones include the Santa Monica Fault North and South (Wright, 1991), western San Vicente Fault, Rancho Fault, Las Cienegas, and the Hollywood Fault. The late Miocene to early Pliocene tectonic transition along the TRSBFS is well documented in the literature; however, a more recent tectonic transition occurring approximately 1 Ma along the Santa Monica-Hollywood Fault System, has not been fully recognized or described until recently (KGS-PSM, 2016).

Many of the east-west trending fault systems along the TRSBFS accommodated oblique reverse left-lateral tectonic strain from the early Pliocene (4-5 Ma) to early Pleistocene (~2 Ma), this dramatically changed approximately 1 Ma when these fault zones transitioned into a nearly pure left-lateral strike-slip system (Figure 1 and Figure 2). These faults include the Santa Monica and Hollywood Fault Zones. Compressional deformation continued to occur but migrated north and south of the TRSBL as suggested by changes in tectonic strain rates in these regions during the early Pleistocene.

The Quaternary kinematic evolution along the western TRSBFS (Santa Monica-Hollywood Fault Zone) involved new fault zones being created and abandoned on the scale of hundreds of thousands of years and involved changes for northwest striking right-lateral faults in the northern Peninsular Ranges. For example, the northward migration and retraction of the Newport-Inglewood Fault Zone during the Pleistocene at latitudes of the central and southern Cheviot Hills.

The Potrero Canyon-Santa Monica Boulevard Fault Zone System was created approximately 1 Ma along what is commonly referred to in the literature as the Santa Monica Fault Zone. The name Potrero Canyon Fault is adopted from Wright (1991) and Santa Monica Boulevard Fault is from (KGS, 2012). These fault zone have ruptured to the surface stemming upwards from the underlying blind Santa Monica Fault Zone to accommodate dominantly left-lateral strike-slip displacement. The Santa Monica Boulevard Fault was determined via a geomorphic evaluation of the Cheviot Hills (KGS, 2011) to be a steeply dipping, dominantly left-lateral fault zone contrary to the current beliefs at the time that indicated the "Santa Monica Fault Zone in this region was an oblique left-lateral reverse fault zone (Figures 3, 4 and 5).

Hence, the upper most strands of the blind oblique reverse left-lateral Santa Monica Fault Zone System became inactive approximately 1 Ma (upper most blind portion of these faults), and the Potrero Canyon-Santa Monica Boulevard Faults developed in the hanging wall of the Santa Monica Fault Zone to rupture to the surface. Recent fault investigations in the central Cheviot Hills-Century City area have determined that the left-lateral strike-slip Santa Monica Boulevard Fault became inactive approximately 200 thousand years ago. These findings led to two obvious conclusions:

(1) compressional deformation occurring along this segment was required on other structures outside of the TRSBFS since the early Pleistocene (~1 Ma to present); and

(2) active left-lateral fault displacement is required along the TRSBFS somewhere along the longitude of the Santa Monica Boulevard Fault Zone since it became inactive.

The primary tectonic kinematic findings from the KGS-PSM, (2016) report include:

- A kinematic change occurred ~1 Ma along the TRSBFS involving previously oblique blind reverse left-lateral fault zones transitioning to dominantly surface rupturing left-lateral strike-slip faults in the BHUSD region.
- That change, occurring ~1 Ma along the TRSBFS, led to the creation of the Potrero Canyon, Santa Monica Boulevard, and cross faults in the western Hollywood Basin to accommodate dominantly left-lateral motion. The near surface strand of the North Salt Lake Fault is proposed to have developed on the hanging wall of the deeper and older normal fault to accommodate dominantly left-lateral motion as well during the early Pleistocene. The Hollywood Fault transitioned from an oblique reverse left-lateral fault zone to accommodate dominantly left-lateral motion utilizing for the most part the same fault strands within its system (Figure 1).
- The dominantly left-lateral strike-slip Santa Monica Boulevard Fault and western Hollywood Basin cross faults became inactive approximately 200 thousand years ago. Hence, these fault zones were active approximately 1 to 0.2 Ma.
- The Potrero Canyon Fault East was created within the past several hundred thousand years to accommodate dominantly left-lateral strike-slip motion no longer occurring on the Santa Monica Boulevard Fault and western Hollywood Basin cross faults (Figure 2). Some left-lateral motion may also be occurring on the blind western San Vicente and Rancho Faults.

- The northwest trending right-lateral strike-slip Newport-Inglewood Fault Zone migrated northward to latitudes of the Santa Monica Boulevard Fault Zone several hundred thousand years ago, but has subsequently "retracted" due to the development of the Potrero Canyon Fault East that essentially cut-off the northern most strands at the central southern Cheviot Hills. The southern Cheviot Hills began to be uplifted once the Newport-Inglewood Fault migrated northward along the eastern side of the hills (compare Figures 1 and 2).
- Active northern most strands of the Newport-Inglewood Fault Zone occur in and immediately east of the southeastern Cheviot Hills, but likely do not extend north of the proposed Potrero Canyon Fault East. Hence, no strands of the Newport-Inglewood fault occur along the southern West Beverly Hills Lineament along antecedent Moreno Creek flowing between the southern and southeastern Cheviot Hills.
- Compressional deformation (strain) that ceased approximately 1 Ma along the TRSBFS (Santa Monica Fault Zone) led to the development of new blind thrust faults (thrust ramps) west of the Newport-Inglewood Fault Zone. These include the Culver City Fault (thrust ramp) in the Beach Cities Region (Figures 1 and 2), and the Dume Fault East located in central Santa Monica Bay, south of Point Dume with a southeast trend to eventually reach the Pacific Ocean coast beneath Playa Del Rey (results via collaboration with Dr. Chris Sorlien). Compressional deformation east of the Newport-Inglewood Fault Zone was accommodated on previously documented blind compressional faults in the northern Los Angeles Basin.
- The Santa Monica Fault North, Santa Monica Fault South, and eastern San Vicente Fault should be considered inactive, and are recommended to be removed from future seismic hazard analysis and fault data bases. The western Hollywood Fault Zone is likely inactive.
- Proposed Cross Fault No.1 (Fault Zone A of KGS, 2012) in the western Hollywood Basin has been determined to be "regulatory" inactive by fault investigations in Century City. However, the northeast strand of Cross Fault No.1 where it connects with the Hollywood Fault is likely active (Figure 2).
- Both the blind Rancho Fault in the southwestern Cheviot Hills, and western San Vicente Fault in the southern BHUSD may be active, possibly accommodating a component of left-lateral slip in addition to reverse thrust motion (oblique).
- Total left-lateral motion across the Potrero Canyon-Santa Monica Boulevard fault system is estimated to be between 0.64 to 1.18 km (average of ~ 1 km). Uplift has occurred along the Potrero Canyon Fault since its inception ~1 Ma due to a restraining bend orientation that has resulted in approximately 135 to 170 meters of horizontal shortening. This magnitude of shortening is consistent with the magnitude of vertical uplift of middle to late Quaternary sediments of ~150 meters across the Potrero Canyon Fault and is also similar in magnitude of vertical apparent separation of Miocene age rocks across the fault (~180 meters). These findings indicate that the Potrero Canyon Fault developed in the early Quaternary consistent with the findings of Tsutsumi et al. (2001). Left-lateral slip rate for the

Potrero Canyon Fault is estimated to be between 2.0 to 1.5 mm/yr (during the past ~1 Ma).

- The West Beverly Hills Lineament (WBHL) that occurs along the eastern edge of the Cheviot Hills along Moreno Creek is subdivided into the *northern* and *southern* West Beverly Hills Lineament because each developed due to different geologic parameters with the exception of ongoing erosion associated with Moreno Creek (from Benedict Canyon) in common. The northern WBHL developed as a function of down to the southeast faulting along cross faults emanating from the Hollywood Fault connecting with the Santa Monica Boulevard Fault with ongoing erosion associated with Moreno Creek. The southern WBHL developed as a consequence of uplift of the southern Cheviot Hills associated with a northwest trending anticline (Figure 3). The eastern limb of the fold extends across the location of Moreno Creek to the southeastern Cheviot Hills. Ongoing erosion associated with Moreno Creek outpaced uplift of the anticline thus leading to the development of Moreno Creek antecedent nature in the southeastern Cheviot Hills (Figure 3).

Figure 1: Regional view of active faulting in the northern Los Angeles Basin, Beach Cities Region and along the TRSBLL between approximately 1 to 0.2 Ma.

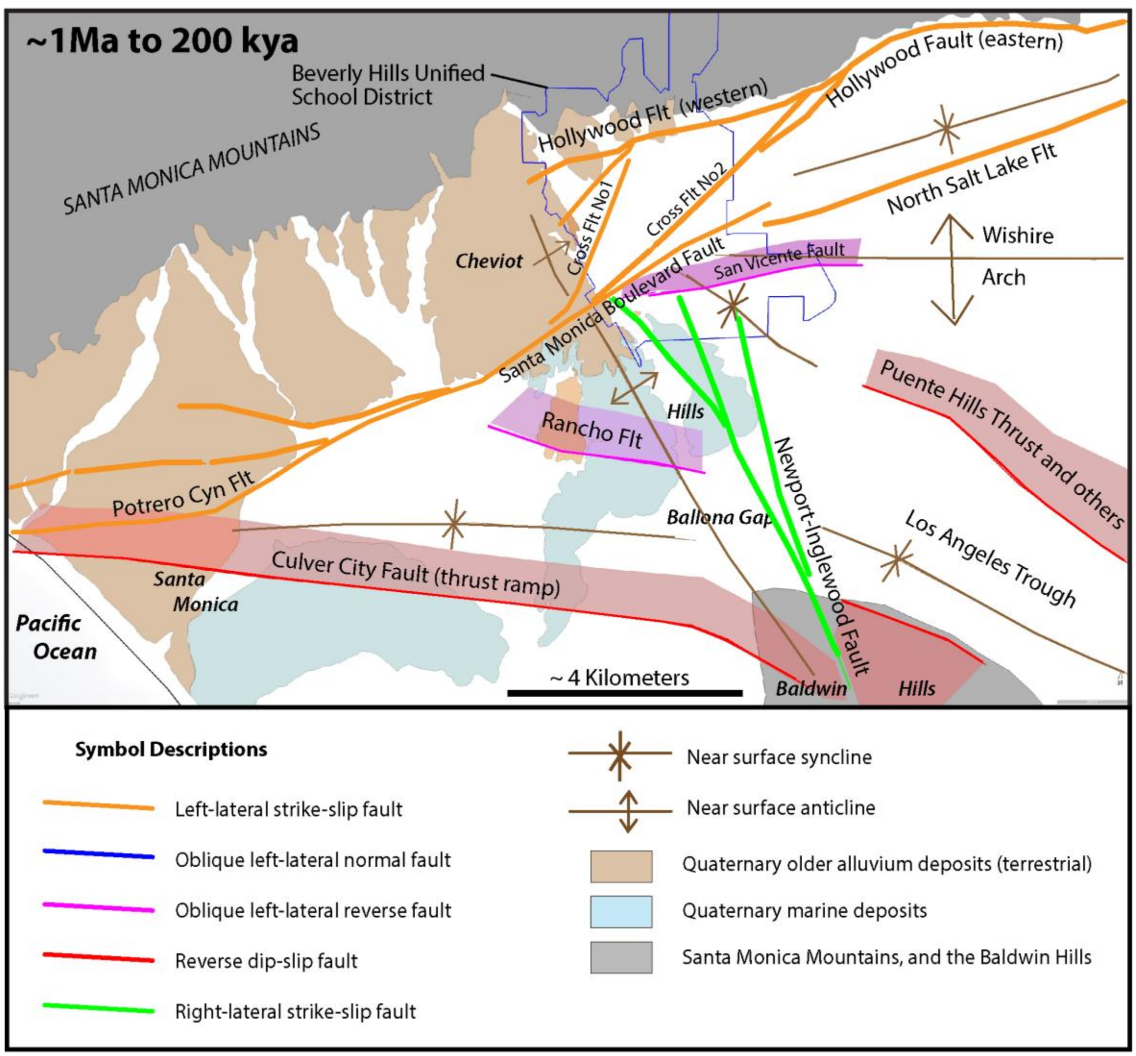

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Figure 2: Active faults and their dominant style of displacement from approximately 200 thousand years ago (Kya) to present time. The dominantly left-lateral strike-slip Santa Monica Boulevard Fault, the western Hollywood Fault, and Cross Fault No.1 have all become inactive. The Potrero Canyon Fault remains active, but has now lengthened towards the east by the development of the Potrero Canyon Fault East. The northeast portion of Cross Fault No.2 and the newly developed Potrero Canyon Fault East accommodate left-lateral displacement from the now inactive Santa Monica Boulevard Fault along this section of the TRSBLL. Fault strands of the Newport-Inglewood Fault north of the Potrero Canyon Fault East have been cut off leading to them becoming inactive. Minor left-lateral slip may also be accommodated on the Rancho and San Vicente Fault Zones.

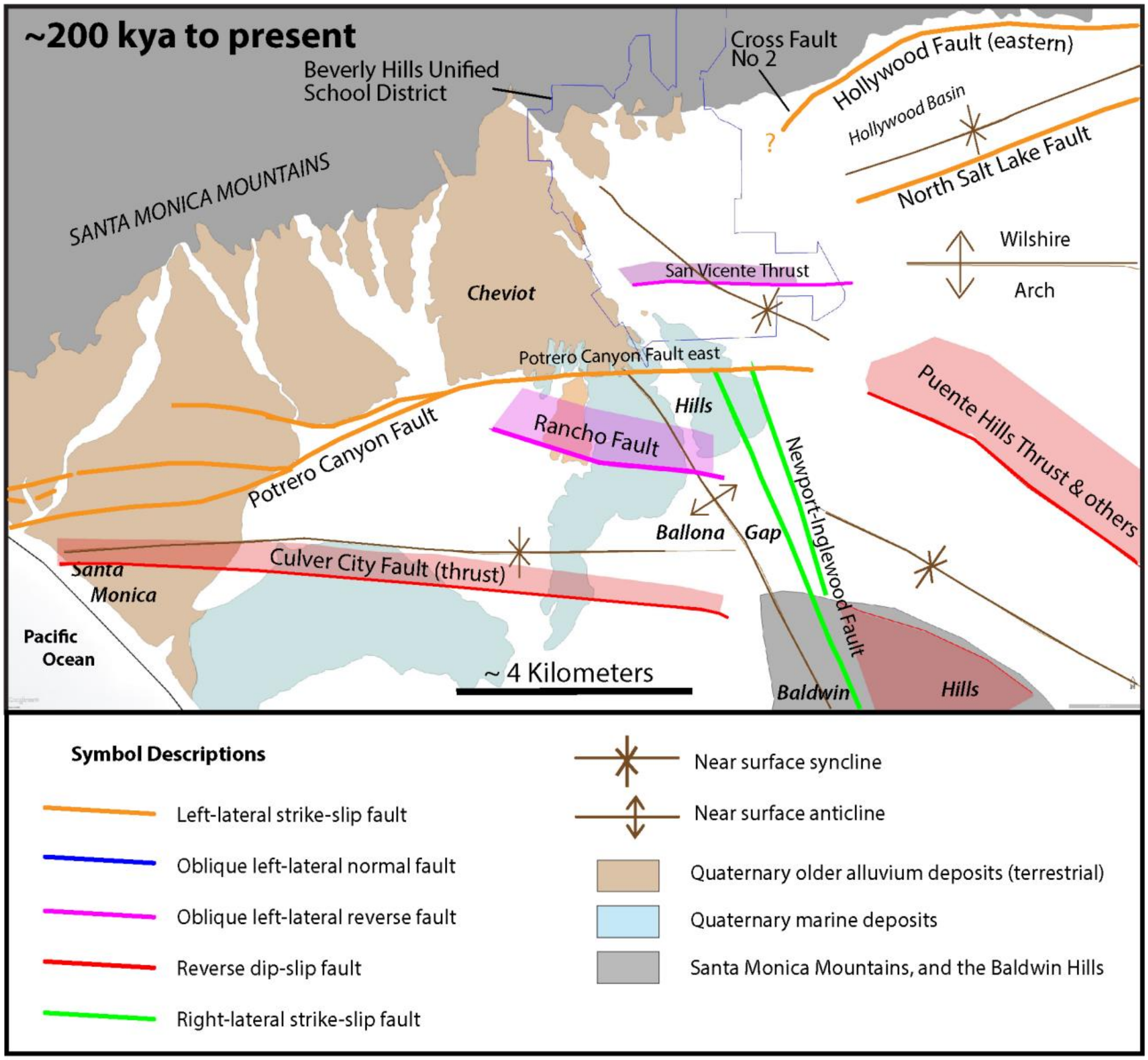


Figure 3: Geomorphic and geologic map of the Cheviot Hills (modified from KGS, 2011, 2012, 2014 and 2016). Cross Sections A-A' and B-B' are provided on Figure 4 and Figure 5 respectively. The location of the MACTEC (2010) seismic study and approximate location of their identified faults are shown.

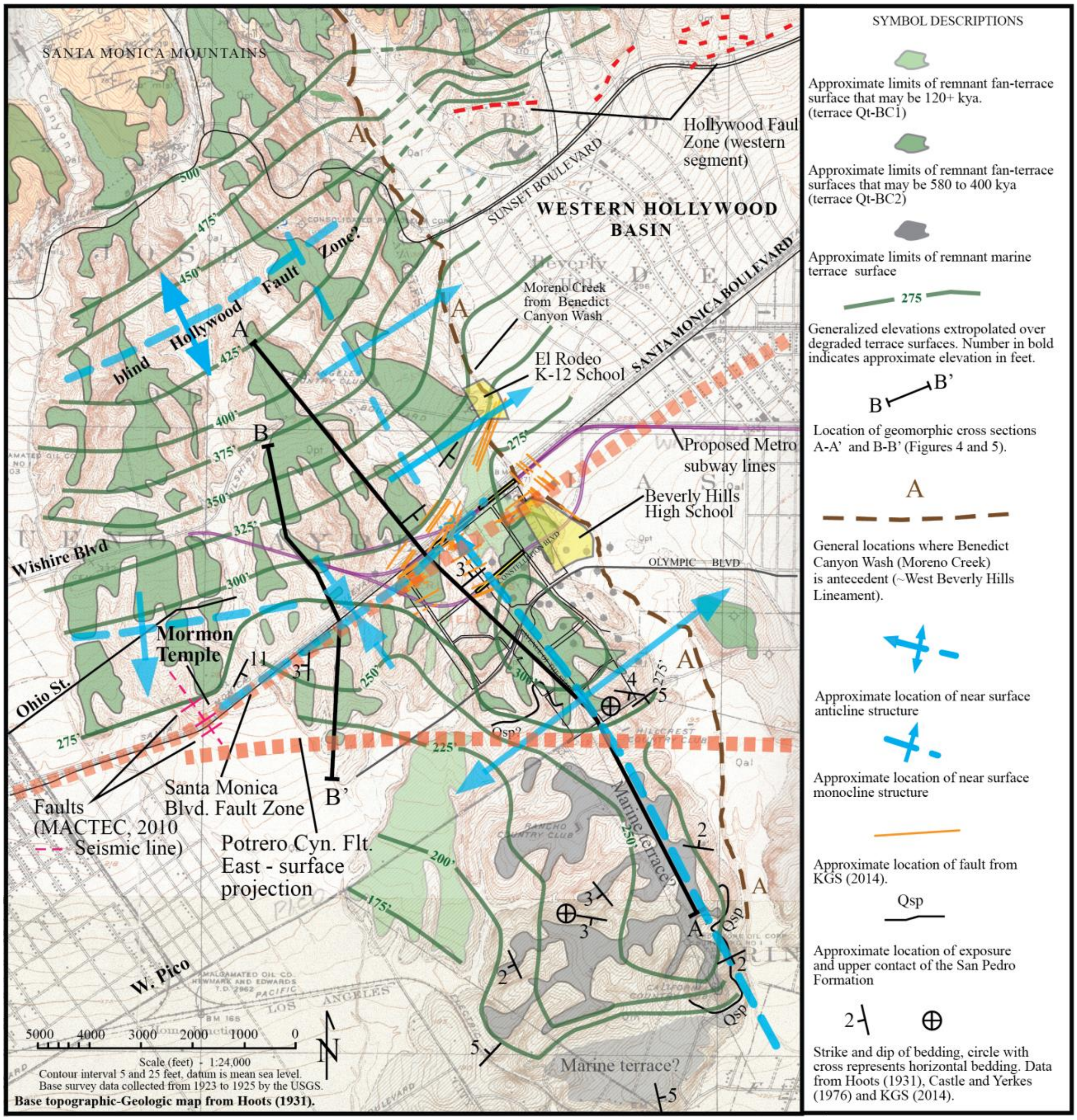


Figure 4: Cross Section A-A' modified from KGS (2011, 2012 and 2014) evaluating geomorphology of the Qt-BC2 preserved fan-terraces estimated to be 580 to 400 kya across the Santa Monica Boulevard Fault (see Figure 3 for location). As evaluated in KGS (2011, 2012 and 2014), the preserved fan-terraces of Qt-BC2 do not exhibit a reverse, up to the north sense of displacement but do show a "kink" (inflection point) across the Santa Monica Boulevard Fault. The proposed scarp of Dolan and Sieh (1992) was interpreted by KGS (2011) to represent an erosional feature along the Santa Monica Boulevard Fault (previously referred to as the Santa Monica Fault) and not a true "fault scarp". KGS (2011) proposed that the Santa Monica Fault (more recently referred to as the Santa Monica Boulevard Fault (KGS, 2012) was dominantly a strike-slip fault and not an oblique left-lateral reverse fault as typically described in most published literature and maps (also supported by KGS (2012, 2014, 2016).

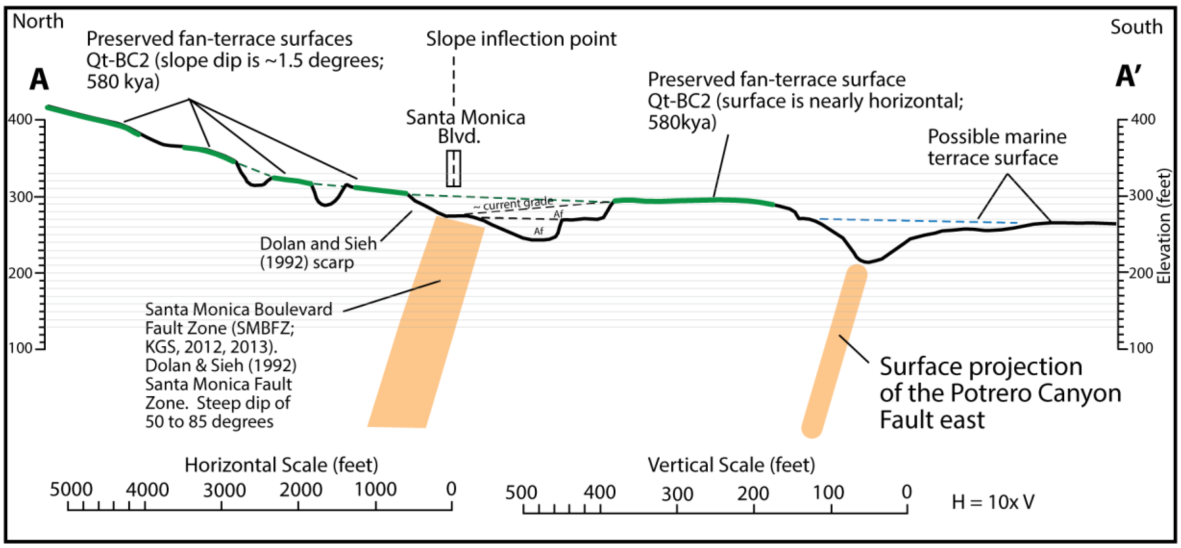
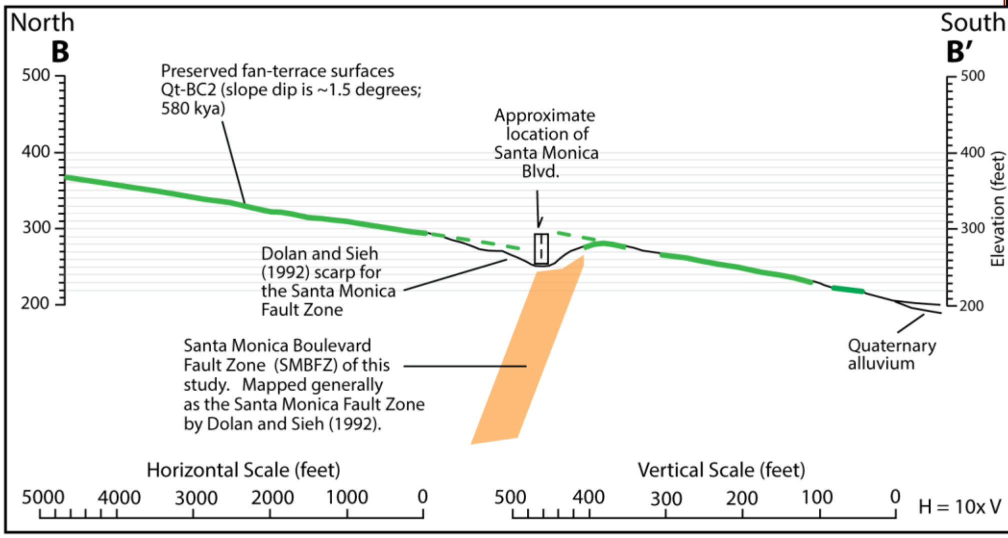


Figure 5: Cross Section B-B' modified from KGS (2011, 2012 and 2014) evaluating geomorphology of the Qt-BC2 preserved fan-terraces estimated herein to be 580 to 400 kya across the Santa Monica Boulevard Fault (see Figure 3 for location). The preserved fan-terraces Qt-BC2 do not exhibit a reverse, up to the north sense of displacement and in fact exhibit a down to the north sense of apparent vertical separation across the Santa Monica Boulevard Fault. KGS (2011) proposed that the Santa Monica Fault (more recently referred to as the Santa Monica Boulevard Fault (KGS, 2012) was dominantly a strike-slip fault zone and not an oblique left-lateral reverse fault as typically described in most published literature and maps (also supported by KGS (2012, 2014, 2016).


North
B
South
B′
500
400
300
200
Preserved fan-terrace surfaces
Qt-BC2 (slope dip is ~1.5 degrees;
580 kya)
Approximate
location of
Santa Monica
Blvd.
Dolan and Sieh
(1992) scarp for
the Santa Monica
Fault Zone
Santa Monica Boulevard
Fault Zone (SMBFZ) of this
study. Mapped generally
as the Santa Monica Fault Zone
by Dolan and Sieh (1992).
Quaternary
alluvium
Elevation (feet)
Horizontal Scale (feet)
5000 4000 3000 2000 1000 0
Vertical Scale (feet)
500 400 300 200 100 0
H = 10x V

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References:

Castle, R. O., Yerkes, R. F., 1976; Recent surface movements in the Baldwin hills, Los Angeles County, California; U.S. Geological Survey (USGS), Professional Paper 882, pp. 1-20.

Dolan, J. F., Sieh, K., 1992; Tectonic geomorphology of the northern Los Angeles basin: seismic hazards and kinematics of young fault movement: in Ehlig, P. L., and Steiner, E. A., eds., Engineering Geology Field Trips: Orange County, Santa Monica Mountains, and Malibu, Guidebook and Volume, Association of Engineering Geologists (AEG), pp. B20-B26.

Hoots, H. W., 1931; Geology of the Eastern part of the Santa Monica Mountains, Los Angeles County; U.S. Geological Survey (USGS), Professional Paper 165-C, pp. 83-134.

Kenney GeoScience (KGS), 2011; Preliminary literature and geomorphic evaluation of the eastern Santa Monica fault zone and potential impacts associated with fault surface rupture relative to proposed LA Metro stations in Century City, California; KGS JN 723-11, report dated May 2, 2011.

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Wright, T.L., 1991; Structural geology and tectonic evolution of the Los Angeles basin, California; Active-Margin basins (Biddle, K.T. editor), American Association of Petroleum Geologists (AAPG), Memoir 52, pp. 35-106.

Note: web-link for the **Kenney GeoScience-PrimeSource Management Regional Seismic Report as well as other pertinent seismic reports for the Cheviot Hills Region are on the Beverly Hills Unified School District Website via www.bhusd.org: go to: “Facilities > Seismic Reports

KGS-PSM 2016 Report: "Facilities > Seismic Reports>-PS 3-30-16 Full report

Direct link to the report is:
http://bhusd.edlioschool.com/pdf/seismic_reports//KGS-PS%203-30-16%20Full%20report.pdf

This work was funded by the Beverly Hills Unified School District.

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Field Trip Stop 2: University High School Campus, located northwest of Barrington and Ohio Avenues, Sawtelle District, City of Los Angeles

Presentation: David L. Perry, CEG, Amec Foster Wheeler, Los Angeles, CA

Geologic / Ground Rupture Hazard Studies at University High School, Sawtwelle District of Los Angeles, California

David L. Perry, CEG

Abstract

The University High School campus is located on the Santa Monica plain near the northwest margin of the Los Angeles basin and about 1½ miles (2.4 kilometers) south of the Santa Monica Mountains (see attached figure-1). The Santa Monica plain is a Pleistocene age surface that has been uplifted, dissected by erosion, and locally infilled with Holocene age alluvial deposits (Poland et al., 1959). The natural geologic materials exposed at the University High School campus consist of upper Pleistocene age marine terrace and alluvial fan deposits and Holocene age alluvial deposits (see attached figure 2, modified from Dibblee, 1991). The Santa Monica fault scarp that bisects the campus separates uplifted and dissected older alluvial fans on the north from late Quaternary to Holocene active fans and undifferentiated Holocene surficial deposits on the south.

Based on a review of historic topographic maps (USGS, 1925 and later years) and aerial photographs, the site topography has not been significantly modified since the early 1920s, although some slopes have been modified by minor cut-fill grading. The northern portion of the campus is bisected by a south-trending drainage, the mouth of which is located in the amphitheater area of the campus. Erosion has locally modified and removed the fault scarp, producing the irregular orientation of the scarp across the University High School campus. Along the base of the escarpment, natural springs occur within the campus and are likely the result of ground water ponding on the north side of the fault against a ground-water barrier formed by the fault zone. The high school campus is included in a City of Los Angeles “fault rupture study area.”

Previous investigations in the eastern portion of the University High School campus were conducted by Crook et al. (1983) and will be briefly summarized at the field trip stop. Amec Foster Wheeler performed fault rupture hazard investigations of the high school campus in 2004 and 2006 (as predecessor company MACTEC, 2004 and 2006) to evaluate the presence, location, orientation, and relative age of the suspected fault traces that traverse the site, and to evaluate the potential for surface fault rupture within the high school campus. The field investigation included drilling and logging of continuous-core hollow-stem auger borings, performing cone penetration tests (CPTs), and performing a high-resolution seismic reflection survey. The results of the 2004 investigation concluded that the campus is bisected by a zone of near-surface, vertical and sub-vertical faults oriented along an east-west trend, similar to that located at the VA campus as reported in Dolan et al (2000). This fault zone forms a barrier to southward flow of ground water, and was defined as an active surface trace of the Santa Monica (north branch) fault zone. The topographic escarpment at the site is a geomorphic feature that is associated with the fault zone.

References:

Crook, R., Jr., Proctor, R. J., and Lindvall, E.E., 1983, "Seismicity of the Santa Monica and Hollywood Faults Determined by Trenching," Technical Report to the U.S. Geological Survey, Contract No. 14-08-001-20523, p. 26.

Dolan, J. F., Sieh, K., and Rockwell, T. K., 2000, "Late Quaternary Activity and Seismic Potential of the Santa Monica Fault System, Los Angeles, California," Geological Society of America Bulletin, Vol. 12, No. 10.

Dibblee, T. W., 1991, "Geology of the Beverly Hills – Van Nuys (South ½) Quadrangles, Los Angeles County, California," 1:24,000 scale, Dibblee Foundation Map #DF-31.

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Poland, J. R., Garrett, A. A., and Sinnott, A., 1959, "Geology, Hydrology, and Chemical Character of Ground Waters in the Torrance–Santa Monica Area, California," U.S. Geological Survey Water Supply Paper 1461.

U. S. Geological Survey, 1925, "Sawtelle Quadrangle", 7.5 minute Topographic Map, Scale of 1 inch = 2,000 feet

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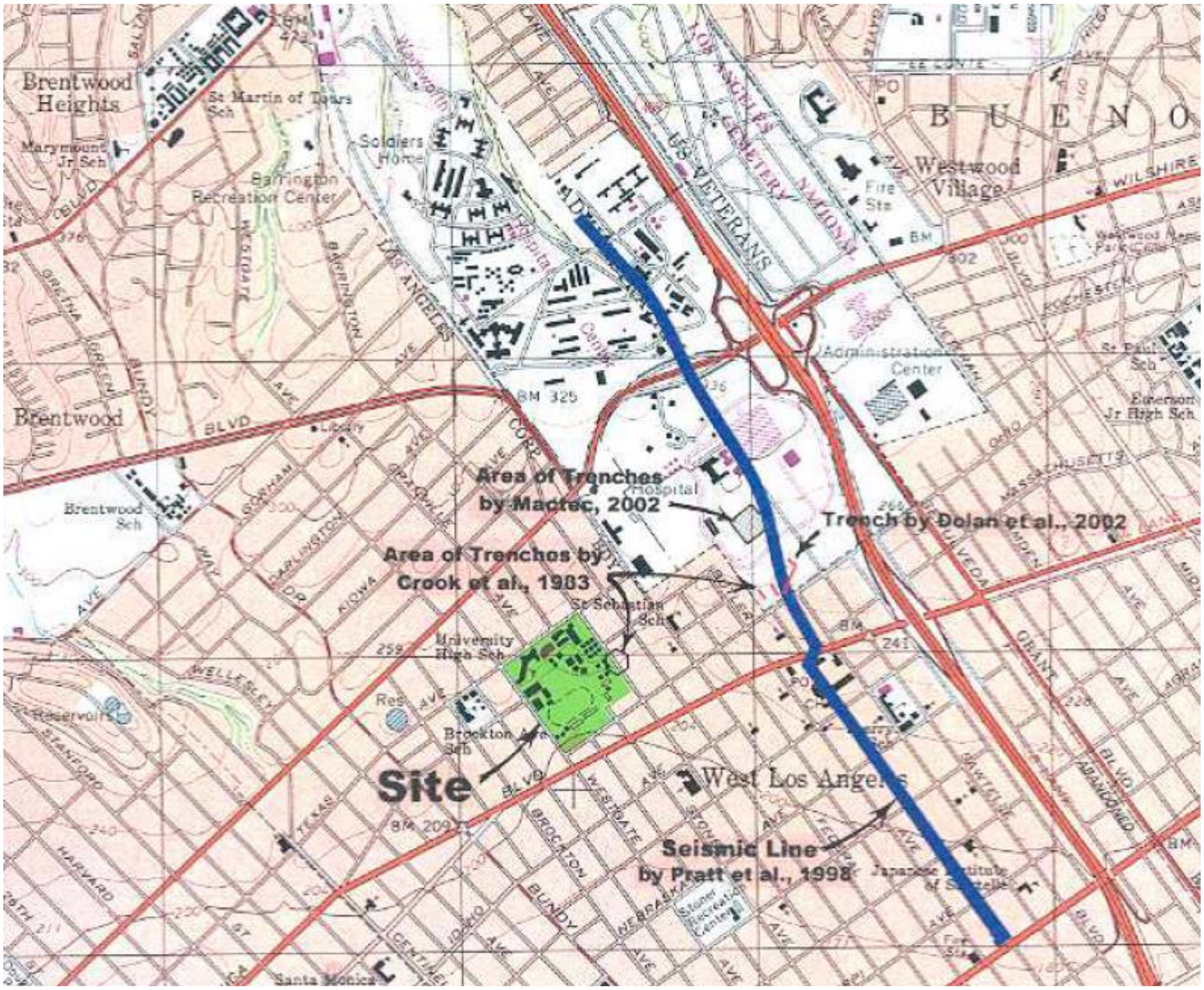

Figure 1 – Site Location Map of University High School Campus, Sawtelle District, City of Los Angeles.

Figure shows prior trench locations of Crook et al (1983) at the east side of the school campus and trench locations on adjacent VA Property to east by Dolan et al (2000) and Crook et al (1983). The thick blue line shows the high resolution seismic traverse of Pratt at al (1998).

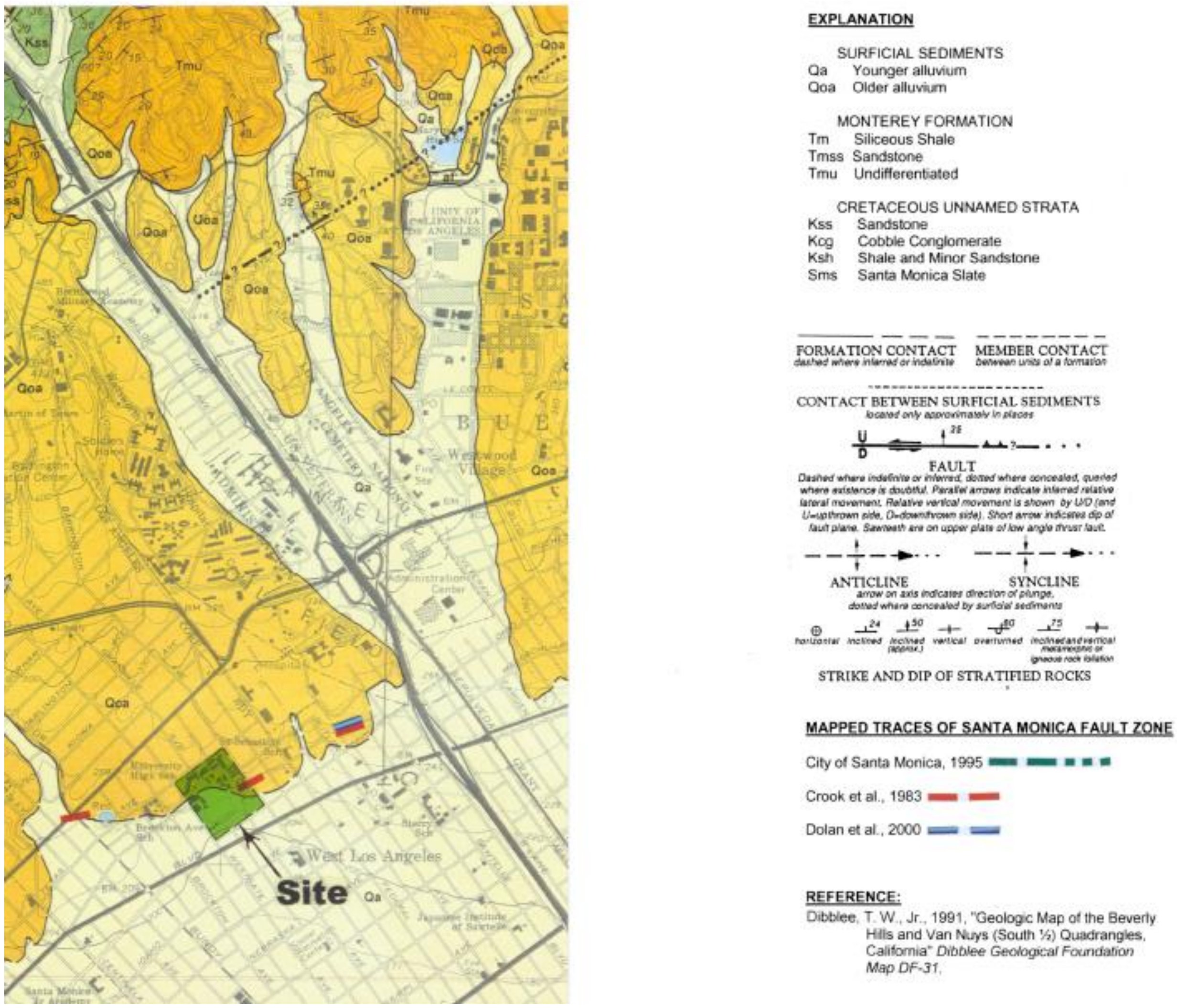

Figure 2 –Geologic Map of West Los Angeles and Sawtelle Districts, City of Los Angeles

Figure modified from Dibblee (1991), showing mapped traces of Crook et al (1983) and Dolan et al (2000)

Field Trip Stop 3: Brentwood Knoll
Presentations: Brian Olson, PG, United States Geological Survey

Geologic studies and geomorphic features suggest the Santa Monica fault zone is located 3-4 km south of the base of the Santa Monica Mountains at this location. While scarp heights along the fault zone typically range from 7-12 m along the fault zone, an exception is the alluvial fan surface just east of Santa Monica Canyon. Here, the fan surface appears to have been broadly uplifted maintaining an overall slope of about 1.5° to the south. The scarps to the east project directly toward this surface, but it is not clear how the fault proceeds to the west. Within this fan surface are ridges, broader fold scarps, and discontinuous slope breaks stepping *en echelon* to the south. At the northeastern edge of this uplifted fan surface is the nearly 25-meter high anomalous Brentwood Knoll, with a low continuous curvilinear scarp and ridgeline extending from the base to the west towards Santa Monica Canyon. Some researchers believe this represents an anticlinal ridge formed over a shallow blind thrust. It is also possible Brentwood Knoll is formed by a backthrust off the Santa Monica Fault, which uplifted the knoll and the fan surface. The ridges and discontinuous slope breaks located predominantly south and west of Brentwood Knoll may represent steep hanging wall normal faults on this model.

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Field Trip Stop 4: Temescal Cyn Park
Presentations: Casey Jensen, PG, CEG, City of Los Angeles, Department of Building and Safety, Grading Division & Eugene D. Michael, PG, CEG, Malibu Geology.

Implementation of Information Bulletin P/BC 2014-129 – Surface Fault Rupture Hazard Investigations

Casey Jensen, PG, CEG

Exemptions

☐ Non-habitable structures or additions to existing structures less than 50% square foot and value of work is less than 50% (Both). See Information Bulletin P/BC 2014-044.
☐ No exemptions for new habitable structures. City of LA does not have an exemption for single family homes.

Research

☐ Research previous regional and site specific studies to characterize the fault in your site areas.
☐ Call the Department to discuss your proposed fault study to see if there are any existing studies in the area and to make sure your proposed exploration is adequate.

Investigation

☐ Determine depth to Pleistocene strata. Even if mapped at the surface, fill and or young soil deposits may cover the Pleistocene soils.
☐ Be sure the exploration locations shadow the proposed structure along all possible fault orientations.
☐ For single family homes, exploration 50 feet beyond is not required. Studies can be limited to within the site unless exploration is limited by existing structures/other limitations.
☐ Trenching is best if Pleistocene strata are shallow; otherwise, CPTs with a minimum 2 continuous core borings. Use the consolidation curves for CPT data to help corroborate similar overburden histories between CPTs.

Age Dating

☐ Most projects use soil profile development or radiocarbon dating. For soil profile development, the logger must be experienced with soil development categorization or utilize a soil development expert.
☐ Be aware of possible contamination of radiocarbon dates, which could provide dates younger than the age of the soil.

Report Contents

☐ Fault studies should be more detailed than the typical fault section used in a geotechnical report. Detailed sections regarding research, geomorphology, fault characteristics, deposit age determination, etc. should be included.
☐ Provide summaries and figures to support your interpretations and text. Summarize exploration data for borings with tables that correlate and support your conclusions.
☐ Figures – provide a figure with buildable areas, setbacks and shadow zones from the end of your exploration data points. The setbacks and shadow zones should utilize the worst case fault orientations when extrapolated away from your exploration data points. If the trend of the fault is not known, use the trend of the AP or City Fault Zone boundary.

Setback Requirements

☐ When an active or possibly active fault is encountered, a 50 foot setback is required unless the consultants can demonstrate the accurate location of the fault with several data points.
☐ The setback should also consider the subsurface orientation of the fault for non-vertical faults.

Speaker 2:

Landslide Risks in a Seismically Active Coastal Zone Pacific Palisades to Malibu, Southern California with Special Notes on Tsunami and Liquefaction.

& Eugene D. Michael, PG, CEG

1.0 INTRODUCTION

1.1 Purpose - to characterize the landslide risk in the RHSMI coastal zone

1.2 Transverse Ranges dyamics and RHSMI fault activity

1.3 RHSMI coastal zone fault nomenclature

1.4 RHSMI coastal zone - focal mechanisms

<u>Mile 00.0 - PCH and Entrada Drive</u>

2.0 PACIFIC PALISADES COAST

2.1 Palisades stability as a possible indication of seismicity

2.2 Huntington Palisades Coastal Segment

2.2.1 Quelinda Estate Landslide

2.2.1.1 Failure history

2.2.1.2 Stabilization

2.2.1.3 Cause

2.1.1.4 Subsequent Failure

2.2.2 Potrero Canyon Fault

2.3 Modelo Formation Coastal Segment

2.3.1 Provenance

2.3.2 Physical Chemistry

2.3.2.1 Spontaneous Combustion

2.3.2.2 Sulfate Expansion

2.3.3 Landsliding

2.3.3.1 Via de las Olas Landslide

2.3.3.2 Asilomar Boulevard Landslide

2.3.3.3 Bel-Air Bay Club Landslide Area.

Mile 2.6 -

3.0 CRETACEOUS-OLIGOCENE COAST

3.1 Major Landslides

3.1.1 Las Tunas Beach Landslide

3.1.2 Big Rock Mesa Landslide

3.2 Tsunami Risk

<u>Mile 8.2</u>

4.0 MIDDLE MIOCENE- UPPER MIOCENE COAST

4.1 Limited Landslide Risk

4.2 Tsunami Risk

<u>Mile 10.2</u>

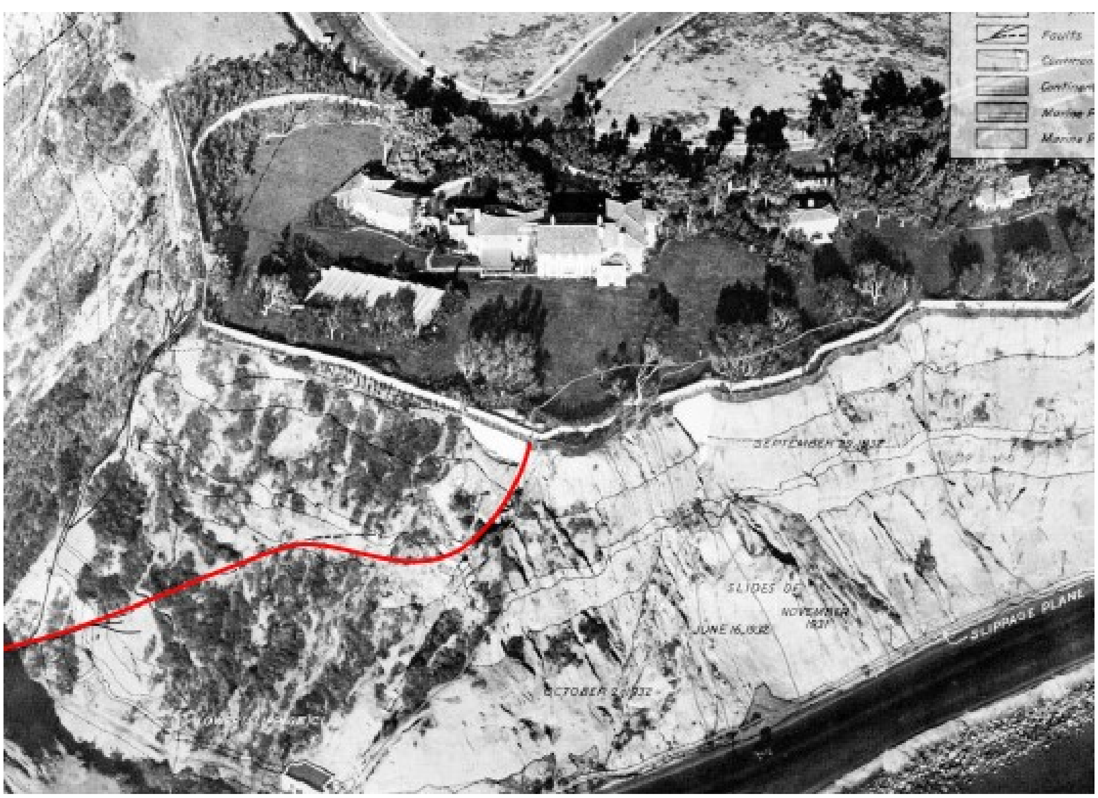
5.0 WINTER MESA

5.1 Overview of the Malibu Civic Center water treatment facility.

5.2 Treatment-plant effluent disposal scheme and the liquefaction risk.

Asilomar Blvd. crown and developing scarp

Jarosite is a basic hydrous sulfate of potassium and iron with a chemical formula of KFe3+3(OH)6(SO4)2. This sulfate mineral is formed in ore deposits by the oxidation of iron sulfides.



Johnson's detailed mapping of Quelinda sea cliff

Field Trip Stop 5: Los Liones Trailhead

Presentations: Philip J. Shaller, Ph.D., PG, CEG, Exponent, Inc., 320 Goddard, Suite 200, Irvine, CA 92618; pshaller@exponent.com

Elevated Marine Terraces Along the Malibu Coast: Implications for Late Quaternary Activity on the Santa Monica Mountains Fault System

Philip J. Shaller, Ph.D., PG, CEG

The Getty Villa museum complex (GVmc) in Pacific Palisades (Figure 1) is located in a complex geologic and tectonic setting. The surrounding coastal area is characterized by an irregularly warped suite of elevated late Quaternary marine terraces resulting from late Pleistocene and Holocene tectonic activity. The elevated marine terraces in the vicinity of the GVmc include the oxygen-isotope Stage 5e “Dume” (125 ka), Stage 7 “Corral” (200-218 ka) and Stage 9 “Malibu” (320-336 ka) wave-cut platforms (Figure 2). These elevated wave-cut platforms provide a record of late Quaternary uplift in the Pacific Palisades area that can be attributed to tectonic activity on nearby components of the Santa Monica Mountains Fault System (Figure 3). The GVmc occupies an unnamed canyon sandwiched between Parker Mesa on the west and Castellammare Mesa on the east (Figure 4). A combination of early, intense residential development and ubiquitous landslides has complicated the interpretation of marine terrace geometries in this area. Geotechnical borings performed for an expansion project at the GCmc in the late 1990s (Shaller and Heron, 2004) helped to clarify the marine terrace geometries in the area (Figure 5). The resulting interpretation of marine terrace uplift, shown in Figure 6, indicates a general increase in marine terrace uplift rates from west to east along the Malibu coast, together with seaward tilting and short-wavelength east-west warping of the wave-cut platforms. The observed record of uplift of marine terraces in the vicinity of the GVmc is consistent with uplift on the Santa Monica Mountains blind thrust at a rate of about 0.23-0.27 mm/yr between Point Dume and Potrero Canyon; higher uplift rates east of Tuna Canyon may be related to deformation associated with the Santa Monica fault. Seaward tilting of the platforms may be associated with drag folding along the offshore Santa Monica fault or movement on the Santa Monica Mountains blind thrust. The inferred east-west warping of the platforms may be associated with 1) Compression associated with a right step between the Santa Monica and Malibu Coast faults; 2) Deformation resulting from cessation of movement on the Malibu Coast fault since ~75 ka; or 3) Deformation associated with the offshore “Wilmington fold and thrust belt” of Hauksson (1990). Overall, the maximum uplift rate along the Malibu coast is estimated to be 0.5 mm/yr, as reported by McGill (1989) at Potrero Canyon.

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Shaller, P.J. and Heron, C.W., 2004. Proposed revision of marine terrace extent, geometry, and rates of uplift, Pacific Palisades, California: Environmental and Engineering Geoscience, Vol. X, No. 3, pp 253-275.

Field Trip Stop 6: Malibu Winter Mesa:

Presentations: Dr.Roy Shlemon, Roy J. Shlemon Center for Quaternary Studies & Eldon Gath, Earth Consultants International.

The Malibu Coast Fault at Winter Mesa: A Tale of Fault Zoning and "Dezoning"

Roy J. Shlemon, Roy J. Shlemon Center for Quaternary Studies, rshlemon@jps.net

It was Friday afternoon and almost 3:00 PM at Winter Mesa in Malibu. A decision had to be made by 5:00 PM Central Time. So the late Howard (Buzz) Spellman, the long-time Chief Geologist for Converse Consultants (Pasadena) bit the bullet! This was in 1985 and cell phones were not around, so Buzz squeezed into the noisy telephone booth adjacent to the Pacific Coast Highway (PCH) at Winter Mesa and called the General Motors Corporation (GMC) in Detroit. With a finger in one ear and yelling into the coin-operated telephone, Buzz told the Project Manager that, after months of geotechnical exploration and logging several, ~25-ft deep trenches, Converse found a likely splay of the Malibu Coast fault (MCF), and that the fault could well be "active" according to State of California definition.

That was it. GMC wanted nothing to do with faults and the likely resulting environmental opposition to their proposed, multi-million dollar Design Center. GMC thus abandoned the project; and the ostensible commercial value of the ~22-acre, ocean-view site plummeted! The trenches were soon observed by many regulators and local geologists who generally agreed with the Converse findings (Rzonka and others, 1991). The California Geological Survey (CGS) eventually established a "restricted Earthquake Fault Zone," no more than ~100-ft long and designated by a few dashes (CGS, 1995). This was probably the shortest, active fault heretofore zoned by the State. However, because of its economic impact, the property owner ultimately sought "dezonation" of this "Winters Mesa fault." This task was neither easy nor inexpensive.

Starting in 1999, Earth Consultants International (ECI) excavated three new trenches at and near the Converse fault site (ECI, 2000). The major attempt was to better constrain the extent and the age (time of last displacement) of the "Winter Mesa fault." From their trench exposures, ECI found that the underlying abrasion platform (substage 5e; ~125 ka) and overlying deposits displayed up to six inches of apparent vertical offset, but no clear evidence of faults extending up into the overlying [Holocene] colluvium. Rather, ECI postulated that a particular “blow sand” and fine fractures were caused by seismically induced liquefaction and related settlement. Critical, therefore, was numerically dating the apparently unbroken sand overlying the Converse-identified fault. This was carried out by optically stimulated luminescence (OSL), a technique that, at the time, was in its infancy for practical, engineering-geology application.

The OSL dates for likely unbroken sediments over the Converse fault averaged ~14 k (ECI, 2002). Thus, although the CGS reviewer (Treiman, 2007) disagreed with the ECI postulated blow-sand origin to explain apparent vertical offset, the accepted ~14 k OSL dates indicate that last movement of the “Winters Mesa fault,” occurred prior to Holocene time and therefore, by California state definition, was then officially deemed “not sufficiently active.” Accordingly, the CGS removed the “Winters Mesa fault” from the Official EFZ for the Malibu Beach quadrangle (CGS, 2007).

In hindsight, this substantially abbreviated tale of the long-lived controversy and fault zoning and dezoning at Winter Mesa offers some philosophical if not practical lessons for engineering geologists:

1. Faults with last displacement at or near the Pleistocene-Holocene boundary are often argued as to their potential for surface displacement. It is therefore now time to modernize pertinent regulations for the benefit of the public in general and for the profession in particular. Indeed, we should likely follow the lead of the engineers and adopt the practical concept of “acceptable risk” to assess the potential impact of surface-fault rupture (Shlemon, 2010, 2015).

2. The current (since 1972) California definition of an “active fault” is questionable, especially since many well characterized faults with a few inches of apparent displacement are amenable to engineering mitigation, regardless of time of last displacement (Bray, 2009). Most California faults can then be classified as either “hazardous” or “non-hazardous,” thus eliminating the public-perceived, fear-provoking term “active fault” (Shlemon, 2010).

3. In the present California regulatory environment, many reviewers opt to be ultra-conservative and thereby designate difficult-to-date faults as “active,” too often ignoring their own professional judgment and the economic implications of

their decision as expressed in the “welfare” component of our mantra, “public health, safety and welfare.”

4. Unfortunately, some regulators avoid decision making by calling controversial faults “active,” and thereby subjecting them to “zoning” and the inherent negative economic, social and political consequences stemming from such classification. “Dezoning” is often technically very difficult, costly, time consuming and seldom accomplished. Indeed, this is well exemplified at Winter Mesa where, despite the officially sanctioned “clearance of active faults,” the original proposed GMC Design Center remains largely in open space.

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SOUTHERN
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Speaker 2:

Late Quaternary geomorphology and neotectonics of the Malibu Creek area

Eldon Gath, Earth Consultants International

Development planning within the Malibu Creek estuary has led to considerable and extensive geologic/geotechnical investigations to address the issues of active fault rupture, liquefaction, flooding, foundation support, estuarine and groundwater water quality, and wastewater treatment/discharge. As these studies unfolded, so too did the late Quaternary geologic history and evolution of the Malibu area. This stop from atop Winter Mesa will discuss many of the studies conducted here over past two decades including the Malibu Coast fault, the marine terrace chronology, Malibu Creek, and the new wastewater treatment and disposal plans.

An understanding of the hazard posed by the Malibu Coast fault remains elusive. Deformed stream channels seem to indicate a dominantly left-lateral strike-slip component, and consequently the fault has been linked to the other left-lateral faults farther to the east; Santa Monica, Hollywood, and Raymond.

Figure 1: Regional index map showing the left-lateral faults east of the Malibu Coast fault that could link into a ~100 km fault.

Although multiple sites have shown fault offsets of elevated marine terraces, only two locations have interpreted Holocene events. In 1985 a geotechnical study on Winter Mesa (Fig. 2), west of Malibu Creek, by Converse Consultants for General Motors resulted in the discovery of three fault traces across the mesa; one of which was shown to be older than 35 ka (F-3), one was equivocal displacing the 120 ka marine terrace but having no younger overlying deposits (F-2), and one (F-1) was interpreted to have a small Holocene displacement (Fig. 3). CGS subsequently zoned this last fault splay under the A-P Act. In 1992, Drumm and others located a paleoseismic trench across another strand of the Malibu Coast fault inland from Pt. Dume and interpreted several Holocene earthquakes based on stratigraphic displacements. But, it has never been confirmed whether these exposures were linked along a continuous fault, or were even on the Malibu Coast fault proper.

In ~1995, Leighton & Associates conducted a geological investigation to locate and better understand the mapped but inferred Malibu Coast fault across the "Civic Center" area of the Malibu Creek estuary as part of a regional planning effort. Two N-S transects were completed essentially from the range front south almost to the coast. Both transects utilized continuously cored borings and cone penetrometers to identify key stratigraphic units that were then correlated across the transects (Fig. 2). The results found that a continuous, approximately horizontal, coarse gravel and cobble zone exists at about 50-feet in depth though the entirety of the western section, and most of the eastern. This unit was termed the "Civic Center Gravels" and was interpreted to be a MIS Stage 3 (60 ka) marine terrace surface. It, and all overlying sediments were continuous across the mapped Malibu Coast fault trace, leading to the elimination of the fault as a planning constraint.

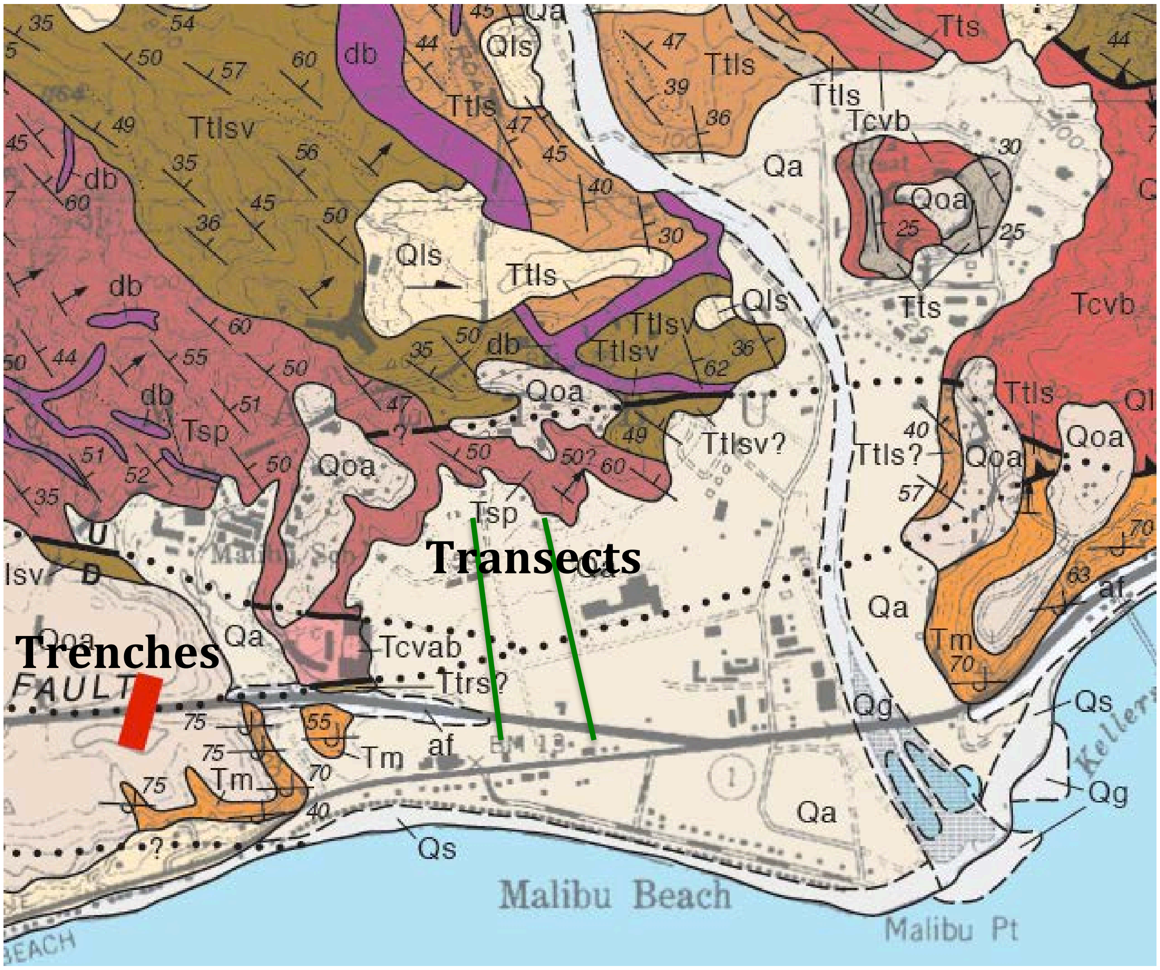
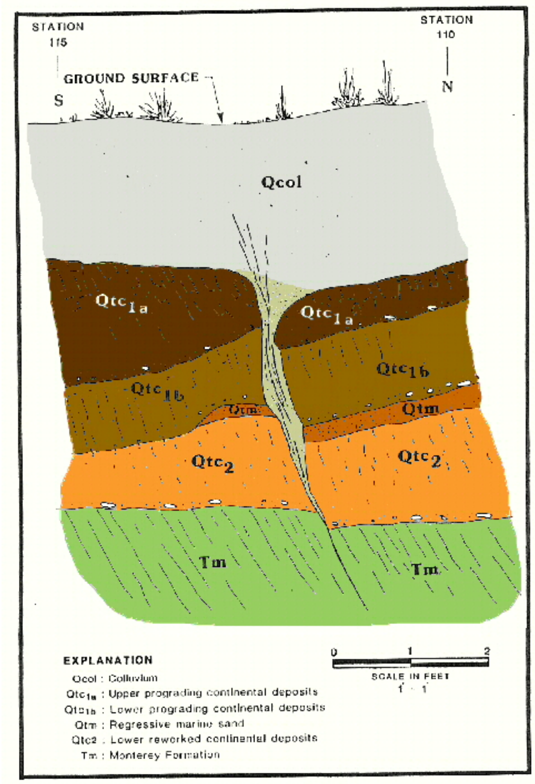


Figure 2: Dibblee's geologic map of the Malibu Civic Center area. The boring and CPT transects for Civic Center planning are shown (approximately) as green lines. The fault trenching area on Winter Mesa is shown (approximately) by red box.

In 1999, Earth Consultants International excavated new trenches on the Winter Mesa site (Figs 2 & 3) to locate the three fault traces identified by Converse, and attempt to confirm or refute the previous interpretations on the age of the displacements for each of the three fault zones. The Holocene fault, F-1, (Fig. 3) was successfully located in two trenches and the F-3 in one trench. The trench across the trace of F-2 did not reach bedrock, but did reveal only continuous, undeformed marine and non-marine sediments, and multiple well-developed paleosols, across the entire length of the trench. All of the trenches were geologically logged for stratigraphy and structure, and pedologically described and sampled for soil age calculations. Samples were obtained from the immediate vicinity of F-1 for Optically Stimulated Luminescence (OSL) age dating.



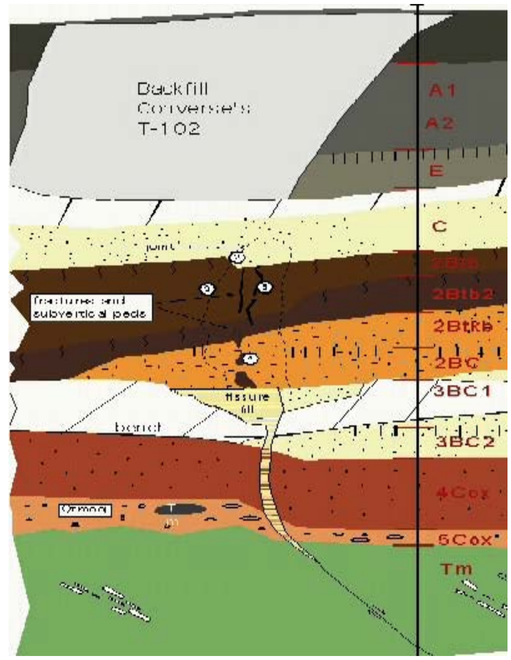


Figure 3: Graphic trench logs from trenching on Winter Mesa. Left, modified (colored to match) from Rzonca et al (1991) of the exposure that originally led Converse (1985) to interpret Fault 1 on Winter Mesa as having had a Holocene displacement event. The fissure is shown as filled with a granular material different from the overlying colluvium. Right, modified from ECI (2000 and 2001) that shows the sand blow ejecta layer preserved and undeformed over the subsided paleo surface of the marine terrace. The brittle sand is not fractured or faulted but does bury the offset paleosurface. Converse's trench excavation is also shown, trending obliquely across the ECI exposure.

Trench T-1 exposed a nearly complete stratigraphic and geomorphic record from 125 ka to the present. Sand from two marine transgressions [probably marine oxygen isotope Stages 5e and 5a/c (Fig. 4)] were deposited above a bedrock abrasion platform, separated by a well developed pedogenic Bt horizon. Lying atop the pedogenically-altered surface of the Stage 5a/c deposits was a fluvial unit graded to a lower sea level stand during Stage 3. Lying atop the pedogenically-altered surface of the Stage 3 fluvial gravels was an ejected sand layer derived from the non-lithified marine sands at the base of the Stage 5a/c deposits. These sands were vented to the surface through a fissure coincident with the bedrock trace of fault F-1. The ejected sands are buried by post-Stage 2 colluvial deposits, upon which the modern soil is developing (Fig. 3).

All three of Converse's fault traces, and several others as well, were shown to be bedding plane shears that formed during the rotational folding of the bedrock to its present overturned north dip. Because the overlying terrace platforms cut across the bedrock and are not similarly tilted northward, this folding must have either greatly slowed, or ceased since 120 ka. Fault F-1, the most likely candidate for Holocene displacement, was confirmed to offset the deepest marine abrasion platform (Stage 5e) approximately six inches, and also displace the base of the Stage

5a/c sands by an equivalent amount implying a single rupture event. The paleo-surface of the Stage 5a/c marine terrace is buried by the Stage 3 fluvial deposits, and both are also disrupted and vertically displaced, but only by two to three inches. This smaller displacement is interpreted to have been created by subsidence as the unconsolidated Stage 5a/c marine sands vented to the surface during an earthquake. These vented sands bury the offset Stage 3 terrace surface, but have not been faulted or deformed since their emplacement. The vented sands have been OSL dated at 14,300 ± 2,400 years, and due to their lack of subsequent deformation, CGS later removed the A-P zonation for this fault.

In summary, the faults on Winter Mesa have not experienced Holocene displacement.

- Fault F-1 cannot be traced more than 100 feet east or west from the original Converse discovery trench.
- Fault F-1's most recent event is shown to be a result of liquefaction-induced subsidence.
- Fault F-1 is overlain by the undeformed liquefaction-ejected sand layer that is OSL dated at 14.3 ka.
- Fault F-2 is overlain by undeformed marine and non-marine sedimentary units pedologically estimated at 40 to 80 ka, and OSL dated at 69.4 ka.
- Fault F-3 is overlain by undeformed sediments, pedologically estimated to be at least 40 ka and OSL dated at 69.4 ka.
- Yet to be determined is whether there is a "Puerco Canyon" fault at the base of the Winter Mesa sea cliff that is responsible for the uplift and folding.

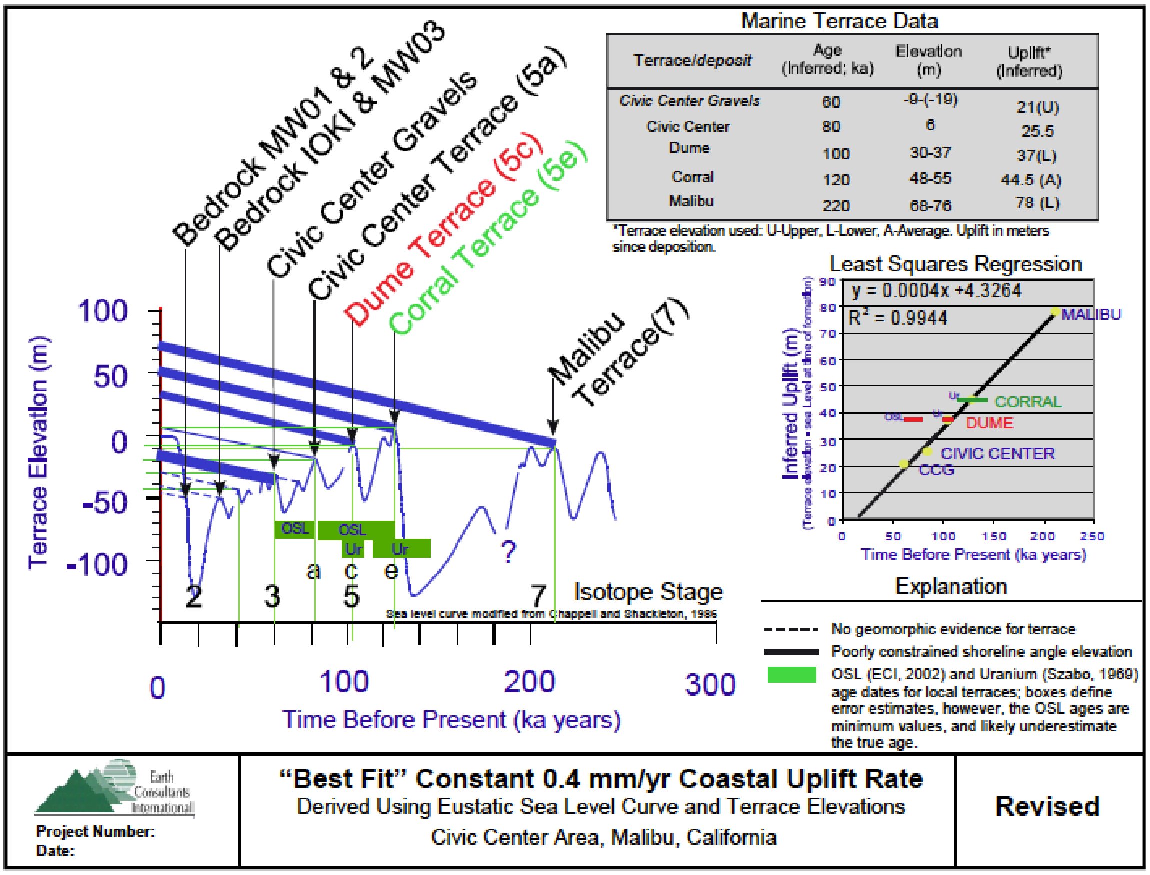


Figure 4: The current best-fit analysis for the age of the various Quaternary units and geomorphic surfaces around the Malibu Civic Center area assuming a constant uplift rate to tie them into the Marine Isotopic Sea Level (MIS) eustatic record.

In the 2000's, ECI and Richard Laton undertook a comprehensive stratigraphic investigation of the 3-D structure and alluvial stratigraphy of the Malibu Creek estuary to support groundwater modeling for a wastewater disposal concept. The scope included MASW profiling, seismic refraction and reflection, core borings, sonic borings to bedrock, monitoring well installations, and pump tests. The geologic model of an evolving Malibu Creek channel location was critical because wastewater disposal into the coarse channel fill beneath the Civic Center Gravels was the preferred discharge scenario.

Because of the disturbed nature of the sonic drilling's "core" collection, it was impossible to determine a visual or density difference between what might be pre-Stage 2 alluvial fill and the post-Stage 2 alluvium. However, abundant wood materials, not organic sediment or charcoal, were collected from the base of the alluvium near bedrock in two borings and radiocarbon dated. The results were >40 ka from the western side where the paleochannel was hypothesized, and 18 ka to 8 ka stratigraphically upwards on the eastern side where the modern channel is located.

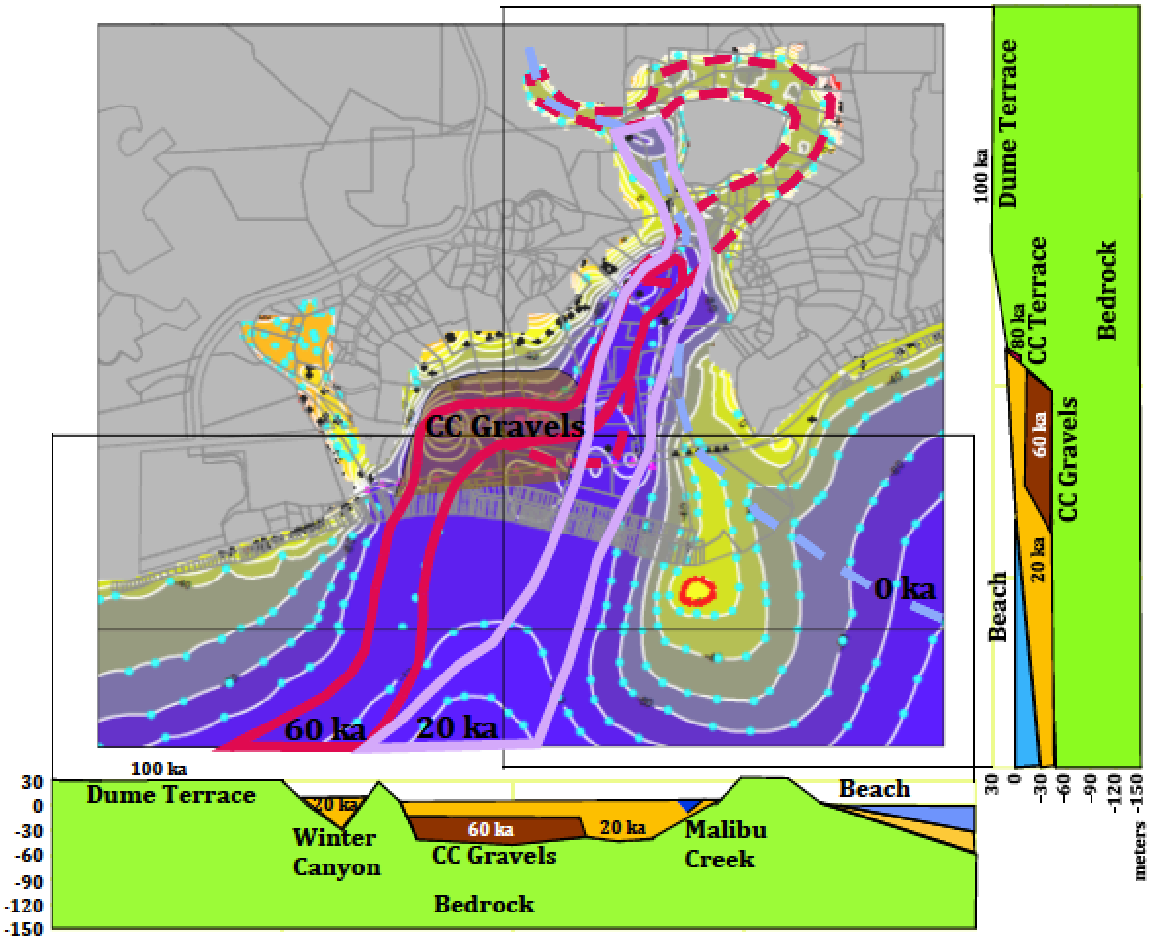


Figure 5: Map showing the easterly evolution of the Malibu Creek channel from >60 ka to the present. At +60 ka, the channel was deflected westerly, carving the east-facing channel margin into Winter Mesa. During the last glacial maximum sea level lowering, Malibu Creek straightened its course, cutting off the ~200 m westerly deflection. The modern Malibu Creek channel now appears to deflect easterly of the former channel, isolating a bedrock-high offshore.

These results support that the hypothesis is correct. The older channel of Malibu Creek deflected to the west until the MIS Stage 3 sea level highstand about 60 ka (Fig. 5), and the nearly horizontal top of the Civic Center Gravels formed a broad marine shelf during that highstand. During the onset of the last glacial maximum, about 30 ka, Malibu Creek abandoned that 200-meter westward deflection and began an incision straight south along the eastern side of the embayment as the shortest path to the sea (Fig. 5). Continued sea level lowering and retreat entrained Malibu Creek into the eastern path erosionally removing the Civic Center Gravels down to bedrock again. Backfill of Malibu Creek commenced about 15 ka, continuing up to the last 2-3 ka when sea level stabilized at modern levels.

Unresolved is whether the 200 meter deflection of the paleo Malibu Creek channel was due to displacement along a now inactive strand of the Malibu Coast fault, or simply a deflection due to other causes.